

CONSTRAINTS TO EMBANKMENT CONSTRUCTION FROM FINES CONTAINING SILT, KAOLINITE, AND CARBONATES

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Recently, BSi published the revised BS 6031, to include compliance with Eurocode 7. This placed emphasis on fill classification and compaction specifications, while setting the Specification for Highway Works (SHW) 600 series as the default approach for earthworks in the UK. The revised BS 6031 (and earlier documents such as the 2001 manual of BRE Centre for Ground Engineering and Remediation) however involves in a number of limitations, highlighted by the earthworks industry. These include self-weight settlement of embankments, sudden subsidence, and increased compressibility under transient loads in fine grained fills of low clay fraction, and partial restoration of collapsibility in placed fill. This paper examines some of these limitations through discussing the past 8 year's research of the first author, including a recent comprehensive lab-scaled modelling work. From this paper, specifications can be developed to detail how a fill can be built from poor quality site-won materials to de-crease the asset maintenance costs.

APPLICATION DU PIÉZOCÔNE POUR L'ÉVALUATION DE LA SÉCURITÉ D'OUVRAGES DE RETENUE FONDÉS SUR DES DÉPÔTS STRATIFIÉS

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L'évaluation de la sécurité d'un ouvrage de retenue requiert une définition précise de la stratigraphie et des conditions d'eau souterraine sous l'ouvrage. Pour l'évaluation de la sécurité de l'ouvrage, on doit produire un modèle du dépôt et de l'ouvrage représentatif des conditions du site. Cet exercice est très difficile (voire impossible) à faire dans les dépôts fortement stratifiés.

Il est de pratique courante d'utiliser, dans ces dépôts, le piézocône comme outil d'investigation géotechnique. Il permet de distinguer de minces couches de matériaux de nature différente et conséquemment ayant des propriétés différentes. En plus de définir une stratigraphie plus précise par rapport aux outils conventionnels, la réalisation d'essais de dissipation, effectués par le piézocône, permet de mesurer ponctuellement les conditions de l'eau souterraine dans les sols. La répartition de la pression interstitielle sous les ouvrages de retenue ou dans leur environnement est aussi un élément important de la sécurité.

L'utilisation des données sur la stratigraphie et sur la piézométrie obtenues par le piézocône permet une compréhension hydrostratigraphique globale des dépôts stratifiés. On peut ainsi bâtir un modèle stratigraphique représentatif du site.

L'article présente deux histoires de cas où l'interprétation des résultats des sondages au piézocône a amélioré la compréhension des conditions existantes et a orienté les travaux à réaliser et justifier leur pertinence.

Le premier cas concerne la digue 2 de l'aménagement Bersimis-2, construit à la fin des années 1950. La réalisation de sondages au piézocône a permis de déterminer que le dépôt argileux contient de nombreux lits silto-sableux. À partir des résultats des essais de dissipation, les matériaux ont été regroupés en unités stratigraphiques de même charge hydraulique. Cette représentation a permis de positionner les strates perméables et déterminer le sens de l'écoulement vertical et longitudinal. Les travaux de confortement ont été conçus en considérant les résultats obtenus.

Le deuxième cas concerne la digue Est de l'aménagement Outardes-2, construite en 1978. Les données des sondages au piézocône ont permis d'identifier un dépôt stratifié beaucoup plus complexe qu'anticipé. L'intégration des résultats de dissipation a démontré que la charge hydraulique des sols en surface était moins élevée que celle des dépôts présents à plus grande profondeur.

Dans les 2 cas, l'intégration des données a permis d'élaborer un modèle représentatif des conditions de site. L'évaluation de la sécurité des ouvrages a été réalisée avec une plus grande confiance basée sur une connaissance plus pertinente des conditions des fondations.

ESTIMATION DE LA CONDUCTIVITÉ HYDRAULIQUE ET DE LA POROSITÉ DES LITHOFACIÈS IDENTIFIÉS DANS LES DÉPÔTS GRANULAIRES DU PALÉODELTA DE LA RIVIÈRE VALIN AU SAGUENAY (QUÉBEC)

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Dans le cadre des travaux d'une caractérisation hydrogéologique des aquifères granulaires du paléodelta de la rivière Valin au Saguenay (Québec), des essais d'estimation de la conductivité hydraulique et de la porosité ont été réalisés sur les différents lithofaciès identifiés sur les faces des sablières sélectionnées dans la zone d'étude. Ces essais, tant pour la conductivité hydraulique que la porosité, ont été réalisés in situ et en laboratoire. Les résultats issus des essais de porosité selon les deux méthodes semblent bien concorder, avec l'enregistrement d'un écart, de moins de 5% pour 75% des cas, entre les résultats obtenus in situ et ceux obtenus en laboratoire. Par ailleurs, ces résultats de porosité ont été utilisés pour fins d'estimation de la conductivité hydraulique en laboratoire selon les expressions empiriques utilisées dans le cadre de cette étude. La comparaison des résultats obtenus de la conductivité hydraulique a permis de rattacher la variabilité des valeurs estimées à trois éléments distincts que sont : 1) l'hétérogénéité des dépôts meubles (variabilité naturelle), 2) les différentes méthodes d'estimation qui ont été utilisées sur le même lithofaciès et au même endroit et 3) des causes d'erreur identifiées lors de la réalisation des essais. Par ailleurs, il s'avère très important d'effectuer des analyses granulométriques et sédimentométriques sur les échantillons de sol représentant les lithofaciès, pour une interprétation plus exacte des résultats portant sur la conductivité hydraulique et la porosité. L'estimation juste de ces paramètres est essentielle à la modélisation de l'écoulement des eaux souterraines dans ce type de structure sédimentaire très hétérogène.

DEVELOPMENT AND APPLICATION OF EXPERIMENTAL PROTOCOLS TO ASSESS THE CONSOLIDATION OF TAILINGS UNDER SATURATED AND UNSATURATED CONDITIONS

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Abstract

This article presents an experimental study aimed at evaluating the saturated and unsaturated consolidation of tailings from hard rock mines. The experimental protocols have been developed to investigate compressibility of these fine-grained, low plasticity tailings using tests in instrumented columns. For the saturated behavior, the compression tests aim at defining the primary and secondary compression parameters of low density slurry, as a function of excess pore water pressures (PWP) and displacements, following the incremental application of a vertical stress. For the unsaturated behavior, the tests involved the application of a controlled suction at the base of the sample through a ceramic disc, while measuring the PWP and displacements during mechanical loading. Two types of experiments have been carried out on the unsaturated tailings: the first was conducted under drained conditions with a constant imposed suction, and the second was performed with a progressively increased suction. The experimental procedures will be described in the article, and representative results will be presented and discussed.

Keys words: laboratory tests, experimental protocol, saturated and unsaturated conditions, compressibility, consolidation parameters, pore water pressure, suction, tailings.

CARACTÉRISATION ENVIRONNEMENTALE DES SOLS ET DU REMBLAI CONTENANT DES MATIÈRES RÉSIDUELLES À L'ENDROIT D'UN ANCIEN DÉPÔT PÉTROLIER SUITE À LA CESSATION DE SES ACTIVITÉS

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Suite à la cessation d'activités d'un dépôt pétrolier, des travaux de caractérisation environnementale ont été effectués afin de vérifier la qualité environnementale des sols et du remblai contenant potentiellement des matières résiduelles aux endroits où des sources potentielles et des enjeux environnementaux ont préalablement été identifiés lors d'une étude d'évaluation environnementale. L'objectif de cette étude de caractérisation était de délimiter les enclaves des sols affectés et celles du remblai contenant des matières résiduelles, afin d'en évaluer les volumes respectifs. À cette fin, les résultats de la présente étude de caractérisation ont été combinés à ceux obtenus lors des études environnementales réalisées antérieurement sur la propriété à l'étude. De l'ensemble des résultats, les enclaves des sols affectés par des hydrocarbures pétroliers semblent se localiser au centre de la propriété avec trois niveaux différents de contamination, soit 1) des sols affectés par des concentrations en excès des valeurs limites fixées de l'Annexe I du Règlement sur la protection et la réhabilitation des terrains (RPRT), mais inférieures aux valeurs limites fixées de l'Annexe II du RPRT; 2) des sols affectés par des concentrations en excès des valeurs limites fixées de l'Annexe II du RPRT, mais inférieures aux valeurs limites fixées de l'Annexe I du Règlement sur l'enfouissement des sols contaminés (RESC) et 3) des sols affectés par des concentrations en excès des valeurs limites fixées de l'Annexe I du RESC. Par ailleurs, quatre zones présentant un remblai contenant moins de 50% de matières résiduelles ont été localisées dans la partie ouest de la propriété, alors que trois zones présentant un remblai contenant plus de 50% de matières résiduelles non dangereuses ont été localisées dans la partie est de la propriété. Cette étude de caractérisation a permis donc de définir une modèle conceptuel, de la répartition des sols affectés et les portions du remblai contenant des matières résiduelles, qui facilite l'élaboration d'un plan de réhabilitation efficace.

NATURAL DISASTERS ANALYSES BASED ON SEVERE STORMS IN BRAZIL

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Climate Changes in many places of world are increasing the frequency and severity of extreme weather events leading to economic losses. In Tropical environmental like Brazil, the main phenomena related to natural disasters are the landslides and flooding. Those events are associated with intense and prolonged rainfalls and they are repeating every rainy season with more severity. This fact justifies the design and implementation of municipal public policies to the risk with a recent federal legislation. It can be highlighted the tragedies that have occurred in the summer of 2009/2010 with 82 municipalities had being affected and 55 deaths at São Paulo State, Brazil. This way, the purpose is a study of the correlation between the rainfall height, intensity and its return period with the severity of the event. For that, a case study was carried out using four cities with: demographic density over the medium of the São Paulo state; I-D-F equation developed and sub-daily precipitation data available. This is a first approach to identify whether the disasters are being caused by episodes of high return period or by recurrent events that are compounded by the urbanization process. A database of such events was developed including the type of disaster, damage, date, time and location. This study considered the information of the Civil Defense from September 2009 to February 2010, comprising the wettest months, when there were greater numbers of disasters. Atmospheric conditions were also compared to the geological, geomorphologic, hydrological, land use and geotechnical comportment for analysis. Through these data and other information from the IBGE (Brazilian Institute of Geography and Statistics) risk and vulnerability indexes were calculated to certain towns. As conclusion, the analysis of the maps showed that the situation of municipalities in relation to atmospheric events is critical, since it combines a number of factors that, together, produce an unfavorable situation for the population, making it increasingly vulnerable. The results demonstrated that the occurrence of the SACZ allied to the influence of El Niño activity was favorable to the occurrence of height rainfall depth records all over São Paulo state increasing the damage occurrences. The association of prolonged rain periods with steep slopes greatly increases the number of landslides in the eastern region of São Paulo state, causing severe damage. The flooding analyses linked to occurrence probability quantification indicated that recurring events with low return period can lead to damage reports by Civil Defense.

DEBRIS FLOW HAZARD ASSESSMENT AND ANALYSIS AT SUNGAI RUIL CAMERON HIGHLAND MALAYSIA

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Landslide in the village of Sungai Ruil, Brinchang, Cameron Highlands, Malaysia occurred on August 7, 2011 at 5:50 pm. This incident has caused six houses buried by debris or mud which engaged seven fatalities and two injuries. This landslide has been classified as debris flow. Total area of the village involved is around 40 hectares whilst the catchment area of the village is around 80 hectares. The landslide forensic investigation was carried out to identify the cause of the failure. There are three methods in conducting the study that involved geological mapping and interpretation for assessment of geological hazards. The second method is the debris flow hazard assessment in all the drainage including rainfall analysis. The rainfall analysis was carried out to produce the snake line and critical line. The third method is an analysis of slope stability in locations with high potential of slope failure in the area. There are three factors identified that resulted from this incident. The first factor is the presence of geological factors weakness (covered by colluviums), weathered material, orientation and location of adversely discontinuities and relict slope failure. While the second factor is the appearance of the morphology of hilly terrain, presence of channel order 0 or 'ephemeral drainage' and river bed gradient more than 35 degrees. The third factor is human activity that build water barrier. While the high intensity of rainfall in a short period of time is believed to be a triggering factor. This paper will discuss in detail on how intensity and duration of rainfall induce the landslide and predict the threshold value at the area

Keywords: Landslide and development mechanisms, Malaysia

USE OF LIGHTWEIGHT FILL, CONCRETE PILE WALLS, AND TIED BACK ANCHORS FOR REPAIR OF EUREKA RIVER HIGHWAY LANDSLIDE: CASE HISTORY OF DESIGN, CONSTRUCTION AND PERFORMANCE

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This paper presents a case history of the investigation, design, construction and performance of a a landslide repair along the north valley slope of the Eureka River in northwest Alberta. The project site was located along Highway 726:02; the primary highway access to the community of Worsley. The investigation revealed a deep-seated landslide seated in a weak clay layer that toed out into the Eureka River located 15 m below the highway. The terrain through the valley is well known for being landslide prone and several other landslides in close vicinity to the project site affect the highway. A realignment option was determined to be technically feasible since a number of other landslide areas could also be avoided. Due to cost and timing issues an alternative mitigation option was chosen. The mitigation design consisted of two lines of concrete piles constructed downslope of the highway spanning through the landslide area. Construction was started in May, 2012 and completed in October, 2013. The upper line of piles was 120 m long and up to 27 m deep, located parallel to and about 4 m downslope of the highway. This wall was tied-back using two rows of grouted anchors that were between 15 m and 44 m long. The lower wall was 60 m long and 20 m deep, installed along an outside bend in the river bank. The lower wall was a cantilever design and was intended to maintain passive soil pressure on the upper wall in order to reduce the size of piles and number of anchors required. In order to reduce the driving forces the hillside above the highway was off-loaded to a small extent and the top 4 m depth of embankment was removed and replaced with 3 m of expanded polystyrene blocks. Loss of material between the piles of the lower pile wall was observed in the spring of 2013. A sheet pile wall was installed to retain the soil and additional rip rap armoring was placed along the river bank. Three slope indicators were installed in the upper pile wall and three slope indicators were installed in the lower pile wall. The slope indicators have not registered any significant wall deflection to date. Load cells were installed at three sets of anchor locations to monitor stresses in the upper and lower anchors in the upper wall.

INFLUENCE DES ÉVÉNEMENTS DE PRÉCIPITATION EXTRÊMES ET DES PROPRIÉTÉS HYDROGÉOLOGIQUES DES MATÉRIAUX SUR LA CAPACITÉ DE LIBÉRATION DE RECOUVREMENT STORE-AND-RELEASE EN CLIMAT SEMI-ARIDE À ARIDE.

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En climat semi-aride à aride, les systèmes de recouvrement Store-and-Release (SR) peuvent réduire les infiltrations d'eau vers des rejets miniers réactifs et ainsi contrôler la production de drainage contaminé. Ces systèmes, de plus en plus utilisés lors de la restauration de site minier, impliquent des matériaux ayant des propriétés hydrogéologiques appropriées. En effet, ces matériaux doivent disposer à la fois d'une bonne capacité de stockage, afin d'emmagasiner l'eau durant les périodes humides, et d'une bonne capacité de libération pour retourner l'eau vers l'atmosphère durant les périodes sèches.

Présentement, peu de travaux se sont intéressés à l'évolution de la capacité de libération des matériaux SR après des événements climatiques extrêmes. L'objectif de ce travail vise donc à étudier, à l'aide du code numérique HYDRUS-1D, l'influence des propriétés hydrogéologiques de matériaux SR (i.e., courbe de rétention d'eau et conductivité hydraulique) sur leur capacité de libération suite à la simulation d'événements de précipitation extrêmes. Quatre systèmes de recouvrement constitués de quatre matériaux SR différents ont été simulés numériquement. Les matériaux possèdent des propriétés hydrogéologiques distinctes mais appropriées à la construction de ces systèmes. Les modèles numériques ont été préalablement calibrés à partir de mesures expérimentales obtenues au niveau de colonnes et de cellules instrumentées de terrain. Une précipitation, considérée extrême (155 mm/24h) pour la zone climatique à l'étude, a été appliquée sur les quatre recouvrements; leur performance a été évaluée en régime transitoire et à long terme.

Les résultats des simulations numériques montrent que les propriétés hydrogéologiques des matériaux SR affectent la performance des recouvrements. Dans le cas d'événements de précipitation extrêmes rapprochés, plus les matériaux sont fins, plus la perte de la capacité de stockage initiale est importante et les risques de percolation sont élevés. A l'inverse, les matériaux plus grossiers possèdent une meilleure capacité de libération leur permettant de recouvrer la capacité de stockage initiale plus rapidement. Ainsi, lorsque vient le temps de concevoir les recouvrements de type SR, en plus des paramètres de design traditionnels (i.e., épaisseur du recouvrement, propriétés des matériaux, conditions climatiques extrêmes), il est important d'évaluer la vitesse avec laquelle les recouvrements peuvent recouvrer leur capacité de stockage initiale après avoir été exposés à des périodes humides importantes.

PERFORMANCE OF RECLAIMED ASPHALT PAVEMENT IN A STRUCTURAL FILL

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This paper describes the greater than expected settlement of a perched bridge abutment footing supported on a Mechanically Stabilized Earth (MSE) wall. One potential reason for the greater than expected settlement could have been the presence of reclaimed asphalt pavement (RAP) used in the MSE backfill. In order to investigate this, a review of available case histories in which RAP had been used was undertaken, and a limited laboratory test program conducted to investigate the settlement potential of RAP.

Our case history review showed that in pavement applications, the highest allowable RAP addition rate was typically about 50%, and the norm was in the 20% to 40% range. A few transportation agencies limit the asphalt cement content, mostly to about 2% of the total mass. Published research on use of RAP in MSE fills showed that long-term creep settlement depends on the asphalt cement binder content, asphalt cement performance grade, age of the asphalt, and the aggregate characteristics. In general it was concluded that although some MSE walls constructed with RAP have performed well to date, the use of RAP is not recommended.

The laboratory test program discussed in this paper consisted of compacting various RAP mixes with asphalt cement binder contents ranging from 2.5% to 4.3% to different densities and at different moisture contents in a greased 150 mm diameter mould. The samples were then loaded to 300 kPa to replicate the foundation loading, and settlement was measured against time. The test results were bench marked against tests done on clean RAP after the asphalt cement binder had been stripped out. The results showed that settlement increased as the asphalt cement content increased, and as water content increased. For example, for RAP compacted to 100% of Standard Proctor Density, total settlement varied between 2.5% and 5.5% of the sample thickness during the loading period whereas the bench mark samples with no asphalt, settled less than 0.5%.

The case history demonstrated the potential for larger than expected settlement of structural fills constructed using compacted RAP. Based on these results we concluded that the settlement of the bridge abutment could have been caused by the presence of RAP. The paper concludes that there is a place for using RAP in structural fills, but its potential for creep settlement and moisture susceptibility must be considered.

RELIABILITY BASED DESIGN CALIBRATION FOR TWO NORTH SASKATCHEWAN RIVER CROSSINGS

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Variability of geotechnical material parameters within a project site boundary is a concern for geotechnical engineers. It is usually the business of geotechnical engineers to assess site sub-surface conditions and rationally develop geotechnical design parameters for use by structural engineers. Methods such as Limit State Design (LSD) are commonly used to express ultimate and serviceability limit states for soil capacity. The use of LSD methodology is straightforward; however it may not clearly translate into reliable and concise parameters that may be justifiably relied upon by structural engineers. Factored bearing capacity values provided by a geotechnical engineer are often factored again by the structural engineer, resulting in considerably redundancy. An alternative method to LSD is Reliability Based Design (RBD). RBD parameters provide bearing capacities based on the statistical reliability of the data obtained during a site-specific investigation. These capacities are directly relatable to most structural designs and do not require additional factors of safety. The main drawback of RBD parameters however is the statistical complexity required to create viable, site-specific calibrations used in RBD calculations.

This paper presents a framework for developing regional reliability based calibrations from existing site characterization and foundation test data accumulated by Alberta Transportation. The focus is on site investigations undertaken for two major bridge crossing projects completed for the Anthony Henday Ring Road within the City of Edmonton municipal boundary. The information from these two sites provides a small sub-regional calibration. Many sub-regional calibrations can be compiled into a regional database that would form the framework for a regional calibration. This methodology points toward the possibility of an Edmonton specific regional calibration RBD model. To achieve such a model will involve further analysis and incorporation of numerous sub-regional statistically manageable datasets to create larger, regional RBD calibrations that are easily referenced.

If successful, this method would permit provincial highway departments to use their existing historical data to readily develop reliability-based calibrations for various regions based on smaller, sub-regional datasets. In addition this calibration method provides GIS ready input for existing databases used for storing and managing all historical site investigations. This data could then be incorporated into any future site investigations such that each subsequent local investigation contributes to the previously developed calibration.

LATERAL PERFORMANCE OF HELICAL TAPERED PILES IN SAND

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Recent years have witnessed a surge in the construction of Solar Farms as an alternative source of energy, driven by the need to abate the elevated levels of carbon emissions associated with the ever-increasing electricity demands. In this study, a novel piling system is proposed to support solar energy panels: a short spun-cast ductile iron (SCDI) tapered pile fitted with a lower helical plate. Combining the efficiency of the tapered section, the construction advantage of helical piles, and the practical size and weight of short hollow iron section, the proposed pile is believed to offer higher axial and lateral capacity, and to present a more sustainable foundation system. The pile is installed using a reduced noise and vibration process. In this article, the lateral performance of the proposed system is investigated. Seven piles, including five SCDI tapered and two steel straight shafts, were installed using mechanical torque in silty sand soil. The piles were laterally tested and their ultimate capacities were evaluated. Two different loading sequences were adopted to assess the effect of previous axial loading on the piles' lateral performance: four piles were initially subjected to cyclic compression loading, and three were subjected to initial monotonic uplift prior to the lateral testing. A three-dimensional finite element model was calibrated using the experimental data and then was used to evaluate the response of the proposed pile when subjected to combined lateral loading and bending moment at its head. The results showed that the tapered piles possess a generally stiffer response and higher ultimate capacity compared to straight piles. The fixation provided by the helical plate had a positive effect on the lateral performance of short piles. The experimental and numerical results showed that spun-cast iron short piles of the proposed configuration would present a viable foundation system for supporting solar panels. Finally, bending moment-horizontal force interaction diagrams were provided to aid in the design of the proposed system when subjected to the expected combination of moment and horizontal loads arising when supporting solar panels.

RIVERBED LIQUEFACTION MITIGATION IN GATINEAU RIVER – APPLICATION OF STONE COLUMNS

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This article represents a case study involving on-shore and off-shore stone column construction and the particularities of working in these conditions. The purpose of the ground improvement was to mitigate liquefaction in the sandy silt material present in both settings in order to prepare for the reconstruction of a bridge spanning the Gatineau River. In total four discrete areas were treated: the location of three bridge piers and the northern abutment. A dry, bottom-fed vibroreplacement method was utilized to construct the stone columns on shore and within the river bed. In both cases the work was completed using a crane fitted with a vibro mast that allows for the placement of aggregate and the compaction of the constructed column. Off shore the work was carried out on specifically designed barges while the individual columns were located using a GPS system mounted at the top of the crane. SPT, CPT and DSS testing were used to verify the performance of the improvement and re-evaluate the liquefaction potential of the site. This article describes the particularities of the project including its geotechnical condition, the design parameters and calculations. Finally, the resulting values are compared to design values.

EVALUATION OF SEISMIC KINEMATIC AND INERTIAL FORCES IN PILES

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Parametric analyses are carried out in the frequency domain by means of nonlinear two-dimensional (2D) finite element (FE) analyses, focusing on normalized seismic forces in the piles as affected by typical characteristics of structures and piles. The results of the study provide a new interpretation of the interplay between pile kinematic and inertial seismic forces. This work shows that for relatively short/stiff piles, the kinematic interaction can be the prime contributor to the seismic forces in the pile provided that the excitation frequency is not close to the natural frequency of the coupled soil-pile-structure system, f_{SSI} . In a frequency band approaching f_{SSI} , the inertial interaction generally prevails imposing large bending moments at or near the pile head. The results showed also that maximum kinematic seismic force does not always occur at the fundamental frequency of the deposit. For certain relative soil-pile stiffness and excitation amplitudes, the largest peak of the kinematic seismic forces in piles can be occurring at the second mode.

APPORT DU SIG ET DE TÉLÉDÉTECTION DANS LA MODÉLISATION SPATIALE DE LA SUSCEPTIBILITÉ AUX MOUVEMENTS DE TERRAIN DANS LA RÉGION D'AL HOCEIMA (RIF ORIENTAL, MAROC).

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L'évaluation du degré de susceptibilité aux mouvements de terrains est devenue une préoccupation majeure dans les terrains montagneux, elle oriente les efforts à entreprendre pour prévenir les catastrophes, minimiser les risques et gérer les conséquences. Les techniques d'analyse spatialisée par système d'information géographique (SIG) et télédétection sont de plus en plus utilisées pour évaluer la susceptibilité des versants aux mouvements de terrain. Dans cette étude, la modélisation par un modèle probabiliste bivarié (théorie d'évidence) a été utilisée pour cartographier les zones susceptibles aux mouvements de terrains dans la région d'Al Hoceima (NE du Maroc). Le SIG est également utilisé pour apprécier la relation entre : (i) les mouvements des terrains et (ii) la distribution spatiale des facteurs causatifs, l'information relative à ces deux composantes a été dérivée des données de terrain, traitements d'imageries satellitaires et les documents cartographiques disponibles. Ces données ont été intégrées dans une base de données SIG avec d'autres paramètres issus des cartes géologiques, topographiques et des stations météorologiques. Cette phase de préparation a été suivie par un test de l'indépendance conditionnelle des facteurs causatifs par rapport aux mouvements de terrain survenus dans la zone. Les paramètres indépendants ont servi aux calculs des poids positifs, négatifs ($W+$, $W-$), et leurs contrastes (C). Finalement, les cartes obtenues des différentes combinaisons ont été évaluées pour retenir la meilleure simulation des facteurs causatifs, sur ce, une série des tests de validation des résultats obtenus par l'analyse de la courbe ROC a été effectuée.

Les résultats ont montrés que la combinaison qui regroupe les facteurs prédictifs : pente, exposition des versants, lithologie et densité de fracturation s'avère être la meilleure combinaison possible. Cette combinaison permet de prédire environ 70% des instabilités existants.

3D-MODELING OF LATERALLY LOADED BATTERED PILES IN SAND

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A series of three-dimensional finite differences analyses have been carried out to evaluate the influence of vertical loads on the lateral response of battered piles as affected by the inclination angle of the piles as well as soil density. Analyses were performed in homogeneous sandy soils. Numerical results show that the influence of vertical loads on the lateral capacity of battered piles is influenced by the value and the sign of the pile batter angle as well as the density of sand. For positive batter angles, the lateral load capacity of battered pile increases substantially with vertical loads and batter angles and the percentage of increase increases with soil density. However, for negative batter angle, the lateral load capacity of battered piles is considerably decreased with the increase in batter angles. Unlike positive batter angle cases, soil density appears to have little effect on the lateral capacity of pile with negative batter angles.

TWO LARGE LANDSLIDES IN SENSITIVE CLAYS TRIGGERED BY THE 2010 VAL-DES-BOIS EARTHQUAKE, QUEBEC, CANADA – IMPLICATIONS FOR RISK MANAGEMENT

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Historical and prehistorical records indicate that large sensitive clay landslides can be triggered by earthquakes in Eastern Canada, sometimes over vast areas as in the case of the 1663 M7+ Charlevoix earthquake, Quebec. Earthquakes of a sufficient magnitude to trigger landslides are, however, uncommon and little is known about pre-landslide conditions for past events, the seismic demand required to induce failure, and the timing of failure. The two large landslides of Notre-Dame-de-la-Salette (NDLS) and Mulgrave & Derry (MD) triggered by the Mw5.2 Val-des-Bois earthquake (Quebec) of June 2010 offer a unique opportunity to document the predisposing factors and mechanisms involved in earthquake-induced failures. The NDLS landslide is a typical flowslide that has mobilized quick-clays with sensitivities higher than 500 and remolded shear strengths less than 0.1 kPa. Its surface area is 5.6 ha and is located at about 12.5 km from the earthquake epicenter. According to reliable eyewitness accounts, it occurred 22 hours after the earthquake, and is interpreted as a delayed failure initiated by a rotational slide that was triggered by the main shock. Slopes before the earthquake event were in a state of marginal stability with a factor of safety close to 1.0. The MD landslide is of a spread/translational type and was triggered near the end or just after the main shock. This landslide has a surface area of 1.3 ha and is located at 16.5 km from the earthquake epicenter. It involved finely stratified sensitive clays, with submillimetric layers of coarse silts to fine sands at the depth of the failure surface. The pre-earthquake factor of safety of the slope was larger than 2.0. In conformity with the shaking intensity and estimated ground motion accelerations within the soil mass, the most plausible explanation of the triggering mechanism of this landslide is the liquefaction of the very thin silt and sand layers. Implications that these two contrasting failure types may have for hazard mapping and risk management are discussed.

EFFECT OF BRINE SOLUTION ON ANTIOXIDANTS OF HDPE GEOMEMBRANES

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Effect of brine solution on antioxidants of HDPE geomembranes

M. Shoaib and R.K. Rowe

ABSTRACT

High density polyethylene (HDPE) geomembranes (GMBs) are used as the primary bottom liner for brine storage and evaporation ponds. The brine arising from the processing of waters recovered from shale or coal gas extraction often contains sodium chloride (NaCl), sodium carbonate (NaHCO₃) and sodium bicarbonate (Na₂CO₃) at very high concentrations. This paper describes an experimental examination of the ageing of four different GMBs immersed in brine solution at four different temperatures to monitor the depletion rate of antioxidants/stabilizers added to the GMB formulation to protect the GMB both during manufacturing and subsequently when deployed in the field. The depletion rate of antioxidants depends on several factors, including the amount and type of antioxidants/stabilizers, GMB temperature, the GMB exposure conditions, the diffusion/extraction of antioxidants from the GMB, and the chemical composition of the fluids with which the GMB is in contact. There is paucity of published research examining the chemical compatibility of HDPE GMB with brine solution. The tests are intended to provide insight regarding the antioxidant depletion rate and its impact on the time to nominal failure of HDPE GMB and therefore will help to provide an estimate of the service life of four different HDPE GMBs immersed in a brine solution.

NEW INSIGHTS INTO THE CONTRIBUTION OF INERTIAL LOADS IN PSEUDO-STATIC APPROACH FOR SEISMIC ANALYSIS OF PILE GROUPS IN SOIL SLOPES

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The seismic response of pile foundations to earthquake shaking is a very complex process in the geotechnical earthquake engineering that is controlled by inertial interaction between superstructure and pile foundation, kinematic interaction between foundation soils and piles, and the non-linear stress-strain behavior of soils. Thus, for pile foundations built in seismic areas, the demands to sustain load and deformation during an earthquake will probably be the most severe in their design life.

In the structural and geotechnical environment, simplified methods are a convenience for design, and pseudo-static approach is one of these methods that is very attractive for pile designers when compared to more complex dynamic analyses. In this respect, many researchers have developed pseudo static procedures to evaluate the soil-pile-superstructure interaction and their main conclusion is that pseudo-static approach gives reasonable results in many practical cases especially for engineering purposes, but it may overestimate the pile response in some conditions. One of the reasons of the overestimate in pile response analyzed using pseudo-static method can be attributed to lack of knowledge about inertial loads. In this respect, this paper aims to provide new insights about inertial loads that should be applied in pseudo-static method so that to obtain reasonable results. Furthermore, Many coastal and harbor structures, bridges, high-rise buildings and transmission towers are constructed on soil slopes and are supported by pile groups. These structures may be subjected to induced lateral loads due to the seismic movements of slope. Accordingly, in this paper, the case of pile groups founded in soil slopes is considered.

PROTECTION METHODOLOGY OF ROADS AND RAILWAYS AGAINST SAND MOVEMENT RISK

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One of the biggest challenges to construct any type of engineering structures in the areas of sand movement in the desert under the effect of surface wind is the amount of sand that will cover or bury these structures. The movement of sand in desert causes many problems for different types of engineering structures such as roads, railways, buildings, pipelines, and oil reservoirs. The focus of this paper will be on the protection methodologies of roads and railways. The major problems of sand movement in the desert can be summarized in two major problems; Erosion and Sedimentation. Therefore, the major point in this paper is related to developing the methodology to protect roads and railways against the risk of sand movement in desert. This methodology can be followed by engineers who are constructing roads or railways inside sandy moving areas to protect them. In addition, the paper includes the mechanical, chemical and biological methods and techniques which can be used to resist sand movement as well as the method of applying them. The paper includes also some important guidelines regarding the construction of roads and railways in sandy desert regions.

THE USE OF TACTILE PRESSURE SENSORS TO MEASURE SOIL PRESSURES AROUND SQUARE BOX CULVERTS

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Tactile pressure sensors are sensors have the ability to measure the normal stresses on any surface but they do not count for the effect of shear stresses exerted due to the friction between the structures and the adjacent soil movements. A series of centrifuge tests performed at the RPI geotechnical centrifuge facility in the USA to investigate the soil culvert interaction and the effect of soil arching on the increase and decrease in the values of soil pressures around square section box culverts. Two different culvert thicknesses were investigated under two different relative densities of Nevada sand as well as surface foundations. To examine the validity of using tactile pressure sensors in providing acceptable results of soil pressures, their results were compared to soil pressures obtained from strain gauge data as well as numerical model using FLAC software. This paper will give a brief description of tactile pressure sensors used and the adapted method of calibration. Then, an example of the vertical and horizontal soil pressures measured on the top slab and side wall of the box culvert presenting the effect of soil self weight and surface foundation will be discussed. A comparison with FLAC model results will be presented to show the effect of culvert thickness on the soil pressures obtained from tactile pressure sensors. The results of this research led to the conclusion that soil pressures measured using tactile pressure sensors can be considered as a bound of the soil pressures expected on the top slab and side wall and therefore even they do not count for shear stresses, they still can give a very acceptable soil pressure estimates.

GEOTECHNICAL DESIGN OF THERMOPILE FOUNDATION FOR A BUILDING IN INUVIK

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A thermopile foundation has been designed for a new RCMP detachment in Inuvik. Challenging geotechnical ground conditions at the site include an up to 3 m thick unfrozen zone (closed talik) below the active layer, up to 10 m thick ice and ice-rich soils, and warm permafrost temperatures. The structural design of the building proposed a total of 128 piles in five pile loading groups with variable pile spacings. The main scope of the geotechnical design of the thermopile foundation was to recommend the design geometries of the thermopiles based on geothermal analyses and geotechnical evaluations. A set of geothermal analyses were carried out to estimate the building foundation ground temperatures with depth and time under normal working conditions of the thermopiles and climatic conditions considering projected climate changes over the building design life of 50 years. Geotechnical evaluations were conducted to estimate the required pipe embedment depths in consideration of specified pile long-term creep settlement criteria and design criteria against potential frost jacking. A total of three design groups of the thermopiles were recommended for the building foundation.

CORRECTIONS EFFECT ON SHEAR STRENGTH PARAMETERS OF LOOSE SANDS

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Triaxial tests are often used to determine the behavior and strength characteristics of soils for geotechnical engineering analysis and design. Triaxial testing involves many sources of error that could significantly affect shear strength parameters if not corrected. These errors and the available correction methods are thoroughly reviewed in this study in a series of monotonic triaxial compression tests on loose Ottawa sand specimens. The significance of each correction on the triaxial test results and the achieved adjustments of the shear strength parameters and void ratio are discussed and evaluated. It is found that negligence in making corrections accounting for these errors could result in an overestimation of as much as 44%, and 14.7% in the measurement of undrained and drained shear strength parameters, respectively.

FORMATION OF SOIL-SETUP SOIL PLUGS WITHIN H-PILES DRIVEN IN STIFF CLAYEY PORT STANLEY TILL NEAR LONDON, ONTARIO

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The formation of soil-setup soil plugs within H-Piles is demonstrated using the results of Pile Driver Analyzer (PDA) tests. Sixteen (16) PDA tests were carried out; six (6) on H-Piles driven continuously to 20 m and ten (10) driven after a 24 hours pause to accommodate pile splicing. Test results on piles continuously driven to 20 m demonstrated shaft resistances that agreed with the pre-construction static analysis and showed virtually no scatter in the measured pile capacities. Test results on all piles driven to further depths after welding demonstrated a severe loss of shaft resistance within the top 20 m indicating that a 24 hour delay provided sufficient soil-setup time for the formation of long soil plugs between the flanges which were subsequently dragged down leaving the upper portion of the pile with no reliable soil contact. This paper also demonstrates the use of PDA equipment to develop site specific soil setup functions for predicting long term capacities of friction piles and to investigate unanticipated pile-soil responses.

EVALUATION OF THE UNDRAINED SHEAR STRENGTH OF CHAMPLAIN SEA CLAYS IN OTTAWA (LEDA CLAY) USING CPT

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An evaluation of the empirical cone factor, N_{kt} , which is used to define the undrained shear strength (s_u) profile of a deposit on the basis of cone penetration test (CPT) data has been carried out for several Ottawa Leda clay sites. Both CPT and field-vane tests were carried out at each site as part of the evaluation of the N_{kt} values. The field-vane apparatuses used were friction compensated digital and Nilcon vanes. In addition, data collected outside of Ottawa in other parts of the Champlain Sea deposit are also presented. N_{kt} values presented in literature typically range from 10 to 18 with recommended values of 14 to 16 in the cases where site specific information is not available. The Ottawa Leda clay sites investigated mostly produced N_{kt} values in the range of 9 to 11. The use of N_{kt} values in the range of 14 to 16 at these sites would have underestimated the strength of the clay by about 33%. A literature review of the soil characteristics which influence N_{kt} and the site specific results are presented and discussed.

LATERAL LOADING OF LARGE-CAPACITY HELICAL PILES INSTALLED IN TYPICAL ALBERTA SOIL

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The lateral performance of large-capacity helical piles is of significant interest because they can offer an efficient alternative to conventional piling systems in many applications. This paper presents the results of two field lateral load tests conducted on 6.0 m and 9.0 m large-capacity helical piles installed in cohesive soil. The test piles were close-ended steel shafts with outer shaft diameter of 324 mm. The piles were double-helix with helix diameter of 610 mm and inter-helix spacing of 1.5 times the helix diameter. The subsurface soil properties at the test site were determined using field and laboratory testing methods. The piles were load tested twice: two weeks and nine months after installation. The load-deflection curves were analyzed and the soil moduli of subgrade reaction were back-calculated to better understand the behavior of the test piles and the effect of pile installation on soil disturbance.

ANALYSIS AND LARGE DISPLACEMENTS OF AN AGGREGATE STOCKPILE

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Potential foundation failure of cone and triangular prism-shaped aggregate stockpiles into an adjacent river was investigated through back-analysis of a previous large foundation displacement event. Ground conditions included fill, thin silty sand layers and an extensive silty clay deposit. Borehole and piezocone investigations, pre- and post-displacement bathymetric river surveys and limit equilibrium slope stability analyses were used to assess displacement mechanisms. A simplified method of accounting for three-dimensional effects within two-dimensional slope stability analysis methods was devised. Parametric analyses with and without 3-D effects subsequently informed operational guidelines for new stockpiles. During a busy construction season, stockpile height limitations were exceeded and large displacements occurred. Rapid site responses including removal of large stockpile volumes avoided full failure into the watercourse. Back-analysis of such displacement events illustrate the utility of simplified approaches to a complex three-dimensional stability problem.

BEHAVIOR OF COMPRESSION PILE IN SANDY SOIL UNDERLAIN BY CLAYRAMI BAKR (1)*(1) Delta University (Mansoura, Egypt)*

Sandy soils appear in many cases at relatively shallow depths underlain by clay soil having reasonable shear strength parameters. Meanwhile the continuous sandy or rocky layers exist very deep. In some regions located in the seismic belt the building codes restrict the building heights. Therefore, relatively low stresses are imposed on the soil. In such cases it is possible to terminate the pile foundation in the shallower sand layer. The long-term settlement representing both consolidation and creep phases should be carefully studied. This study focuses on the evaluation of the factors affecting the behavior of piles rest in sandy layer underlain by clay. Eighteen cases were investigated and included in this study. Effects of soil properties, pile length, pile diameter, as well as the distance between the pile toe and the top surface of the clay soil are investigated by field static load tests. The results showed that both the pile length and the pile diameter are affecting the pile behavior. The pile capacity increases significantly as any of both length and/or diameter of pile increases. The presence a layer of soft soil underlain the pile bearing sandy layer does not affect the pile behavior as long as the frictional capacity is not reached.

GEOTECHNICAL DEEP FOUNDATION DESIGN CHALLENGES IN DISCONTINUOUS PERMAFROST OF NORTHERN MANITOBA

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Northern Manitoba has recently seen a boost in hydroelectric power generation projects and with that a growing demand for infrastructure associated with power transmission. Manitoba Hydro has embarked on a very ambitious project named BIPOLE III involving a 500 KV HVDC transmission line linking northern power complex on the Lower Nelson River and delivery system in Winnipeg and two converter stations one on each end. This paper presents the geotechnical foundation design challenges associated with converter station located at the generation end in Northern Manitoba, east of Gillam called Keewatinohk. Keewatinohk is a remote site in the discontinuous permafrost and peat land evolution in the Northern Hudson Bay Lowlands, south of Churchill.

The freezing index for the general project area is about 3300 Degree Days C (based on the period 1931 to 1960) and 3750°C-days (based on the period 1958 to 2007). The mean annual air temperature (MAAT) for the area is currently approximately -1°C. The mean air temperature during winter is expected to be around -20°C. The seasonal active layer in this area generally is estimated at about 3 m. Due to the remoteness and cold climate of the site the owners prefer a relatively longer service life and less maintenance during operations. Winter construction and operations without access issues was expected.

Site conditions consist of swampy peat bog with discontinuous permafrost present to varying depths. Subsurface conditions comprise peat followed by a variable ice-rich mixed zone of silt/clay/sand/till to several meters before encountering hard to very hard clayey till. Several foundation options were examined and tubular steel pipe piles were selected as the technically preferred alternative. This paper presents the deep foundation design challenges associated with dealing with potential thawing consolidation settlement and its associated drag forces, thaw weakening for lateral support, and adfreeze forces.

The subsurface conditions also include cobbles and boulders. Their size and frequency and the correct strength assessment of the underlying hard till were challenges to deal with for pile foundation installation. The paper presents the planning and options considered and pile drivability analysis carried out to address these challenges. The paper also presents some monitoring of the ground thermal regime at the site and plans for further investigation and monitoring to improve on database for design refinements. An advanced pre-production pile installation program is planned and is discussed.

CLIMATE CHANGE VULNERABILITY STUDY – DEMPSTER HIGHWAY, YUKON AND NORTHWEST TERRITORIES

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The Dempster Highway is the only road connection to the western Arctic, linking southern Canada through the northern Yukon (Dawson City) to the Northwest Territories communities of Fort McPherson, Tsiigehtchik and Inuvik, NT. It was designed and constructed in the 1960's and 1970's, and opened to traffic in 1978. The design and construction was managed by Public Works Canada, with a number of private contractors providing construction services for different sections. This was the second major highway across the permafrost regions of northern Canada. Experience with construction and operation of the Alaska Highway in the 1940's provided the only precedent for construction of linear infrastructure over permafrost terrain. The original design intent was to maintain the permafrost by providing a minimum fill thickness as an insulating cover, together with flatter sideslopes.

In this region of northern Canada, climate warming has been observed since about 1970, and ground temperatures in the permafrost are increasing. This paper summarizes the first phase of a study to assess the vulnerability of the Dempster Highway in YT and NT to the potential impacts of current and future climate warming.

The paper will include photos and explanations of climate change effects on the Dempster Highway (as opposed to routine maintenance requirements) that are related to warming air and permafrost temperatures, as well as those related to rainfall and flood events caused by extreme weather.

EFFECTS OF TUNNELING ON THE BEARING CAPACITY OF SHALLOW FOUNDATIONS

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Urban tunnelling can induce distortion to the existing three-dimensional stress regime due to the development of ground arching and the associated stress redistribution. In some cases this may decrease the bearing capacity of nearby foundations which could cause damage to the overlying structures especially in soft soils and/or densely populated areas. Thus, the effect of tunneling on the performance and capacity of nearby foundations may be significant and should be considered in their design. This paper uses the finite element method with an elastic-plastic model and the Plaxis 3D software to study this interaction problem considering a number of parameters such as the tunnelling processes, construction sequence, proximity, and the burial depth. Accordingly, recommendations for the design of shallow foundations in close vicinity to shallow tunnels were proposed.

KEYWORDS: tunnelling, foundation, ground settlement, bearing capacity, finite element method.

SOIL-STRUCTURE INTERACTION OF A STABILIZED NATURAL SLOPE

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Marginally stable slopes coupled with heavy rainfalls represent a conventional challenge to rapid urban development in hilly terrain especially near high slopes. It may lead to landslides that can be disastrous causing significant damage to nearby properties and loss of lives. Slope stability analyses are commonly assessed using limit equilibrium techniques and recently the finite element method has been employed as a more powerful alternative to limit equilibrium. In this paper, the stabilization of an 83 m high natural slope was analyzed using a finite element analysis and limit equilibrium slope stability analysis. The soil-structure interaction of the used post-tensioned ground anchors and face plates was considered. The finite element analysis was able to capture the behavior of the slope before the stabilization and its performance after the stabilization. It was found that the two analyses determined similar factors of safety.

Keywords: Soil-Structure Interaction, Slope Stability, Landslides, Limit Equilibrium, Finite Element Analysis, Ground Anchors.

CHEMICAL STABILIZATION OF DISPERSIVE CLAY BY LIME AND NANO MONTMORILLONITE

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In this paper Chemical Stabilization of dispersive clay by Nano Montmorillonite is evaluated and comprised with the results of remediation by lime. The studied clay taken from residuals of a constructing dam, called "Mirzakhanloo", located in Zanjan province, northwest of Iran.

First the application of nanotechnology in the improvement of dispersive clayey soils is described. In which the concept of nanotechnology as well as the new concept of nanosol is explained.

Then the results of soil remediation by conventional lime stabilization method are described. Also the use of Nano Montmorillonite as an additive in order to reduce the dispersion potential is presented. The effects of both remediation additives on the mitigation of disperse potential evaluated in conjunction with the sidelong effects on the plasticity and resistance of soil samples.

It could be summarized that both materials have good effect on the mitigation of disperse potential, but the Nano Montmorillonite improve the plasticity characterizations of soil and also the resistance of soil with more efficiency.

USING MICROPILES TECHNIQUE AS A SETTLEMENT CONTROL TOOL IN UNDERPINNING OF LIMITED HEADROOM CASES

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Micropiles technique plays a very important role in ground improvements. This technique can be used effectively in both new and existing buildings to treat the foundation problems. Micropiles are often installed in restricted access and limited headroom situations. Micropiles are used in almost any type of ground to transfer the building loads to bearing layers. Micropiles were originally small diameter (5 to 10 cm), low-capacity piles. However, advances in drilling equipment have resulted in design load capacities in excess of 300 tons and diameters in excess of 25 cm. This research focuses on the feasibility of using this technique in the underpinning of the foundations of the existing buildings. A site located in Mansoura city, Egypt is selected for this study. This study was conducted in 2014. The Micropiles technique was used to underpinning the foundations of a building consists of a basement and twelve floors. This building was constructed in three stages through 2004 to 2012. The building has reinforced concrete raft foundation of thickness of 110 cm. the borehole log indicates a thick soft clay layer of about 5m therefore it has been removed and replaced by sandy gravel layers. The eccentric vertical loading and existence of thick clay layer caused a dramatically increasing differential settlement. Therefore fast and sudden rotation has occurred upon the completion of the construction. Micropiles were installed in a specific arrangement such that the center of gravity for vertical loads coincides with the center of resistance for both raft and Micropiles. Both settlement and rotation results were routinely recorded for ten months. The results showed that the settlement has completely stopped and the building became stable.

UN MODÈLE POUR DÉCRIRE LA VARIATION DE LA DENSITÉ DES REMBLAIS EN FONCTION DE LA HAUTEUR DE CHUTE

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Dans plusieurs cas, nous avons besoin d'estimer la variation de la densité d'un remblai (sols, grains, poudres, etc.) en fonction de la hauteur de chute de déposition, que ce soit pour le stockage des grains dans un silo, pour des conduits enfouis dans une tranchée, ou pour le remblayage d'un chantier minier souterrain. Pour la plupart des cas, le remblayage est réalisé par une méthode de déposition naturelle ou "sauvage" sans avoir un contrôle précis sur la hauteur de chute ou sur l'intensité de déposition. Un autre cas couramment rencontré pour évaluer la variation de la densité d'un remblai en fonction de la hauteur de chute est la préparation des échantillons reconstitués en laboratoire par une méthode de déposition, appelée pluviation où on a un contrôle précis sur la hauteur de chute et sur l'intensité de déposition. Les résultats expérimentaux montrent que la densité d'un remblai peut varier non seulement avec la hauteur de chute mais aussi avec l'intensité de déposition.

Jusqu'à date, les travaux antérieurs se sont consacrés sur les aspects expérimentaux. Dans cet article, un modèle est proposé pour décrire la variation de la densité d'un remblai en fonction de la hauteur de chute et de l'intensité de déposition. Les comparaisons entre les résultats mesurés et estimés montrent que le modèle proposé décrit bien la variation de la densité des remblais en fonction de la hauteur de chute de déposition.

Mots clés : Remblai; Densité; Hauteur de chute; Modèle

ESTIMATION OF THE PAST AND FUTURE INFRASTRUCTURE DAMAGE DUE THE PERMAFROST EVOLUTION PROCESSES

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All kind of geocryological condition change due to additional activity of geocryological processes. The climate warming is favorable for thermokarst and the frost heaving is linked with climate cooling. The geocryological processes such as thermokarst, frost heaving and fracturing, icing, thermal erosion are the source of immediate danger for the structures.

The economical losses during the construction procedures in the permafrost area are linked also with the other geological processes that have the specific character in cold regions. These processes are swamping, desertification, deflation, flooding, mudflows and landslides.

Linear transport structures are most vulnerable component of regional and national economy. Because the high length the transport structures have to cross the landscapes with different permafrost conditions that have the different reaction to climate change. In result the structure falls in the circumstances that are not predicted in the construction project. Local engineering problems of structure exploitation lead to global risks of sustainable development of regions.

Authors developed the database of geocryological damage cases for the last ten years in Russian territory. Spatial data have the sophisticated attributive table that was completed by using the published information from permafrost conference proceedings. The table contains the data that are organized by using the classifiers in following fields: Type of object (depending of scale of the problems), Type of geocryological process, Branch of industry, Recipient of damage, Stage of object exploitation, Period of process impact, Temporal characteristic of the process (seasonal or perennial), Type and Amount of damage, References.

The preliminary GIS-analysis of gathered data showed the widespread territorial distribution of the cases of negative consequences of geocryological processes activity.

Authors expect the expanding of database by similar data from other sectors of Arctic. It is important for analyzing the regional, time and industrial tendencies of geocryological risk evolution. Geocryological forecast will be based on the ground temperature regime models and regional models of climate evolution. Such information could be used in insurance procedures and in information systems of decisions support in different management levels.

The investigation was completed with financial support by Russian Foundation of Basic Research (Project #13-05-00462).

EXPERIMENTAL STUDY ON THE STRENGTH AND DEFORMATION OF FROZEN SILT WITH SEGREGATED ICE

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Mechanical properties of frozen soil with segregate ice differ from the integrated frozen soil because of the difference of the morphology and distribution of ice in the soil. The paper presents results from the uniaxial compressive strength testing of frozen silt with segregated ice. The frozen silt with segregated ice was prepared through controlling the temperature conditions in the laboratory. The uniaxial compressive strength tests were carried out at different temperatures (-2 to -10 °C) and different strain rates (10^{-5} to 10^{-3} s⁻¹). The stress - strain behavior, strength and failure characteristics of frozen silt with segregated ice were obtained. The strength of frozen silt with segregated ice and integrated frozen soil was also compared.

EFFECTS OF SPATIAL VARIABILITY OF SOIL PARAMETERS ON THE FRAME STRUCTURES, SSI

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One of the distinguishing features of geotechnical reliability analysis, compared to other structural reliability analysis such as concrete and steel structures is material properties are different from site to site. The sources of uncertainties in reliability analysis are usually classified in four categories, namely physical uncertainty, model uncertainty, statistical uncertainty and gross error.

The purpose of this study is to quantitatively evaluate the physical uncertainty, taking the settlement and the differential settlement prediction of circular shallow foundations on statistically homogeneous elastic ground, as an example; however, this study is extended to show the effects of the spatial variability of soil on the frame structures.

PILE BEARING CAPACITY PREDICTION CONSIDERING AIR TEMPERATURE WARMING IN COLD REGIONS

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It is well known that the pile bearing capacity will change when the air temperature is warming on the Qinghai–Tibet Plateau, but how to build the relationship between variation regularity of pile bearing capacity with air temperature warming is an urgent problem to be solved for the safety of pile engineering. In this paper, Piles in seasonal frozen and permafrost regions were categorized and corresponding pile-soil interaction model were built according to pile-soil interaction theory and pile tip buried depth. The average surface temperature during freezing and thawing periods were obtained by establishing the relationship between the air temperature and ground temperature; the relation formula of active-layer thickness and average surface temperature and permafrost thickness was set up to get the variation of active-layer thickness and permafrost thickness with time; Based on existing norms and considering different soil physical parameters, a correlation equation of air temperature and pile bearing capacity was ultimately established combined with the pile different working conditions in seasonal frozen soil and permafrost and the pile-soil interaction model with temperature which was applied to predict the pile bearing capacity with air temperature. The above method was used to the actual project to predict the pile bearing capacity. The results show that the difference between predict value and experimental value is only 2.9%, so the above methods can be applied to predict similar pile bearing capacity in cold regions on the Qinghai–Tibet Plateau.

RECENT DEVELOPMENTS IN LABORATORY FROST HEAVE TESTING OF SOILS

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This paper describes some recent advances in frost heave testing, suitable for a large scale project where several tests and freeze cycles can be carried out at the same time. Many test procedures freeze the soil too fast for practical field applications (i.e. chilled pipelines). Other shortcomings may include ignoring the side-friction component of stress, blockage of the drainage filter for water intake, inadequate permeability measurements to estimate suction at the freezing front, and only occasional water intake measurements. Each of these oversights involve a non-conservative (unsafe) assessment of the frost heave response of the soil.

Two types of end temperature control are employed, i.e. constant end temperatures and ramped (linearly decreasing) end temperatures. Each method produces a different pattern of frost penetration with time, and provides a greater range of frost heave parameters for different frost penetration rates. Clogging of the sample filter layer at the water intake end of the sample is an issue for high clay content soils, and significant improvements have been made in this area. Freezing from the sample base upwards is strongly recommended to reduce potential side friction. Side friction is further reduced by using a greased rubber membrane around the sample.

A test procedure is described that addresses and rectifies each of these issues, and a demonstration series of tests on an artificial soil is carried out. The results are presented in detail, and illustrate how the frost heave parameters required for design can be extracted from the data. The results are interpreted in terms of the Segregation Potential (SP) method, and also in terms of the Discrete Ice Lens approach.

Continuous evaluations of heave, water intake, frost depth, SP, suction and freezing rate are made using software written to accept the raw laboratory data. The method of selecting an SP value for design purposes depends on the design application, and some guidance is provided on this aspect. An alternative interpretation of the test data is also provided based on the Discrete Ice Lens method.

ASSESSING AND MONITORING THE IMPACTS OF LANDSLIDES ON PIPELINES

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Many pipelines are routed through unstable areas with large very slow moving deep-seated landslides. Typically, geotechnical assessments of these landslides characterize the movement using conventional geotechnical techniques involving subsurface assessments/monitoring and surface surveying techniques. These conventional geotechnical techniques provide a means to accurately characterize landslides but do not provide information on the landslide/pipeline interaction. In the past, soil structure interaction modeling has been used to determine impacts of landsliding on pipelines.

Many new techniques of direct measurement of localized pipe strain, pipe deformation and pipe strain have become available to quantify rather than model the impacts of landslides on pipelines. Vibrating wire/fiber optic strain gages can be installed to monitor changes in strain on pipelines. Geometry pigs can allow for the accurate measurement of the pipeline shape and spatial orientation. In the past the only direct measurement technique for determining the state of strain in a pipeline was destructive testing either with shallow pits or strain relief cut-outs. Recent experimental electro-magnetic permeability (EMP) techniques provide a non-destructive assessment of the state of strain in a pipeline either manually from the outside of a pipeline or recently using an experimental module mounted on a smart pig.

Case studies demonstrating the use of direct pipeline measurement techniques to identify, characterize and monitor the impacts of very slow moving landslides are provided.

In the future direct pipeline measurement techniques will become more refined and new ones may become available. Going forward, it is expected that a significant portion of work assessing impacts to pipelines crossing very slow moving deep seated landslides will likely favor direct pipeline measurement techniques as opposed to soil structure interaction modeling.

EVALUATION OF THERMAL PROPERTIES OF OIL SAND FLUID FINE TAILINGS

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The first end pit lake in the oil sands region has been developed by Syncrude Canada Ltd. as part of their closure design for the Mildred Lake Mine site, 40 km north of Fort McMurray. The end pit lake, referred to as Base Mine Lake, was constructed within a mined-out pit, and incorporates 186 million cubic metres of fluid fine tailings (FFT) below an 8 m water cap. The thermal regime within the water is central to establishing a sustainable lake ecosystem. Fluid fine tailings are deposited at elevated temperatures, relative to natural groundwater temperatures, and act as a heat source to the overlying lake. In order to evaluate the long-term evolution of the thermal regime within the FFT and lake water, the thermal properties of these tailings must be defined.

Samples of FFT were collected from Base Mine Lake at various depths. Water was added or removed from one sample to create multiple tailings sub-samples of varying water content, while other characteristics such as particle size distribution and bitumen content remained constant. The thermal conductivity and volumetric heat capacity of each sub-sample was measured with a KD2 Pro Probe (Decagon Devices, Inc.) to establish relationships between thermal properties and water content. This procedure was repeated on multiple samples, each with a distinct bitumen content and particle size distribution, in order to assess the effects of these additional characteristics on the thermal properties of FFT. The test results were then compared to existing theoretical relationships relating the thermal conductivity and heat capacity to water content and soil mineralogy.

CASE STUDY: A SIMPLIFIED EVALUATION OF LOAD TRANSFER FROM A MONOPOLE FOUNDATION

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This case study outlines design recommendations completed for a monopole foundation proposed within close proximity to an existing earth retention structure and a deep utility line. There were multiple loading cases for the proposed foundation, which resulted in a critical case loading on the earth retention structure at a distance of approximately three pile diameters away, and on the deep utility at a distance of approximately one pile diameter away. Boreholes advanced at the location of the proposed foundation identified existing subsurface profile consisting of gravel overlying bedrock, but minimal as-built detail for the surrounding infrastructure was available due to their age. In the absence of as-built detail for the structures, two design approaches were considered. Initially, the anticipated load transfer on each structure was evaluated for critical case loading conditions using a simplified analysis. The second design approach incorporated a means of eliminating load transfer from the monopole foundation to the surrounding infrastructure. The end result was the successful completion of a pile foundation that mitigated risk stemming from unknown design and construction details of surrounding infrastructure. The case study also provides insight on the lessons learned that could be incorporated into future projects.

CHARACTERISATION OF PHYSICAL MASS TRANSPORT THROUGH OIL SANDS FLUID FINE TAILINGS IN AN END PIT LAKE: A MULTI-TRACER STUDY

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More than thirty end pit lakes have been proposed for mine closure in the Athabasca Oil Sands region. The lakes will be constructed within mined-out pits, and many will incorporate fluid fine tailings (FFT). The feasibility of isolating the underlying FFT while establishing sustainable biological communities in the lake water has yet to be fully evaluated. Chemical constituents of concern may move from the FFT into the lake water via two key processes: (1) advective-diffusive mass transport with upward pore water flow caused by settling, dewatering and finally, consolidation of the FFT; and (2) free convection (mixing) created by wind events or unstable density profiles through the lake water and upper portion of FFT. Assessing the physical movement of constituents of concern through the system is central to determining the ability of end pit lakes in sequestering FFT, and for defining the chemistry of the water.

Synchrude Canada Ltd. has developed the first end pit lake, referred to as Base Mine Lake. Base Mine Lake contains 186 million cubic metres of FFT in a previously mined-out pit, capped with approximately 8 m of water. In September 2013, vertical thermistor strings were installed off of central platforms on Base Mine Lake to measure seasonal temperatures within the lake water and FFT. In July 2014, FFT and water samples were taken at 10 cm intervals across the FFT-water interface. The samples were analysed in the laboratory to determine the stable isotopes of water signatures through the tailings with depth.

Numerical modelling was undertaken, based on field results described above, to evaluate the various forms of heat transport (e.g. conduction; forced convection) and mass transport (e.g. diffusion; advection) within the FFT below to the lake. The thermal and mass transport models produced similar estimates of the rates of water flow (~0.004 m/day) contributing to advective mass transport (or forced convection for heat transport). However, high spatial and temporal monitoring of the temperature across the FFT-water interface suggested that mixing is present in the upper portion of FFT during overturning of the lake water during the fall. Inclusion of this mixing event within the heat and mass transport models was able to constrain the depth of mixing within the FFT. The two different models provide a similar description of the processes that control heat and mass flux, and provided initial estimates of both mass and energy loading from the FFT to Base Mine Lake water.

THE SANTANA EXPORT TERMINAL PORT ACCIDENT: COULD IT BE A SENSITIVE CLAY FLOW SLIDE UNDER THE EQUATOR?

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In March, 28, 2013, an abrupt failure involving about half million cubic meters of soil took place at an Iron Ore Export Terminal Port, situated in the city of Santana, State of Amapá, in the left margin of the mouth of the Amazon river, some 170 Km from the Atlantic Ocean. Most of the failed material flowed under water to the river channel, for a distance of about 350 meters, causing bottom elevations up to 10 meters. The soil involved in the movement was dark grey soft and very soft organic clayey silt. The failure caused six casualties and the complete interruption of the iron export operation.

After failure, aiming at understanding the cause(s) of the accident, geological, hydraulic and geotechnical studies have been carried out, including a comprehensive site and laboratory geotechnical testing program.

This paper is the first publication after failure and intends to present:

- the basic sequence and mechanism that characterized the failure, based on eye witnesses and comparisons of before and after topography and bathymetry;
- the typical geotechnical sections and soil parameters;
- the main results of backanalyses of the movement such as viscous flow and limit equilibrium;

As for the cause of failure, no evidence has been found of river erosion and there was no dredging in the area. The region is free from relevant earthquakes. No loads apart from small operational loads have been applied to the lower area of the Terminal that came to fail. The iron ore was stockpiled in the upper areas (patios) in which the terrain is constituted by hard soils, which did not participate in the movement. It is believed, by exclusion, that the best explanation for the failure is progressive loss of strength induced by tidal cyclic loading. The river level in the Amazon mouth area is dictated by the Atlantic Ocean: it oscillates twice a day with amplitudes around 3 meters.

The flow that followed failure, in a behavior similar to quick clays, is unheard of in the Amazon mouth region and, in fact, does not seem to have precedents anywhere in soft fine soil deposits anywhere in the Brazilian coast or any other tropical climate areas.

IMPACTS OF SNOW COVER ON THE PERMAFROST IN QINGHAI-TIBET PLATEAU BASED ON THE FIELD OBSERVATION AND SIMULATION

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Using the observational data of the real-time snow depth obtained by ultrasonic snow depth sensor SR-50 at two comprehensive monitoring sites in permafrost regions on Qinghai-Xizang Plateau, belong to Cryosphere Research Station on the Qinghai- Xizang Plateau, characteristics of surface snow cover was introduced and analyzed. The results indicate that surface snow cover appeared in each month throughout the year in permafrost regions on the Qinghai-Xizang Plateau. The snow covered days mainly concentrated in the winter half year. Overall the snow depth on the Qinghai-Xizang Plateau is much thinner compared with that of high latitude regions, and the duration of snow cover is much shorter. In 2005 to 2008, the instantaneous maximum snow depth of the region was 22 cm, and the days with daily mean snow depth below 5cm occupied most. Furthermore, we discussed the impacts of surface snow cover on soil temperature, moisture and surface energy allocation under different snow depth conditions through simulation results of land surface model.

EFFECT OF INITIAL SHEAR STRESS DIRECTION AND OVERCONSOLIDATION ON THE RESPONSE OF SAND UNDER MONOTONIC LOADS

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The behaviour of granular materials is direction dependent due to inherent and induced anisotropy. Hence, yielding and plastic flow of granular materials will also depend on the rotation of principal stress axis during loading. The commonly available triaxial device can also be used to explore the effects of a specific case of stress rotation. Under monotonic loading condition this rotation of the direction of the principal stresses would just occur once and it will only be a jump rotation of 90°. A series of triaxial compression and extension tests have been performed to study the effect of this jump rotation on sands consolidated to different states. Samples consolidated anisotropically to a constant mean confining stress of 100 kPa but at different ratios of vertical to horizontal effective stress, $k_c = (\sigma'_{vc}) / (\sigma'_{hc})$ ranging from 0.5 to 2.0 were sheared monotonically in this research program. The range of k_c values used allows the simulation of static shear stresses in both directions on the 45° plane, and permits an evaluation of the effects of jump rotation of principal stresses during subsequent shearing.

In addition to the effect of the direction of the initial shear stress, the effect of overconsolidation on the response of Fraser River sand to the static loading is also studied. Samples of Fraser River sand were prepared at the maximum attainable void ratio using water pluviation technique. Specimens were then consolidated to maximum mean effective stress values of 100, 125, 150, and 200 kPa and then unloaded to the mean effective stress level of 100 kPa to yield specimens at overconsolidation ratios (OCR) of 1.25, 1.5, and 2.00 (in addition to the normally consolidated specimen). Both normally consolidated and overconsolidated samples were consolidated isotropically and anisotropically to further investigate the combined effect of overconsolidation and stress rotation.

These tests provide an insight into the combined effects of initial stress direction, principal stress rotation and loading mode, and enable a more comprehensive understanding of sand behaviour under monotonic loads. Test results indicate a clear dependency of the monotonic response (at a given OCR) on the initial anisotropic consolidation state and stress rotation. While overconsolidation increases the tendency for dilation compared to normally consolidated, the response is mainly controlled by the direction of the initial shear stress and the loading mode.

COMPARISON OF MINING-INDUCED SEISMICITY WITHIN A FOOTWALL FAULT BETWEEN OVERHAND AND UNDERHAND STOPING METHODS

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The behaviour of faults in underground mines has been attracting much attention from rock mechanics and geophysics specialists, as mining-induced fault-slip can cause devastating damage to mine openings. In this study, a comparison between overhand and underhand sublevel stoping methods is made whilst focusing on the static and dynamic behaviour of a footwall fault intersecting with a 1500 m deep, steeply dipping orebody. A mine-wide numerical model is constructed, in which the geological structures and the orebody are modelled. First, static analyses are performed to extract stopes in the orebody. The stope extraction is carried out in accordance with mining sequences as per the two mining methods. Based on relative shear displacements taking place on the fault during the stope extraction, seismic moment is computed. It is found from the result that the stope extraction with the underhand mining method produces more seismically active conditions on the fault, compared to the overhand method. When the orebody is extracted with the overhand stoping method, cumulative seismic moment is 2.14×10^{12} N·m, while cumulative seismic moment is 3.91×10^{12} N·m when the underhand stoping method is employed. Interestingly, seismicity occurring during the mining sequence with the underhand method is lesser active, compared to the overhand mining method, until the first six levels are mined out. However, seismic activity drastically increases thereafter. In addition to the static behaviour of the fault, its dynamic behaviour is investigated based on the stress states after extracting all the stopes with the two mining methods. Fault-slip is simulated with an instantaneous change of the friction law from static to dynamic. The analysis result shows that the maximum near-field peak particle velocity induced by seismic waves arising from the fault-slip is up to 2.6 m/s and 2.4 m/s for the underhand and overhand mining methods, respectively. It indicates that there is no significant difference in the intensity of near-field ground motion between fault-slips induced by the stope extraction with the two mining methods. Based on these results, it can be concluded that when a steeply dipping orebody intersects with a footwall fault, mining-induced seismicity due to fault slip will most likely take place regardless of the mining direction. The decision between overhand and underhand sublevel stoping methods should be based on other equally important factors such as state of stress around the stopes leading to potential strainburst and volume of remaining ore at risk.

EVALUATION OF THE STRESS DISTRIBUTION IN INCLINED BACKFILLED STOPES

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Backfilling is commonly used in underground mine operations around the world. Adding backfill in mine stopes improves ground stability and helps reducing the volume of solid wastes disposed on the surface. To ensure the safe use of backfill, practical tools are required to assess the stress distribution in the stopes, on the surrounding rock mass, and on support structures. Backfills are generally much less stiff than the rock mass. After their deposition in the underground stope, the self-weight settlements of the fill material generate shear stresses along the rough walls of the opening. Such frictional stresses act to transfer some of over burden pressures to the rock mass, causing an arching effect.

The majority of existing analytical solutions for the stresses in backfilled stopes have been developed for vertical openings. In reality, stopes often have inclined walls. In inclined stopes, the shear stresses developing along the walls is not the same on each side of the opening. Because of this, the arching effect related to the stress transfer between the soft fill and stiff rock mass is typically less well developed in inclined stopes.

In this paper, numerical results will be presented to illustrate the interaction between the backfill and rock mass in inclined stopes. The influence of strength parameters of the backfill and stope geometry (in terms of height, width and inclination) will also be examined using numerical simulations. These results are then used to develop and validate a new semi-analytical solution for the stress distribution in backfill placed in inclined openings.

CONSTRUCTION OF DRILLING PADS ON TOP OF PEAT IN OIL SAND DEVELOPMENT PROJECTS IN NORTHERN ALBERTA

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Construction of drilling pads on top of organic soils in oil sand development projects in Northern Alberta is a big challenge for geotechnical engineers. The continuous settlement of the organic soil over time and the relatively high loads of the drilling instruments are important aspects of the geotechnical analysis. In this paper, the construction of a drilling pad on top of a four meter thick medium decayed peat underlain by soft lacustrine clay is studied. Different engineering solutions including use of timber mats, geogrids and wick drains and preloading are considered to improve the bearing capacity of the ground. Both numerical and analytical solutions are considered for the proposed scenarios and the required construction times and final settlements are compared. The most important aspect of the behavior of the organic soil which is nonlinearity is considered by modifying the geotechnical parameters of the ground with both time and strain level. The results of the analysis show that a combination of different engineering solutions would be the most economical way to construct the pad.

ASSESSMENT OF DIFFERENT TREATMENT METHODS OF MICROBIAL-INDUCED CALCITE PRECIPITATION FOR CLAYEY SOIL IMPROVEMENTLiang Cheng (1), Mohamed Shahin (2)*(1) Murdoch University (Perth, Australia); (2) Curtin University (Perth, Australia)*

Microbial-induced calcite precipitation (MICP) for soil treatment is of particular interest to engineers as a method to alter and improve soil characteristics. MICP utilises the metabolic pathway of ureolytic bacteria to form calcium carbonate (CaCO_3) precipitation throughout the soil matrix, leading to increased soil strength and stiffness. MICP proved to be an efficient technique for treatment of clean sand; however, research into the use of MICP for treatment of clayey soils is lacking. This paper assesses three different MICP treatment methods for clayey sand containing up to 20% clay content. The methods evaluated include the injection method (i.e. traditional sequential injection of bacteria and cementation solution), premixing method (i.e. premixing of bacteria followed by injection of cementation solution), and diffusion method (i.e. premixing of bacteria followed by diffusion of cementation solution). The results indicate that the injection method was only applicable to sand columns of clay content < 5%, resulting in an exponential relationship between the unconfined compressive strength (UCS) and calcite content similar to the pure sand samples. For sand columns with clay content > 5%, a poor infiltration of bacterial cells and a crust layer formation around the inlet was observed. Premixing method allowed a homogeneous placement of bacteria cells in the clayey sand columns. The subsequent injection of cementation solution under low pressure of 100 kPa enabled an adequate bio-cementation along the specimens, resulting in up to 150% increase in the UCS values. However, for sand columns with clay content > 10% and low hydraulic conductivity, the cementation solution was drastically consumed before reaching the lower part of the sand columns. The results also show that sand columns with 20% clay content can be treated using the diffusion method, with UCS increased by up to 200% depending on duration of treatment. The overall conclusion of this study is that bio-cementation of clayey soil is a tremendous challenge and requires further investigation on the ureolytic bacteria placement and supply of cementation solution at large scale before field application.

CHANGES OF SOIL THERMAL AND HYDRAULIC REGIME IN PERMAFROST REGIONS OVER NORTHERN HEMISPHERE LANDMASS IN 21ST CENTURY

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Soil moisture (SM), snow cover and temperature are crucial factors for soil thermal and hydraulic regime in permafrost regions. In this paper the contribution of SM, snow and temperature to changes in activity layer thickness (ALT) over permafrost regions are analyzed during the early (2016-2035, EP), middle (2046-2065, MP) and late (2080-2099, LP) period of the 21st century in the Northern Hemisphere (NH) landmass with global climate modes, which are from the Couple Model intercomparison Project Phase 5 (CMIP5). With relatively real SM, the permafrost extent are estimated by the Kudryavtsev's model during 1986-2005 is 16.71×10^6 km², which well agrees with the observation from the International Permafrost Association (16.23×10^6 km²), furthermore, the importance of SM in the estimation for permafrost extent is discussed. The results show that the relation between ALT and SM, snow depth (SND) and mean annual air temperature (MAAT) varies with regions and periods. Observed results show that MAAT and SM significantly contributes to ALT over the TP, snow cover and MAAT have well relation with ALT in Europe during 1986-2005, however, relative to the reference period 1986-2005, the relative contribution of snow and SM gradually declines with the increase of temperature during the EP, MP and LP of 21st century. MAAT, Snow cover and SM in the thermal and hydraulic regime over the TP, Europe and NA show different role. For the high emission (RCP8.5), MAAT plays a dominate role in ALT over the TP and NA, however, snow cover effects will be enhanced under low-middle emissions (RCP2.6 and 4.5), this illustrates the difference of thermal and hydraulic regime of permafrost between middle and high latitude. The snow cover has strong effects in permafrost in Europe, however, this effect only occurs under low RCP, with temperature increasing, the importance of SM and SND alternates changes under the low and middle emission, and gradually declines for high emission (RCP8.5). In general, MAAT is the main contributor to ALT in 21st century, while the impact of SM and snow gradually declines, with the temperature increasing.

INITIAL MONITORING OF AN INSTRUMENTED TEST SECTION ALONG THE INUVIK-TUKTOYAKTUK HIGHWAY

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There is uncertainty in the mechanical behaviour of embankments that were initially constructed with frozen fill and then experienced natural thawing during the summer following construction. Side-slope sloughing and fill cracking can occur because of localized thaw settlements under the shoulders and side slopes of the embankment. Two instrumented test sections were constructed side by side along the Inuvik-Tuktoyaktuk highway and are being continuously monitored after its construction to address these uncertainties. This paper presents the initial monitoring recorded from the completion of the test sections until the first thawing season. Test Section A, the control section, is the unreinforced slope section conforming to the original design of the embankment. Test Section B is the reinforced slope section with geotextile layers at the slope acting as its reinforcement. Section A and Section B are both instrumented with thermistors for temperature readings, ShapeAccelArrays (SAAs) for the vertical and lateral displacements, vibrating wire piezometers for porewater pressures, and tensiometers for suctions. Strain gauges were also installed in the geotextile reinforcements for Section B.

A PRACTICAL CONSTITUTIVE MODEL FOR SANDS

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This paper will focus on the typical behavior of granular materials under monotonic loads and presents a constitutive model that is simple yet practical for engineering application. The behavior of granular materials, more specifically sands, is usually studied under triaxial stress state in drained and undrained conditions. Under drained triaxial setup, in loose sands an increase in deviatoric strain is associated with hardening and progressive compaction; as the deviatoric stress increases and stress state approaches the failure condition the volume change tends to zero. Dense sands show similar hardening behavior up to a peak point or failure which is typically associated with formation of shear band and strains-softening behavior. In dense sands at the initial stage of deformation process the material undergoes compaction, and then at some point a transition from compaction to dilation occurs. The behavior under undrained condition typically is such that the compaction and dilation in drained condition are equivalent to generation of positive and negative pore pressure in the sample. The generation of excess pore water pressure in very loose sands might lead to liquefaction of the material. Because of the generation of negative pore water pressure, very dense sands can endure high levels of deviatoric stress.

The most common constitutive model in geotechnical engineering practice is the Mohr-Coulomb model. On top of the elastic properties to define this model one needs to input three additional material properties, i.e. cohesion friction and dilation angles. The evaluation of these parameters, especially the friction angle and cohesion, is common practice. The proposed constitutive model in this paper is based on Mohr-Coulomb model with only one additional parameter and a new definition for the plastic flow.

The applicability of the model is demonstrated by simulations of triaxial tests, and various model tests [1] including strip foundation and tunnels with and without nearby surface load. To further investigate the practicality of the model for engineering practices a well-documented benchmark problem that has been simulated by other researchers and commercialized geotechnical software, has been analyzed with the proposed model and a comparison between the numerical results and field observation is presented.

[1] "Constitutive modeling of geomaterials; principles and applications", Teruo Nakai, CRC Press, 2013.

THE GROUND THERMAL REGIME ACROSS THE MACKENZIE VALLEY CORRIDOR, NORTHWEST TERRITORIES CANADA

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In 2006-07, the Geological Survey of Canada installed temperature cables in about 50 boreholes in the Mackenzie Valley to enhance an existing monitoring network and provide baseline permafrost information. Ground temperature data collected from the network of over 70 boreholes, enabled the development of a snapshot of permafrost thermal state from the Arctic Coast of NWT to northern Alberta. The snapshot provides a baseline against which future change in ground thermal conditions can be measured and provides essential information to support land use planning decisions in the region.

Temperature at the depth of Zero Annual Amplitude (ZAA) at permafrost sites ranges from close to zero to about -2°C in the discontinuous permafrost zone while temperatures in the continuous zone are below -4°C . Mean ground temperature at ZAA can vary a great deal over short distances, particularly in the northern portion of the discontinuous zone, and is greatly affected by site factors. The depth of ZAA ranges from < 5 m to about 20 m in the valley. Where permafrost is ice-rich and temperatures are close to zero, the depth of ZAA is shallow due to the significant latent heat effects and the low apparent thermal diffusivity. For coarser grained material of lower ice and moisture content, latent heat effects are lower at temperatures close to 0°C resulting in higher apparent thermal diffusivity and greater depth of ZAA. In colder permafrost however, the depth of ZAA is generally deeper than 10 m and can be greater than 20 m for sites in granular, ice-poor sediments or bedrock locations. Under these conditions, latent heat effects are minimal and apparent thermal diffusivity is greater, resulting in greater penetration of the annual temperature wave. Where unfrozen conditions exist, depths of ZAA are generally greater than 10 m. Apparent thermal diffusivity is an order of magnitude greater for colder permafrost at temperatures below -2°C (on the order of 10^{-6} m^2s^{-1}) compared to warmer permafrost for which the apparent thermal diffusivity is typically 10^{-8} to 10^{-7} m^2s^{-1} .

Comparison of temperatures measured in 2012-14 to those in the 2007-09 baseline indicates negligible change in ground temperature especially in the discontinuous zone. Longer term records indicate a general warming of permafrost since the 1980s with a lower rate of temperature increase since 2000.

DYKE DESIGN IN COMPLEX GEOTECHNICAL AND GEOTHERMAL CONDITIONS AT THE GAHCHO KUÉ PROJECT

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As part of the development of the Gahcho Kué Project in the Northwest Territories, a total of 14 dykes are required to access the Kimberlite pipe, manage the site water during the life of mine, and achieve the controlled area boundary at the project site. All of the proposed dykes are planned for construction on difficult and variable permafrost terrain. The focus of this paper is on the characterization of the geotechnical and geothermal conditions across the project area and the associated dyke designs.

Surficial geology mapping, geophysical surveys, borehole drilling and field and laboratory tests were performed to provide a detailed understanding of the subsurface conditions. As part of the site investigation program, 18 multi-bead ground temperature cables were installed in the boreholes across the project area to understand the ground thermal regime.

The climate of the project area is classified as sub-arctic and lies along an approximate boundary between continuous and widespread discontinuous permafrost. The project area lies on the Slave Craton of the Canadian Precambrian Shield and was glaciated repeatedly during the Pleistocene. The area is predominantly underlain by medium-coarse grained granite to highly foliated granitic gneiss. The overburden materials in the project area appear to have been deposited in the late Wisconsin Glaciation and primarily consist of glacial till, glaciolacustrine, glaciofluvial, and esker deposits.

Permafrost extends over most of the on-land area of the project site, except beneath lakes with depths greater than one meter where taliks (i.e., year-round unfrozen soils/bedrock) may be encountered. Most of the project area includes glacial veneer and blanket with the mean annual permafrost temperatures between -0.5°C to -3.5°C . The maximum thickness of the active layer (3.7 to 4.0 m) was estimated to occur in exposed bedrock areas.

The focus of this paper is on four dykes that are lined with a key trench design concept that uses a geosynthetic liner system as the primary containment barrier. The principal function of these dykes and associated ancillary structures is to retain site runoff and pit water before it is released to the surrounding environment or segregate different areas within the main lake body. The results of engineering analyses are presented to support the integrity of the design concept for these dykes along with key construction issues that were considered during the planning stage.

CRYOGENIC BLOCK STREAMS: CHARACTERISTICS AND CLASSIFICATION.

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Cryogenic block streams consist of a stream of rocks in permafrost areas resembling a stream deposit, usually on valley or gully floors or on slopes less steep than the maximum angle of rest of coarse sediments. There are two main kinds forming today, viz., active block streams and lag block streams. The blocks in active block streams move down slope at up to 1.2 m/a. They are common on the Tibetan Plateau and in the more arid parts of Siberia, but the processes forming them are different. The Tibetan type moves by the individual blocks sliding down slope on an icy coating in areas of very low winter precipitation. The diode effect operates even under a thin covering of stones. The Siberian type is found in areas with a 15-80 cm deep snow-pack and an MAAT of -4 to -17 degrees C. In this environment, the movement is due to creep of snow and ice and collapsing of the rocks down slope during thawing. The diode effect is muted or absent beneath this type of block stream. The blocks in lag block streams are stationary and the interstitial sediment is gradually washed away by flowing water in spring or after heavy rain storms. They occur in cold, semiarid mountains such as the Chinese Tien Shan. The blocks in active lag block streams are considerably less angular than the angular-sub-angular blocks moving down slope in active block streams.

Both types of block streams are known as relict sediments in older deposits under various climatic regimes that are unsuitable to sustain their development. An example of a relict lag block stream is found at Felsen, Germany. The term "felsenmeer" originated there. The large rounded to sub-rounded boulders occur as streams filling valley floors on the forested mountainsides. Similar examples occur near Vitosha, Bulgaria, as well as in the United States. Some are more angular, including the stone runs in the Falkland Islands. They often have a complex history. In both Tasmania and the Falkland Islands, evidence of former tropical weathering producing core stones in residual clays has been found beneath the veneer of block streams. Sometimes the surface of the relict block stream is rough and sometimes it is flat. Block streams are also found overlain by cold-based till in Sweden.

DRILLED SHAFT PILE TIP RESPONSE IN GLACIAL TILL SOILS – COMPARISON BETWEEN CONVENTIONAL AND CFA METHOD

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The load-settlement behavior of four drilled shafts (also called cast-in-place concrete or bored pile) was analyzed based on pile load test results. Three of the test piles were constructed using continuous flight auger (CFA) method, also known as augercast piles and the remaining test pile was constructed using conventional drilled method. All of the piles were founded on similar soil conditions. The soil conditions where pile load tests were carried out is typical of glacial till encountered in the Canadian Prairies. The unit end bearing capacity of each test pile was predicted using the current drilled shaft foundation design procedures recommended in two commonly used North American foundation engineering manuals. The load-settlement behavior of drilled shaft widely varied between CFA and conventionally drilled method of installation and pile end bearing capacity is significantly lower for pile installed by conventional drilled method.

SEISMIC MICROZONATION OF EL-FAYOUM NEW CITY, EGYPT

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Seismic micro hazard zonation for urban areas is the first step towards a seismic risk analysis and mitigation strategy. Essential here is to obtain a proper understanding of the local subsurface conditions and to evaluate ground shaking effects. In the present study, an attempt has been made to evaluate the seismic hazard considering local site effects by carrying out detailed geotechnical and geophysical site characterization in El-Fayoum New City. Seismic hazard analysis and microzonation of El-Fayoum New City are addressed in three parts: in the first part, estimation of seismic hazard is done using seismotectonic and geological information. Second part deals with site characterization using geotechnical and shallow geophysical techniques. In the last part, local site effects are assessed by carrying out one-dimensional (1-D) ground response analysis using equivalent linear method by program SHAKE 2000. Finally microzonation maps have been prepared. The detailed methodology, along with experimental details, collected data, results and maps are presented in this paper.

DIFFERENTIAL SETTLEMENT OF DEEP FOUNDATIONS

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Current foundation design practice for serviceability limit states involves proportioning the foundation to ensure, to some probability, that the foundation settlement is less than some target maximum settlement. However, it is usually differential settlement which leads to problems in the supported structure. The design question, then, is how should the target maximum settlement of an individual foundation be selected to ensure that differential settlement is not excessive? Evidently, if the target maximum settlement is increased, the differential settlement between foundations will also tend to increase, so that there is a relationship between the two, but not a simple relationship. This paper investigates how the target maximum settlement specified in the design of an individual foundation, given a design algorithm, relates to the distribution of the differential settlement between two identical foundation elements, as a function of the ground statistics and the distance between the two foundations. A probabilistic theory is developed, and validated by simulation, which can be used to prescribe target maximum settlements employed in the design process to avoid excessive differential settlements to some acceptable probability.

INTEGRATED GEOTECHNICAL AND GEOPHYSICAL ASSESSMENT OF CLIMATE EFFECTS ON RAILWAY EARTHWORK STABILITY

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Many parts of the UK's rail network were constructed in the mid-19th century long before the advent of modern construction standards. Historic levels of low investment, poor maintenance strategies and the deleterious effects of climate change have resulted in critical elements of the rail network being at significant risk of failure. A recent study conducted by Network Rail, who own the largest network of earth structures in the UK, has revealed that 50% (or 5000km) of their network of earthworks are considered to be in a "poor" or "marginal" condition thereby necessitating regular and expensive maintenance. The majority of failures which have occurred over recent years have been triggered by extreme weather events.

Advance assessment and remediation of earthworks is, however, significantly less costly than dealing with failures reactively. It is therefore crucial that appropriate approaches for assessment of the stability of earthworks are developed, so that repair work can be better targeted and failures avoided wherever possible. This paper discusses the combined use of geophysical and geotechnical methods for assessing the stability of railway earthworks. Calibration of non-invasive geophysical measurements, such as Electrical Resistivity Tomography (ERT) and Multichannel Analysis of Surface Waves (MASW), with climate and geotechnical measurements monitored on a test site in Gloucestershire, England has revealed the potential use of these approaches for assessment of climate effects on railway earthwork stability.

MODELING THE PERFORMANCE OF A HIGHWAY EMBANKMENT FAILURE RECONSTRUCTED USING LIGHTWEIGHT TIRE DERIVED AGGREGATE (TDA) OVER A SOFT MARINE CLAY: A CASE STUDY

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A large embankment failure occurred during construction of a four-lane divided highway in southern New Brunswick, Canada. The highway embankment was approximately 12 m in height when it failed, just short of the target 14 m. The cause of the failure was attributed to the rapid rate of embankment construction and the intensity of loading on the 15 m thick layer of soft marine clay foundation. Several repair options were explored to reconstruct the embankment ranging from soil improvement methods of the foundation to reconstruction of the embankment using lightweight fill over the failed marine clay. The lightweight fill option was ultimately selected and the highway embankment was successfully reconstructed and opened to the public.

The lightweight fill embankment reconstruction process included the installation of pre-fabricated vertical drains (PVDs) through the marine clay foundation and reconstruction of the embankment using Tire Derived Aggregate (TDA) from 1.4 million tires. Geotechnical instrumentation was installed throughout the embankment reconstruction process to allow the "observational approach" to be adopted, which was considered to be of the utmost importance due to the many unknowns and uncertainty. The geotechnical instrumentation included vibrating wire piezometers in the foundation clay, total stress cells, slope inclinometers, temperature probes, settlement plates and settlement pins in the asphalt surface.

The fully instrumented prototype embankment described in this case study was monitored on an on-going basis during and after the embankment reconstruction process over a period of 28 mos. A description of the design of the lightweight fill embankment and the results of the performance monitoring is presented in this paper. This paper also provides the results of our numerical modeling and compares the results to the measured performance parameters over various stages of the reconstruction process.

INNOVATIVE DEEP FOUNDATION SUPPORT USING DUCTILE IRON PILES

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Working in urban environments presents unique logistical challenges beyond those typically associated with traditional geotechnical analysis and design. These challenges often include constrained sites with limited access, vibration concerns for adjacent structures and working from variable grades or in excavations. For decades, European engineers and contractors have used specially-manufactured Ductile Iron Piles to provide reliable and cost-effective foundation support to help address these issues as an alternative to more traditional deep foundation systems. While the system has historically been used only sporadically in a few local North American markets, the economic, technical and construction benefits are now being realized on a more wide-spread basis in the U.S. and Canada.

Pre-fabricated Ductile Iron Piles are manufactured using a centrifugal-casting process to produce the ductile iron pipe sections with high strength and superior impact resistance for drivability. The piles employ a proprietary Plug & Drive spigot and socket connection system that ensures rapid pile connections in the field and easily allows for variable pile lengths without additional equipment or splicing. Ductile Iron Piles are installed using an excavator-mounted hydraulic hammer fitted with a special drive adapter that advances the pile into the ground using a combination of excavator crowd force and the percussive energy from the hammer. This allows the system to be used in constrained, urban sites with limited clearance where material laydown and access often present practical construction challenges.

Ductile Iron Piles resist a combination of compression and tension loading demands through either end-bearing or frictional resistance. End-bearing piles are installed by driving the interlocking-sections to refusal on rock or "set" on a competent bearing layer. Friction piles are installed by driving the pile sections with a patented enlarged grout tip while continually pumping sand-cement grout to form a micropile-type system. Installation proceeds into a bearing layer where a bond zone is constructed to resist the applied compression loads. The addition of a central threaded reinforcing bar is used to also provide additional tension resistance with the system.

This paper describes the construction, design and quality control details including load testing of the Ductile Iron Pile system. Project applications and system benefits are also described. The paper presents practical examples of North American projects where the system provided economic, construction and technical advantages. The paper details an innovative foundation alternative to traditional micropiles and other deep foundation systems.

EFFECT OF CORROSION ON THE SOIL STRUCTURE INTERACTION OF STEEL CULVERTS

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Effect of corrosion on the soil structure interaction of steel culverts

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ABSTRACT

Adequate long-term performance of buried culvert structures depends in part on the durability of steel in service. In some cases, culverts may experience degradation when exposed to chloride contaminated groundwater. This paper uses a comprehensive 3 dimensional finite element model to examine the influence of corrosion on the stability of corrugated steel culverts. The geometrical and material details of the backfill, as well as the construction process, culvert geometry, and earth and vehicle loads were considered in the model. The corrosion was simulated using a non-linear finite element (FE) model that accounts for soil-structure interaction and the nonlinear stress-strain response of the soil and steel. The nonlinear FE model was used to calculate radial stresses in culverts with local corroded areas and that are subject to standard truck loads. Based on the results of the analyses, a preliminary guidance on the tolerable limits of culvert corrosion was proposed.

KEYWORDS: steel culverts, soil-structure interaction, corrosion, numerical modelling, truck loads.

SUBSURFACE MODELING AND BIM

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Large infrastructure projects, ever increasing stringent geotechnical and geoenvironmental regulations, and sustainable design initiatives dictate an interdisciplinary approach in design, maintenance and operation of infrastructure objects including geoenvironmental and civil engineering structures.

Large amount of data that must be collected, analyzed, processed, reported, coordinated and interchanged among various stakeholders. Management of subsurface data is discussed and evaluated in this presentation with emphasis on modeling subsurface strata.

The paper evaluates how subsurface database management fits into or complements the traditional procedures and practices in geoenvironmental engineering and enable easier interoperability with other engineering disciplines. The presentation reveals how subsurface data, when properly managed in geoenvironmental database can be easily turned into information and supplied to engineers in various disciplines in a desirable form that can be easily interpreted. While managing and modeling subsurface data consists of many aspects, in this presentation an emphasis is placed on modeling of subsurface strata, Building Information Modeling (BIM) and interdisciplinary approach. For subsurface strata modeling Kriging and Minimum Curvature are briefly introduced.

In geostatistics, Kriging or Gaussian process regression is a method of interpolation for which the interpolated values are modeled by a Gaussian process. Kriging gives the best linear unbiased prediction of the intermediate values. Interpolating methods based on other criteria such as smoothness need not yield the most likely intermediate values. The method is widely used in the domain of spatial analysis and computer experiments.

Minimum Curvature method is largely used in the earth sciences. Minimum Curvature generates the smoothest possible surface while attempting to honor source data as closely as possible. However source data is not always honored exactly. Minimum Curvature produces a grid by repeatedly applying an equation over the grid in an attempt to smooth the grid.

NEW APPROACH IN REMEDIATION OF CONTAMINATED SEDIMENTS IN SHALLOW HARBOURS

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Harbour areas, particularly on the bank of large rivers, have been facing deposition of sediments. Moreover, significant amounts of pollutants are received at these areas from land and river and most of them are adsorbed by sediment. Therefore, shallowness and accumulation of contaminants in harbour areas become the challenging issue.

Because of the concentration of pollutants in sediments, ex-situ remediation after dredging is until now the only viable option and in-situ techniques are mainly used to reduce the mobility of the contaminants. Moreover, conventional in-situ methods are not applicable for shallow harbours as they enlarge the shallowness. Ex-situ techniques also require dredging, which is costly and can increase the risk of mobility and availability of pollutants. Alternatively resuspension of sediment is introduced to address these issues.

The resuspension technique is a new approach to remediate contaminated sediments in shallow area. The concept of this method is that finer sediments (i.e. clay and silt) have more tendency to adsorb the contamination. Due to the high specific surface adsorption and ionic attraction, finer sediments carry higher concentrations of pollution. In the resuspension process, those particles are targeted for removal. Subsequently, the concentrations of contaminants will be reduced and quality of the remaining sediment will be improved. This study evaluated the capability of resuspension technique for remediation of contaminated sediment samples, mainly polluted by heavy metals. Sediment samples were taken from a harbour in St. Lawrence River, Qc, Canada.

Based on the particle size analysis results as well as the concentrations of heavy metals in suspended sediments, finer particles (i.e. about 26 percent of the sediment lower sizes) were 50 percent more contaminated than the bulk sediment samples on average. The resuspension method was successful for reducing the concentration of eight selected heavy metals in sediment samples by more than 20% on average, while the quality of water did not change drastically. Short-time resuspension of contaminated sediment in a confined column not only enhanced the quality of sediments, but it also improved oxidation-reduction potential and dissolved oxygen after 48 hours of the test. This method is more simple and cost effective than ex-situ methods since dredging the sediment from the whole area is not required. Moreover, money and time can be saved on transportation of contaminated sediments to the secure landfill due to the lower volumes.

LABORATORY AND NUMERICAL STUDY OF PROPAGATION OF PORE PRESSURE CHANGES WITHIN CLAY

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Time lag is one of the significant factors characterizing pore pressure measurement in clay layers. For a given pore pressure measurement device, permeability and compressibility of the porous media control the measuring system response time. For low permeability materials like clay and sand-bentonite mixes, standpipe piezometers require several weeks or months to reach equilibrium. Although modern piezometers with diaphragm transducers are designed to reduce the response time, this type of transducer may also have a significant time lag within compressible clay layers because of the slow propagation of pore pressure changes. At a given time, when the external load is changed, the measured pore pressure is never equal to the actual pore pressure due to the delayed response. Failure to take into account the time lag can have an impact on the monitoring of field performance. For example, a neglected time lag may lead to erroneous interpretation regarding pore pressure dissipation in a clay layer beneath an embankment.

This paper looks at the propagation of pore pressure changes in low permeability materials. The paper first describes laboratory tests that were conducted to evaluate the propagation of pore pressure changes in undisturbed Champlain clay samples and in low permeability sand-bentonite mixes. The sand-bentonite mixes were made by mixing respectively 10 and 15 weight percent of bentonite with a uniform sand with a median diameter of 0.33 mm. The laboratory tests were carried out on cylindrical samples by applying a pore pressure change at one end of the sample and by measuring the pore pressure equalization at the other end.

The paper also presents some results for a finite element analysis of the propagation of pore pressure waves in materials with a low permeability. The mechanical and hydraulic properties of the Champlain clay and artificially made sand-bentonite mixes which are required for the numerical simulation were obtained with triaxial permeability tests and oedometer tests. In the numerical simulations, the linear elastic and modified Cam clay models were used to model the relationship between effective stress and deformation.

USE OF HELICAL TIEBACK ANCHORS FOR PERMANENT SHORING AND SLOPE STABILIZATION FOR A BEACHFRONT RESIDENCE IN DELTA, BC (CANADA)

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A case study involving foundations, shoring works and slope stabilization associated with the construction of a new beachfront residence at Delta, BC is presented. Particular challenges faced on this project include potential distress issues of the slope following the demolition of the existing house, the complex geomorphology of the site area characterized by a very steep slope, difficult access to the site and stringent municipal regulations which limited the choice of construction technologies for both foundations and the retaining wall.

In order to reach the foundation level along one of the construction gridlines, a shoring system was required. Shoring of the excavation was completed using helical tieback anchors and reinforced shotcrete facing. Stabilizing effects of both helical tiebacks and helical piles installed along the foundations of the new structures were required for the stability of the shoring wall and the slope at its final configuration. The solution was verified through applications of limit equilibrium methods. A soil/structure interaction analysis was also attempted in order to estimate movements of the structures and estimate, via the phi-c strength reduction method, the potential failure mechanism of the slope and retaining wall at their final configurations. However, major uncertainties about the in-situ stress state in the soil due to the load/unload history of the soils and occurrence of slope distresses prior to construction diminished the confidence on the validity of the results.

Construction of the shotcrete retaining wall and screw piles tie-backs has proven successful for the completion of the project in a zone previously subjected to local slope stability issues. No considerations were given to the global stability of the surrounding area which presents its own stability problems and has been constantly monitored in recent years.

NUMERICAL STUDY ON THE THERMAL CHARACTERISTICS OF MULTIPLE-LANE VENTILATION-DUCT EMBANKMENT FOR EXPRESSWAY IN PERMAFROST REGIONS

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For the application of ventilation duct in multiple-lane embankment for expressway in permafrost regions, embankment height, duct diameter, longitudinal duct spacing and mean annual ground temperature (MAGT) are main parameters. To investigate the impact of these parameters on the thermal characteristics of permafrost embankment, numerical models were established for embankment with/without ventilation duct. Up to 18 study cases were designed with embankment height changing from 1.0m to 4.0m, duct diameter changing from 0.4m to 0.6m, longitudinal duct spacing changing from 1 times of to 3 times of duct diameter, and MAGT changing from -1.0°C to -1.5°C. From the numerical result, 3 indexes including artificial permafrost table, MAGT and absorbed heat were calculated for each study case. Through analyzing the variation of the 3 indexes against the main design parameters, it was concluded that: 1) the ventilation duct obviously improved the thermal condition of permafrost embankment by uplifting artificial permafrost table and decreasing MAGT and absorbed heat, 2) under all of the study cases with the same MAGT, the MAGT 20 years later was almost the same, illustrating that other parameters behaved almost no impact on MAGT, 3) the absorbed heat decreased with increase of duct diameter and decrease of longitudinal duct spacing. The study result would provide guideline for application and design of ventilation-duct embankment for expressway in permafrost regions.

DIFFERENTIAL THAW SETTLEMENT OF WIDEN HIGHWAY EMBANKMENT IN PERMAFROST REGIONS

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Differential thaw settlement in widen embankment is studied using in-situ monitoring data of widen embankment in Qinghai-Tibet highway. The analysis studies the cause and development of differential thaw settlement in widen embankment that underlain by permafrost. Often permafrost in Qinghai-Tibet highway widen embankment contains inclusions of thick ice lenses and therefore susceptible to thaw. As a result of differential solar radiation acting on embankment slope, differential permafrost degeneration develops beneath embankment between sunny slope and shady slope. When new roadway embankments are constructed at side-slope of original roadway embankment, they have a large influence on the thermal regime of the slope toe. The preexisting surface condition and associated ground energy balance of slope toe are modified by new building roadway embankment, resulting in thawing of permafrost, especially when original roadway embankment broadens at sunny slope. Consequently, permafrost thawing making consolidation develops beneath widen embankment and it leads to differential thaw settlement between new building roadway embankment and original roadway. The result of present study show that differential thaw settlement of widen embankment is mainly caused by the new building roadway embankment, and the differential thaw settlement often occurs at juncture of new and old roadway embankment, furthermore, additional load due to new widen embankment making consolidation of the active layer beneath original embankment and leads to settlement of the original roadway, and this settling rate is lower than that of new widen embankment, finally, the differential settlement is increasing yearly. Time varying ground temperature and embankment settlement of widen embankment is analyzed and the results are visualized in the form of isotherm and curve plots for different year.

SUNNY-SHADY SLOPE EFFECT ON PERMAFROST ROADBED ALONG THE QINGHAI-TIBET HIGHWAY AND ITS INFLUENCES ON ROADBED INTEGRAL STABILITY

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The Qinghai-Tibet Highway (QTH) traversed about 550 km permafrost regions in the Qinghai-Tibet Plateau. Due to the main strike of the highway, the sunny-shade slope effect of roadbed from different solar exposure was significant. Based on the temperature and roadbed deformation monitoring data from 1999 to 2011, the influences of the sunny-shady slope effect on thermal regime and integral stability of roadbed were analyzed. Due to the different solar exposure, the soil temperatures on the sunny slope were higher than those on the shady slope. The differences of main annual soil temperatures on sunny and shady shoulders could reach about 3 °C. Under this asymmetry thermal boundary, an obvious asymmetry temperature field developed beneath roadway. Affected by current climate warming, permafrost tables beneath the highway roadbed all descended during the monitoring period. The descending rate of permafrost table beneath the sunny slope was about 23.5 cm/a, while beneath the shady slope it was only about 6.3 cm/a. For roadway sections without shady-sunny slope effect, the descending rates of permafrost table beneath west-facing slope and east-facing slope were 20.3 cm/a and 18.5 cm/a, respectively. Since the permafrost warming and thawing, all roadbed along the highway experienced obvious settlement during the monitoring period, and the ratio of roadway disease caused by permafrost degradation was 10.5% in 2012. Meanwhile, the settlement rates on sunny shoulders were greater than those on shady shoulders. These differential deformations on roadway gave raised to roadbed crack, and the ratio of embankment crack along the highway in permafrost region was 2.49% in 2012.

A CRITICAL REVIEW OF RECLAMATION TECHNIQUES FOR MINE WASTES DISPOSAL SITES PRODUCING ACIDIC EFFLUENTS

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A critical review of reclamation techniques for mine wastes disposal sites producing acidic effluents
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Abstract: The formation of acid mine drainage (AMD) remains one of the major environmental challenges for the mining industry. When mine wastes stored on the surface are a potential source of AMD, it is essential to take adapted measures to limit their environmental impact during operation and upon mine closure. The active (chemical) treatment of acidic effluents is not a sustainable long-term solution for the reclamation of acid generating sites, notably due to the treatment infrastructure that must be maintained, the related costs, and the production of large amount of sludge for an indeterminate duration. The preferred option for effectively limiting the environmental impact of AMD consists of controlling the generation of acid through the use of preventative techniques. This implies using methods that inhibit sulfide oxidation reactions at the source. Such approach may also be combined with reduction (also called attenuation or mitigation) measures that act on the influence factors. More specifically, the principal objective is to exclude at least one of the constitutive elements of the oxidation reaction, these being water, air (oxygen), and sulfidic minerals. It is also possible to reduce the rate of sulfide oxidation by acting on various factors such as bacterial activity, temperature, pH, overall mineralogy, and the state of the particles surface. In this article, different approaches for the prevention and control of acid mine drainage are outlined. The main methods used in practice will then be addressed, with particular emphasis on water covers, various types of multi-layer covers (including CCBE and geosynthetic covers), and the elevated water table technique (with a mono-layer cover). The advantages, limitations and uncertainties associated with these techniques are also presented, based on documented cases. Attention will also be paid to materials that could be used for the construction of these various components. Finally, the article will provide an overview of some new and/or alternative approaches applicable to particular cases, such as the addition of alkaline or cement-based amendments, and reclamation techniques for mine sites in the article.

THE VARIABILITY OF SOIL THERMAL AND HYDROLOGICAL DYNAMICS WITH VEGETATION COVER IN A PERMAFROST REGION

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Understanding the interactions between the soil thermal-water regime and variations in vegetation cover is a key issue in land surface models and in predicting the responses of alpine ecosystems in permafrost regions to climate changes. Declines in vegetation cover in the alpine meadows resulted in an increase in the soil thawing temperature and moisture, a decrease in the soil freezing temperature and moisture, an advance in the onset of seasonal changes in soil temperature, and increased variability in soil temperature and moisture. Changes in vegetation cover had reciprocal effects on soil thermal and water dynamics in alpine swamps and alpine meadows. The annual variations in active soil temperature and moisture dynamics were controlled by the synergic influences of climate and vegetation cover changes; as vegetation cover decreased, the sensitivity to climate changes increased with greater shifts in annual soil temperature and water dynamics. An empirical Boltzmann formula for the soil water-temperature relationship was identified to understand the functions of vegetation cover in inhibiting or driving permafrost changes by varying the soil water-thermal coupling cycle. These results confirmed that vegetation cover is one of the most important factors controlling the soil water and thermal cycles in permafrost. The degradation of vegetation could accelerate the effects of climate change on the permafrost environment.

ÉTUDE DE L'INFLUENCE DE LA CIRCULATION DE L'EAU À TRAVERS UN PONCEAU CONSTRUIT SUR PERGÉLISOL (NOTE : L'ARTICLE SERA EN ANGLAIS)

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En présence de pergélisol, la construction d'ouvrages, tels que les bâtiments et les routes, représente un défi important. L'apport de chaleur que peuvent induire ces ouvrages est susceptible d'affecter le régime thermique du sol sous-jacent. Les changements touchants l'équilibre thermique entraînent la fonte du pergélisol et, par conséquent, la perte de capacité structurale et fonctionnelle de l'infrastructure. Les conditions de drainage de l'eau aux abords de l'ouvrage peuvent contribuer à la sévérité des instabilités.

Sur l'Alaska Highway au Yukon (Canada), des problèmes d'instabilités sont fréquemment observés et certains se situent aux abords des ponceaux. En autorisant la libre circulation de l'air et de l'eau à travers une conduite, des perturbations thermiques additionnelles sont infligées au sol environnant. Afin de documenter ces perturbations, deux ponceaux ont été choisis sur l'Alaska Highway. Le premier est situé au site expérimental de Beaver Creek; le deuxième est proche de la frontière avec l'Alaska.

Chaque heure, les températures du sol autour des ponceaux et la température de l'air dans les ponceaux ont été enregistrées pendant une année; tandis que la température de l'eau entrant et le débit ont été enregistrés pendant deux printemps et étés. La collecte de ces données a permis de développer une relation empirique liant la température et vitesse de l'eau avec la température de parois du ponceau. Cette relation a été basée sur le principe suivant : le flux de chaleur par conduction dans le sol et le flux de chaleur par convection associé à l'écoulement dans le ponceau sont égaux à l'endroit où la température de parois est mesurée.

En parallèle, un modèle 2D a été développé à l'aide du logiciel TEMP/W de GeoStudio et calibré avec les données de terrain. À partir de la relation empirique établie, des simulations de variation de débit et de température de l'eau ont été appliquées afin d'obtenir la température de parois entre le contact eau-sol. Cette variation de température de paroi a été appliquée dans le modèle thermique 2D afin de déterminer l'influence du débit et de la température de l'eau sur les températures du sol sous le ponceau. Des simulations similaires ont été conduites en faisant varier des paramètres de conception comme la présence ou non de l'isolant ainsi que son emplacement, le diamètre du ponceau, la hauteur de remblai. Basés sur ces analyses, des pratiques et paramètres de conception seront identifiés et le régime thermique autour des ponceaux sera documenté.

STUDYING THE IMPACT OF THE CONSTRUCTION OF AN UNDERGROUND PEDWAY ON THE EXITING LRT TUNNELS

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An underground pedway with ten meter span is being constructed above the exiting Light Rail Transit (LRT) twin tunnels in a crowded area in Edmonton, Canada. The pedway is constructed with tangent pile walls and concrete roof and floor slabs using cut and cover method. The roof slab is located two meters below the ground surface. The bottom elevation of the construction is within one meter of the top of the LRT tunnels. The bottom clearance progressively increases along the alignment. The pedway also veer horizontally, with the start location almost exclusively above the East tunnel and shifting towards the pillar. The subsurface stratigraphy consists of clay fill, underlain by glacio-lacustrine clay, underlain by glacial clay till, underlain by Empress Formation sand.

This paper presents the procedures and results of the Finite Element Modelling (FEM) of the construction sequence using PLAXIS software. The behavior of the tunnels and the response of the ground are also closely monitored using installed instrumentation. Different construction scenarios are explained and the advantages and disadvantages of each one are discussed. The goal of this analysis is to better understand the response of the surrounding ground and the existing tunnels to different stages of the construction of the pedway and to minimize the impact. The response of the tunnels are studied based on the deformation of the concrete lining and resulted structural stress. It is shown that during the excavation stage, the movements are upward towards the cavity. The rate of the heave increases as excavation proceeds and reach a maximum and then decreases as the backfilling starts and switches direction to downward as the pile walls loading is transferred to the ground.

SUIVI DU COMPORTEMENT THERMIQUE ET MÉCANIQUE DE L'ADAPTATION AUX CHANGEMENTS CLIMATIQUES DE LA ROUTE D'ACCÈS À L'AÉROPORT DE SALLUIT AU NUNAVIK, QUÉBEC.

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La route d'accès à l'aéroport de Salluit traverse, à flanc de pente, un dépôt d'argile instable au dégel sur environ 800 m. Elle constitue l'unique accès terrestre reliant la communauté de Salluit et l'aéroport. Les changements climatiques (CC) et la construction de la route ont conjointement contribué à la dégradation du pergélisol sous l'infrastructure endommageant celle-ci prématurément. Les dégradations observées indiquaient un potentiel de rupture du remblai si le dégel du pergélisol s'accroissait. Afin d'assurer la pérennité et la sécurité de cette route, à l'été 2012, le Ministère des Transports du Québec (MTQ) a effectué des travaux de réhabilitation pour la stabiliser thermiquement et mécaniquement en adaptant sa conception au contexte de CC.

La conception utilisée a pour objectif de favoriser la remontée du plafond du pergélisol sous la route. Les travaux ont consistés en 1) la mise en place d'un drain thermique pour générer une convection d'air dans le remblai du côté aval; 2) l'aménagement d'une pente de remblai adoucie du côté amont pour minimiser l'accumulation de neige et éloigner l'écoulement d'eau en pied de remblai; 3) l'amélioration du système de drainage pour minimiser les risques associés à l'accumulation et à l'infiltration d'eau sous le remblai.

Ce projet d'adaptation aux CC constitue la première application à grande échelle de la technique de drain thermique permettant de documenter les bénéfices technologique, économique et opérationnel liés à l'implémentation des solutions d'adaptation sur une infrastructure de transport nordique. Plus précisément, il permettra de documenter l'efficacité du drain thermique pour, au besoin, en améliorer la conception. De plus, il évaluera la performance du système de drainage adapté, visant à canaliser l'écoulement pour limiter le transfert de chaleur au sol, et l'érosion thermique en aval des ponceaux. Pour effectuer le suivi du comportement du remblai, plusieurs instruments ont été installés lors de la construction. D'abord, des câbles à thermistances verticaux enregistrant la température du remblai et du sol. Puis, des inclinomètres verticaux et horizontaux mesurant les mouvements potentiels du remblai. De plus, la technologie à fibre optique "Distributed Temperature Sensing", permettant de mesurer la température du sol en tout point en bordure de la route, a été utilisée comme outil de détection et suivi des points chauds, correspondant notamment à l'accumulation d'eau.

Cet article présentera les résultats de deux années de suivi thermique et mécanique, ainsi que des conclusions préliminaires sur l'efficacité des techniques utilisées et sur la stabilité de la route.

DESIGN AND CONSTRUCTION OF SHORELINE FORTIFICATION TO PROTECT MAINLINE RAILWAY CORRIDOR, PORT HOPE, ONTARIO

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The shoreline along the north shore of Lake Ontario at Port Hope has experienced ongoing erosion for a long period of time. At the time that the CN mainline was constructed in the 19th Century, the distance from the edge of the rail corridor to the crest of the shoreline bluffs was more than 30 m. Erosion of the bluffs had reduced this width to only a few metres in the 1990's, and this would compromise the safety of the railway lines unless stopped. Other nearby features prevented a move of the railway tracks from their position and thus, there was a requirement to design and implement appurtenances to arrest the erosion.

The shoreline bluffs are about 20 m high in the affected area. The soil profile consists of an upper layer of compact to dense sand lying on a stratum consisting of stiff to hard silty clay till. Groundwater percolating through the sand layer towards the Lake had caused internal erosion in the sand, with the development of chasms several metres high. These chasms would collapse when gravity overcame the temporary forces overlying the soil arch. Wave effects on the till stratum at the base of the bluffs, especially at the time of the spring thaw resulted in undercutting of the slope. The combined effects of internal erosion and toe erosion resulted in slope regression.

A phased approach was developed to implement corrective measures. The first phase of the work involved the design and construction of a soil bentonite slurry wall through the sand soil unit to cut off the seepage of groundwater, collect the water and discharge harmlessly. This work prevented the future occurrence of internal erosion in the sand unit. That work was followed by design of a rockfill dynamic revetment which covered the full height of the affected length of slope. The constructed work has successfully arrested slope erosion and supported the narrow width of table land between the railway line and the slope crest. Subsequent to construction, no abnormal maintenance has been required to maintain vertical and horizontal alignment of the rail tracks.

LATERAL RESISTANCE OF HELICAL AND DRIVEN PILES

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Helical piles has gained a wide acceptance in the industry as a robust foundation option in the last few years. As a result of that, numerous full-scale helical pile load tests were documented and reported in the literature. However, available studies documenting their lateral performance are few. To date helical piles with shaft diameters up to 1200 mm have been used. The new generation of high capacity helical piles necessitates exploring their lateral performance. The results of a lateral pile load test programs and the field monitoring of helical and driven piles with shaft diameters varied between 219 mm and 508 mm, installed in firm to stiff clay till were presented in this paper. Load testing programs were carried out at two different sites. Soil stratifications and groundwater conditions for both sites were also summarized. Direct comparison between lateral resistance of helical and driven piles were also performed. The results of the load tests are compared to a theoretical model using L-Pile 2013 (ENSOFT 2013). Based on the results of this study it was found that helical piles can develop considerable resistance to lateral loads and this resistance is almost exclusively controlled by the shaft diameter.

NUMERICAL SIMULATION OF GAS HYDRATE STABILITY ZONE USING LOG DATA OF A SCIENTIFIC DRILLING BOREHOLE IN THE PERMAFROST REGION, CHINA

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Due to its great significance for gas hydrate accumulation, gas hydrate stability zone (GHSZ) is the essential condition for gas hydrate exploration in the permafrost region, which is usually controlled by three main factors including gas components, geothermal gradient and permafrost thickness. Based on the core and conventional log data in depth of 0 - 1700 m of the scientific drilling borehole in the permafrost region of China, the CSMHYD program was adopted to simulate the influences of gas components, geothermal gradient and permafrost thickness on the thickness of GHSZ, and the gas hydrate favorable reservoirs were also discussed. When gas components of the gas hydrate were CH₄, C₂H₆ and C₃H₈ with the CH₄ percentage ranging from 50% to 100%, the average GHSZ thickness can reach 1000 m according to the forward simulation results. When the gas hydrate were composed of CH₄ and one of C₂H₆, C₃H₈, H₂S and CO₂, the influence order of the above four gases on the thickness of GHSZ is: H₂S > C₂H₆ > C₃H₈ > CO₂. Under the gas components of 90% CH₄, 5% C₂H₆ and 5% C₃H₈, the thickness of GHSZ decreased rapidly as geothermal gradient increased following an exponential relation with a correlation of 99.94%, and increased slowly as permafrost thickness increased following a linear relation with a correlation of 99.9%. Besides, the thickness of gas hydrate favorable reservoir was determined by porosity log methods as 500 m, which was consistent with the result from acoustic imaging logging method. The research results could lay a foundation for the prediction and assessment of the gas hydrate resource in the permafrost region of China.

POST CONSTRUCTION DEFORMATIONS OF SOIL NAILED WALLS- CASE STUDIES

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Deep excavations and retaining structures are constructed in the city of Tehran, due to the recent demand for the construction of high-rise structures and shopping malls having various basements. Soil nailing method has been extensively employed in Iran as temporary retaining walls. Baran, Eram and Yas are some of the deep urban excavation projects in Tehran, reach to 19.5-29.3 meters in depth that are surveyed in this study. The performance of the walls was monitored by Laser Total Station recordings from the reflectors that were installed about the top nail rows, in parallel to the excavation progress and in service at the perimeter of the project line.

Recommendations of FHWA suggest horizontal deflections of $0.005 H$, as an upper limit of acceptable performance during construction and it states that the post construction deformation typically increases up to 15 percent of the deformations observed soon after construction.

The mentioned walls had horizontal deformations were smaller than $0.005H$ during construction, but the reported post-construction deformations of the walls exceeded of 15 percent and it varies from 69 to 122 percent of the deformations observed soon after construction accomplishment. We applied numerical models to simulate these differences by staged construction modeling.

PERFORMANCE ANALYSIS OF A SOIL NAIL WALL OF A DEEP EXCAVATION

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The demand for urban deep excavations for obtaining enough parking spaces resulted to greater number of basements below the high-rise structures within the city of Tehran resulted to extensively employing of soil supporting system such as soil nail walls as temporary retaining walls in recent years. This study surveys the performance of a temporary soil nail wall with maximum height of 30.6m in Amirkabir complex project, located in Tehran. The water table located 15m under natural ground surface. The performance of the soil nailed walls monitored by Laser Total Station recordings at certain time intervals during the excavation process. Some numerical models were developed using a Finite Element software, based on results of field and laboratory tests. Simulation construction process of the soil nailed wall was carried out considering the sequence of construction stages. The modeling results were analyzed and compared with the in-situ monitored data. The results demonstrate, the model's horizontal deformations are generally greater than in-situ monitored values. Therefore the parameters of soil layers were back analyzed to conform the results of models and monitored data. As it was an EPC project, the results of monitoring and back analysis are applied to optimize system design during construction.

GEOTECHNICAL PROBLEMS OF CHUKCHI SETTLEMENTS ASSOCIATED WITH PERMAFROST DEGRADATION

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Eastern Chukotka is a region populated mostly by indigenous people's representatives: Chukchee and Eskimos. During Soviet Union their communities had been getting consolidated into settlements with timber and stone houses, somewhere with central water supply and sewerage. The settlements considered in the study are Inchoun, Neshkan and Uelen, situated on the Chuckhi Sea coast; Lorino and Lavrentiya situated on the Bering Sea coast. «New» facilities in them been weakly adapted to exploitation on permafrost and had been having negative, but non-critical impact on frozen grounds. Since 1990s socio-economical situation has changed, and consumer service of engineering systems has deteriorated. This had lead to building deformations, geotechnical risk increasing and intensification of negative cryogenic processes.

The study methods included geophysics, thermal modeling, field geodetic surveys, using archival topographic maps, data of permafrost engineering surveys, modern space high resolution imagery, etc.

Majority of living houses in Eastern Chukotka built before 1990 has deformations, following numerous cracks in walls and floors. Frequent fresh water leakages form swampy areas, which often leads to thermoerosional ravines formation. Study revealed existence of technogenic taliks under old living houses. Built-up areas of studied settlements have changed permafrost conditions that can be dangerous for further exploitation and development.

The communities of Chuckhi peninsula are experiencing sea impact to a different degree, because they confined to the shores of the Bering and Chukchi seas, as the general population depends on the production of marine mammals. The information about many settlements of the region known since XVI-XVIII centuries that allows indirectly judge about relative stability of coast sections, on which they are located. However, the comprehensive analysis has revealed the fact of retreat in recent years coastal sections located within some communities. Some engineering facilities, situated near the sea either has been destroyed or under threat of destruction.

The studied problem may have more acute way in the future. Thus, forecast of cryogenic processes development and key recommendations for mitigation and adaptation to changing permafrost conditions has been made.

VOID EFFECTS ON THE BEARING CAPACITY OF SHALLOW FOUNDATIONS USING LIMIT ANALYSIS METHOD

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Void effects on the bearing capacity of shallow foundations were investigated analytically using two dimensional finite element based lower bound limit analysis method. Several factors, such as void location, void size, foundation width and soil type affect the bearing capacity of foundation. The variation of bearing capacity with the variation of aforementioned parameters was scrutinized and relevant charts were presented. The Mohr-Coulomb yield function and an associated flow rule are adopted for the soil behavior. The analytical results indicate that there exists a critical region for a void under the footing foundation, and the bearing capacity is significantly affected by the void only when the void is within this region. The results were compared to some other solutions that are available in the literature in order to verify the suitability of the methodology used in this research.

JRM: HIS EARLY ACCOMPLISHMENTS, 1950 TO THE MID 1980S

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Ross Mackay was trained as a physical geographer but his main accomplishments were as a permafrost scientist. His first visit to the Canadian Arctic was in 1951 when he spent time on Bathurst Island. In the subsequent decade, and supported by the Geographical Branch, he travelled by motorized canoe down the Mackenzie River to its mouth at the Beaufort Sea spending approximately 3 months in the field each year. He published short notes on many of the geographical features he encountered, these included his 1962 paper describing the closed-system pingos of the Mackenzie Delta. His first seminal contribution was a monograph on the Mackenzie Delta, NWT, published by the Geographical Branch in 1963.

In 1968, when the PCSP Western Arctic logistics base moved to Tuktoyaktuk, Mackay commenced long-term permafrost studies in the delta region. In the early 1970s, his permafrost interests related largely to the importance of ground ice and to understanding the mechanisms of pingo growth. He documented the formation and growth mechanisms of pingos through the precise survey of growing pingos, and the drilling and examination of their ice cores. He also promoted a segregation-injection origin for the massive ground ice bodies that are well exposed in the Tuktoyaktuk area, arguing from careful stratigraphic observation and crystallographic and geochemical analyses. His observations upon active layer processes were only to appear in the late 1970s and early 1980s. Fluvial, Pleistocene and palaeoenvironmental studies appear to have been of secondary interest. His most elegant field experiment was the artificial draining of a tundra lake (Illisarvik) in the summer of 1979 and the subsequent monitoring of the aggradation of permafrost on the lake-basin floor in the following years.

By the late 1980s, Mackay had completed more than 30 field seasons in the Western Arctic and made numerous scientific contributions to permafrost science. He had become the foremost authority on permafrost in Canada, and probably the world.

FRASER HEIGHTS BRIDGE – GEOTECHNICAL CHALLENGES OF TOP-DOWN CONSTRUCTION

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The Gateway Program, a regional upgrade of the transportation system in Metro Vancouver, BC, included the Port Mann/Highway 1 (PMH1) Improvement Project and the South Fraser Perimeter Road (SFPR). The PMH1 was a \$2.5B project delivered under a Design/Build Agreement (DBA). It included widening of the Trans-Canada Highway 1, construction of the new 10-lane Port Mann Bridge and several overpasses, as well as the eastern 2 km section of the SFPR referred to as the Fraser Heights Connector (FHC). The FHC is located in northeast Surrey, BC.

The Fraser Heights Bridge (FHB) is situated along the FHC in an environmentally sensitive wetland. A key requirement for the project was construction of the bridge without impacting the wetland. The bridge was constructed span-by-span, using a top-down approach, starting from the east side.

The FHB is approximately 450 m long and consists of two separate west- and eastbound structures, supported on 27 and 25 piers/bents, respectively, as well as the east and west abutments. Each bent consisted of two 762x19 mm driven steel pipe piles. The east and west approach fills are approximately 3 to 4 m high at the abutments.

The soil profile varied significantly along the bridge as it extends from Fraser Heights glacial uplands on the west to the peat wetlands on the east. Toward the west, it consisted of dense glacial materials at relatively shallow depths. Near the central part, it typically consisted of up to 4 m of peat, over 3 to 10 m of overbank silt, over dense glacial material. Near the east, it typically consisted of 1 to 5 m of fill, over 2 to 3 m of peat, over 10 to 13 m of overbank silt, over approximately 1 m of buried amorphous peat, over up to 5 m of sensitive marine clay, over dense glacial material.

The geotechnical design and construction challenges included: limited number of borings due to access restrictions onto the environmentally sensitive wetland; high variability of the glacial materials; obstructions (cobbles/boulders/glacial erratics); artesian pressure; high compressibility and seismic softening of silts, sensitive clays and peat; and, liquefaction and lateral spreading of hydraulically placed sand fills in some areas of the bridge footprint.

The major challenge of the top-down construction was that construction proceeded in series resulting in minimal time to address unexpected geotechnical issues such as damaged or obstructed piles.

The FHB was open to traffic in December 2012.

LAKES OF THE WESTERN CANADIAN ARCTIC: PAST CONTROLS AND FUTURE CHANGES

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The Western Canadian Arctic is lake rich with over 40,000 lakes in the Mackenzie Delta, and thousands more to the east of the Delta. Professor J. Ross Mackay understood the importance of these lakes to the peoples of the Western Arctic, and to the fish, waterfowl and mammals that live on and in these lakes. Despite the obvious importance of these lakes, it was clear that our understanding of the links between climate, permafrost and hydrology could not fully explain their existence or distribution across the landscape. In order to better understand these lakes, Professor Mackay published at least 16 lake papers over the period 1956 to 2002. These papers outlined many of the controlling processes and considered the complex interactions between lakes and the permafrost landscape. Subsequent research has built on Professor Mackay's legacy and has gradually developed a better understanding of the hydrology and ecology of these lakes, as well considered the interactions between climate, permafrost and hydrology. This paper will outline what is known about the lakes of the Western Canadian Arctic, and consider the impact of a warming climate on the future of these lakes. We will consider: the impact of rising sea level on lakes of the Mackenzie Delta, melting permafrost and lake expansion, catastrophic lake drainage, and the potential role of a warming and drying climate on lake levels.

INFLUENCE OF THE LENGTH OF CONTROLLED MODULUS COLUMNS ON LOAD TRANSFER MECHANISM OF EMBANKMENTS ON SOFT SOIL

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Recently, the use of controlled modulus columns (CMC) has gained popularity in the support of rail and road bridge approach embankments on soft soils. If the columns are extended into a competent firm soil, and designed to take nearly all the vertical loads, they become rigid inclusions. The advantage of this design approach is that the settlement will be controlled, while the disadvantage is that the columns will attract greater load, including bending moment and shear force in situations where non-uniform loading or ground conditions exist. For the composite soil-CMC mass, the load is uniformly distributed by the upper layer of compacted sand blanket; therefore, the CMC inclusions are not necessarily end-bearing. In this paper, the effect of normalized CMC length on the load transfer mechanism, in particular stress concentration ratio, is numerically investigated. Time dependent deformation of the soil is numerically simulated while interface elements capable of simulating gapping and sliding between CMC and the surrounding soil are considered in three dimensional modelling. In particular, a clear comparison is made between the stress concentration ratio in the case of floating and end-bearing columns. Stress concentration ratio is the key factor in the design of columnar ground improvement techniques, and is defined as the ratio of the load carried by the column to the load carried by the surrounding soil. Results of this study can help practicing engineers to adopt the optimum penetration depth for the CMC inclusions for soft soil improvement projects.

Keywords: Controlled modulus columns, Ground improvement

RETROGRESSIVE THAW SLUMPS: FROM SLOPE PROCESS TO THE LANDSCAPE SENSITIVITY OF NORTHWESTERN CANADA.

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Retrogressive thaw slumping is a dynamic form of thermokarst and a significant agent of geomorphic change in ice-cored, glaciogenic landscapes in northwestern Canada. The first part of this paper summarizes recent research on growth processes of retrogressive thaw slumps and their environmental impacts. Focus is on large slumps (5 to 40 ha) that have developed in formerly glaciated, ice-rich, fluvially incised foothills of the Richardson Mountains, northwestern Canada. Analysis of Landsat images (1985 to 2011) reveals that the number and size of active slump surfaces and debris tongue deposits has increased significantly with a recent intensification of rainfall. High-resolution climatic and photographic time-series for the summers of 2010 and 2012 show that ground-ice thaw supplies melt water and sediments to the slump scar zone and drives diurnal pulses of surficial flow. However, temporal coherence in debris tongue deposition across the region, and fine-scaled observations of slump sediment flux indicates that heavy rainfalls stimulate mass flow events. Rainfall-induced evacuation of sediments from slump scar zones maintains headwalls of exposed ground ice, propagating larger disturbances that now characterize the landscape. These mega slumps commonly exceed 15 ha in area and can displace 10-6 m³ of materials from slopes to valley bottoms, reconfiguring slope morphology and drainage networks. Disturbances of this magnitude have significant and enduring consequences on slope and fluvial geomorphology, and downstream ecosystems.

In the second part of the paper, the spatial patterns of terrain impacted by thaw slumping are considered. Recent compilations of high resolution (SPOT 4 and 5) remote sensing imagery have provided a tool to assess terrain impacted by slumping over a 1,275,000 km² area of northwestern Canada. Grid-based mapping indicates that slump impacted terrain characterized about 140 000 km², or 11% of the total mapped area. The distribution of slump-impacted terrain across northwestern Canada follows a striking pattern bounded by the maximum westward extent of Laurentide Ice Sheet. Slump-impacted landscapes are largely restricted to ice-rich moraine deposits. The occurrences of large thaw slumps indicate that these glacially conditioned landscapes host large stores of relict Pleistocene ground ice. In conjunction with process oriented thaw slump studies, this mapping and analyses provides a spatial platform for re-evaluating the distribution of ice-cored permafrost and establishes geomorphic context within which to consider the potential for climate-driven landscape change in northwestern Canada.

PIPELINE BUILDING IN A SUBARCTIC PERMAFROST REGION —A REVIEW FOR THE CHINA-RUSSIA CRUDE OIL PIPELINE (CRCOP) FROM MO'HE TO DAQING, NORTHERN NORTHEAST CHINA

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The China-Russia Crude Oil Pipeline (CRCOP) crosses 441 km of permafrost along the Da Xing'anling Mountains (subarctic environment), in which 120 km underlain by warm, ice-rich permafrost. It has an 813-mm diameter, design pressures of 8-10 MPa, and annual throughput of 15 million tons to transport oil with a temperature originally estimated at -6.4 to +3.6°C. The active construction period was 18 months (May 2009 to October 2010), and the operation began in January 2011. A 3-D model was established for thermal analysis of the pipeline-soil system, and changes in oil temperatures were predicted. Possible changes in the freeze-thaw cylinders around pipeline and in effective stress/strain of pipeline foundation soils were analyzed under different insulation configurations, oil pressures, pipe-wall thickness and for frozen-unfrozen transition zones. When traversing slopes underlain by fine-grained soils, differences in pipe and soil temperatures could result in hydraulic channeling of supra-permafrost water, subsequent enhanced erosion and drainage, and geohazards. Strain-based pipeline design was proposed and adopted for the CRCOP due the large deformations of foundations soils. This was on the basis of thermal and stress/strain analyses of CRCOP, steel type, and environmental concerns. Strain limits are compared based upon relevant codes and recommendations. Drainage Control and refills should be undertaken for the modified burial construction mode, and proper extension of the frozen-unfrozen transition zones for lowering effective stress on ice-rich permafrost slopes. Many of these study results were proven effective and extensively adopted by the CRCOP construction and operation. In retrospect, due to the higher oil temperatures (annual average 7.7°C, range of 0.7-20.4°C) from Russia, thaw settlement has significantly exceeded the earlier estimates. Some additional studies and mitigative measures have been undertaken. Foundation soils around the pipeline were thawing, with maximum thaw under the pipeline of about 1.0-4.5 m and increased maximum thaw depths of 0.5-3.7 m. However, in the areas with dense vegetation, insulation or thermosyphons, permafrost has been better protected, with only minor thaw settlement. In prospect, the second CRCOP and China-Russia Natural Gas Line from Hei'he-Daqing will be soon built, and related work are under way. They are all to be operating at higher oil/gas temperatures (about 10-20°C) across hundreds of kilometers of warm, ice-rich and discontinuous permafrost, and different thaw settlement of foundation soils will be the primary concerns.

DEGRADING PERMAFROST IN CHINA AND ITS ENVIRONMENTAL IMPACTS

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The warm and thin permafrost in China is thermally unstable and sensitive to climate warming. Permafrost degradation has been accelerated. Ground temperatures have been rising at an annual rate of 0.02-0.07°C since the 2000s. In regions of warm permafrost, detachment of permafrost has been extensively observed, and the thermal impacts from climate warming on cold permafrost has been detected at depths of 60 m. During the last 30 years, the permafrost table has been generally lowered by about 25-30 cm, and 70-80 cm in some areas. The active layer has deepened more substantially on marginal areas. Taliks have been expanding. The lower limit of plateau permafrost has extensively risen by 40-80 m, and the lower limits of permafrost along the Qinghai-Tibet Highway has shifted by 3-12 km. Permafrost in the Xing'anling Mountains also has warmed and thinned, or even disappeared. Major ecological impact of the degrading plateau permafrost is grassland degradation, but alpine meadows have shrunk more evidently. The symbiotic permafrost-wetland system has concordant degrading processes. Permafrost degradation has resulted in enhanced thaw subsidence, thermal erosion and thermokarst geohazards. In the Xing'an Mountains, permafrost has been degrading remarkably in areas with patchy permafrost, which has affected ecological functions of forests and wetlands. In Northeast China, technogenic impacts on permafrost has overtaken the climate warming. Land desertification, drying and shrinking wetlands and enhanced carbon emissions may have feedbacks to climate warming and drying. In some areas, permafrost degradation has resulted in an inverse recharge-discharge relationship of ground and surface water systems. As a result, supplies for the supra-permafrost water has declined sharply, as evidenced by much reduced or even vanished water resources at shallow depths, diminishing runoff generation and more uneven seasonal distribution, shrunk or dried lakes and wetlands, and declining soil moisture vital for plant communities. In particular, under the roadbed of Qinghai-Tibet Highway, many segments have found with persistent and enlarging saturated taliks. They have further lowered the permafrost table and enhanced differential thaw settlement. During the last decade, the talik under the roadbed has again thickened by 30-50 cm and ground temperatures have been rising. Although some protective or mitigative measures have been taken, the long-term stability of the underlying permafrost foundation soils could be compromised under a persistently warming climate and accelerated degrading permafrost.

IN-SITU MEASUREMENT OF REMOLDING ENERGY OF SENSITIVE CLAY

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In highly sensitive clays, flow slides of large extent usually start with an initial slide of limited extent. For such flow slides to occur after an initial slide, it is necessary that (1) the slide debris is sufficiently disintegrated or remolded and (2), the slide debris has a possibility to flow out of the slide area. Flow slides are less likely to occur if sufficient disintegration of sensitive clay does not take place. In the literature, several indicators of the potential for a flow slide in sensitive clay slopes to develop have been suggested, e.g. the remolded shear strength (c_{ur}), the liquidity index (IL), the sensitivity (S_t), the quickness (Q) or the stability number (N_c). Although these parameters are useful indicators, the single use of these individual criteria cannot assess with confidence if a flow slide will develop. In order to nuance the picture it is here proposed to study the disintegration process of sensitive clays, which involves an understanding of complete stress-strain behavior. This can be done using the remolding energy (RE) concept. Determination of the RE of sensitive clay in the laboratory requires some special arrangements so that the specimens can be deformed to their residual strain level. This is not a straight forward task. However, Tavenas et al. (1983) did some pioneering work to estimate the remolding energy of seven different Canadian sensitive clays. Efforts have yet to be made for Norwegian sensitive clays in terms of experimentally determining the remolding energy. Given the challenges associated with the sampling of soft sensitive clays, in this study an effort was made to perform an in-situ measurement of the disintegration process of a Norwegian sensitive clay using the electric vane shear apparatus. Afterwards, a procedure to develop a complete stress-strain curve for the sensitive clay, i.e. from the intact to the remolded state is developed and discussed. The significance of the testing procedure and the results are evaluated in light of the available analytical and the laboratory test results. This is also evaluated in light of previous work reported in the literature. The work suggests that parameters like remolding energy and quickness (Q) can be deduced from the shear vane.

EVALUATING THE PERFORMANCE OF A FROZEN CORE DAM FOUNDED ON ICE RICH SALINE MARINE SILTS AND CLAYS

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Tailings management for the Doris North Project in Nunavut Canada entails sub-aqueous deposition into an existing shallow lake. Environmental containment will be provided by two precedent setting water retaining frozen core dams. The first, the North Dam was completed in 2012.

Site characterization confirmed the presence of up to 30 m thick ice-rich, saline glacial marine silt and clay, or fine sand below the footprint of the North Dam. This led to the decision to construct a frozen core dam which would ensure a continued bond between the cold permafrost and the dam core.

The North Dam is approximately 200 m long, with a maximum crest height of 10 m. The engineered (non-saline) core must maintain a temperature below $-2\text{ }^{\circ}\text{C}$, whilst the underlying saline permafrost foundation must be maintained at temperatures at or below $-8\text{ }^{\circ}\text{C}$. Under these conditions the dam will act as an impermeable barrier to seepage while mitigating against creep deformation, differential settlement, and maintaining overall long-term stability. As a contingency, especially for upset conditions (including climate change scenarios), sloped single pipe passive thermosyphons were used in the base of the key trench to enhance foundation cooling.

What makes this design so unique is that, due to the high ice content and salinity of the foundation, the dam was designed accommodate long-term shear strains in the core and foundation approaching 2 % and 10 %, respectively. To help manage these levels of deformation, very shallow slopes of 6H:1V (horizontal to vertical) on the upstream and 4H:1V on the downstream were adopted.

The core consists of a frozen mass of fine crushed basaltic rock placed in a near saturated state. Along the upstream side of the core, geosynthetic clay liner (GCL) was installed to provide secondary water-retaining capability. The core is surrounded by a transition layer that acts as a filter and an outer shell constructed of run-of-quarry rock acts as a thermal protection layer and provides buttressing against creep deformation.

To ensure adequate performance the dam was instrumented with a large range of instrumentation, including ground temperature cables, slope inclinometers and survey hubs. After two full years of data the dam appears to have reached a steady state condition, and observations as to the dam performance relative to the design predictions can be made. This paper will present this data, demonstrating the success of this precedent setting design.

THE USE OF THE GEOPIER® INTERMEDIATE FOUNDATION® SYSTEM FOR SUPPORT OF SEVEN WIND TURBINE FOUNDATIONS IN EASTERN ONTARIO

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The use of wind energy in Ontario has been steadily increasing, and multiple farms of a few to hundreds of wind turbines are being constructed at any given time in Ontario. The need for high stiffness foundations due to large overturning moments, and therefore large edge pressure acting on the base of the foundation can prove challenging when soft or compressible soils at the turbine site do not provide adequate bearing capacity. The use of Geopier® Intermediate Foundations® has been used to provide increased bearing capacity and foundation stiffness for hundreds of wind turbine foundations around the world.

This paper describes the design, construction and performance of three Geopier techniques which include Geopier GeoConcrete™ Columns (GCCs), Geopier GP3®, and Geopier Impact® to support seven wind turbines in Eastern Ontario.

INFLUENCE OF PARTICLES SHAPE, SIZE AND UNIFORMITY OF SANDS ON THE VOID RATIO RANGE AND CONSEQUENTLY ON THE DYNAMIC PENETRATION TESTS RESULTS

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It has been discussed in the past and earlier in the 21st centuries that the particles shape, size, uniformity and distribution have a great influence on geotechnical properties such as the void ratio range ($e_{max} - e_{min}$) consequently on the field and laboratory tests results. Although this is very well known, a minor progress for studying their effects on the void ratio range has been carried out as a parametric study. this is due to three reasons; first: These parameters are deeply integrated with other parameters such as the relative density (D_r). second: There are insufficiency in the most common used techniques to differentiate between these parameters; e.g. in the sieve analysis test there is failure to differentiate between the real size of particles and the shape effect (sphericity-elongation). Third: The overview has shown that there is no certain quantitative descriptor used in the geotechnical field for some parameters instead of the qualitative descriptors as existing for the shape (sphericity-elongation, roundness-angularity and roughness-smoothness). This paper presents a literature review on such parameters and initially proposes some solutions for the problem by several techniques such as the Image analysis and the 3D scan which seem to be promising tools. correlation between the old and new techniques are also proposed and finally a majority of correlations of $(N_1)_{60}$ with such geotechnical parameters are discussed.

Keywords: Sand, shape, size, uniformity, relative density, void ratio range, Image analysis, $(N_1)_{60}$.

LABORATORY INVESTIGATION ON THE EFFECT OF GRAIN SIZE DISTRIBUTION OF GRANULAR MATERIAL ON CONE PENETRATION TEST RESULTS

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This paper initially compares and discusses a majority of correlations of (q_c) and (f_s) with typical geotechnical parameters such as relative density (D_r), the effective overburden pressure, void ratio (e), mean grain size (D_{50}), the degree of uniformity (C_u), lateral stress, mean confinement pressure, overconsolidation (OCR), aging, and angularity. The paper then presents the results of a series of experimental simulations for cone penetration test (CPT) on both polydisperse spherical glass beads and natural sands samples with different mechanical properties as well as different loading conditions. Stress-strain records along the soil samples are monitored during the tests. Results obtained for (q_c) and (f_s) are correlated with typical geotechnical parameters and the corresponding graphs are plotted in order to predict the real behavior of natural soils in the field and to use these graphs to validate numerical simulations based on FEM or DEM.

Keywords: CPT, mean grain size, degree of uniformity, relative density, void ratio.

COORDINATION AND COMPLETION OF MULTI-YEAR GEOTECHNICAL INVESTIGATION IN THE CANADIAN ARCTIC: CHALLENGES AND LESSONS LEARNED.

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The Northwest Territories Department of Transportation is currently in the midst of constructing an all season highway connecting the Hamlet of Tuktoyaktuk with the Town of Inuvik and southern Canada. The Inuvik to Tuktoyaktuk Highway (ITH) development will comprise over 140 km of two lane, gravel surface highway. The new highway will require close to 10 million m³ of material for its construction and operation thus requiring the completion of a borrow source investigation program along the proposed new corridor.

The execution of the investigation program required the development of risk management strategies with an emphasis on project team roles focusing on the logistical aspects of the project and the associated challenges while maintaining technical oversight and quality. As such, a significant effort was spent on planning the program, including the identification of areas deemed most probable to contain suitable borrow. This included a significant effort and cooperation between geotechnical staff and terrain staff using new technologies to complete an initial desktop review of the study area in order to identify investigative areas of interest. Overall, close to 700 test holes were drilled in less than 70 days spent on-site spread over three winter seasons. This paper will present the overall approach, planning, and execution strategy utilized to achieve the overall objective, which was to locate the required volume of borrow material along the proposed highway alignment prior to the start of construction.

PERMAFROST OCCURRENCE IN SUBARCTIC FORESTS OF THE GREAT SLAVE REGION, NORTHWEST TERRITORIES, CANADA

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A three-year (2010 to 2013) investigation in the Great Slave region, Northwest Territories, determined that permafrost in this region occurs, in addition to beneath peatlands, in unconsolidated fine-grained sediments beneath black spruce (*Picea mariana*), white birch (*Betula papyrifera*), and mixed deciduous and coniferous forests. Winter conditions are generally the most important controls on the ground thermal regime, but as snow cover thickness and air temperature are regionally consistent, spatial variation of ground temperatures primarily reflects organic-layer and soil moisture conditions. Latent-heat effects in the active layer and near-surface permafrost significantly dampen the surface temperature wave, as indicated by long freezeback, narrow ground temperatures envelopes, shallow depths to zero annual amplitude (7 m or less), and warm annual mean ground temperatures that range from -1.4°C to near 0°C . Extensive discontinuous permafrost (65%) is confirmed in the Great Slave Lowlands ecoregion, in direct relation to the distribution of forested areas in unconsolidated fine-grained sediments. Sporadic discontinuous permafrost occurs northward within the Great Slave Uplands ecoregion where bedrock outcrops are more extensive. Whereas climate-driven, ecosystem-protected permafrost at forested ecotopes may be sustained over time by latent-heat effects, a transition to permafrost retained primarily within ecosystem-protected peatlands implies a substantive reduction to isolated patches. Thus, future permafrost distribution in the Great Slave Lowlands would be considerably less than contemporary conditions south of Great Slave Lake in the Taiga Plains Mid-boreal ecoregion where sporadic discontinuous permafrost is associated with a greater extent of peatlands.

PERMAFROST EVOLUTION IN SOUTH YUKON IN 20 AND 21 CENTURIES

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A multidisciplinary study was carried out for a mountainous region in the south Yukon to predict the permafrost evolution due to recorded climate change in the 20th century and predicted climate change in the 21st century. The study included statistical analysis of historical air temperature data, prediction of future air temperatures based on doubling of carbon dioxide content in the atmosphere, aerial photograph interpretation, analytical assessments and computer modeling of main permafrost parameters such as mean annual ground temperature, thickness of active layer, seasonal frost penetration, and permafrost thickness. The study area occupies approximate elevations of 1000 m to 1500 m above sea level and located at a distance of 50 km west from the Town of Carmacks. A notable peak in the study area is Mt. Nansen. Data of Dawson and Carmacks weather stations and short period data for air temperature within the study area were used for the statistical analysis. The study area is positioned in the discontinuous permafrost zone which is characterized by warm permafrost temperatures (usually not colder than -2°C) and insignificant permafrost thickness (in the order of 50 to 100m). Due to warm permafrost temperatures, insignificant permafrost thickness and shallow bedrock; expected climate warming would dramatically change the permafrost distribution and location of the permafrost table and base. A statistical analysis of 10 year sliding air temperatures has shown a very distinguish climate warming trend from the middle of the 20th century to the present resulted in the increase of the mean annual air temperature for central and south Yukon at about 2.5°C for Dawson and Carmacks weather stations. No change in snow accumulation was found for Dawson and Carmacks weather stations (100 and 50 years observations, respectively). Based on previous investigations it was found that even if there is no change in snow thickness, insulating effect of snow decreases when winter air temperature increases. Three permafrost maps were created for the study area (middle of the 20th century, 2013, and middle of the 21st century). The maps show that permafrost area within the study area was reduced at about 40% and it was predicted that the permafrost area will be considerably less (approximately 10% of the total area in the middle of the 21st century). Predictions have also demonstrated that considerable area will still have relict permafrost with location of the permafrost table at a depth of 10-20 m from the ground surface.

THERMAL AND PHYSICAL STATE OF DISCONTINUOUS PERMAFROST IN THE GREAT SLAVE LOWLANDS, NWT, WITH WARMING AND DISTURBANCE IMPLICATIONS ON HIGHWAY INFRASTRUCTURE

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This paper examines the thermal and physical state of extensive discontinuous permafrost in undisturbed and disturbed settings in the Great Slave region, Northwest Territories, and discusses implications in regards to present disturbance and climate warming on highway infrastructure in this region. Herein we examine the mean annual ground thermal regime at a range of undisturbed and disturbed locations, and utilize a dataset of more than 100 boreholes to review the generalized stratigraphy and historical physical state of permafrost in the region. Permafrost occurs extensively outside of peatlands (which occupy a nominal proportion the area) primarily within coniferous and deciduous forest terrain. Ground temperatures in permafrost are typically warmer than -1.4°C in undisturbed terrain, and many areas show evidence of surface warming. Regional stratigraphy is typically silty sediment overlying silty-clays of glacio-lacustrine origin, with an underlying unit of coarse-grained sediment (till diamicton or glaciofluvial sediment) overlying bedrock. Ground ice in silty-clay sediments is common, and is attributed primarily to segregation ice. Moisture contents associate with ground ice typically exceed the plastic limit, and even liquid limit of sediments, implying the ground is thaw sensitive. Potential thaw settlement in the upper 4 m of permafrost may be on the order of 40-60 cm, whereas subsidence exceeding 30 cm/m may be associated with ground ice thaw below 4 m depth. Permafrost had historically aggraded into the highway embankment of the old Northwest Territories Highway 3 between Behchoko and Yellowknife due to the fine-grained fill material comprising the embankment and removal of snow, but permafrost degradation occurred along much of the highway right-of-way. Between 1999 and 2006, the alignment of the highway was straightened and reconstructed, and the road surface chip-sealed. Permafrost is unlikely to be sustained within the new highway, composed primarily of blast-rock, due mostly to advective heat transfer associated with water movement beneath the embankment and continuous thawing of the highway right-of-way, coupled with warming air temperatures.

SLOPE STABILIZATION AT KM 229 AND KM 701-703 OF THE ALASKA HIGHWAY: SITE CHALLENGES AND LESSONS LEARNED

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This paper presents a case history of recent slope stabilization works completed at Km 229 and Km 701-703 of the Alaska Highway in northern BC in order to improve public safety and reduce highway maintenance costs. The challenges of working in remote northern areas and other lessons learned during construction are also discussed.

The Alaska Highway was constructed during World War II to connect Alaska with the continental United States through Canada. The highway, completed in 1943 at a total length of approximately 2,450 km, traverses numerous areas of difficult, landslide-prone terrain across northern BC and the Yukon. In BC the highway is maintained by Public Works and Government Services Canada (PWGSC) between Km 133 near Fort St. John and Km 968 at the BC / Yukon Border. South of Km 133 the highway is maintained by the BC Ministry of Transportation and Infrastructure.

At Km 229, an approximately 300 m long section of the southbound lane and adjacent shoulder had experienced ongoing slope movements since the highway was reconstructed in the late 1980s, and continual repairs were required to maintain the highway grade. Tetra Tech EBA Inc. evaluated the site for PWGSC in 2009, finding that movement of the slope was occurring along a very weak sliding plane in glaciolacustrine clay. Groundwater levels were monitored continuously using portable dataloggers, revealing significant seasonal variations and sharp increases during periods of heavy rainfall. To stabilize the slope a total of 16 counterfort drains were installed next to the highway and the existing drainage ditches and culverts were also upgraded. Construction of the slope stabilization works was completed in October 2011. Follow-up monitoring suggests that the slope movements have slowed but not stopped.

At Km 701-703, three sections of the highway along the eastern shore of Muncho Lake had a dangerously narrow shoulder due to erosion and slumping of the shoulder material into the lake. Tetra Tech EBA Inc. evaluated the site for PWGSC in 2012 and 2013, finding that the road shoulder was supported by deteriorating gabion baskets founded on timber cribbing and blast rock. To stabilize and widen the shoulder, SierraScape® Mechanically Stabilized Earth (MSE) walls were constructed using wire-form basket facing elements infilled with locally sourced rockfill. Select gabion baskets were also repaired/replaced and additional riprap was placed at either end of the MSE walls for scour protection. The project was successfully constructed ahead of schedule in October 2014.

ACTIVE LAYER VARIABILITY AND CHANGE IN THE MACKENZIE VALLEY, NORTHWEST TERRITORIES

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The Geological Survey of Canada has maintained an active layer monitoring network in the Mackenzie Valley and Delta since the early 1990s. The network currently includes 45 functional sites representative of vegetation and surficial material in the region. Thaw tubes are utilized to determine maximum annual thaw penetration and maximum surface heave and subsidence. Air and near-surface ground temperatures are measured at most sites.

Active layer thickness (ALT) in the Mackenzie Valley ranges from less than 50 cm in the north to greater than 100 cm in the south and generally increased between 1991 and 1998. The 1998 maximum was followed by a decrease in ALT to 2005, with increasing ALT to 2012. Where soils are ice-rich, significant surface settlement has accompanied increases in thaw penetration. North of treeline, a direct relation between air temperature and ALT is evident where active layers in warmer years (1993, 1998, 2006) are on average ~3-9 cm thicker than the 2003-2012 mean. South of treeline, greater inter-site variability is observed and is a consequence of the insulating effect of the vegetation in summer and variable snow cover in winter. The effect of warmer (1998) and cooler (2004) years is still noticeable with ALT on average ~5 cm greater and ~6 cm less than the long-term average, for both years respectively. In the south the modulating effect of vegetation on active layer development is also observed with near-surface Thawing Degree Days (TDD) displaying a better relationship with ALT than air TDD. This is in contrast to the tundra where minimal surface insulation results in a more direct relationship between air TDD and ALT. For all regions, a greater temporal variability in winter air temperature indicates that Freezing Degree Days may be an important factor influencing the long term variability of active layer thickness.

Changes in the active layer thickness and associated ground movements have implications for ground stability, and infrastructure and environmental integrity. Information acquired through long-term monitoring is improving our understanding of the impacts of a changing climate on a permafrost environment and can support design of adaptation strategies for northern infrastructure and resource development projects.

DETECTION OF ICE-RICH PERMAFROST AND MASSIVE ICE USING MICROGRAVIMETRY AND THERMAL PROFILING

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From an engineering point of view, the most important information needed to manage the construction and maintenance of transport infrastructure in northern regions is the location and the ice content of ice-rich permafrost.

The proposed paper describes a project done as part of the Arquluk permafrost engineering research program at Laval University in Canada. The project has two components: using microgravimetry for the detection of massive buried ice and ice-rich permafrost, and using longitudinal thermal profiles below the ground surface in order to detect thermal anomalies.

The approach based on the use of microgravimetry is aiming at the detection of anomalies between materials of different density in the ground. The ice being about half the density of the surrounding soil, negative gravity anomaly corresponding to the presence of buried ice should be detectable. A Scintrex (CG5) gravimeter was used for data acquisition.

The approach based on the detection of sub-surface temperature anomalies is a new concept that will be developed based on data acquired in the field. The assumption is that significant bodies of ice or abrupt changes of ice content in the soil in the top part of permafrost, should influence the temperature of the soil surface on a linear tracking survey. Temperatures are measured 50 cm below the surface using a high-precision thermometer in a hole drilled using an auger or a metal rod.

The paper will summarize the results of tests conducted in the Yukon (Dry Creek) and in Greenland (Kangerlussuaq and Iluissat) where the presence of ice-rich soils and massive ground ice has been validated by resistivity measurements and drilling.

ROLE OF AIR-ENTRY VALUE IN THE PREDICTION OF THE UNSATURATED PERMEABILITY

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The unsaturated coefficient of permeability function is an important soil property function required in the numerical modeling of saturated-unsaturated soil systems. The permeability function is generally predicted by integrating along the soil-water characteristic curve (SWCC) based on a particular integral formula. The Fredlund, Xing and Huang (1994) permeability function is one of the most flexible integration techniques used in calculating the unsaturated coefficient of permeability. The original permeability theory published by Fredlund et al., (1994) specified the air-entry value, ψ_{aev} (AEV), as the lower limit of integration when calculating the permeability function. However, since there was no analytical procedure available for the calculation of the air-entry value on the SWCC, it became common practice to start the integration procedure from a value near zero. The assumption was made that the error associated with starting the integration from an arbitrary low value was minimal. While this might be true for some situations, the error can be quite significant in other situations. This paper undertakes a parametric study on the effect of the lower limit of integration on the estimation of the permeability function. A comparison is made between starting the integration from various values below the AEV and starting the integration from the air-entry value, ψ_{aev} . A mathematical algorithm is also proposed for the calculation of the AEV for integration purposes. The results reveal that the relative coefficient of permeability can be significantly under-estimated if the lower limit of integration is smaller than the AEV. The recommendation is that the AEV always be used as the lower limit of integration in the Fredlund et al (1994) permeability equation.

MINIMIZING THE SCALING EFFECT ON THE MEASURED VS USING THE P-RAT

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Unlike most of geotechnical parameters (e.g., N-SPT and qc-CPT) that can be measured only in the field, shear wave velocity, V_s can be assessed either in situ or in laboratory using traditional techniques such as BE. These techniques may effectively be used to study and quantify the effects of various parameters on V_s . They proved their versatility, convenience, and usefulness especially to augment limited field data. However, number of issues is increasing in the same way as the number of BE tests increase and It could be the reason that BE is not yet standardized. Many explanations and hypotheses were made, but few signaled that the geometry of sample can affect the shear wave propagation. This paper focuses on experimental investigation of size sample effect on the measured V_s using the piezoelectric ring-actuator technique (P-RAT). This technique is incorporated into the traditional odometer apparatus to obtain V_s values of the same granular soil having different sample sizes. The experimental results show that the use of P-RAT in determination of V_s could minimize the scaling effect.

LABORATORY TESTING PROGRAM FOR RAINFALL RUNOFF PREDICTION FOR SOIL COVER SYSTEMS

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Soil covers are commonly utilized to prevent and mitigate Acid Rock Drainage (ARD). The design procedure depends primarily on the net infiltration into the system. Infiltration prediction models require proper calibration using water balance controls. This calls for rainfall runoff measurements to be available, yet, these measurements are rarely done. Alternatively, accurate predictions of rainfall runoff for soil cover systems facilitate the calibration procedure.

A laboratory-testing program was developed in order to formulate a reliable model to predict rainfall runoff for soil covers. Both a single layer and a multi-layer soil profile were tested in a specially designed rainfall simulator apparatus. Simulated precipitations of different intensities on different initial conditions were conducted. Runoff volumes were measured as time lapsed simultaneously with rainfall volumes. In addition, a number of instruments were installed to monitor changes in matric suction and volumetric moisture content as the wetting fronts propagated.

The experimental results show that rainfall runoff volume is primarily governed by the applied rainfall intensity and saturated hydraulic conductivity in saturated soils, whereas it is governed by the applied rainfall intensity and infiltration capacity in unsaturated soils.

ARCTIC CITIES, PERMAFROST AND CHANGING CLIMATIC CONDITIONS

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Climate change resulted in permafrost degradation in numerous locations across the Arctic. The effects of climate change are exacerbated in areas of intensive human activity, particularly in large industrial centers on permafrost. We used a combination of modeling techniques and field observations to evaluate how changes in climatic conditions affected permafrost geotechnical properties in generalized regions of Russia and in the large settlements located in each these regions such as Noril'sk, Salekhard, Yakutsk, Anadyr. The foundation bearing capacity was used as a quantitative indicator of the ability of piling foundations to support the structural weight of houses in each settlement assuming that passive construction method was used and no active solutions (such as thermosyphons) influenced ground thermal regime during entire lifespan of the structure. The permafrost-geotechnical model based on the Russian Construction Norms and Regulations was forced with the climate data available at the local weather stations and with projected climate available from CMIP5 models for 1960-2060 period under the the RCP8.5 scenario. Decreases of bearing capacity of various degree are found in all of the study settlements on permafrost. For example, the bearing capacity of foundations in the largest settlement on permafrost, Noril'sk, showed a decrease by $10\pm 9\%$ 2000 for the buildings erected in 1970s. By 2030, the bearing capacity decrease is projected to be $37\pm 22\%$, and may exceed safety coefficients for buildings built in the late 1970-80s. By 2050, the ability of foundations to support structural weight will decrease by two thirds, according to several CMIP5 models ($68\pm 28\%$). The significant increases in air temperature relative to 1961-1990 are expected in the Russian Arctic and are from 1.4 to 2.2oC by 2030 and from 3.1 to 4.1oC by 2060 according to the majority of CMIP5 models, but variability is large. These changes lead to increase of ground temperature and thickening of active layer leading to decreasing foundation bearing capacity in all regions of the Russian Arctic with the highest changes found in West Siberia and Chukotka. While the permafrost warming is more pronounced in the northern permafrost regions, the settlements located in the southern fringes of permafrost are found to experience higher decreases of foundation bearing capacity.

SOIL CONSOLIDATION AID FOR CLAY-BASED UNPAVED ROADS

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Soil amendments such as lime or cement are widely accepted as a means of chemical stabilization to increase the strength and stiffness of soils for road building applications. Sulphonated petroleum compounds are currently being used as an alternate method to chemically stabilize clay-based unpaved roads. However, limited laboratory testing has been carried out to quantify the levels of improvement. The chemical compound is sprayed onto scarified fine grained soils then compacted and cured. During the curing process the compound replaces pore fluids and causes the fine grained soils to become hydrophobic in nature rather than hydrophilic. The compound increases the strengths of soils in two ways; displacing pore fluids allows for the particles to be better compacted, and the hydrophobic properties of the soil prevents moisture from re-entering the pavement structure. A small scale laboratory rutting test was developed to demonstrate the effectiveness of the compound in reducing the deflections of a surface subjected to cyclic loading. Tests were completed on soil samples obtained from three Canadian provinces to provide a variety of grain size distributions and mineralogical compositions. Each soil sample was tested both before and after the compound was applied to demonstrate the relative improvements. The results were compared and reported in terms of the California Bearing Ratios (CBR) which is commonly used in practice as an indication of shear strength.

Keywords :Ground Improvement, California Bearing Ratio, Shear Strength, Rutting, Sulphonated Petroleum Compound

MITIGATION FOR INFILLING AROUND PIPELINES WITH CYCLIC LATERAL DEFLECTIONS

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The soil response around a high temperature pipeline proposed for construction was evaluated. Infilling of backfill around pipelines at side bends subjected to temperature changes may accumulate during cyclic displacements leading to ratcheting and possibly buckling of the pipeline. A medium-scale laboratory model testing program was used to gain a better understanding of how silty sand backfill migrates around a pipeline when subjected to cyclic lateral loading. Several mitigation techniques using geosynthetics and compressible materials were evaluated in order to both delay and reduce the net downward soil movement from pipe displacement cycles.

Keywords: Ratcheting, Geosynthetics, Ethafoam, Cyclic Deflections, Infilling

LABORATORY ASSESSMENT OF ENERGY EFFICIENCY IN VIBRATORY COMPACTION OF GRANULAR MATERIALS

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Laboratory testing equipment was customized to assess energy-efficiency in the compaction of granular materials using a vibratory hammer. The equipment is based on Standard Test Method ASTM D7382-08 (Method A) supplemented with continuous monitoring of density and energy during the compaction process. The density growth is derived by tracking the downwards displacement of the tamper in contact with the surface of a constant mass of granular material contained in a standard compaction (Proctor) mold. The energy is estimated as the product of the elapsed compaction time and the impact power rated by the manufacturer of the vibratory hammer.

The graphic representation of density versus the cumulative energy consumed during the compaction test produces a density growth curve. With increasing energy the material density increases from a loose (uncompacted) value towards a maximum density, and the rate of increase is characterized by the material's compactibility. Energy-efficient compaction is achieved when the desired state of compactness is reached at the expense of lesser energy. The paper describes a laboratory test method used to evaluate both the compactibility and the maximum density attainable by the vibratory compaction process. Results of laboratory testing on one type of granular material are discussed for compaction energy-efficiency. This approach can be used in support of sustainable earthwork construction practices to guide the optimal selection of compaction variables such as vibratory frequency/amplitude, surcharge or lift thickness.

LIQUEFACTION-INDUCED DAMAGE TO BURIED GEOTECHNICAL STRUCTURES DURING EARTHQUAKE: A REVIEW

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This paper provides an overview of the current understanding of the failure mechanisms of underground structures due to liquefaction and subsequent ground settlement and/or flow failures when the ground is subjected to strong shakings. The geotechnical structures buried near the ground surface have a wide range of applications, from small scale pipelines such as means of gas transmission, telecommunications, water supply, and sewerage pipelines, to large scale structures including tunnels for various transportation systems. Based on post-earthquake investigations, experimental laboratory data as well as numerical simulation of underground structures published in geotechnical engineering books, theses and journals, liquefaction may cause serious damage to those infrastructures. In particular, lifeline systems, such as sewage pipes and manholes, buried in liquefiable soil had a severe impact on residents in the affected areas. Among failure mechanisms presented and detailed discussed in this paper, we can mention: a) lifting due to the liquefaction of replaced fill soils, b) the shear failure and uplift of underground structures, and c) disconnection of pipe joints due to the liquefaction of filled soils and the surrounding ground.

FORCE MONITORING OF PRE-STRESSING ANCHORS IN GEOTECHNICAL APPLICATIONS USING DYNA FORCE SENSORS

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The maintenance of infrastructures has been of particular concern to the engineering community. As the world's infrastructure expands and existing infrastructure ages, monitoring and evaluation of the structures have become more critical than ever. A large number of retaining walls, bridge abutments, dams and other geotechnical structures are post-tensioned. Some existing structures need repair using the post-tensioned system. There are few testing methods available to assess the anchor forces in the structures. However, high cost, complicated equipment and limitation of space often prevent these methods from being implemented. DWYDAG-Systems International (DSI) has been involved in the development, testing and utilization of DYNA Force® sensors to measure the force in the anchors during construction and at any time during the lifetime of the structure.

These sensors are manufactured based on the magneto-elastic properties of ferrous material. A readout unit is designed to magnetically energize the steel through the sensor and measure the response of the steel to a direct force reading. It can be used for bare, coated and even grouted steel. In addition to the long-term monitoring benefit of using the sensor, it may also be used to check the load during stressing to address the safety of the structure. It will eliminate the use of large equipment during a lift-off operation. The force reading can be collected manually, automatically and also remotely. The DYNA Force system is stand alone and it can also be incorporated with other health monitoring instruments.

DYNA Force sensors have received attention in terms of accuracy, performance, ease in installation, durability, and cost effectiveness. They have been used over sixty projects. This paper will describe its application in tie-back force monitoring of Patton Creek Shopping Center in Birmingham, AL, USA, anchor force monitoring for slope stability of bridge abutment in Sellwood Bridge in Portland, OR, USA, tie-back force monitoring in permanent concrete retaining walls along I-405 in Los Angeles, CA, USA and forces in tension ties in Ottawa confederation line in Canada.

NUNAVUT PERMAFROST DATABANK

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There is considerable work currently being undertaken in Nunavut on permafrost mapping and characterization; however, the results of this research are largely difficult to access and are spread out across a number of separate forums. Due to this lack of centralized access for permafrost data in Nunavut, there is a high risk of data loss and for data to be inaccessible when it is most critically needed by northern decision-makers.

To address this concern, the Government of Nunavut's Climate Change Section is developing a centralized Permafrost Databank that will house permafrost temperature data for Nunavut. This databank will serve to make data, in its various forms, more accessible to practitioners. The major components of the project include collecting permafrost temperature data from various sources, including governments, academia, and industry, and integrating it into an online interface. This databank is being designed for user-friendly accessibility, and is intended for Nunavut researchers, government staff, as well as the general public. Due to the varied formats and sources of data, the databank will be developed as a geo-referenced map, linking to other online forums that contain key permafrost data, publications, or references. This project is not intended to duplicate existing work or databases, but rather to compile and centralize these sources into one centralize location. The Government of Nunavut is still in the development phase of this project and welcomes feedback on its design and data sources before the Permafrost Databank is released in 2016.

EVALUATION OF EQUIVALENT CYCLES LIQUEFACTION CONCEPT BASED ON TSS TEST RESULTS

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The concept of equivalent number of cycles is that, an irregular earthquake load can be replaced by uniform cycles that have the same effect on the soil to trigger liquefaction. In this paper, irregular cyclic strain-controlled tests have been carried out using the new (combined triaxial simple shear) TSS apparatus on different saturated reconstituted samples of Ottawa sand. A conversion of these irregular loadings to an equivalent damaging number of uniform cycles (N_{eq}) having 65% of maximum shear stress amplitude has been then carried out. Based on such a conversion, the obtained uniform cycles are then applied to sand samples with the same conditions in order to verify the consistency between results of both patterns. The experimental results show that the concept of equivalent cycles based on 0.65 of maximum shear stress amplitude must be used with cautions.

ÉVALUATION EN LABORATOIRE DES PROPRIÉTÉS THERMIQUES DU BASSIN SÉDIMENTAIRE DES BASSES-TERRES DU SAINT-LAURENT.

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Durant les dernières décennies, le développement de l'énergie géothermique comme une ressource efficace et propre a augmenté dans plusieurs pays du monde. À côté du chauffage des bâtiments, des tentatives pour utiliser la géothermie profonde à des fins de production d'électricité ont abouti à des résultats positifs. L'évaluation du potentiel géothermique pour une application ou une autre nécessite une bonne connaissance des caractéristiques thermiques du sous-sol. La conductivité thermique figure à la tête de la liste des paramètres d'intérêts.

C'est dans ce contexte qu'une évaluation des propriétés thermiques en laboratoire a été effectuée sur une cinquantaine d'échantillons de surface issus des principales formations de la plateforme des Basses-Terres du Saint-Laurent. Cette étude fait partie d'un plus vaste projet destiné à évaluer la possibilité de produire de l'électricité à partir de la géothermie profonde dans la province de Québec. Les échantillons ont été ramassés dans la portion québécoise du bassin sédimentaire et forment une collection quasi représentative de toute la colonne stratigraphique de la plateforme des Basses-Terres du Saint-Laurent. Les analyses de conductivité thermique ont été réalisées avec une sonde à aiguille sur des échantillons majoritairement secs et parfois humides. La composition minéralogique et la porosité ont également été estimées avec des lames minces pour chaque échantillon. Ceci a permis d'évaluer approximativement la capacité thermique et par conséquent la diffusivité thermique.

Les résultats démontrent que les formations argileuses à l'instar de l'Utica et du groupe de Sainte-Rosalie sont les plus isolantes, avec une conductivité thermique de l'ordre de $2.5 \text{ W K}^{-1} \text{ m}^{-1}$, une capacité thermique massique de près de $850 \text{ J kg}^{-1} \text{ K}^{-1}$, et une diffusivité thermique qui ne dépasse pas $1.45 \text{ mm}^2 \text{ s}^{-1}$. En revanche, les formations gréseuses se présentent comme les meilleures unités conductrices de chaleur. Les grès de Potsdam par exemple montrent une conductivité thermique allant jusqu'à $6 \text{ W K}^{-1} \text{ m}^{-1}$, une capacité thermique massique de $700 \text{ J kg}^{-1} \text{ K}^{-1}$, et une diffusivité thermique qui peut dépasser $3.5 \text{ mm}^2 \text{ s}^{-1}$.

Cette étude demeure une première caractérisation thermostratigraphique à l'échelle du bassin sédimentaire qui pourrait servir de référence à des recherches plus poussées sur le sujet.

EFFECT OF PRECIPITATION ON LONG-TERM VARIABILITY OF UPPER PERMAFROST TEMPERATURES IN CENTRAL YAKUTIA, NE RUSSIA

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In certain settings, air temperature is secondary to other meteorological factors in influencing upper permafrost temperatures. This is the case where the seasonal snow cover is very loose. One such area is Central Yakutia in the interior of north-eastern Russia, where long-term studies indicate that snow cover and soil moisture have a greater combined effect on ground temperatures than does air temperature. Snow cover depth depends on the amount of winter precipitation. Heat losses from the ground in winter are reduced with greater snow depth, resulting in warmer ground temperatures. Higher rainfall, especially in the second half of summer, increases soil moisture contents prior to the winter season. As is known, this leads to the greater heat expenses on freezing, as well as to the higher insulating effect of the snow cover. Central Yakutia is characterized by strong interannual variations in snow depth and rainfall, so that the interannual amplitude of mean annual permafrost table temperature is up to 3-4°C. Our observations over the last 17 years have clearly shown 3-5-year cycles in ground temperature variation, which correlate well with the interannual variations in snow cover and pre-winter soil moisture content. The highest ground temperatures are associated with higher pre-winter soil moisture contents and greater early-winter snow depths. Local permafrost degradation with attendant thermokarst activity were observed during such years. As yet, the long-term variability of upper permafrost temperature has not shown any significant trend in Central Yakutia. In the authors' opinion, permafrost temperature changes in the nearest future will depend on the relation of wet and dry years.

LONG-TERM ACTIVE LAYER OBSERVATIONS, BARROW, ALASKA

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Understanding variations in active layer thickness (ALT) over multi-decade periods is critical to both engineering and environmental concerns. Beginning in the early 1950s with work by the U.S. Geological Survey, Barrow, Alaska has been the site of numerous active layer and permafrost investigations. These early studies were followed in the 1960s by the U.S. Army's Cold Regions Research and Engineering Laboratory (CRREL), in the early 1970s under the International Biological Programme's Tundra Biome studies, from 1992 to present by the Circumpolar Active Layer Monitoring (CALM) program, and since 2002 by the Global Terrestrial Network for Permafrost (GTN-P) boreholes. The present report builds on a 2010 publication that reported recent decadal variations in ALT in moisture-controlled landscapes, and compares empirical data on maximum seasonal thaw with modeled values of ALT based on available Barrow meteorological data back to 1924. The average measured ALT obtained by physical probing for the combined CRREL (1962 -1970) and CALM (1991-present) periods was 35 cm, with a minimum of 22 cm in 1992 and a maximum of 45 in 1968. We also compare our probed ALT values with those calculated from measured soil-permafrost temperatures at several locations in the Barrow area. At these moderately well-drained sites maximum ALT during the period 1997 to present ranged from 33 to 63 cm with freeze back dates ranging from October 9, 2001 to November 12, 2012. The average modeled ALT calculated from modeled soil-permafrost temperatures for 1924 to present was 34 cm with a minimum of 18 cm in both 1945 and 1969 and a maximum of 54 cm in 1998. Comparison of the same thaw periods (1991-present) indicates that modeled thaw values are somewhat greater than those measured by mechanical probing.

NUMERICAL SIMULATION STUDY ON TEMPERATURE FIELD OF THE SHALLOW LAKE

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Water temperature is an important factor in science study on lake and reservoir, and the foundation of understanding the physical, chemical and biological phenomena and dynamic processes. Water temperatures, to a large extent, depends on solar radiation, and in some situation heat flux of water - sediment interface are also important in vertical temperature distribution. The traditional water temperature model only places solar radiation to the surface and ignores the process of temperature rising on water body absorbing solar radiation at different depth. Moreover the bottom water adopts the thermal adiabatic boundary condition, thus contains obvious errors. In order to overcome the inefficiency of the traditional model, we proposed a water temperature model that applies for shallow lakes. Put the solar radiation which is traditionally regarded as part of heat budget in air-water interface, into the convection-diffusion function. The model for heat flux of water - sediment interface, based upon EFDC (Environmental Fluid Dynamics Code), adopts an modified heat balance function to describe the heat exchange process between water body and sediment bed. The model introduces operator splitting method to solve the hydrodynamics-water temperature partial differential equations. Lake Dong is chosen as the research subject to simulate the water temperature, and explores the daily and monthly changing process.

DURABILITY OF LIGHTLY STABILISED GRANULAR MATERIAL SUBJECTED TO WET-DRY CYCLES

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The technique of stabilization of granular base materials using cementitious binders has been in practice for many years to improve their mechanical properties. Stabilisation improves the properties of the unbound material and makes it suitable for many applications. The cost associated with cementitious materials and the possible shrinkage cracks in the cemented material limited the use of stabiliser and resulted in lightly stabilised material.

Typical strength and stiffness tests on stabilised granular material do not assure long term durability of the material. Durability of stabilised material is another concern for the mix design of stabilised granular material. Wet-dry (w-d), one of the factors affecting the durability, can lead towards the deterioration and premature failure of pavements. Currently, there is no standard test method available to assess the durability against w-d of the lightly stabilized granular material.

In this study, three different element testings, namely, unconfined compressive strength (UCS), repeated load triaxial test and flexural test is selected to study the effects of w-d cycle. Cylindrical specimen of 115 mm height and 100 mm diameter is to be selected for UCS; beam specimen of 76 mm×76 mm×285 mm is to be selected for flexural testing; cylindrical specimen of 195 mm height and 100 mm diameter is to be selected for the repeated load triaxial test. Binders, general blended cement and fly ash of 1.5% at the ratio of 3:1 will be used to stabilize the granular material.

After specific curing period, the specimen will be subjected to different w-d cycles and then tested for UCS, flexural and repeated load triaxial test. A w-d cycle consisting of submerging the specimen in the water for 5 hours and keep the specimen at 60°C for 42 hours. The UCS and flexural test is to be conducted using monotonic loading whereas the repeated load test will follow a haversine shape of 10Hz with 0.9s resting period. The proposed study will evaluate the effect on w-d cycle on UCS, flexural strength, resilient modulus and permanent deformation.

FLEXURAL, COMPRESSIVE, AND THERMAL PROPERTIES OF A COMPOSITE GEOFOAM-GEOGRID MATERIAL FOR EMBANKMENTS ON POLYGONAL GROUND

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Permafrost degradation and thawing of ice wedges (polygonal ground) can cause excessive differential deformations or embankment failures caused by sinkholes, resulting to significant maintenance efforts and safety hazards. The mechanical and thermal properties of a composite geofom-geogrid material known as Reinforced Polymer Base® (RPB) were studied in the laboratory. This material provides a contiguous composite base which can insulate the polygonal ground and bridge weak areas when ice wedges are thawed. Results from laboratory tests will help assess the effectiveness of the composite material as base insulator and reinforcement of road or railway embankments on polygonal ground and how embankments with RPB can be designed in the future. Preliminary results of the study are presented in the paper.

ANALYSE DE LA DÉGRADATION PRÉMATURÉE DE L'ENROCHEMENT DU BRISE-LAMES DE RIVIÈRE-AU-RENARD SOUS UNE APPROCHE DE RÉSISTANCE AUX CYCLES DE GEL/DÉGEL, GASPÉ, QUÉBEC

Philippe Morin (1), Guy Dionne (1)
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En raison du contexte géologique particulier de la Gaspésie, y trouver des pierres de bonne qualité pour être utilisées dans le cadre d'ouvrages maritimes et côtiers représente un défi que les différents intervenants impliqués dans ces projets doivent sans cesse relever. Suite à seulement quelques années d'opération, il n'est pas rare que l'enrochement utilisé initialement dans ces ouvrages se dégrade de manière prématurée et ce, malgré leur conformité aux essais normalisés en vigueur.

Parmi ces ouvrages, on y retrouve le brise-lames principal et le quai principal de Rivière-au-Renard qui se trouvent tous deux à l'anse de la Rivière-au-Renard dans une baie ouverte sur le golfe du Saint-Laurent. Ces deux ouvrages avaient pourtant fait l'objet de travaux correctifs majeurs en 2004 par Travaux publics et services gouvernementaux Canada (TPSGC).

Les services professionnels d'Inspec-Sol inc. ont ainsi été retenus par TPSGC afin d'effectuer une expertise géologique dans le cadre d'un second projet de réfection de ces ouvrages. Le besoin d'effectuer cette expertise géologique s'est avéré nécessaire suite à l'apparition d'un phénomène de détérioration prématurée de pierres mises en place lors des travaux de 2004, notamment sur des pierres composées de dolomie et de grès.

Cette expertise avait pour objectif de cibler les pierres problématiques sur les ouvrages existants ainsi que les carrières d'où elles proviennent et de faire ressortir, grâce à des essais spéciaux en laboratoire et d'observations de terrain, les causes les plus probables de leur détérioration. Afin de compléter les informations provenant des essais normalement utilisés dans l'industrie pour déterminer les caractéristiques intrinsèques des pierres, des essais de résistance aux cycles de gel/dégel (ASTM D5312-04) et de mouillage/séchage (ASTM D5313-04) ont également été réalisés sur des tranches de roches provenant de pierres ayant été échantillonnées dans les différentes carrières ciblées. Ces essais sont rarement réalisés dans l'industrie en raison de leur complexité et de leur durée.

Suite à la réalisation de cette expertise, c'est l'essai de résistance aux cycles de gel/dégel sur des tranches de roche qui a permis de recréer le plus fidèlement les phénomènes de dégradation ayant pu être observés sur les ouvrages maritimes actuels.

ANALYSE ET MODÉLISATION DES GLISSEMENTS DE TERRAINS DANS LA RÉGION D'ALGER: CAS D'EL ACHOUR

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Les glissements de terrain représentent une menace majeure pour la population, les bâtiments et les différentes infrastructures, ils sont très fréquents dans la région d'Alger, dont fait partie notre site d'étude, où a été observée différents problèmes d'instabilités tels que fissuration des murs, rupture de chaussée et de canalisation, mouvement de terrain etc. ces mouvement ont été localisés principalement dans les marnes du Plaisancien qui couvrent une large surface du Sahel algérois (littoral en arabe) avec des pentes qui peuvent varier de 5 à 30% et représentent le substratum sur lequel le développement de la ville se dirige. Les tentatives de constructions sur ces formations géologiques ont été mal conduites ce qui a induits des problèmes d'instabilités dans le sol avec des conséquences financières importantes. Cette études consiste en une analyse et une interprétation des paramètres géotechnique des marnes plaisanciennes. Une approche de modélisation de ce phénomène par un code de calcul par éléments finis (Plaxis) sera présentée dans cette étude en introduisant différents scénarios nous permettant d'analyser la stabilité de la pente de la région d'El Achour (Alger), menacé par les glissement de terrain.

SPATIAL VARIATIONS AND CHARACTERIZATION OF WATER ISOTOPES IN THE SOURCE AREA OF THE YELLOW RIVER

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The source area of the Yellow River is situated in the northern part of Qinghai-Tibet Plateau, the regions with continuous and discontinuous permafrost, seasonally frozen ground and lake taliks contributed to the complex hydrogeological structures; Due to the remark global warming, the local water environment have been faced serious challenges and it would affect the water security in Yellow River's middle and lower reaches. In order to improve the understanding of local water movement, hydrogen and oxygen stable isotopes as well as tritium concentration are analyzed for water samples collected from lakes, rivers, springs during April, July, August, 2014. The 2H and 18O ratios showed special spatial and temporal distribution characteristics; the isotopic differences in different types of water revealed the influence of evaporation on the water resources and the changes of hydrological paths qualitatively; and the tritium had been used to study the ages of soil water and ice in permafrost aquifers. These information would be useful for monitoring of local water cycle and the management of water resources .

IMPACTS OF PERMAFROST DEGRADATION ON ROADWAY ENGINEERING ALONG THE QINGHAI-TIBET ENGINEERING CORRIDOR

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Economic development has brought extensively expansion of human infrastructures, especially roadway engineering, within the Qinghai-Tibet Engineering Corridor (QTEC). The QTEC has a total length of 1120 km, and of which permafrost impacts about 550 km. For roadway engineering in these permafrost regions, embankments, pavements, bridges and culverts were bothered significantly by frost heave, permafrost creep and thawing settlement. Based on field monitoring and investigation, permafrost-related geotechnical problems on roadway engineering were analyzed along a highway and a railway within the QTEC. Results indicated that along the highway about 80 percent of embankment hazards were caused by permafrost thawing settlement and mainly performed as significant differential settlement. As a consequence, local subsidence, longitudinal and transverse cracks occurred on the pavement. Geotechnical problems on bridges along the highway mainly occurred on affiliated structures and upper structures. Damages and failures on culverts were mainly resulted from freezing-thawing actions, aeolian sand- and icing-flows and unreasonable construction method. While for the railway, the main geotechnical problems were considerable settlements on earthen embankments and uneven settlements at embankment-bridge transition sections. These settlements were closely related to underlying permafrost warming and thawing. In addition, some geological phenomena within the QTEC, including frost mound, ice mantle and thermokarst lake, and their potential destructive impacts on roadway engineering were discussed.

A STUDY OF TIME-DEPENDENT BEARING CAPACITY OF DRIVEN PILES

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Driven steel H-piles (HP 310 x 110) of up to 50 m in length were adopted to support two multi-span bridges in Greater Toronto Area. The founding soils at the sites generally consisted of compact to dense cohesionless deposits and stiff to hard cohesive deposits. Due to absence of bearing stratum at the pile founding depths, the piles are generally regarded as friction piles, as the pile capacity mainly consists of shaft skin friction.

During installation of the piles, Pile Driving Analyzer (PDA) tests were carried out to measure the pile capacity. It was found that the pile capacity values measured at the end of initial driving (EOID) were well below the design capacity. Typically, the pile capacity at EOID is about 30% to 50% of the design capacity. However, it was observed that the pile capacity would increase significantly with time. At about two weeks after EOID, the pile capacity increased to about 2 to 3 times the capacity at EOID, which met the design requirements.

This paper presents a study of pile capacity increase with time using PDA test results. Based on analyses of test data, the skin friction capacity is separated from the end bearing capacity of the piles. Comparison of skin friction distributions along the pile depth at EOID and within 2 weeks after EOID was made. It was found that the increase of the end bearing capacity with time was limited. The increase of pile capacity with time mainly results from the increase of skin friction resistance due to set-up effect. For example, the bearing capacity of a 44 m long pile had increased from about 1200 kN at EOID to about 3200 kN at 9 days after EOID, with 90% of the capacity increase being due to the increase of skin friction resistance. The mechanism of the pile capacity increase with time has also been discussed in this paper.

PERMAFROST ENVIRONMENT PROBLEMS AND COUNTERMEASURES IN THE PROCESS OF COAL MINING

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The effect of resources mining on permafrost is rapid, extensive, and direct. Its environment impacts surpass those of all other human activities. In particular, due to the intense effect of coal mining activity, the permafrost environment becomes more fragile in the mining area. Muli coalfield mining area of Qinghai Province is located in the permafrost zone with Altun-Qilian mountain alpine belt in Qinghai-Tibet Plateau. It is more sensitive to the permafrost ecological environment that Muli mining area is situated on the ecological function zone with water conservation in Datong river upstream. Based on the analysis of regional permafrost distribution and characteristics of permafrost, we discuss the permafrost environmental problems in the process of coal mining. The permafrost environment problems include the permafrost change and the natural environment change of the permafrost region in Muli coalfield mining area of Qinghai Province. Finally, the protection measures are proposed to avoidance and mitigation disadvantage impact on the permafrost environment in the process of coal mining. It will provide scientific basis for the resource's utilization and protection in cold regions.

THE EFFECTS OF PERMAFROST DEGRADATION ON THE HYDROLOGICAL REGIME OF SUBARCTIC PEATLANDS

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Permafrost thaw is a direct consequence of human disturbance in Arctic and Subarctic regions. Thin and warm permafrost is most sensitive to surface disturbance and may disappear within a few decades following an initial disturbance. Seismic lines are one of the most common types of linear disturbance, yet their impact is poorly understood. A distinctive feature of seismic lines is their geometry. These straight cut lines cross fens, bogs, peat plateaus, rivers and lakes thereby connecting hydrological units, which were otherwise disconnected. . The relatively warm water from lakes and fens may enter these lines contributing to further degradation of permafrost.

The purpose of this study is to characterize ground water dynamics between major hydrological units in the region of discontinuous permafrost in the Scotty Creek basin (at 61.310677N and 121.309181W), approximately 60 km SE from Fort Simpson, North West Territories. A number of geophysical surveys were conducted to delineate permafrost, peat and mineral soil borders. Temperature and water level observations were carried out throughout the year to understand the impact of thawing permafrost on hydrology of the research area. We found that as soon as the permafrost table descends below the water table, the seismic line creates a link between fens and bogs, slowly conveying water along the line. The water flow may take place all year round if it is not interrupted by accidental freeze of the talik layer between the active layer and permafrost.

LESSONS LEARNED FROM TEACHING A FOUNDATION DESIGN GRADUATE COURSE AT RYERSON UNIVERSITY

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This paper presents a course development and lessons learned from teaching a graduate course-Advanced Foundation Design at Ryerson University. This course considers practical design of shallow and deep foundations for various structures. The topics cover a review of soil mechanics, subsurface investigation, foundation type, design principles, shallow foundation, pile design for axial and lateral loads, pile group, shaft design, and numerical simulation of foundations using software. This course was developed eight years ago. So far it has been offered four times in every other year to graduate students on an average of 24 students each time. The tasks for students include attending regular lectures and guest talks, conducting personal readings and individual and team projects, critical reviewing of a research paper, making a public presentation, and finishing a final exam. The results from last four offers will be discussed based on statistics analyses of student compositions, student performance, and feedbacks. In the end, it will be discussed on how to improve the quality of teaching and enhance the students' learning experience for future geotechnical courses.

ASSESSMENT OF PERMAFROST CONDITIONS IN SUPPORT OF THE REHABILITATION AND ADAPTATION TO CLIMATE CHANGE OF THE IQUALUIT AIRPORT, NUNAVUT, CANADA.

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This study uses a GIS approach that makes up for the absence of an appropriate characterization before the construction of the Iqaluit airport during WWII and in the 1950's. Mapping of surficial geology, hydrography and landforms indicative of the presence of ground ice (e.g. tundra polygons) was produced by interpreting aerial photographs, maps and plans dating back from the initial phases of construction (1948) and air photographs taken at intervals since then, to the most recent high-resolution satellite images. An extensive drilling program with extraction of permafrost cores from below the runway, taxiways, aprons and surrounding terrain allowed the acquisition of detailed cryostratigraphic and geotechnical data and support geophysical interpretations. Geophysics methods, such as ground penetrating radar (GPR), were used to enhance distribution of ground ice and stratigraphic units. The installation of 6 thermistors cable allowed the monitoring of active layer and permafrost temperatures at the airport since 2010. Modeling of ground temperature regime of the permafrost and active layer using past and current climate data is currently being conducted to assess the behavior of the infrastructure according to climate warming scenarios. Results show that the original terrain conditions prevailing before the construction of the airport have a significant impact on the current stability of the infrastructure. Sectors affected by differential settlements and instabilities are generally coincident with the original hydrographic network that has been filled and diverted to extend the facilities. In addition, paved surfaces are affected by frost cracking. Continuity with nearby terrain and hyperbolic reflectors under the larger linear settlements on GPR profiles suggests that part of the actual frost crack network follows pre-existing ice wedge patterns. Drilling in the differential settlements areas confirmed that the foundations of the infrastructure lie on several meters of ice-rich permafrost such as massive ice associated with large ice wedges. Temperature data acquired with thermistor cables in the runway, in a taxiway, in the apron and in nearby natural terrain shows that the thickness of the active layer varies between 90 centimeters for the sectors covered with vegetation and almost 3 meters below paved surfaces. This means that thaw depth has now reached down into the original terrain under the infrastructure, thus causing settlements due to melting ice-rich soils. This established context of permafrost is now used by the stakeholders for the rehabilitation of the airport and its adaptation to climate change.

SOFT CLAY DRAINAGE CONSOLIDATION USING ELECTRICALLY CONDUCTIVE WICK DRAINS (ECWD)

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Traditional electro-osmosis (EO) method has not been widely used for drainage consolidation of soft clay in practice because of two key problems; (i) metal electrode corrosion, and (ii) high electric energy consumption. With the recent advancements in the conductive plastics, some researchers are working on using conductive plastic electrodes instead of metal electrodes to accelerate the drainage of soft clay.

This paper presents the details of an in-situ EO test using a new type of patented electrically conductive wick drain (ECWD) and a specially designed power supply system on a soft clay ground in Jiangsu Province, China. The in-situ tests and laboratory tests were conducted to evaluate the treatment effectiveness after EO for a period of 21 days. The results suggest that the EO method, i) decreased the moisture content of the soft clay from 62% to 36%; ii) increased the dry density and the vane shear strength, respectively from 1030 kg/m³ to 1500 kg/m³ and from 0 kPa to 25.5 kPa. In addition, the ground bearing capacity also increased from 0 kPa to 74 kPa. The electric energy consumption for this EO treatment is only 5.2 kWh/m³. Investigations to date suggest that the new type of ECWD presented in this paper is encouraging for use in the drainage consolidation of soft clay with high water content.

ESTIMATION OF UPLIFT FRICTION OF SINGLE PILE IN EXPANSIVE SOIL USING THE MECHANICS OF UNSATURATED SOILS

Yunlong Liu (1), Sai K Vanapalli (1)
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Pile foundations installed in expansive soils are typically subjected to uplift friction forces along the pile shaft during the swelling of the expansive soils upon infiltration. However, the influence of these forces is not taken into account in the conventional design of single piles. This leads to the redistribution of the pile axial force and possible upward movement of the pile body. It is therefore necessary to check the pull-out stability and tension capacity for pile foundations in expansive soils with respect to infiltration. In this paper, the conventional β method that is used for the estimation of the single pile bearing capacity is modified to estimate the ultimate uplift lateral friction considering the influences of swelling pressure and matric suction. The modified β method proposed in this study requires the information of the Soil-Water Characteristic Curve (SWCC) and the saturated soil shear strength parameters. Experimental data on Regina expansive clay is used in the proposed method to analyze the distribution and variation of the uplift friction along the shaft of an ideal pile installed in Regina expansive clay. The proposed method is simple for use in the rational design and analysis of pile foundations in expansive soils.

DÉTERMINATION DE PROPRIÉTÉS PHYSIQUES ET MÉCANIQUES DU PERGÉLISOL DU NUNAVIK (QUÉBEC, CANADA)

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Comme elles sont inaccessibles par voie terrestre, les 14 communautés nordiques du Nunavik (Québec, Canada) dépendent toutes du transport aérien afin d'assurer en tout temps un lien rapide et efficace avec le reste du Canada. Certaines pistes d'atterrissage, construites sur pergélisol vers la fin des années 1980, ont montré des signes de détérioration quelques années seulement après leur mise en service. De nombreuses études portant sur l'effet que les pistes ont sur le régime thermique du sol indiquent un dégel localisé en bordure de remblai ainsi qu'aux endroits où il y a des problèmes de drainage. De plus, depuis une vingtaine d'années, on observe une augmentation marquée des températures moyennes annuelles de l'air au Nunavik, entraînant ainsi la dégradation du pergélisol et des tassements importants au niveau de pistes d'atterrissage. En raison des changements climatiques, la dégradation du pergélisol au Nunavik est maintenant inévitable et devient préoccupante pour l'intégrité des infrastructures aéroportuaires appartenant au ministère des Transports du Québec.

Le présent projet consiste à déterminer l'épaisseur sensible de sols gelés et certaines caractéristiques physiques et mécaniques du pergélisol du Nunavik, jusqu'alors peu documentées, afin d'évaluer les tassements reliés au fluage à long terme ainsi qu'à la consolidation au dégel. Pour y arriver, une campagne de forage a été réalisée dans le but de récupérer des échantillons gelés et de caractériser le pergélisol aux emplacements problématiques. Ces sondages ont été effectués sur sept pistes d'atterrissage et deux routes d'accès. Les échantillons intacts récupérés ont été ramenés au laboratoire de l'Université Laval pour être soumis à des essais de fluage en cellule triaxiale et à des essais de consolidation au dégel en cellule oedométrique. Les résultats de ces essais ont permis d'obtenir une estimation du taux de déformation en fluage à long terme pour deux types de sol à différentes contraintes et températures. Pour les essais de consolidation au dégel, les tassements associés à ces deux types de sols ont également été évalués, et ce pour différentes teneurs en glace.

À la lumière de ces résultats, les tassements des pistes peuvent être anticipés en s'appuyant sur des scénarios de réchauffement climatique et sur les profils de température relevés en continu sur le terrain. Le ministère des Transports du Québec, en collaboration avec l'Université Laval, pourra ainsi développer une stratégie réaliste d'adaptation des infrastructures de transport du Nunavik affectées par les changements climatiques.

SOLAR POWER IN ONTARIO – GEOTECHNICAL LESSONS LEARNED

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In 2009 the Ontario Government passed the “Green Energy and Green Economy Act” and the associated Feed in Tariff (FIT) Program, subsequently transitioning to the Large Renewable Procurement (LRP) Program commencing in 2014. These Programs encourage and promote greater use of renewable energy sources. Since the introduction of these initiatives, the construction of solar power generating facilities (particularly of sites in the order of 10 MW) has burgeoned in the province. However, the design and construction of these facilities has not been without significant hurdles. This paper explains some of the difficulties encountered with the geotechnical aspects of design and construction of solar farms in Ontario and discusses the differences in the scope of the geotechnical investigations, what the short-comings of the investigation programs are, and what the implications have been for design and construction. The paper recounts a number of cases where project difficulties occurred due to: the presence of cobbles and boulders in the prevailing soils, caving of pre-drilled micro-pile holes; inability to install helical piers; and heaving of piles due to the adverse effects of frost. In many cases, these difficulties lead to claims by general contractors and their foundation sub-contractors. The paper concludes with a number of “Lessons Learned” specific to: defining the content and refining the scope of the geotechnical investigation; addressing problematic field conditions and specifically the adverse effects of frost; and, the application of and adherence to best-practices in construction.

ADAPT MONITORING AND DATA BASE PROGRAM

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The Canadian project Arctic Development and Adaptation to Permafrost in Transition (ADAPT) brings together a broad spectrum of expertise on Arctic environments, including geomorphology, geophysics, biochemistry, microbiology, ecology and civil engineering, to study the mechanisms and impacts of permafrost degradation within an integrative and interdisciplinary systems framework. ADAPT aims to provide an improved understanding the physical and biogeochemical linkages between the land, freshwater, vegetation, and the atmosphere in order to identify the processes that couple environmental change to the rate and state variables of permafrost geosystems and ecosystems, and ultimately to model permafrost, vegetation, and associated carbon fluxes at regional and pan-Canadian scales. To develop statistical and numerical models that represent permafrost behavior at multiple space and time scales including downstream effects on connected environments, ADAPT was required to standardize fieldsampling, observation and data management protocols. These protocols are designed to optimize intersite comparisons, and to maximise exchange and the use of data produced by each ADAPT researcher at all ADAPT sites across Canadian Subarctic and Arctic. A set of standardized protocols have been developed for characterizing the active layer, the overlying vegetation in the buffer layer, and the underlying permafrost layer. Stand methods have also been developed for laboratory analyses and data compilation to provide inputs to these regional models and to help integrate across sites. ADAPT is thus generating standard cryostratigraphic information of permafrost, which includes borehole logs with CT-scans of the cores, and field photos providing general stratigraphic descriptions, presence and nature of visible ice (ice lenses, large crystals, section of wedges and veins larger than 200 micrometers), air temperature and soil properties (mineral-organic content). ADAPT is also contributing to the global question of carbon sequestration and release by permafrost by performing CHN content analyses from active layer samples and cores containing frozen organic matter. Carbon 14 dating is also being applied according to a standradized sampling regime. Finally, according to subproject objectives, further analyses such as geomorphological, geotechnical and microbial DNA analyses are being performed, with subsampling based on the interpretation of the borehole logs. The regional ADAPT data sets, along with continuous air and borehole temperature records, are being made available via the digital object identifier (DOI)-referenced, open access data publication series Nordicana D (<http://www.cen.ulaval.ca/nordicanad>). For several of these aspects, ADAPT is collaborating with the European Seventh Framework project Changing Permafrost in the Arctic and its Global Effects in the 21st Century (PAGE21).

USE OF LIDAR IMAGERY AND FIELD OBSERVATIONS TO VERIFY THE STABILITY OF SOIL AND ROCK SLOPES NEAR KITIMAT, BC

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The overburden along the Bish Creek valley generally comprises of complex assemblages of glacial till and coarse glaciomarine sediments, which were deposited along the valley bottom in close proximity to the decaying, fluctuating glacial margin, and were variably overridden by ice. Fluvial downcutting and freshwater leaching of the glaciomarine silt and clay in post-glacial time has resulted in the development of potentially highly sensitive clays/silts. Historical landslides (e.g. 1953, 1962, 1975 and 1993) and construction-induced failures in these deposits have previously occurred and are well documented. As a result, the assessment of slope stability and prediction of cut slope performance has been one of the key geotechnical challenges in this general area.

Ground reconnaissance of the site was planned and performed along some of the Forestry Service Roads (FSR) and natural slopes of the Bish Creek valley located southwest of Kitimat, BC. The purpose of the program was to assess the condition of natural and manmade slopes and to explore shallow subsurface soil and groundwater conditions where possible. Detailed notes of the slope height, slope angle, soil conditions, estimated shear strength, vegetation, groundwater and signs of instability were recorded at numerous locations across the site.

In addition to the general reconnaissance of the FSR side slopes, the available LiDAR imagery for the site was analyzed using ArcGIS software and key areas of interest were identified. These areas of interest were further explored as part of the site reconnaissance and included arcuate topographical landforms thought to represent existing or ancient slope instability back scarps, gullied glaciomarine terrain with the potential for associated soil exposures and slope instabilities, as well as large rock slopes and bedrock outcrops potentially subject to rock fall and debris slide hazards.

The collected data from the site is reduced and presented in various plots (e.g. observed slope height vs. inclination, etc.), providing valuable insights into the slope stability and anticipated performance of the cut slopes. The presented data may be used as a secondary tool to verify the performance of the natural and manmade slopes in the general area.

FACTORS AFFECTING PERMAFROST TEMPERATURES BENEATH RAISED STRUCTURES

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Designs of heated structures on permafrost often utilize raised foundations to create an air gap between the structure and the ground surface. Ice-rich permafrost soils experience significant settlement when thawed, and therefore the air gap virtually eliminates any direct heat transfer from the heated structure to the ground surface. Long-term ground temperatures adjacent to and beneath raised structures are the result of multiple and seasonally varying heat transfer mechanisms at the ground surface. These mechanisms, which include solar radiation, longwave radiation, convective heat transfer with the atmosphere, and evapotranspiration, are quantified as energy fluxes. Construction of a raised structure changes the individual energy flux components in different ways, and can result in higher net annual heat extraction from the ground and correspondingly colder ground temperatures relative to adjacent terrain. For example, in addition to eliminating virtually all solar radiation and snow cover from reaching the ground surface below the structure, the structure also emits longwave radiation toward the ground surface and reduces wind driven air flow over the ground surface beneath the structure. This paper explores the range of variability of surface energy flux components caused by raised structures to assess their individual and combined effects on permafrost temperatures.

IN-SITU AXIAL LOAD TESTS OF DRILLED DISPLACEMENT STEEL PILES

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Drilled Displacement Steel Pile (DDSP) is an innovative pile type that fully displaces the soil during installation. DDSP consists of a cone tip with steel blades and a steel pipe. DDSP is different from conventional fully or partially displacement piles in that the installed piles will remain in the ground to avoid the re-shearing of the soil surrounding the steel shaft. DDSP may have many advantages over conventional displacement piles, especially in Western Canada's soils: rapid installation, large axial and lateral capacity, and immediate usability after installation. Due to these advantages, DDSP has recently been widely used in varieties of engineering applications in Western Canada.

Despite the wide applications, the axial behaviour of DDSP has not been well understood by designers or researchers, and a design guideline has not been developed. In order to investigate the bearing capacity and load-transfer mechanisms of DDSP, a series of in-situ load tests of full-scale DDSP were conducted at two cohesive testing sites in Alberta. Three axial compression and two tensile tests were conducted on densely instrumented piles. The paper analyzes load test results and evaluates the applicability of different design methods that were adopted for other types of fully or partially displacement piles. The paper also evaluates the load-transfer mechanisms during axial compression and tension using the in-situ test results.

MODULUS OF ELASTICITY ESTIMATION WITH ONE DIMENSIONAL CONSOLIDATION TEST

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The modulus of elasticity has primary importance in geotechnical engineering, since it defines the deformability of soil under existing stresses. Elastic modulus (E_s) is most commonly derived from field tests and laboratory tests. Apart from these methods, empirical relations may also be used to predict E_s from one dimensional consolidation test, where other methods are inapplicable.

Determination of material properties is a prerequisite for stability assessment of geotechnical structures. When the stability analysis of a dam is of concern, E_s of tailings in this structure is one of the crucial parameters as compacted tailings serve as dam body.

In this study, E_s for copper tailings were predicted from oedometer test in order to use it for understanding of the deformation behavior of slurry. The main reason for this approximation is that, tailings at the surface of the dam was not intact and made it impossible to do undisturbed sampling and in-situ testing.

According to Sture (2004) and Piedrahita (2009), oedometer test may be used to estimate E_s . Grammatikopoulos et al. (2000) stated that the value of elastic modulus obtained from oedometer test is different from the value resulted from an unconfined compression test. This is due to the prevention of horizontal displacement, which causes horizontal stresses.

In the context of this study, oedometer tests were conducted on two samples, in order to obtain E_s under expected effective stresses at various depths in the field. Consolidation of loose tailings under their own weights was represented with these tests. Accumulated tailings in the dam were divided into three layers according to their depths. It is found that, those layers are nearly under the effect of 2 kg/cm², 4 kg/cm² and 6 kg/cm². Time-deformation readings were used to obtain void ratio and water content within the specimen and these were used to obtain oedometer modulus for the samples.

At the end of the experiments and calculations, a relationship between load and E_s was obtained. In order to check the performance of the study, it was compared to a similar study with nearly the same mixture percentages.

This study presents the E_s values for copper tailings, which essentially contributes to predictions in similar case studies. Therefore, this method could be used to find modulus of elasticity of soils whenever undisturbed sampling and field testing is not applicable.

MODELING THE BEHAVIOR OF A SHALLOW FOUNDATION IN COMPACTED CLAY

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Shallow foundations are typically used for lightly loaded structures in both natural and compacted fine-grained soils. The bearing stratum of these foundations in many scenarios is located close to the ground surface and is partly or totally above the natural ground water table. Both the bearing capacity and the settlement behavior of shallow foundations are significantly influenced by soil suction in the unsaturated zone of the soil, which is influenced by soil the moisture / soil suction regime due to the soil-environment interactions. The stiffness and the shear strength parameters of the bearing stratum are the key information required to model or estimate the settlement behavior and bearing capacity for shallow foundations. These parameters can be reliably estimated or determined extending the mechanics of unsaturated soils. Such an approach greatly contributes to the rational design of shallow foundations.

This paper presents experimental studies of a model shallow foundation loaded in compacted clay highlighting the significant influence of the soil suction on the settlement behavior and bearing capacity. The experimental results are modeled using numerical software, Plaxis considering the variation of the stiffness and the shear strength parameters of the compacted clay with respect to soil suction. The stiffness and the shear strength parameters are estimated using two different models extending the mechanics of unsaturated soils. There is a good agreement between the experimental observations and numerical simulations. The study presented in this paper highlights the importance of using rational unsaturated soil parameters in the modelling of the load-settlement behavior of shallow foundations. The approaches used in modelling studies are simple and reliable and thus can be extended in the conventional geotechnical design practice.

ESTIMATION OF THE WETTING FRONT DEPTH IN A LOESS SOIL DEPOSIT IN RESPONSE TO ENVIRONMENTAL FACTORS

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The extent of wetting depth in loess soil deposits associated with environmental factors is the key information that is required for the reliable estimation of field collapse settlement. This information is also useful in the reliable interpretation of rainfall-induced loess landslides because the sliding surface is typically close to the depth of the wetted zone. More recently, the extent of wetting depth has been determined by artificial field rainfall tests combined with other monitoring techniques, laboratory infiltration tests as well as numerical methods using permeability functions. From these studies, it is concluded that the extent of wetting front depth is affected by soil properties and environmental factors such as rainfall, evaporation, relative humidity. In this paper, case study results of a site in Northwestern China are discussed in greater detail. The moisture contents of soils within 10 m below the surface were monitored and measured for a period of one year. The wetting front extension was determined graphically by understanding the progressive trends of soil moisture in response to environmental changes at various levels of depth. In addition, commercial software VADOSE/W was used to simulate the flow behavior in loess deposits to get the variation of moisture content profile with respect to time using the local climate data (i.e., rainfall, evaporation and temperature) and vegetation data (i.e., root depth and leaf area index). The VADOSE/W is found to be a useful tool for reasonably simulating the measured wetting front. The results of the present study are promising as they can be used for reliable estimation of field collapse settlements and stability analysis of natural slopes in loess soil deposits.

MÉTHODOLOGIE DE CARACTÉRISATION ET DE VALORISATION DES SÉDIMENTS MARINS EN TECHNIQUE ROUTIÈRE

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La position géographique du Grand Port Maritime de Dunkerque (GPMD), associée à l'importante dynamique hydrosédimentaire caractéristique du détroit du Pas-de-Calais et à la présence de grands bancs sableux, contribue largement à l'engraissement rapide du port. En conséquence, de nombreux dragages d'entretien sont engagés annuellement par le GPMD. En plus de volumes importants de sédiments à draguer immergeables, le volume estimé de sédiments non immergeables à draguer d'ici 2015 est de l'ordre de 500.000 m³.

Cette étude porte sur la faisabilité de la valorisation des sédiments marins en technique routière. Cette étude vise à proposer une démarche de valorisation sur la base d'évaluation de paramètres, physiques, chimiques et mécaniques des matériaux alternatifs élaborés à partir de sédiments de dragage. Le principal objectif du travail consiste à prévoir le comportement mécanique et l'aspect environnemental de la formulation proposée à base des sédiments non-immergeable.

Dans cette étude, une valorisation des sédiments marins en couche de fondation est proposée, selon un mélange 1/3 de sédiments marins et 2/3 de sable de dragage traité à la chaux vive et au liant hydraulique. L'étude de valorisation se divise en deux phases. La première phase s'est déroulée en laboratoire afin de caractériser le comportement des sédiments introduits dans la formulation routière et d'évaluer leurs performances mécaniques et environnementales afin d'établir la possibilité d'utilisation en technique routière. La deuxième phase s'est conduite sur le terrain, en réalisant une première route expérimentale en France à Dunkerque. Un plot expérimental a été conçu pour le suivi environnemental et pour l'estimation de la durabilité de la route. L'étude démontre que ce type de sédiment peut être utilisé avec succès en géotechnique routière si on se conforme à la méthodologie développée.

TRENDS IN PERMAFROST PATCH SIZE ACROSS THE SPORADIC AND ISOLATED PERMAFROST ZONES, YUKON TERRITORY AND NORTHERN BC.

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Little is known about trends of permafrost patch size, distribution and dynamics from the margins of the isolated patches through to the boundary between extensive discontinuous and continuous permafrost. This research focused on initiating measurements of permafrost patch size along a 1400 km transect in western Canada. Sampling was undertaken in marginal discontinuous permafrost between Fort St-John, BC and Whitehorse, YT. A total of 10 study sites were examined during the summer of 2014.

The methodology used during fieldwork consisted of electrical resistivity tomography (ERT), active layer measurement and near-vertical aerial photography using a remotely-controlled airborne photography platform. The previous year's climate data (air temperature, ground surface temperature, snow cover thickness and temperature at the base of the active layer) were downloaded during site visits. ERT was the main tool to assess patch boundaries. ERT uses the contrast in electrical properties in frozen and thawed ground to generate a two-dimensional image. Several profiles with varying orientations (e.g. south-north/west-east) were undertaken at each site. Frost probing along the ERT profiles and at some sites, shallow boreholes, were used to interpret the resistivities. The aerial images were compared to historic aerial photos of sites, where available, to evaluate temporal change.

Field observations suggest that strong relationships may exist between permafrost boundaries and topography, drainage, soils (including the organic mat), and past disturbance. For example, analyses of field site MP 681, which represents the middle of the transect, show a strong correlation between local drainage and the boundaries of a permafrost patch. Where permafrost is present at the site, ground temperatures vary from 0°C to -0.5°C. Snow cover, topography and vegetation were not significant factors influencing the permafrost distribution at MP 681. A comparison of the new imaging with aerial photos from 1964 show no significant changes over the past 50 years. Ongoing data analysis is expected to establish whether spatial trends in permafrost patch size and characteristics exist along the transect or whether local factors are the primary controls.

ESSAIS D'INDENTATION SUR UNE ARGILE SENSIBLE

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Les sols argileux sont les types de sol les plus représentatifs de l'Est du Canada. Au Québec, les argiles, dites sensibles, couvrent environ 70% des régions peuplées des basses terres du Saint-Laurent, de la vallée de l'Outaouais et du Saguenay-Lac-Saint-Jean. Ces argiles peuvent causer de sérieux problèmes de déformations et de ruptures aux infrastructures et aux ouvrages qui y sont implantés, et ce en raison généralement de leur faible résistance. Les caractéristiques spécifiques de ces sols imposent des études approfondies préalables au dimensionnement des ouvrages. Ces études préalables passent par une caractérisation physique et mécanique des sols argileux, effectuée habituellement à l'aide d'essais pouvant être réalisés in situ et/ou au laboratoire.

Parmi les divers essais in situ, l'essai au scissomètre de chantier et l'essai au pénétromètre au cône ou au piézocône représentent probablement les meilleurs essais pour déterminer la résistance des sols argileux sur place. La prise d'échantillons permet compléter la connaissance des sols étudiés par la réalisation d'essais de routine et de résistance au laboratoire.

Dans le cadre de la présente étude, des essais d'indentation ont été effectués sur des échantillons intacts d'une argile très sensible prélevée dans la région de Beloeil, sur la rive sud de Montréal. Ces essais qui ont été réalisés avec différents types d'indenteurs ont permis de déterminer la résistance au cisaillement non drainée S_u et le module de déformation E du sol. Ces propriétés ont été comparées à celles obtenues à l'aide d'essais au laboratoire conventionnels. L'analyse des résultats obtenus a été faite en transposant les connaissances acquises depuis de nombreuses années dans le domaine des matériaux métalliques ou non-métalliques à l'aide de ces types d'essais.

Les principaux avantages des essais d'indentation réalisés dans la présente étude résident dans la rapidité et la répétabilité des mesures ainsi que dans la possibilité d'effectuer un grand nombre d'essais sur un même échantillon.

Mots clés : Sol argileux naturel, essai d'indentation, Module d'Young, caractérisation au laboratoire.

AN IMPROVED SOLUTION FOR THE EXPANSION OF CYLINDRICAL CAVITIES IN MODIFIED CAM CLAY

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Recently the authors presented a semi-analytical solution for the undrained plane strain expansion of vertical cylindrical cavities in Modified Cam Clay. That solution hinged on the simplifying assumption that the hardening parameter α , which controls the size of the yield surfaces, remained constant during shearing, and allowed the determination of explicit, closed-form, expressions for the principal effective stresses generated in the surrounding soil. The objective of that paper was to show that results could easily be obtained using a simple numerical approach without having to resort to sophisticated numerical codes.

In the present paper, the restriction imposed on α is relaxed, as it varies during undrained shearing in Modified Cam Clay. New, rigorous expressions are obtained for the principal effective stresses. The present semi-analytical solution is applied for illustration purposes to a well-known benchmark case involving remoulded Boston Blue Clay. Comparisons are first made with the case of α constant and then with both a finite difference solution and published finite element results. It is shown that the assumption of the constancy of the hardening parameter α applies better to a normally consolidated clay than to an overconsolidated clay.

KEY WORDS

Expansion of cylindrical cavities, undrained and plane strain conditions, Modified Cam Clay, variable hardening parameter, applications and comparisons.

THE HYDROCHEMICAL BEHAVIOUR OF THE ALDERMAC ABANDONED MINE SITE AFTER ITS REHABILITATION

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The Aldermac site was considered until 2008 as one of the most problematic abandoned mine site in Quebec due to the high production of acid mine drainage (AMD) by mine tailings. This site was reclaimed between 2008 and 2009 to minimize any further tailings oxidation, or future production of AMD. For that purpose, the technique of elevated water table combined with a mono-layer cover was used to act as an oxygen barrier on the north zone of the site. By maintaining the water table close to the interface between the granular cover and Aldermac tailings these tailings are kept at a high degree of water saturation. This water saturation allows limiting oxygen migration and inhibits AMD production.

To assess the performance of the elevated water table, a network of piezometers was installed. These piezometers are used for continuous measurement of the phreatic surface level and for groundwater sampling. Measurement results show that the phreatic surface is close to or higher than the interface between Aldermac tailings and granular cover. Consequently, since the rehabilitation of the Aldermac mine site, the cover behaves as expected and effectively limits oxygen migration from the atmosphere to the sulphide tailings. To evaluate the influence of the reclamation scenario, water sampling campaigns were performed between 2011 and 2013 to evaluate the groundwater and surface water quality evolution at the rehabilitated Aldermac mine site.

This paper presents the rehabilitation technique used at the Aldermac mine site, a description of different aquifers followed by a brief description of water sampling methods used. Hydrochemical results are presented and analyzed using the principal component analysis. This paper ends by a discussion and conclusion about the impact of the rehabilitation to improve the water quality of the north zone of the Aldermac mine site.

EVALUATION OF PRIMARY AND SECONDARY CONSOLIDATION SETTLEMENTS OF WABA DAM

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The proposed paper is part of a study to investigate the long-term settlement performance of Waba Dam. Waba Dam is 1100 m long earth fill embankment dam with a maximum height of 17 m above its foundation level. The unique feature of this project is a 65 m thick marine clay under the dam. The dam was placed into service in 1976. During last four decades, the dam has accumulated more than 1.6 m settlement due to its marine clay foundation.

This paper presents a numerical investigation of both primary and secondary consolidation settlements of Waba Dam. The Modified Cam Clay model is used to model the marine clays and various creep models will be tried to simulate the secondary consolidation of Waba Dam. The focuses are on the selection of model parameters for marine clay layers from field investigation programs. The model will be used to predict the final settlement and lateral deformation of the dam during its service life with reasonable accuracy.

INUVIK TO TUKTOYAKTUK HIGHWAY EMBANKMENT THICKNESS DESIGN CONSIDERATIONS

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The Inuvik to Tuktoyaktuk Highway (ITH) consists of 140 km of two-lane, gravel surfaced, roadway that is currently under construction, and will provide an all-weather connection between the communities of Inuvik and Tuktoyaktuk, NT when the highway is completed in 2017. The highway will serve as an important community link connecting Tuktoyaktuk to southern Canada and completing the overall national dream of connecting Canada from coast to coast to coast.

Many elements of the ITH project are unique including traversing challenging permafrost and periglacial terrain, and designing an entirely fill embankment using locally available, naturally variable, frozen borrow material placed in winter months when the tundra is frozen and assessable. Unique project-specific design considerations, presented herein, were developed as the project advanced through a collaborative effort with the Department of Transportation (DOT), Government of Northwest Territories (GNWT) and the Project Team. These included forming a rationale and design criteria for traversing remote, variable permafrost terrain, evaluating embankment thicknesses required to limit thawing of the foundation permafrost, and establishing minimum embankment fill thicknesses based on terrain type, road segment location, geometric, geothermal and geotechnical considerations, and expected overall performance and risks.

Minimum embankment heights for generalized terrain types along the route were developed based on site-specific data collected from a winter geotechnical investigation program and ground thermal analyses. Primary findings incorporated into the design included: (1) ground temperatures collected along the alignment were warmer and less variable than originally estimated, (2) ice-poor terrain (with a well-developed active layer) were not encountered in the most favorable terrain investigated along the route, (3) highly variable ground ice and subsurface conditions over short distances were encountered along the alignment. Minimum embankment thicknesses were established from subsurface ground conditions and ground temperatures, along with good engineering practices and judgement for preservation of permafrost utilizing available geotechnical information. One-dimensional geothermal analyses were conducted to estimate the maximum thaw depths into and beneath the road embankments under various ground and climatic conditions. Two-dimensional (2D) analyses were also performed to evaluate the ground temperature distributions with time for selected road embankment geometries.

HWY 621 – PEMBINA RIVER BRIDGE, AB SLOPE STABILIZATION: A CASE STUDY

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Highway 621 extends west from Hwy 22, north of Drayton Valley, AB for approximately 30 km to Cynthia, AB and serves as the high load corridor for transport traffic between Edmonton, AB and Grande Prairie, AB as well as an important route for regional oil and gas development. A bridge carrying Hwy 621 over the Pembina River was undergoing severe structural distress due to the headslope movements along the east bank and slope of the river that was pushing the bridge abutment against the girders. Slope instability has been plaguing the bridge since construction in 1960. Because of a structural assessment of the bridge, stabilizing the slope was proposed to slow or halt the slope movements and preserve the bridge structure until scheduled replacement in approximately 10 years.

The movements at the east headslope of the river were occurring at approximately 18 m below the highway surface and attributed to high pore water pressure within a high plastic clay zone within the glacial clay till. The high pore water pressure was due to artesian conditions within an underlying sand and gravel aquifer, with pore water pressure measured up to 4 m above the highway elevation. The estimated rate of slope movement prior to 2013 was about 23 mm/yr. Slope stabilization involved installation of groundwater drains to reduce pore water pressure within the clay till. Slope movements have slowed to about 3 mm/yr, one year after installation of the designed groundwater drain system.

A summary of the instrumentation program, design and construction details and issues, and post construction monitoring results is presented. In addition, the results of this slope stabilization project in comparison to other highway stabilization projects where groundwater drains were installed is discussed in terms of performance and lessons learned.

ASSESSMENT OF SOIL MOVEMENTS DUE TO THE INSTALLATION OF THE CONTROLLED MODULUS COLUMNS GROUND IMPROVEMENT TECHNIQUE

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The use of Controlled Modulus Columns (CMC) technique for ground improvement has become more popular in Australia in recent years. During CMC installation, a rotary displacement auger is used to form a vertical cylindrical cavity, by displacing the surrounding grounds both laterally and vertically. While the installation method eliminates the spoils at the surface and creates a higher load bearing capacity column, the excessive lateral displacement of the soils surrounding the column could cause damage to the freshly grouted adjacent CMC and may impose additional loads on the nearby bridge abutment piles. There has been greater interest in optimising CMC installation layout and construction sequence so that such effects can be minimised. This paper provides a review of the current state of the art in the investigation of the installation effects of screw displacement columns in general and - of CMC in particular - on the surrounding soils and structures. Advantages and limitations of currently available numerical techniques and soil constitutive models are assessed, especially those that can accommodate large deformations. Factors that influence installation effects, such as pattern of the CMC grids, auger penetration rate, rotation speed, soil type, and some other factors, will also be discussed. Results of numerical simulation of the installation process using Finite Difference Method - Large Strain (FLAC3D) are also provided as an example of such investigation.

PERMAFROST IN MOUNTAINOUS AREAS OF CANADA

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About one third of the global permafrost region is situated in mountainous terrain, and in Canada, large areas underlain by permafrost have mountainous topography, particularly in the Western Cordillera, but also in Labrador and the eastern Arctic islands. Although mountain topography and terrain-related mass movements yield a much greater diversity of ground materials and temperatures per unit area than encountered in polar lowlands, the governing physical principles are the same. Permafrost in mountainous regions thereby enriches the variety of permafrost-related phenomena encountered beyond what is typically found in lowland areas. As a consequence, dedicated research is required to understand the effects of terrain complexity on permafrost conditions. Permafrost thaw in mountains is relevant as it may increase the potential for geohazards such as debris flows, rock falls, rock avalanches, and displacement waves. There are also implications for surface and subsurface hydrology, water quality, and aquatic and terrestrial ecosystems. Increased sediment input from rock fall and debris flows can have long lasting effects on bed load and channel geometry of rivers in mountainous terrain.

This paper stems from an NSERC Partnership Workshop on impacts of permafrost thaw in mountain areas of Canada and beyond, held in Autumn 2014. We argue for better integration of permafrost research in mountainous areas with mainstream permafrost research and education in Canada. To this end, we outline the general characteristics and relevance of permafrost in mountains areas, provide a synopsis of past research on permafrost in Canadian mountains, and identify priority research and development needs.

GROUND ICE AND THERMOKARST ALONG THE MILNE INLET ACCESS ROAD, BAFFIN ISLAND

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Various types of ground ice and thermokarst relief features were visually assessed in 2008, 2009 and 2014 along approximately 100 km access road which connects the Mary River Mine Camp to tidewater at Milne Inlet in the northern part of Baffin Island. The ground ice, which is exposed in some of more than 90 borrow sources of predominantly glaciofluvial origin developed within the 30 m road alignment right-of-way and in several road cuts, includes ice wedges and composite wedges in glaciofluvial, glaciolacustrine and organic deposits, tabular massive ice bodies of both buried and segregated origin in predominantly glaciofluvial deposits and thin lenses of segregated ice in finer grained silty soils of glaciolacustrine origin. The ice wedge polygonal patterned ground is the most striking geomorphological feature along the Milne Inlet access road. It is well-developed within the naturally well-drained granular uplands, terrace-like glaciofluvial landforms. Thermokarst and other permafrost terrain degradation features, both natural and man-induced, the latter being primarily associated with development of the borrow sources, consist of sinkholes of various shapes and dimensions, thaw lake basins, tunnels, caverns and thermal erosion features, i.e. short gullies developed along melting ice wedges etc.

EFFECT OF FLUID CHEMISTRY ON THE MICROSTRUCTURE OF LIGHT BACKFILL: A X-RAY CT ANALYSIS

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Bentonite-sand mixture is considered as the candidate material for sealing nuclear wastes based on the swelling capacity and hydraulic conductivity, which largely depends on its microstructure as well as the pore distribution. To investigate the effect of pore fluid chemistry, 50% Wyoming bentonite and 50% Silica sand were mixed with two different salt solutions (NaCl and CaCl₂) at two different concentrations (50 and 100 g/L). The mixture was compacted at a dry density of 1.24 Mg/m³ to prepare light backfill (LBF). One-dimensional consolidation test and X-ray CT observation were performed to demonstrate the relationship between hydraulic conductivity and the microstructure of LBF. Although most of the research focused on the macroporosity, as high resolution is required to acquire images at the micro scale. A limited research was found that covers the relation between the micropore and permeability. Therefore, in order to overcome this limitation, the X-ray source, detector, and specimen were placed very close and a very small size (5 mm in diameter) was scanned with X-ray having a voltage of 60 kV and current 10 A. The voxel of the scanned image was found to be 1.15 x 1.15 x 1.15 μm, which indicates particles having a diameter greater than 2 μm can be easily observed. Finally, 3D microstructure of the water and air pore was constructed to determine the porosity of the LBF and the effect of pore fluid was observed accordingly.

COORDINATION AND COMPLETION OF A REMOTE GEOTECHNICAL INVESTIGATION UTILIZING HELI-PORTABLE DRILLING EQUIPMENT.

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In response to the rapidly increasing development of natural gas production from northeastern British Columbia, NOVA Gas Transmission Ltd. (NGTL), a wholly owned subsidiary of TransCanada, is proposing to construct, own and operate the North Montney Mainline (NMML). Located in the Peace River Regional District, the NMML project will be approximately 301 kilometres (km) of pipeline split into two sections and will include associated metering facilities, valve sites, and compression facilities. The Aitken Creek section will be approximately 182 km of 42-inch diameter pipeline. The south end of this section is to be located approximately 35 km southwest of Fort St. John, and the north end will be approximately 100 km northwest of Fort St. John. The Kahta section will be approximately 119 km of 42-inch diameter pipeline connecting to the north end of the Aitken Creek section.

The successful execution of the remote heli-portable geotechnical investigation program required development of detailed project execution plans with an emphasis on project team roles and communication focusing on Health & Safety, logistical aspects of the project and the associated challenges while maintaining technical oversight and quality control. The scope of work was multi-disciplinary and included a terrain hazard assessment, geotechnical drilling, geophysical investigation and hydrological assessment. As such, a significant effort was spent on planning the program, including coordination of a phased approach such that drilling locations were optimized. Compressed schedules resulting from environmental and wildlife restrictions as well as National Energy board (NEB) filing dates contributed to 24 hour per day drilling being pursued. Overall, 79 test holes were drilled to depths of up to 115 m (377 ft.) using a combination of air-rotary (ODEX), mud-rotary and diamond drilling techniques. This paper will present the overall approach, planning, and execution strategy utilized to achieve the project objective of evaluating seventeen (17) proposed Horizontally Directionally Drilled (HDD) trenchless crossings of rivers, potentially unstable slopes, and highways.

CHARACTERISTICS OF CKD, CKD-AMENDED TT AND GEOPOLYMER-AMENDED TAILINGS FROM ALBERTA

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In the past, cement kiln dust (CKD) was dumped into landfills. Later, cement plants decided to market CKD as a useful by-product, eg, in the stabilization/solidification of oil sands tailings and for civil engineering applications. Given these potential applications, it is important to evaluate the potential impact of CKD, CKD-amended thickened tailings (TT) and geopolymer-amended tailings on the environment. Mahmoud and Rimes (2012) carried out analyses on the leaching characteristics of CKD from Lehigh's Inland Cement Plant in Edmonton, Alberta. Their work also evaluated the leaching properties of CKD from Lafarge's Cement Plant in Exshaw, Alberta. Comparison of the leaching test results against the Canadian Drinking Water Quality (CDWQ) standards, indicated exceedances in both the Inland and the Lafarge CKDs with respect to lead and selenium. This paper focuses on the leaching tests on Lafarge's CKD only. The results show that Lafarge's CKD-amended TT had high concentrations of iron and manganese, although these metals also showed exceedances in the untreated TT samples. Evaluation of the leaching properties of geopolymer (CKD and fly ash)-amended TT and MFT (mature fine tailings) are also presented in this paper. Exceedances in iron and manganese were found when compared with CDWQ standards, with exceedances in iron, copper and zinc found when compared with the Alberta Surface Water Quality (ASWQ) standards. The results suggest that the Lafarge CKD and related geopolymers (CKD and fly ash) are considered a good solution for further investigation when applied in stabilizing and treating of oil sands tailings.

SHEAR WAVE VELOCITY ESTIMATION FROM COMBINED USE OF MULTICHANNEL ANALYSIS OF SURFACE WAVES AND SMALL SCALE MICROTREMOR MEASUREMENT FOR EARTHQUAKE ENGINEERING SITE CHARACTERIZATION

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Average shear wave velocity up to the depth of 30 m (AVS 30) have increasingly been used for many years in earthquake engineering site characterization. AVS30 is used to classify the soils of the site by National Earthquake Hazards Reduction Program (NEHRP), Uniform Building Code (UBC) to determine the amplification factor of the upper soft soils for earthquake engineering design. Shear wave velocity is directly related to the shear modulus which is a very important parameter for the seismic design of structures. AVS 30 can be estimated directly and accurately using Down-hole Seismic (DS) and Cross-hole Seismic (CS) methods that are invasive and less economic for small projects in terms of data acquisition, analysis and cost. On the other hand, Multichannel Analysis of Surface Wave (MASW) and Small Scale Microtremor Measurement (SSMM) are non-invasive and the most economic survey techniques to accurately determine AVS 30. MASW using active and SSMM using passive sources have been carried out to estimate AVS30 at 41 points in Chittagong City which is the second largest city of Bangladesh. In MASW, 12 channel seismic receivers with a spacing of 2 m were placed along a line of 22 m. In SSMM, 11 channel seismic receivers with a spacing of 6 m were installed along an L-shaped line of 60 m having each arm of L is 30 m. The shear wave velocity profiles of MASW and SSMM have been combined to calculate AVS 30. The AVS30 of the ground of the city varies from 123 m/sec. to 420 m/sec. The AVS30 estimated using MASW and SSMM has a good correlation with the AVS30 of Down-hole Seismic. Therefore these methods can be a very promising tool to estimate AVS30 for earthquake engineering site characterization.

EVALUATION AND CONTROL OF COLLAPSIBLE SOILS IN OKANAGAN-THOMPSON AREA

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Collapsible or moisture-sensitive soil is one of the problematic types of the soil. The structure of this soil can hold high pressure during its dry phase; however, it starts losing strength and destroying the honey-comb arrangement of soil particles as the moisture content of it is increased. Collapsible soil has open and partially unstable structure with cementing agents that stabilizes the soil particles in their unsaturated condition. Introduction of water to this type of the soil will result in softening of inter-particle bindings and change in their volume. Various sources can increase the percentage of saturation in the collapsible soil. Some of the most common reasons behind the introduction of water to the soil are sewer lines, broken pipes, water runoff, pools and basins. Settlements associated with penetration of water to the system often lead to expensive repair of structures built on top of collapsible soil. A sudden reduction of volume, due to an increase in moisture content, has caused this type of the soil to become one of the most costly geological hazards. In this study different soil parameters responsible of collapsibility of the soil such as density, moisture content, clay content, porosity, suction level, and the amount of soluble salts included in the collected soil are investigated. This paper aims to predict the collapsibility of the soil based on these factors.

THE INUVIK AIRPORT RUNWAY – AN EVALUATION OF 50 YEARS OF PERFORMANCE

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The community of Inuvik, Northwest Territories was selected in the mid-1950's to replace Aklavik, which was prone to flooding and was constrained to generally poor construction sites. Thus, Inuvik was an engineered community in a region of continuous permafrost, with all infrastructure being designed and constructed in accordance with the state of the practice at the time.

The Inuvik airport was constructed just off the Mackenzie Delta, about 11 km southeast of the community. The site is also continuous permafrost. The overburden is predominantly fine grained till, and is ice-rich.

The runway was constructed entirely as a fill section, using locally quarried rock. The fill thickness was selected such that the active layer would be confined to the fill, and the underlying, native soil would remain in a permafrost condition (Johnston 1982). The runway was paved in 1969. Ground temperature monitoring until 1974 indicated that the runway was performing in accordance with the design, from a ground thermal response perspective.

A climate warming trend in the western Canadian Arctic was first noticed in the 1970's and the Inuvik region was identified as a "hot spot". At Inuvik, the mean annual air temperature has averaged about -8.0°C over the last 30 years. The embankment was designed when the mean annual air temperature was about -10°C .

Analysis of current ground temperatures in the vicinity of the runway indicate that the original design premise used to chose a minimum embankment thickness is no longer valid. Seasonal thaw is now extending below the embankment at some locations. The thaw of ice-rich subgrade soil has resulted in settlement. This is exacerbated by seepage through the thawed base of embankment and subgrade soils. Measures to mitigate the thaw are have been proposed and are described.

REMOTE SENSING AND GROUND BASED MEASUREMENTS TO IDENTIFY GEOMORPHOLOGICAL PATTERNS IN PERMAFROST

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Ice content, sediment composition, and vegetation are key variables in predicting how and where permafrost will respond to projected Arctic climate warming. Of particular interest are zones of relatively “warm” permafrost where disturbances such as fire or infrastructure development can dramatically affect the thermal state of permafrost. For engineers, accurately identifying the character and extent of ground ice promotes cost effective and innovative infrastructure designs. For biogeochemists and hydrogeologists, the carbon cycle, soil mineralogic composition, and hydrogeologic processes link permafrost terrains with the rest of the world. A major challenge for work in the Polar Regions is the remote locations of field sites and the lack of real time measurements. These limit our ability to take measurements of trends at one locale and “apply” these results at another area. Orbital and suborbital remote sensing tools, historical imagery, pattern detection, LiDAR, and landscape transition analysis can be combined to provide a holistic view of how and where the landscape will respond to climate warming. However, this information can only provide realistic results when it is calibrated with field measurements representing a variety of terrain states, seasonal variations, and physical and chemical processes. This presentation will include remote sensing, field survey, and ground based geophysical measurements from a variety of discontinuous permafrost terrains in interior Alaska. We have combined electrical resistivity tomography, airborne LiDAR, active layer measurements, and high resolution surveying to link landscape features with permafrost ice content, hydrogeologic processes, and the soil thermal regime. The ultimate goal is to identify patterns, features, and characteristics of permafrost terrains, at a variety of scales that can provide insight into how similar locations will behave in a warmer future.

ELASTO-PLASTIC BEHAVIOR OF SAND UNDER CYCLIC LOADING CONDITIONS

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The strength and deformation characteristics of dense granular soil such as sand and gravel are significantly affected by cyclic loading due to stress repetitions. Under cyclic loading conditions, the behavior of granular soil can be characterized by elastic or resilient and plastic or permanent behavior. The number of loading cycle, amplitude and frequency are the most important factors that affect this elasto-plastic behavior. The resilient modulus and permanent deformation are the most common approaches to express the elasto-plastic behavior of granular soil. The elastic behavior is generally expressed by resilient modulus which is based on the correlation of stress state whereas the plastic response is commonly expressed as cumulative permanent strain as a function of number of load cycle or stress condition. Some empirical formulations are available in the literature to predict the resilient modulus and cumulative permanent strain of granular soil. However, studies regarding the modulus of elasticity in the unloading and reloading phase, the individual permanent strain and their variation with number of load cycle are rather limited in the literature.

In this study, an attempt has been made to investigate the elastic and plastic responses of dense sandy soil by conducting laboratory cyclic load triaxial tests with different combinations of confining pressure and loading amplitudes. Laboratory experiments were conducted for a large number of loading cycles (about 10000). Based on triaxial test results the unloading and reloading modulus were calculated separately for each cycle and observed their behavior with respect to the number of load cycle. A simple generalized equation was also proposed to predict the permanent strain behavior.

The test results showed that, for a particular combination of confining pressure and loading amplitude, the unloading modulus was almost consistent with respect to the number of load cycle. Similar observation, with a lower value than unloading modulus for the corresponding tests, was found for reloading modulus. The proposed equation for permanent strain was used to calculate the cumulative permanent strain value and compared with the experimental results. A considerably good agreement was found.

SOIL STRENGTH AND STIFFNESS DEGRADATION OF A CLAY BENEATH A WIND TURBINE FOUNDATION.

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Wind is a major source of renewable energy and is projected to capture 11% of the energy generation capacity for Ontario by 2018. However, to achieve this expansion some major technical and policy issues must be addressed by the Canadian wind sector. Some of these issues are associated with the construction and design of foundations for wind turbines. Foundations for onshore wind turbines usually consist of large gravity bases and mono-piles. The geometry and foundation type depends on the wind climate, power regulation philosophy, physical characteristics of the machine, uplift criteria, required foundation stiffness and geotechnical characteristics of the site. The critical analyses for design include bearing capacity and overturning resistance, horizontal/rotational displacements, and dynamic soil-structure interaction.

Turbines are subjected to millions of load cycles from the wind during their design lives. Some potential performance issues are also related to fatigue experienced in various components from this long-term loading regime. Unfortunately there is a paucity of appropriate field and laboratory scale datasets, suitable for calibration and validation of current state-of-the-art analytical and numerical design approaches. A multi-disciplinary research project is underway to integrate laboratory element testing, scaled physical laboratory testing, full scale field monitoring and numerical modeling of a wind turbine founded on a shallow foundation in carbonate-rich silty clay till in Southern Ontario. A significant component of the project is to provide understanding of the full 'wind-chain' from the incoming wind field to the underlying soil and its effects on the performance of the wind turbine.

This paper describes a detailed laboratory study of repetitive loading on the carbonate-rich silty clay till from South Western Ontario. The laboratory study involves small strain controlled cyclic triaxial tests of high cycle count across a range of stress states simulating the cyclic loading experienced beneath the foundation. The laboratory testing methodology and analysis process are described herein and the effects on the soil strength and stiffness degradation due to the associated loading of the wind turbine and the general damage accumulation of small load cycles are discussed. The implications of soil strength and stiffness degradation beneath a commercial wind turbine foundation are hypothesized for long term performance.

THERMAL UNCERTAINTYS AND AN EVALUATION OF PERMAFROST MODELS IN AN AREA OF WUDAOLIANG BASIN

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Ground temperatures were measured to 5-m depth by 15 boreholes at each of four sites in a small area at Wudaoliang basin, Qinghai-Tibet Plateau (QTP). And the variations in ground thermal regime were studied from 2012 to 2014. Measurements from four sites show that there was a great thermal difference between sites and between boreholes. The standard error Se of the annual mean temperature at ground surface (T_s) could reach 0.15 to 0.23 in all sites for three years, showing a great uncertainty to model the permafrost ground using T_s . An evaluation of the algorithms for thermal conductivity parameterization, unfrozen water parameterization, active layer thickness (ALT) and the ground temperature at permafrost surface (T_{ps}) show that the Kudryavtsev Model is more accurate to estimate permafrost in Wudaoliang Basin. According to Wudaoliang Meteorological Station from 1957, the model indicates that annual mean T_{ps} has little changed but ALT has increased by 1.6 m to 2.1m from 1957 to 2014.

PERMAFROST THERMAL REGIME AT NORTH AND SOUTH SLOPES, KUNLUN MOUNTAIN, QINGHAI-TIBET PLATEAU

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Surface conditions and ground temperatures from 0.5m to 15m depth were measured for six years at south and north slope in Kunlun Mountain, Qinghai-Tibet Plateau, to characterize the ground thermal regime and determine if the variations in ground temperature were associated with the slope aspect. Climate conditions at north slope close to south slope, but the ground temperatures were greatly diverse. At the near-surface, about 50 cm depth, the annual mean ground temperature (Ts) at north slope was approximately 0.6 °C lower than that at south slope, resulting in a greatly difference in active layer thickness (ALT). The ALT was about 1.0 m thinner at north slope than that at south slope. As a result, the annual mean ground temperature at permafrost top (Tps) was about 1 °C lower at north slope than that at south slope. The difference of annual mean ground temperature at two sites decreased with depth, and it was about 0.2 °C at 15 m depth (Tg). These significant differences present an important effect of slope aspect to permafrost, especially at shallower layer.

SUBTERRANEAN STREAM PIRACIES IN THE PERMAFROST AREA: NO ADVANTAGE TO SUBSEQUENT SURFACE CAPTURES

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In this paper, a subterranean stream piracy is described occurring in the continuous permafrost region, on the continental divide between the Pacific and Arctic Oceans, NE Russia. Being of interest itself, this phenomenon contributes to resolving the problem of stream captures. A popular opinion is that a surface capture is preceded and prepared by the subterranean stream piracy undermining the interfluvium and thus enabling the captor stream to break through the belt of no erosion. But the case discussed demonstrates that the peculiarities of groundwater circulation determined by the fact of permafrost existence preclude development of the processes that could undermine the interfluvium. Nevertheless, surface stream captures are usual in this part of the continental divide causing its general inland retreat. Therefore they are performed by some other universal mechanism, and the only candidate seems to be bedrock fissuring due to active faulting across the divide – principally the same cause as that of subterranean stream piracies.

DEVELOPED STRENGTH AND ENGINEERING PROPERTIES OF STABILIZED ORGANIC SOIL USING CHEMICAL ADMIXTURE: A LINEAR REGRESSION MODEL

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This study illustrates the developed strength and engineering properties of stabilized organic soil using chemical admixtures at varying curing periods. To these attempts, organic soil samples were collected from four selected locations, namely, Teligati, Rangpur, Sonadanga and Khulna University campus, Khulna Bangladesh at a depth of 10.0, 7.5, 5.5 and 12.0 ft, respectively, from the existing ground surface. The admixtures such as cement, lime and bentonite were added to the organic soil, as the percentage of the dry soil mass in the range of 5, 10, 15, 20 and 25%. Based on the measured unconfined compressive strength (q_u) in the laboratory and using SPSS 16.0 software, a linear regression model was developed. However, the reliability and accuracy of the developed model were checked by comparing the predicted values of compressive strength against the measured values. Based on the regression analysis, it can be noted that R^2 values were ranging from 0.726- 0.965, 0.536-0.930 0.909-0.984 were observed, for bentonite, lime and cement stabilized organic soil. Here, it can be depicted that correlation coefficient R^2 at 95% confidence interval is 0.914, meaning roughly that 91.4% of the variance in q_u is explained by the model. This value is statistically significant and therefore suggested that measured and predicted values of q_u are comparable.

COOLING CHARACTERISTICS OF CRUSHED-ROCK EMBANKMENTS WITH DIFFERENT STRUCTURES IN A WARM PERMAFROST REGION

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Crushed-rock embankment, as a typical technique to cool roadbeds, has been widely used in the embankment engineering of the Qinghai-Tibet Railway (QRT) in permafrost regions. Its cooling effect has been paid special attention under a climate warming scenario and the warm and ice-rich permafrost. Ground temperatures of three kinds of crushed-rock embankments along the QTR were measured for ten years (2003-2013), in Chuma'er High Plain where the permafrost is warm ($>-1.0^{\circ}\text{C}$), to determine their cooling effects and characterize thermal differences among each embankment structures. The results show that all the three kinds of embankments have the active cooling effects on the underlying permafrost but the cooling effects and characteristics vary significantly with different embankment structures. Obvious asymmetries existed in the ground temperature field within the crushed-rock basement embankment (CRBE). The ground temperatures under the sunny slopes increased gradually though the permafrost table was elevated evidently, indicating thermal regime of the CRBE were disadvantageous for its thermal stability. In contrast, the ground temperature fields of both the crushed-rock sloped embankment (CRSE) and the U-shaped crushed-rock embankment (UCRE) were well symmetrical. However, the UCRE gave better thermal stability than the CRSE because slow warming of deep permafrost was observed under the CRSE. We also find that a warming associated with construction occurred in the CRSE and the UCRE, however the latter structure took a shorter period to release the thermal disturbance. Generally, the UCRE structure can be very advantageous to its thermal stability, even in a warm permafrost region. It is helpful in providing references for improved engineering design and maintenance of roadbeds in permafrost regions.

THE EFFECT OF FREEZING ON THE MICROSTRUCTURE OF CLAYS CONSOLIDATED AT HIGH PRESSURE

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Freezing the soils including clays which have been consolidated at high formation pressures is an essential step for freezing shaft sinking in deep alluvium. The mechanical behavior of the frozen soil is important for the stability of the well-known frost wall and depends largely on its microstructure formed during freezing process. Although there have been many studies on the microstructure of frozen soil which underwent freezing treatment prior to consolidation, little investigation on that of frozen soil which underwent high pressure consolidation before freezing has been reported in the literature. To investigate the effect of freezing treatment on the microstructure of clays consolidated at high pressure, we conducted first a dozen of one-dimensional compression tests with the maximum consolidation pressure being up to 8MPa on the remolded saturated clayey soils which were taken from a mine in East China at the depth of about six hundred meters. Then the specimens combined with steel container used in the above compression tests were placed in a freezing chamber and frozen by cooling the platens in contact with their both ends. The deformation of the specimens was kept fixed and both the pressure and temperature in the specimens were monitored throughout this freezing process. After the tests, an environmental scanning electron microscope (ESEM) was used to examine the microstructural characteristics of three types of clay specimens including the first ones that were frozen after the consolidation, the second ones that were only consolidated and the third ones that were frozen at atmosphere pressure after the consolidation. Comparison of ESEM observations on the second ones with the third ones reveals the effect of the pure freezing treatment on the microstructure, and the comparison of ESEM observations on the first ones with the third ones reveals the combined effect of the freezing treatment and the inevitable unloading phase. It was shown that the effect of freezing treatment on the microstructure of high pressure consolidated clays is related to the physical properties of the adsorbed pore water. Last but not least, the analysis on the effect of the inevitable unloading phase on the microstructure of the unfrozen clays which were consolidated at high pressure provides a chance to know the real microstructure, which has been "locked" into the specimens by means of the freezing treatment with the compressive deformation fixed, of the high pressure consolidated clays.

THE APPLICATION EFFECT ANALYSIS OF THE TWO-PHASE CLOSED THERMOSYPHON EMBANKMENT OF THE QINGHAI-TIBET HIGHWAY IN PERMAFROST REGIONS

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The two-phase closed thermosyphon embankment (TPCT) is an effective engineering structure which can mitigate or even control the embankment distresses. Thus, in this study, based on the monitoring data of test embankment engineering of the Qinghai-Tibet Highway from 2004 to 2012, the working state, temperature fields and freeze-thaw process of the TPCT embankment were analyzed. It was found that the TPCT is a high-performance thermal device and plays a rapid cooling effect after construction. Compared with traditional embankment, the embankment distresses were obviously weakened for a long freezing period in a year of the underlying permafrost, which was offered by the TPCT. However, the TPCT embankments also showed some different distresses compared with the traditional embankment, which were mainly caused by its temperature field form. To quantitatively analyze the cooling effect of the TPCT embankment, a thermal budget evaluation is proposed. The calculated results revealed that the annual average energy of the TPCT transferred in a year was between 1500 MJ and 2000 MJ. This result could provide a design criterion of the TPCT embankment in permafrost regions.

EFFECT OF LONG-TERM STATIC LOAD ON THE L-SHAPED RETAINING WALL INSTALLED WITH THINNED WOODEN PILE AND FIBER OPTIC GEOGRID USING BOTDR METHOD

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The application of wooden pile in soft ground using the bottom panel system structure of the foundation has been discussed with reference to the published design and construction manual referred for the applications to the waterway box culvert and pre-cast L-shaped retaining walls to reduce the load on the thinned wooden pile head using geotextile. The load meter was installed to the wooden pile head for the L-shaped retaining wall. The effect of long-term static load was aimed to observe the load on the pile head, straining of geogrid and use of optical fiber using an actual vehicle dump truck on the constructed L-shaped retaining wall using BOTDR method. Cone penetration test, field density test and Swedish sounding test in the targeted regions have been carried out. Results of measurement of load meter were incorporated after 160 days of construction using the actual vehicle dump truck passing through the retaining wall. The observation showed that the load acting on the pile increases with time and approached the allowable bearing capacity of 28.9 kN/pile group. In the meantime, the scattered light generated by the optical fiber measured the straining by BOTDR method at the interval of 55 mm. The change in strain measured immediate after the construction was found to be decreased after four months due to stress relaxation on the geogrid. The strain under static live load was checked with a rear wheel of the dump truck to a virtual rear portion of L-shaped retaining wall and at the central portion of the bottom panel width of L-shaped retaining wall. Both conditions revealed tensile straining in the periphery. It is found that the straining on geogrid is relatively small and be able to bear the load of the dump truck to some extent.

SPATIAL VARIABILITY OF SOIL TEMPERATURE AND ACTIVE-LAYER THICKNESS IN THE PERMAFROST REGIONS OF RUSSIA DURING THE LAST FIFTY YEARS

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Permafrost plays an important role in balance of greenhouse gasses, functioning of northern ecosystems and in geotechnical environment of the northern settlements. Arctic has been warming at twice the global rate demonstrating the strongest temperature changes since 1980, while snow cover depth has also increased across the regions of Northern Eurasia. These changes have important implications for the permafrost system. Increases of permafrost temperature, lowering of permafrost table and increases of the active-layer thickness (ALT) are reported in numerous locations across the Arctic. However, observational network on permafrost is limited to a relatively few locations with rather short time series making assessment of these changes rather difficult task. To fill this gap, we used a combination GTN-P CALM and soil temperature data collected by the Russian Weather Stations network to estimate spatial and temporal trends in ALT and soil temperature in permafrost regions of Russia. Analysis of soil temperature at 3.2 m depth show increasing trend over the last fifty years, with the most significant changes found in north of West Siberia and Northern part of East European Plain (0.02-0.04°C/y), and in Central Siberian Plateau (0.04-0.05°C/y). Majority of locations show 1-3 cm/y increase in ALT over the same period, however there are some regions, such as southwest Yakutia, where ALT decreased significantly. Positive trends of ALT are found in the regions of East Siberia and Far East (1 cm/y), however some stations show decreasing trends. To evaluate sensitivity of permafrost system to changing climatic conditions we used a permafrost sensitivity index (PSI) as a ratio of linear rate of change in soil temperature at 1.6 m depth to that of air temperature. The hot-spot analysis was used as a tool to find the regions where changes in permafrost characteristics were most pronounced. PSI close to zero shows relative stable permafrost conditions, while PSI of 0.4 and higher shows strong reaction of permafrost on climate change. Regions of West and Central Siberia have low PSI index, while regions of East Siberia and Far East have $PSI > 0.4$. The last fifteen years (chosen to correspond with majority of the observations at the Russian CALM sites) are characterized by considerably higher rate of change compared to 1963-2013. The highest increases of ALT found in Russian European North, Northwest Siberia and Chukotka. These results can be used in environmental and geotechnical applications and as validation of climate models in permafrost regions of Russia.

A CRITICAL APPRAISAL OVER THE SAMPLE-QUALITY-ASSESSMENT METHODS APPLIED TO LOW PLASTIC SENSITIVE SOFT CLAY SAMPLES

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The issue of sample disturbance is very important in regards to determining reliable and representative parameters for fine-grained soils. Design processes in geotechnical engineering rely heavily on site characterisation using soil sampling and laboratory testing. Therefore, the sample quality is essential in the geotechnical profession. In the literature, there exist several useful assessment criteria to determine the accuracy of laboratory parameters, such as strength and stiffness.

In Norway, the guidelines say to use the sample quality assessment method for evaluation of sample disturbance proposed by Lunne et al. (1997). The criterion is based on the normalized change in void ratios, $\Delta e/e_0$, when a sample is consolidated to in situ effective stresses. This criterion is used for assigning a confidence level to the laboratory results to establish the design values for geotechnical calculations. Recently, Karlsrud and Hernandez-Martinez (2013) have proposed a criterion based on the shape of the oedometer curves, using the correlation between sample quality and oedometer stiffness ratio, M/ML , where M is the maximum constrained modulus in the overconsolidated stress range and ML is the minimum constrained modulus after pre-consolidation pressure. This criterion is based on a vast amount of data collected from 22 different sites in Norway, of which a few only concerns the low plastic sensitive soft clays.

In central Norway, the silt content in low plastic sensitive clays can be around 70%, which makes the soft clays extremely sensitive to sample disturbance during sampling and preparation for laboratory testing. Norwegian University of Science and Technology (NTNU) has done extensive work related to the geotechnical characterization of high quality block sampling and piston sampling (54 and 73 mm in diameter) of such clays (plasticity index $<10\%$ and sensitivity between 80 and 300) from different sites around central Norway. In this paper, the authors have made an effort to critically review the robustness of the sample quality assessment criteria, specifically for low plastic sensitive soft clays. The results presented in this paper show that the different assessment methods based on oedometer testing indicate different conclusions regarding sample quality for the same test result, an aspect which is discussed herein. Finally, the paper makes an effort to evaluate the criteria.

QUALITY ASSESSMENT OF MONITORING THE THERMAL STATE OF PERMAFROST BY THE GTN-P

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The newly established dynamic Global Terrestrial Network for Permafrost (gtnp.org) Database contains time series for borehole temperatures and grids of active layer thickness as well as air and surface temperatures from terrestrial Panarctic, Antarctic and Mountainous permafrost areas. To assess the quality of the global permafrost monitoring, we analyse the database content and perform statistics on the GTN-P metadata set to characterize the inhomogeneity of the spatial sample distribution mainly focussed on the Panarctic area. We detect main geographical gaps and link the results to relevant environmental parameters, such as the spatial distribution of organic carbon contents and the expected temperature differences at the end of the 21st century according to global climate models.

Permafrost temperature measurements, commonly performed with permanently installed multi-thermistor cables in boreholes, enable a good accuracy of 0.1°C. The logger resolution and measurement frequency, however, varies with the type and the depth of the individual borehole. Due to high geomorphological surface and subground dynamics, the relative vertical position of testing probes can change and bias the depth indications of old boreholes in sensitive areas. Therefore, based on the GTN-P data, the average deviation of the numbers of temperature recordings within a borehole is significant, ranging from 0 to 57 measurements (values along the borehole) difference between the recording seasons.

The active layer thickness data have generally fewer numbers of potential errors due to their rather simple technique conceived as measurements of permafrost thaw depths either in grids, transects, thaw tubes or boreholes. The complex nature of grid metadata, however, causes inconsistency in the structure of the primary data files. Future improvement of the quality of permafrost data of the northern countries depends to great extends on the commitment of the National Correspondents of GTN-P to revise the metadata (e.g. correct coordinates, fill out missing information). The overall metadata completeness for GTN-P datasets reveals coverage of 63 % for active layer monitoring sites. Borehole metadata reveal coverage of ca. 50 %.

With the help of the National Correspondents, the GTN-P Database management group aims to produce a consensus document that identifies data quality key parameters of permafrost variables, recommendations for international standard methods and protocol definitions. These efforts are important to integrate Essential Climate Variables from permafrost areas into international standards and to provide interfacing of new data possibilities to the global modeling community.

EVALUATION OF SEISMIC PERFORMANCE OF PILE USING DYNAMIC ANALYSIS FOR NEAR FIELD EARTHQUAKES

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Near an active fault, the ground motions are mainly affected by mechanisms of fault, fault direction and static deformation of ground which is related to fling step earthquake. These types of seismic ground motions make a building to dissipate energy by large displacement. Therefore in the design of deep foundations under near field earthquakes, several items influence on the pile behavior under seismic loading. These can be divided into three general categories: Pile characteristics, soil characteristics and the characteristics of the incoming seismic load. In this article, the changes in these factors and the importance effects of each, in the final response of pile (force - displacement) are examined. Three-dimensional finite element method, which includes the main parameters (relative stiffness of pile-soil, earthquake frequency and amortization) on the response of the pile, in all cases the kinematic interaction effects on deformation of the pile and soil, as well as the bending moment distribution in the pile is investigated. The Pile evaluations are carried out by using the OpenSees software. The results show that whatever stiffness of pile is higher than soil so the moment created in the body of the pile will be higher and displacement of the pile will be limited. This issue is directly involved in the optimal design of pile.

APPLICABILITY OF THE RADIOMAGNETOTELLURICS FOR PERMAFROST INVESTIGATIONS

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Many years of experience with surface impedance measurements in the frequency range from 10 to 1000 kHz in Yakutia have shown that apparent resistivity and impedance phase depend very strongly on natural moisture content and volumetric ice content of permafrost soils. Apparent resistivity of soils in this frequency range changes five or more times, increasing with soil freezing and decreasing with thawing. Phase impedance changes by several degrees if the permafrost contains thin conductive layers or ice-rich formations in fine soils.

Variations in apparent resistivity and impedance phase induced by the condition and structure of permafrost allow them to be used for profiling measurements at a single frequency, express sounding at two frequencies and sounding at several frequencies to solve the following permafrost problems. Profiling measurements can be used to map the distribution of thaw zones, ground water, ground ice, and ice-rich zones. Express sounding can be applied to map the unfrozen layers below permafrost and to monitor changes in their state and distribution. Frequency soundings are used to obtain, from one- and two-dimensional interpretation, the subsurface conductivity profiles of permafrost and 3D-images of the permafrost structure at the study site, to estimate the thickness of permafrost, and to monitor the changes in the state and parameters of permafrost layers.

This paper presents the results of numerical modeling of the frequency dependence of apparent resistivity and impedance phase, as well as the experimental results of profiling measurements, express sounding and frequency sounding from typical settings in Yakutia to demonstrate the following potential applications of radiomagnetotellurics for permafrost investigations: delineation of the thawed and frozen zones in the soil; determination of the active layer thickness accurate to 0.1 m; determination of the thickness of frozen soils accurate to 10%; determination of the depth to and thickness of cryopegs accurate to 5% (for the higher-lying layer); determination of the depth to and thickness of ice-rich deposits and ground ice accurate to 10%; determination of permafrost thickness accurate to 10%; mapping of the distribution of groundwater in permafrost, seepage zones, and cryopegs; mapping of ice-rich soils and ground ice; monitoring of permafrost conditions at construction sites, around and below buildings and facilities.

TRANSITION LAYER AND MONITORING OF PERMAFROST CONDITION BASED ON HIS LONGITUDINAL CONDUCTIVITY

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With regard to the geoelectric structure, it would be appropriate to divide the layer of annual temperature fluctuations into two layers - the seasonally thawed layer and the permanently frozen layer of seasonally changing parameters, defined here as the transition layer. Its temperature and thickness are variables. Electrical resistivity of the transition layer is also variable, which depends on phase states of free and interfacial water contained. It is a perennially frozen layer with seasonally changing values of thickness, temperature and electrical resistivity, which differ from the constant values for the underlying layer. The transition layer is characterized by longitudinal conductivity. The thickness of the transition layer is in the range of 1 to 20 m, and its electrical resistivity is in the range of 10² to 10⁵ Ohm*m. Accordingly, longitudinal conductivity values may be in the range of 0.01 to 200 mS.

The seasonal variations of the transition layer longitudinal conductivity obtained at experimental sites show that its changes correspond to the processes of ground freezing and thawing. For example, in the sounding area of the forest site the longitudinal conductivity values increased from 0.4 mS in May to 2.5 mS in October.

The transition layer is formed as a result of heat penetration into the soil during the warm months or cold penetration into the soil during the cold season. Changes in longitudinal conductivity of the transition layer soils are more rapid, than those of the seasonally thawed layer due to its greater thickness. For example, during the thaw period from 31.05.07 to 31.07.07, longitudinal conductivity of the seasonally thawed layer increased 3 times and longitudinal conductivity of the transition layer increased 5 times. Changes in soil temperature of the transition layer occur in the range of 0 to -10°C, i.e. in temperature range at which free and then part of interfacial ground water begin to freeze. Therefore, the corresponding changes in its electrical resistivity are significant.

Seasonal changes in longitudinal conductivity of transition layer are more significant and more dynamic than those of the active layer of permafrost in Central Yakutia.

For these reasons, the geoelectrical monitoring of the ground state and its geocryological condition will be more efficient if the monitoring is conducted based on longitudinal conductivity changes of the transition layer.

Monitoring of longitudinal conductivity of the transition layer in permafrost should be based on the radioimagnetotellurics interpretation data at several frequencies.

INFLUENCE OF STRENGTH AND MECHANICAL BEHAVIOUR OF BAGASSE ASH AND QUICK LIME STABILIZED EXPANSIVE SOIL

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This paper presents the results of an experimental study undertaken to investigate the effects of using bagasse ash and quicklime for improving the strength and mechanical properties of expansive soil. The bagasse ash, a fibrous waste by-product of the sugar cane refining industry, and the expansive soil samples were collected from Queensland, Australia. The specimens were prepared by varying the percentage of bagasse ash up to 18% by dry weight of expansive soil mixed with various quick lime contents. A series of experimental tests have been undertaken on untreated and treated soil samples consisting of Atterberg limits, linear shrinkage limits, compaction, unconfined compressive strength (UCS) and California bearing ratio (CBR) tests after various curing time periods of 3, 7 and 28 days. Results of this investigation are analysed to illustrate the influence of quick lime and bagasse ash treatment on mechanical properties and stress-strain behaviour of expansive soil. The findings indicate a considerable increase in strength and stiffness, mechanical properties with increased quick lime-bagasse ash contents and curing time. An optimum combination of quick lime and the soil bagasse ash stabilized expansive soil are also presented. Results are significant in that the chemical stabilization using quick lime-bagasse ash not only improves the strength and mechanical properties of expansive soil, but also the use of waste material facilitates to cope with environmental issues.

Keywords: Expansive Soils, Quick Lime, Bagasse Ash, Index Properties, Strength, and CBR.

HOW RELIABLE IS THE MASS VARIATION IN THE SIBERIAN PERMAFROST REGION AS OBSERVED BY GRACE MISSION?

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Permafrost generally and in Siberia (Russia) especially plays a key role for global hydrological mass transport, climate change and the eco-system of the Earth. In this study, surface and sub-surface mass variations in the Siberian permafrost region based on the gravitational approach (i.e. GRACE) are estimated, and investigated to what extent the mass transport estimates are reliable and realistic. On the other hand, the hydrological mass variation in this region is determined based on the geometrical approach using satellite (radar/laser) altimetry re-tracking data (e.g. Jason-2, ICESat) and satellite imagery (e.g. LandSat). In addition, hydrological surface mass variations are extracted from global hydrological water cycle models based on various in-situ hydrological observations, e.g. precipitation, evapotranspiration and run-off data.

In this study, we quantify the individual signal contributions to the integral mass variations in Siberia including error bars and determine to what extent GRACE results can provide mass variations which are caused by permafrost changes.

COMPORTEMENT MÉCANIQUE D'UN GRAVIER À L'ÉTAT SATURÉ ET NON SATURÉ

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Peu d'études ont porté sur des sols granulaires compactés à l'état non saturé. Un gravier fin angulaire (GW-GM) en état saturé et non saturé a donc été étudié à l'aide d'essais consolidés drainés (CD), consolidés et cisailés à teneur en eau constante (CW) et d'essais servant à tracer la courbe caractéristique sol-eau (SWCC). Une attention particulière a été portée sur l'influence des variables d'état (suction matricielle et contrainte nette de confinement) sur les caractéristiques mécaniques du gravier. La même attention a aussi été portée sur la courbe caractéristique en mesurant l'influence de la contrainte nette de confinement sur le comportement volumique et sur la valeur d'entrée d'air. Des éprouvettes de gravier fin ont été moulées par compactage statique jusqu'à un indice des vides de 0.30. Les essais ont tous été menés à l'aide d'un appareil triaxial à déplacement, volume et chargement contrôlés et où la suction est mesurée ou contrôlée par translation d'axe. L'effet sur la résistance au cisaillement de la double membrane utilisée pour le confinement de l'éprouvette a été mesuré expérimentalement de même que la variation de volume parasite due à la pénétration de la membrane. Le matériau présente un angle de frottement interne de 43° sous essais CD saturés, ce qui est appréciable, mais comparable à d'autres études. Le confinement produit de même un accroissement proportionnel du module de Young. Les essais CD en état non saturé donnent le même angle de frottement interne de 43° à toutes les succions appliquées. L'angle de frottement associé à la suction matricielle (f_b) décroît pour sa part comme la suction augmente. En conséquence, l'accroissement de la suction matricielle produit une augmentation non linéaire de la cohésion apparente c . Les essais CW ne permettent pas, par leur nature, de déterminer si l'angle de frottement interne est le même, mais il apparaît que la cohésion apparente est différente. Les mesures de la courbe caractéristique montrent pour leur part que la contrainte nette de confinement modifie la forme de cette même courbe. Les chemins de sorption et de désorption diffèrent selon la contrainte nette appliquée. La valeur d'entrée d'air est très faible et augmente avec la contrainte nette de confinement. Les résultats permettent d'affirmer que la suction ne forme pas une variable d'état pour les essais CW. Le degré de saturation jouerait mieux ce rôle.

CONCEPTION D'UNE DIGUE SUR UNE FONDATION D'ARGILE GLACIO-LACUSTRE D'ABITIBI

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Dans le cadre d'un projet de gestion de résidus miniers, trois digues doivent être construites sur une fondation d'argile molle et de résidus miniers silteux en place depuis plus de 30 ans. Le site est localisé en Abitibi, au Québec, une région reconnue pour la présence d'argile glacio-lacustre typiquement varvée. Une campagne d'investigation géotechnique a permis de mesurer sur le terrain des résistances au cisaillement non-drainé (Cu) aussi faibles que 13 kPa. De plus, la digue D-1 projetée doit être construite en partie sur une digue existante dont la composition interne n'est connue que partiellement. Un bassin d'eau d'environ 7 mètres de profondeur est contenu par la digue existante. La hauteur finale de la digue D1 projetée atteint 19 mètres. La conception de cette digue a été effectuée de façon à respecter les règles de l'art, notamment les exigences de la Directive 019 du MDDELCC. La future digue aura des pentes 3H : 1V en enrochement avec un noyau de sol argileux. Étant donné que cette digue sera fondée sur des couches de 9 mètres de résidus miniers et de sol argileux de faible résistance, la conception a été dictée par la stabilité en premier lieu, puis par le tassement en deuxième lieu. Comme la consolidation de la fondation argileuse est très longue, des bermes en amont et en aval sont proposées pour assurer la stabilité de la digue à court et long terme. Des simulations numériques ont été effectuées à l'aide du logiciel GEO-SLOPE afin de vérifier la stabilité de la digue à l'état final et à différentes phases de la construction. La première phase de construction sera la plus critique, avec l'atteinte d'une hauteur de 14 mètres pour la digue D1. Une séquence de construction est élaborée pour cette phase afin d'assurer la stabilité des ouvrages durant les travaux. Cette séquence aborde notamment la construction de bermes en amont et en aval de la digue, ainsi que l'utilisation d'un bassin d'eau existant afin de stabiliser la pente amont pendant les travaux initiaux. Finalement, un programme d'instrumentation et de suivi est proposé afin de pouvoir mesurer dans le temps le comportement réel des ouvrages projetés. Les prédictions de tassement faites au moment de la conception pourront ainsi être comparées aux données de terrain.

DEFORMATION CHARACTERISTICS OF THE MAIN EMBANKMENTS OF THE QINGHAI-TIBET RAILWAY IN PERMAFROST REGIONS

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A principle of 'cooling roadbed' was proposed during the construction of the Qinghai-Tibet Railway (QTR) in permafrost regions. Now the embankments of the QTR has serviced for ten years since they were constructed in 2003. It is necessary to analyze deformation characteristics of the embankments of the QTR with different structures, so that to evaluate their mechanical stability. The main embankments include crushed-rock basement embankment (CRBE), crushed-rock sloped embankment (CRSE) and U-shaped crushed-rock embankment (UCRE), along with traditional embankment (TE). Ten years of monitored data show that, the deformation of all the embankments generally show as settlement. The deformations are related to geological conditions of the underlain permafrost, thermal regimes and their changing processes of the roadbeds. However, the nearby surface water can also influence the deformations. Among the four types of the embankments, the CRBE has a maximum settlement value, which is more than 30 cm. The UCRE has a minimum settlement value, which is only around 7 cm. For an embankment, different deformations occur in the two shoulders with north-facing slope and south-facing slope. Therefore, considering the mechanical stability, cooling effect, symmetry of the ground temperature regime, material property and construction technique, the UCRE is the first one that can be recommended for future application in roadbed construction in permafrost regions. And also some improvement measures for the other embankment structures are proposed.

UNCERTAINTY IN SNOW AVALANCHE RISK ASSESSMENTS

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Snow avalanche risk assessments are applied in planning for residential areas, energy corridors, transportation corridors, industrial sites, ski area expansions, as well as for short-term operational decisions for work sites, ski areas and commercial backcountry recreation. While many of these assessments are qualitative, some planning assessments are quantitative. Increasingly, uncertainty has become an explicit part of snow avalanche risk assessments. The explicit inclusion of uncertainty is necessary in projects following the ISO 31000 risk management standard, which defines risk as the effect of uncertainty on objectives. However, projects following other risk management conventions are also increasingly specific about uncertainty in risk assessments.

In risk assessments for natural hazards, the aleatoric and epistemic components of uncertainty are often considered separately. The former represents the natural variability of the inputs to risk assessment and the latter reflects a lack of knowledge. While epistemic uncertainty can potentially be reduced by improved measurement of the inputs or better modelling, the natural variability in the inputs needs to be well represented and cannot be reduced.

Sources of sources of uncertainty in snow avalanche risk assessments including weather, climate, snowpack, vegetation, terrain, as well as the exposure of people and things of value. Strategies for reducing epistemic uncertainty in the assessment process include the use of independent methods as well as reviews.

To reduce the frequency of death and damage from snow avalanches, there are methods for ensuring much of the uncertainty lies below the applicable threshold of acceptable risk. These methods include non-exceedance probabilities, quantitative safety factors, qualitative margins of safety, as well as estimating the maximum avalanche magnitude and minimum return period.

Finally, strategies for communicating uncertainty to the risk owner are reviewed. For qualitative assessments, these include limiting the number of levels in risk matrices, specifying estimated ranges of magnitude and associated return periods, using words such as “typical” and “average” as well as clear statements regarding assumptions and confidence. In addition to these strategies, communication of quantitative risk can include non-exceedance probabilities or confidence intervals.

SEISMIC STUDIES OF FROZEN GROUND IN RUSSIAN ARCTIC REGIONS

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Seismic surveys have been applied to investigate the structure of frozen ground, to identify and contour unfrozen layers (taliks), to constrain the position of the permafrost table in the Arctic inner shelf. The classic seismic methods and new techniques specially designed in the Earth Cryosphere Institute for different wave components were used.

The specificity of seismic soundings in frozen ground is defined by the features of permafrost-related wavefield. The joint use of P- and SH-waves is workable in estimating the state and properties of frozen ground and provides a higher-quality interpretation of seismic data in permafrost applications. In case of a single wave component, shear waves are advantageous over P-waves according to authors' years-long experience.

Seismic surveys in permafrost have several main objectives: estimating the depth to the permafrost table, studying the structure of frozen/unfrozen ground and its physical parameters.

Different near surface and borehole seismic methods and techniques were used for solving these problems. Investigations of permafrost table were carried out within surface and coastal shallow waters. An original devices and technique of seismic surveys were developed to conduct researches on bottom on P- and SH-waves to a depth of water 3-4 meters. Also using vertical seismic profiling (VSP) some positives results were obtained in winter in boreholes at distance more than 500 meters from coastline. These seismic techniques provide to solve geocryological problems.

Some unique results of seismic properties and its' spatial distribution (due to varying salinity) were obtained on permafrost table on "Marre-Sale" key-site (coast of Kara sea, Yamal). These results were confirmed later on different areas of Russian Arctic.

Basing on the analysis of the literary sources and authors' researches it has been determined that Poisson's ratio can be used for identification of permafrost. For watersaturated sandy-clay deposits there is interval of values of Poisson's between their frozen and thaw states. Using the Poisson's ratio for the identification of geocryological boundaries in clay plastic frozen deposits is mostly effective.

The available experience shows that seismic methods can have many applications in permafrost studies. The use of SH-waves is especially successful, joint analysis velocity patterns and velocity ratios (Poisson's ratio) are useful to estimate the state of permafrost.

LIQUEFACTION MITIGATION USING RAPID IMPACT COMPACTION AND A COMPARISON OF SPT AND CPT CONFIRMATION TESTING

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The East Quadrant Water Distribution System in Kemptville, Ontario was expanded in 2014 to include a new pump station and at-grade water silo. The geotechnical investigation for the expansion identified a 2.3 to 3.8 m thick layer of potentially liquefiable sand. Rapid Impact Compaction (RIC) was specified to densify the sand layer, thereby increasing the factor of safety against liquefaction to be confirmed using Standard Penetration Testing (SPT). After completion of the SPT confirmatory testing the resulting SPT N60 values were found to have a wide range of results. Cone Penetration Testing (CPT) was carried out to supplement the SPT results. This paper discusses the use of RIC to densify the sand layer within a 5 m radius of the expansions and discusses and compares the results of both the SPT and CPT confirmatory testing.

COMPARAISON DU TAUX DE CISAILLEMENT CYCLIQUE DÉTERMINÉ PAR APPROCHE NUMÉRIQUE 1D ET 2D POUR UN BARRAGE EN TERRE.

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Comparaison du taux de cisaillement cyclique déterminé par approche numérique 1D et 2D pour un barrage en terre.

Cyclic stress ratio comparison between 1D and 2D approach for an earth embankment dam.

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La sollicitation sismique d'un sol peut parfois provoquer sa liquéfaction. Ce phénomène peut avoir des impacts majeurs sur la capacité des ouvrages de retenue à remplir adéquatement leur rôle. Le coefficient de sécurité contre le potentiel de liquéfaction est défini comme le rapport entre le taux de cisaillement cyclique (CSR) et la résistance cyclique (CRR). Plusieurs approches peuvent être considérées pour évaluer le CSR, notamment à l'aide de la méthode simplifiée proposée par Youd, T. L., Idriss, I. M., 2001, ou par modélisation numérique unidimensionnelle (1D) et/ou bidimensionnelle (2D).

La méthode simplifiée et l'analyse numérique unidimensionnelle sont largement utilisées par les ingénieurs dans la pratique courante pour déterminer le taux de cisaillement cyclique (CSR) de par leur facilité et leur rapidité d'application. Toutefois, ces méthodes ont été développées pour l'analyse en champ libre (terrain plat) ou pour un terrain légèrement inclinés et peuvent difficilement, voir nullement, incorporer les effets de site, telle la géomorphologie, la géométrie de l'ouvrage ainsi que les contraintes de pré-cisaillement dans les calculs du CSR. Ces effets de site, considérés dans la modélisation bidimensionnelle, peuvent avoir un impact considérable sur les signaux sismiques, telle leur amplification.

Cet article présente la valeur des CSR déterminée par analyse numérique unidimensionnelle (logiciel FLAC) en comparaison avec celle déterminée par analyse numérique bidimensionnelle (logiciel FLAC) pour un barrage en terre de type homogène construit sur dépôt de mort-terrain également homogène. Les paramètres variables dans les modèles numériques sont les suivants :

- hauteur de l'ouvrage ;
- épaisseur des fondations ;
- rigidité des fondations.

Les profils des CSR seront calculés à différents endroits, notamment aux pieds amont et aval de l'ouvrage, à mi-hauteur du parement amont et parement aval ainsi qu'en crête du barrage. Des facteurs de correction seront proposés pour pouvoir les incorporer dans une analyse de liquéfaction simplifiée.

HIGH CAPACITY FOOTINGS IN NATURAL AND FILL SOILS USING SUSTAINABLE RAMMED AGGREGATE PIERS®

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Larger/taller buildings with higher column loads in some areas of Toronto can present construction, design and performance challenges resulting from relatively low available net bearing pressure. Spread footings are typically the most cost-effective foundation option, if the net allowable bearing pressure is suitable for the loads imposed. If the allowable bearing is too low, other options for these structures have typically included deep foundations (driven piles, caissons, etc) or mass sub-excavation and engineered fill placement. Deep foundations deliver desired performance, but are often cost-prohibitive. Sub-excavation and replacement for natural soils is often not practical, and for fill soils, this technique requires additional costs associated with temporary shoring or dewatering. The carbon footprint for pile production and installation or energy consumption associated with mass grading is less than desirable.

This paper describes the use of an innovative, sustainable Intermediate Foundation™ system used to reinforce the site of a large infrastructure project in Toronto, Ontario. Descriptions of Rammed Aggregate Pier® construction, design approaches, and field performance are presented. Footings before and after applying the RAP system are compared. LEED enhancements provided by the Intermediate Foundation™ system contributing to this LEED Gold targeted structure are described.

THE PERMAFROST OUTCROP BATAGAY IN ARCTIC SIBERIA BRINGS LIGHT TO INTERGLACIAL VEGETATION OF BERINGIA

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A new outcrop of permafrost deposits, situated in 15 km south east of Batagai in the Yana highlands, Yakutia was studied for the reconstruction of Late Quaternary palaeo- vegetation and environment. The 60 meter high exposure is an exceptional archive of Late Pleistocene palaeoenvironment of Western Beringia since numerous plant remains are preserved in excellent condition. The outcropped sequence reveals palaeoenvironmental information from the Middle Pleistocene till Holocene. In an estimated depth of about 44 meters below the ground surface at the base of syngenetic Ice Complex deposits regarded representing the last (Wisconsin) cold stage, we sampled an up to 2 m thick layer of plant remains filling ice wedge casts. The AMS radiocarbon dating confirmed that the material is older than 50.000 years indicating a Last Interglacial (MIS 5e) origin of the sample.

Numerous remains of plants prove a mixture of northern taiga plants as they occur today at the study site like larch (*Larix gmelinii*), birch (*Betula* spp.) and alder (*Alnus fruticosa*) with indicators of open disturbed ground. As a main difference to modern vegetation, stone pine (*Pinus pumila*) was not detected. This might indicate high wind exposure and snow cover thickness during Last Interglacial of less than 40 cm [Okitsu and Ito, 1984; Khromentovsky, 2004]. The northern taiga in the Yana Highlands seems to have been interlocked with steppe vegetation during the Last Interglacial as is indicated by the presence of *Potentilla Tollii*, an endemic steppe plant in this area. Occurrence of char-coal in relatively high amount (15% of the plant remains) clearly indicates fire events during the time of deposition. Another contrast to modern vegetation at the site is the occurrence of open ground plants including grassland species such as *Poa* sp., *Festuca* sp., *Sonchus arvensis* and *Puccinellia* sp. The latter are typical of saline meadows, which occur under arid conditions in continental climate. Also xerophilous plants like *Potentilla tollii* and *Papaver* Sect. *Scapiflora* indicate locally dry habitat conditions.

The Last Interglacial plant macrofossil assemblage of the Batagai outcrop represents a mosaic of woody and open ground plant communities in a dry, herb-rich, light-coniferous taiga that experienced wildfires.

INVESTIGATION OF UNDRAINED SHEAR STRENGTH USING CPTU CORRELATION AND FISSURING EFFECTS

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A number of earth dams in Canada are founded on glaciolacustrine clay deposits. This type of soil is frequently associated with stability issues in aging dams particularly in Manitoba and nearby prairie provinces. Environmental loading such as wetting-drying and freezing-thawing produce fissures and cause reduction in strength of clay foundation soils. This study has provided the opportunity to investigate the nature and distribution of fissures with depth in glaciolacustrine clay. To characterize the insitu properties of the soil, a comprehensive field investigation is conducted using Piezocone Tests (CPTu). Further, traditional Shelby tube (4") and large tube (28") soil samples are obtained from seven different sites and are tested by means of consolidated-undrained compression tests and direct shear tests. Soil samples are subjected to Scanning Electron Microscope (SEM) and X-Ray Diffraction Tests (XRD) to examine the fissure features and geometry at the microstructure level. Local cone factors (N_k , N_{kt} , N_{ke} , $N_{\Delta u}$) are determined by developing an empirical correlation based on the determined undrained shear strength of the triaxial tests and the CPTu results. Evaluated cone factors are then compared to earlier work completed and the recommendations are provided for estimating the undrained shear strength of the clay foundation soils. Moreover, qualitative effects of fissures on the undrained shear strength of glaciolacustrine soil are also described.

EVALUATION OF PILE PERFORMANCE IN DIFFERENT LAYERS OF SOIL

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The use of pile foundations technique is developed to support structures and buildings on soft soil. The most important dynamic load that can affect the pile structure is earthquake vibrations. From 1960s the comprehensive investigation of pile foundations during an earthquake excitation are collected that indicates, piles are subject to damage by affecting the superstructure integrity and serviceability.

The main focus of these researches has been in the behavior of liquefiable soil and investigate the behavior of laterally spreading load on the piles. During an earthquake, two types of stresses can damage the pile head, inertial load that is caused by superstructure and the response and deformation caused by the surrounding soil. Soil deformation and inertial load are associated with the acceleration developed in an earthquake. The acceleration amplitude at the ground surface depends on the magnitude of earthquakes, soil properties and seismic source distance.

According to the investigation, the damage is between the liquefiable and non-liquefiable layers and also soft and stiff layers. This damage crushes the pile head by increasing the inertial load which is applied by the superstructure. On the other hand, the cracks on the piles due to the surrounding soil are directly related to the soil profile and causes cracks from small to large. And the larger inertial load, liquefaction and lateral spreading can create wider cracks. The elastic behavior of pile is the main objective of designers in the liquefiable soil by allowing the deflection at the top of the piles. Moreover, absence of plastic hinges in piles should be insured, because the damage in the piles is not observed directly.

In this study, the performance and behavior of pile foundations during liquefaction and lateral spreading are investigated. The key factors in pile distortion are going to be considered during an earthquake and emphasize on the soil behavior in the liquefiable and non-liquefiable layers.

INFLUENCE OF TEMPERATURE ON MECHANICAL PROPERTIES OF EXPANSIVE SOIL TREATED WITH CEMENT

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Temperature effects on the behavior of compacted soil should be studied mainly in the landfill barrier materials subjected to elevated temperatures due to bio-chemical reactions of the waste contained, and swelling soils subjected to desiccation at high temperatures during dry season in semi-arid areas. Research on unsaturated fine-grained soils subjected to elevated temperatures indicate change of properties such as swell potential, swelling pressure, shrinkage characteristics, compressibility, hydraulic conductivity and shear strength. During the last decades, researchers and engineers have tried to find solutions the problems which posed by different types of expansive soils. Various mitigation methods have been introduced improving aforementioned properties of expansive soils. Cement is one of the additives used for stabilization which has proved to be a feasible solution providing efficient results. Soil cement is strongly compressed mixture of pulverized soil, Portland cement and water as the cement hydrates which make hard forms, durable and inexpensive paving material. Portland cement can be effects on quality of the soil with increased strength and durability to transform it into a cemented mass. This research work is aimed to investigate the effect of temperature on mechanical behavior of expansive clays mixed with 5% Portland cement tested under temperatures of 40°C and 50°C. Preliminary experimental findings showed that thermally induced volume change and strength properties vary under different temperatures. The results will be concluded in the final paper.

ICE-WEDGE THERMOKARST LEADS TO GREATER HETEROGENEITY OF ARCTIC ECOSYSTEMS

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The Canadian High Arctic is home to a polar desert biome that is set to experience some of the greatest mean annual air temperature increases on the planet. It is thus imperative to describe the dynamic relationship between the geomorphic changes of melting ice-rich permafrost (thermokarst) and the resident vegetation in light of a warming climate. For this study we have selected a site having undergone thermokarst on the Fosheim Peninsula, Ellesmere Island, Nunavut (80°N, 85°W) to examine the effects of ice-wedge thermokarst on ecosystem processes. Results show that subsidence caused by the degradation of ice-wedge troughs catalyzes a suite of environmental and biotic changes: a new hydrological balance has altered community composition and abundance of vascular vegetation, creating distinct soil chemistries and a detectable ground penetrating radar (GPR) signal of disturbance. Biotically, plot-level species richness declines with the increase of thermokarst while the overall species pool richness does not change. While thermokarst plots favour a set of species distinct from the polar desert, these show no significant phylogenetic clustering or over-dispersal despite significant abiotic environmental stressors. Additionally, thermokarst areas shows greater species turnover (β -diversity) between plots and exacerbated abiotic differences between top/trough microtopography. This suggests that with projected thermokarst increase in the region, ice-wedges will be catalysts in creating a more heterogeneous high arctic landscape. Additionally, it is of significant importance that areas of thermokarst have increased vegetation cover - resulting in lower soil ground temperatures, shallower active layers, and higher soil moisture. The end result of thermokarst processes appears to be a stabilizing feedback system in this area of the high Arctic.

PERFORMANCE OF GROUTED-IN VW PIEZOMETERS AND SAA IN A SLOW MOVING LANDSLIDE

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The performance of instrumentation in moving landslides has always been a challenge in the geotechnical industry. This is especially true when the boundary conditions of the landslide are dynamic where changes in pore pressure and displacement rates are expected. For such situations frequent and reliable instrumentation readings are required to develop an understanding of the mechanisms driving the movements. Also the movement of the landslide can cause issues with the performance of instruments due to shearing of cables or the breaking of grout used for installation.

The Ripley Landslide is one of several slow moving landslides in the Thompson River Valley, near Aschcroft, B.C. Both the Canadian Pacific and Canadian National Railway lines cross this landslide. The site is an important part of Canada's transportation network and has been investigated and monitored with the goal of developing an operational strategy for the railroads. In April 2013, vibrating wire piezometers and a Shape Accel Array were installed in the site to provide hourly pore pressure and displacement readings. The grouted in piezometers were installed in the bedrock, within a few centimetres of the well developed shear zone, and in the clay above and below the shear zone.

Using a piezometer placed in the river, a rating curve was validated for predicting the river level at the base of the landslide. Over three thousand hourly river level readings were compared to the predicted values. The maximum difference over this period was 0.29 m with an average difference of 0.11 m.

The fully grouted piezometers exhibited some unexpected behaviours. The most notable finding was that all of the piezometers at various depths were showing response to barometric pressure changes. The hourly data, when compared to a 12 day moving average of the data, varied by the same amount as the variation in barometric pressure. After applying a correction using data from a nearby weather station, the apparent barometric noise in the pore pressure was removed.

It was also noted that there was a strong correlation between the rate of movement of the landslide and the magnitudes of the pore pressures, relative to the river level. The data shows that the variation in the river level has a strong effect on the movements of the slide. In this paper the instrumentation performance will be reviewed and the reliability of grouted-in-piezometers and a Shape Accel Array in a slow moving moving landslide assessed.

PERFORMANCE OF NESTED FULLY GROUTED PIEZOMETERS SUBJECTED TO TRANSIENT FLOW CONDITIONS

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Piezometers can be installed within clay layers with either the fully grouted or traditional method. With fully grouted piezometers, the sand filter around the piezometer is eliminated and the borehole is grouted completely after having positioned the transducer. Advocates of this method claim that it has the following advantages: no risk of failure for the sand pack of deep wells, ease of installation, and reduced installation costs, especially from the opportunity to install several piezometers and geotechnical instruments within the same borehole.

The hydraulic conductivity of the cement-bentonite grout, vertical gradient, and borehole depth within clay layer are the most significant factors for the success of the fully grouted method under steady state conditions. This paper presents a coupled numerical model using the GeoStudio finite element code to assess the effect of various factors on piezometric error for a fully grouted piezometer completed under an embankment to monitor the consolidation of the clay layer. The studied factors comprise the permeability ratio (grout permeability to surrounding soil permeability), vertical hydraulic gradient, borehole length within clay layer, and clay rigidity. The simulation results highlight several practical implications relating to the above mentioned factors.

AN INTEGRATED MANAGEMENT TOOL FOR ROCKFALL EVALUATION ALONG TRANSPORTATION CORRIDORS: DESCRIPTION AND OBJECTIVES OF THE PARACHUTE RESEARCH PROJECT

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The aim of the ParaChute research project is to integrate various technologies into a common approach and to test its application to the southernmost segment of 220 km of the railway linking Port-Cartier to Fermont. This transportation corridor oriented approximately N-S crosses different types of terrain and climatic conditions, including the Monts Groulx, where permafrost conditions are met. Natural and man-made rock slopes are frequent along the railroad and rockfalls are a major threat. Our work will focussed around different objectives: (1) to optimize the use and integration of terrestrial, mobile and airborne laser scanners data into terrain analysis, structural geology analysis and rock fall susceptibility rating, (2) to further develop the use of unmanned aerial vehicles for photogrammetry applied to rock cliff characterization, (3) to consider climate change impact on mass movements, and (4) to integrate rock fall simulation studies into a rock slope classification system similar to the Rockfall Hazard Rating System using ArcGIS. This 3-year project will extend until the spring of 2017, so in this paper we want to share our approach and preliminary results.

GEOTECHNICAL CHARACTERISTICS OF BARLOW-OJIBWAY CLAY IN NORTHERN ONTARIO

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After the Late Wisconsinan glaciation retreat, the last proglacial lake was formed by Lake Barlow-Ojibway in northern Ontario and Quebec. Thick deposits of glaciolacustrine massive and varved clays were deposited from the Quebec to Manitoba border. The clay is known to be typically slightly overconsolidated, sensitive, soft to firm in consistency and with a high compression index. Published literature has investigated geotechnical challenges for design and construction at select sites in Ontario and Quebec.

To date a consolidated study based on large scale data in order to provide typical range of geotechnical properties and possible correlations for this specific deposits has not be conducted. Hundreds of geotechnical investigations have been carried out within the Lake Barlow-Ojibway clay deposits in northern Ontario by the Ministry of Transportation of Ontario and others since the 1950s for highway embankments, bridge structures, dams, tailing ponds and buildings. In addition, numerous published and unpublished data document the geotechnical properties of these clays by laboratory and in situ testing. This paper presents a summary of all the testing available to the authors in conjunction with the results from published literature. An analysis of the compiled results is further provided to characterize the compressibility characteristics of the Lake Barlow-Ojibway clays and its correlations with simple geotechnical index properties.

PERMAFROST DEGRADATION ADJACENT TO SNOW FENCES ALONG THE DEMPSTER HIGHWAY, PEEL PLATEAU, NWT.

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In permafrost regions, snow fences alter the ground thermal regime by increasing snow cover. Near-surface ground temperatures in winter are considerably higher where snowdrifts accumulate. The objective of this study was to examine long-term ground thermal effects of snow fences on Peel Plateau, west of Fort McPherson, NWT. A secondary objective was to describe resulting active-layer thicknesses and vegetation changes near the fences. Mean annual ground temperatures in the tundra on Peel Plateau are commonly >-2 °C due to the effects of air temperature inversions and blowing snow, which raise these values above conditions in forest on Peel Plain at lower elevation. Shallow ground thermal, active-layer, snow, and vegetation conditions were examined in detail during 2012-14 at a 1-m high snow fence (Fence 1) located beside the Dempster Highway at the Midway Airstrip, about 36 km from Fort McPherson. Active-layer thicknesses were measured in August 2014 at three other 1-m high snow fences, to assess fence effects in a range of topographic settings. Since the fences were erected in the early 1980s, present conditions reflect the effects on permafrost of over 30 years of modification to snow conditions. Snow depths were up to 1.5 m in drifts near Fence 1, while in surrounding tundra, snow was commonly <1 -m deep. The mean annual ground temperature at 1-m depth beside Fence 1 was -0.1 to 0.6 °C, while at an adjacent control site, the temperature was -0.8 to -1.1 °C. More than 1.25 m of permafrost has degraded near the fence, and the ground has subsided at least 0.5 m. Active-layer thicknesses of >1.75 m were measured beside the fence, while in undisturbed ground they are about 0.5 m. Ground subsidence has caused moisture accumulation within 10 m of the fence, and vegetation is now dominated by moisture-tolerant sedges. The combined effects of increased snow cover, active-layer thickness, and moisture content have prevented winter freezeback of the active layer near the fence, so that a talik has developed at the site. Among all fences studied, active-layer thicknesses were statistically related to the distance from the fence at flat sites, but not at sites with slope $\geq 5^\circ$. This paper is a tribute to J. Ross Mackay, who published a pioneering study in 1978 on ground temperature alteration by snow fences at Garry Island, NWT.

THE USE OF A 2D DYNAMIC FLAC MODEL AND 3D STATIC FLAC MODEL TO EVALUATE THE PERFORMANCE OF GROUND IMPROVEMENTS UNDER SEISMIC LOADS

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Using slurry wall methods, a stabilized perimeter is being constructed around the two-mile circumference of the coal ash landfill at TVA's Kingston, Tennessee, facility. The landfill is being built within the footprint of the ash impoundment that experienced a catastrophic, static liquefaction failure in December 2008. The closed facility is designed to meet current regulatory requirements, and must withstand a 2,475-year seismic event. The lower deposits of coal ash will remain saturated and, like the deeper alluvial sands beneath the site, will liquefy in the design earthquake. The stabilized perimeter, consisting of a grid of walls beneath a new perimeter berm, will buttress the ash embankment and retain the liquefied ash under dynamic loading. Two-dimensional numerical modelling is commonly used to predict the stresses and displacements within the slurry walls during the dynamic loading from an earthquake event however this method does not evaluate the structural integrity of the slurry walls. This paper presents a case study on the analysis completed using a dynamic 2D FLAC model, and static 3D FLAC model in order to evaluate the various failure modes expected at the site under the design earthquake.

THICKENED TAILINGS DEPOSITION: PROGRESSIVE PLACEMENT MODELING USING A LARGE STRAIN CONSOLIDATION MODEL

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The use of thickened tailings (TT) has increased over the last forty years due to the perceived benefits of using this technology for tailings disposal. Amongst the benefits attributed to TT are the possibility to form a self-supporting stack, the decrease in bleed water released in the tailings storage facility and the non-segregating behavior depending on the initial solids content of the TT. Observations from self-weight consolidation tests performed in settling columns on gold mine tailings indicated that thickened tailings at higher solids content typically exhibit self-weight consolidation behavior only. Based on this observation, the CS2 code was used to model the experimental consolidation behavior of thickened tailings observed in the settling columns. The results from CS2 were conclusive and lead to further modeling the 1D progressive tailings placement using the CS4 code, which is based on the same formulation as CS2 but considers an accreting soil layer rather than an instantaneous filling. The numerical formulation of the two codes accounts for large strain and variable compressibility and hydraulic conductivity during the consolidation process. First, the constitutive parameters were determined by calibrating our output curves with the experimental results from the settling column tests. The constitutive parameters were then used in CS4 to model thickened tailings progressive deposition in a tailings disposal facility at a given rate. Despite the lack of in situ observations that would permit a real comparison with an accreting TT impoundment, the suggested approach appears to be sound and could be used to estimate TT progressive settlement resulting from simultaneous self-weight consolidation and primary consolidation. Consolidation greatly influences the storage capacity of tailings disposal facilities and therefore needs to be well understood. Finally, some typical factors influencing TT self-weight consolidation behavior, such as the initial solids content are discussed.

A SIMPLE APPROACH FOR ESTIMATING 1-D HEAVE OF EXPANSIVE CLAY WITH RESPECT TO TIME

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Several investigators proposed various methods that can be used for prediction of the potential 1-D heave of expansive soils. Practicing engineers are however more interested in the information of the variation of heave of expansive soils with respect to time taking account of the influence of environmental factors for the rational design of structures. However, there are limited studies reported in the literature from this direction. These studies need soil properties from extensive experimental studies and other information that are time consuming to obtain along with cumbersome numerical modeling studies. Such studies are therefore expensive for use in conventional geotechnical engineering practice. For this reason, in the present study, a simple approach is proposed to predict the variation of 1-D heave with respect to time. This approach integrates the use of commercial software (VADOSE/W) for estimating the net changes in soil suction and a semi-empirical model for predicting the variation of swelling pressure with respect to time, and a heave calculating equation modified from Fredlund (1983) equation, which was originally proposed for estimating the maximum 1-D potential heave. VADOSE/W uses the information of soil-water characteristic curve (SWCC), the coefficient of permeability, climate and vegetation data for estimating the variation of soil suction with respect to suction in the active zone depth. The semi-empirical model predicts the variation of swelling pressure, P_s with respect to soil suction using the SWCC as a tool. With available information of swelling pressure, the modified Fredlund equation is then used for estimating the 1-D heave of unsaturated expansive soils with respect to time. The information of swelling index, C_s which is also required in the modified Fredlund equation is estimated using only the information plasticity index, I_p . The proposed simple approach is extended on case study information of Regina clay for validation. The estimated results of the soil suction as well as ground heave variation with respect to time are compared to the measured data available in the literature. The results of the study are encouraging as there is a good comparison between the measured and estimated heave values with respect to time.

EVOLUTION OF A NEW CSA STANDARD FOR DESIGN OF BUILDING FOUNDATIONS WITH THERMOSYPHONS IN REGIONS OF PERMAFROST

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The Canadian Standards Association (CSA) published a new standard, CSA-S500-14, in August 2014, entitled “Thermosyphon Foundations for Buildings in Permafrost Regions”. It is the first of a suite of new standards being developed as part of the Standards Council of Canada’s Northern Infrastructure Standardization Initiative (NISI). Thermosyphons have been used as a means of providing long-term stability for foundations systems across arctic Canada since the 1970’s. Buildings in northern communities have become larger and more complex during the past two decades and performance of these foundation systems has not always met expectations. This paper addresses the purpose for the new standard and its evolution.

The author chaired a working group of ten people that included Engineering Consultants and Project Managers with more than half from the three northern territories. The reasons for producing such a standard and how it could or should be used most effectively was vetted at length among the group. The performance issues that have arisen with some projects led to a realization that the design process has been inconsistent. It did not always recognize the importance of properly modeling the new geothermal regime that will be created in permafrost that must support the new structure. Many factors such as buried utilities and surface water management add complexity as does climate variability over the design life of the structure.

The paper reviews the basic requirements that would need to be met in order to comply with the standard. Recommendations are also provided within the standard that are intended to help the designer make decisions that are consistent with successful use of this technology on past projects. The requirement for on-going monitoring of ground temperatures and other foundation performance factors are also stressed.

SLOPE STABILITY ANALYSIS OF NANYANG EXPANSIVE SOILS

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Stability problems in surficial layers of expansive soil slopes are frequently reported in the literature in many countries around the world; including Canada, China, India, Spain United Kingdom, and United States. The engineering properties of the surficial layer can gradually degrade with time due to the influence of cyclic environmental factors that contribute to an increase in the saturated coefficient of permeability associated with cracks development and decrease in saturated strength parameters due to strain softening. The shallow failures within the surficial layer are often triggered predominantly due to prolonged infiltration (e.g. rainfall or snow melting, etc.). To investigate the effect of these factors on the stability of expansive soil slope, a field study conducted by Zhang et al. (2010) in Henan Province, China, is analyzed using a comprehensive numerical procedure that involves the coupled hydro-mechanical finite element analysis, which is combined with the finite element stress based method. The effect of cracks on the flow behaviour under rainfall condition is considered using a bimodal Soil Water Characteristic Curve and bimodal permeability functions. The volume changes and stress redistribution is computed extending a framework of coupled hydro-mechanical analysis. The parametric study shows that increase in saturated coefficient of permeability by 2-3 orders in comparison to the laboratory measured value within a bimodal permeability function can very well represent the actual the hydraulic properties of unsaturated cracked expansive soils. An increase in saturated coefficient of permeability and use of residual shear strength parameters can both significantly shorten the time to failure of this slope under rainfall condition. The study highlights the importance of using reliable field saturated coefficient of permeability and bimodal permeability function in the reliable evaluation of slope stability in expansive soils.

THREE DIMENSIONAL FINITE ELEMENT ANALYSES OF PARTIALLY SUPPORTED WATER MAINS

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Buried water mains used in water distribution systems are subjected to aggressive environmental conditions and undesirable soil conditions. The aged pipelines, which are constructed over several decades ago, are vulnerable for accelerated deterioration. Due to the structural deterioration along with several other factors, a number of water mains fail every year across the municipalities. Approximately 700 water main failures in North America every day were reported in the literature. Pipe wall thinning due to corrosion is generally considered as the primary cause of the failures. However, the researchers have recognized that mechanisms of pipe failures are more complex than the wall thinning only. Pipe failure modes observed in the field are often different from that predicted based on conventional analysis. The conventional analysis predicts wall cracking in longitudinal direction resulting from excessive circumferential stresses. However, majority of the pipe failures in the field shows circumferential cracking that would have resulted from excessive longitudinal stresses.

The longitudinal stress on pipe wall may be caused by non-uniform soil support. Particularly, the deterioration of pipe may cause leakage of water that erodes surrounding soil. The erosion creates voids in the vicinity of the pipe and loosens bedding soil, resulting in a non-uniform support condition. Localized concentrated loads are also expected on the pipe wall due to the presence of large rock pieces when the fine soil particles are eroded away. These erosion effects may compromise the performance of the pipes, which can be investigated using three-dimensional finite element analysis. Only limited research information is currently available in the literature on the longitudinal stresses on buried water mains accounting for the erosion effects. Previous research on finite element modelling of erosion voids was limited to regular void dimensions that are symmetric about invert and springline of the pipes. However, regular/symmetric voids are not usually expected in the field.

In the current research, three dimensional finite element analyses are carried out for water mains subjected to bedding erosion. A cast iron pipeline buried in an elastoplastic soil, subjected to soil, surcharge and frost loads is considered for the analysis. The results are compared using analytical solutions available in the literature for evaluation. A parametric study is followed up in order to investigate the influence of the pipe material and size, soil conditions etc on the three dimensional stresses on the pipe wall.

HYDROCARBON SEEPAGE AND FORMATION OF AUTHIGENIC MINERALS IN THE PERMAFROST OF WEST SIBERIA

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In geocryology, permafrost is hitherto considered impermeable screen with low activity of biochemical processes. However, some publications have reported that hydrocarbon seepage can lead to the development of near-surface oxidation-reduction zones and the formation of a variety of hydrocarbon-induced chemical and mineralogic changes.

The frozen core of Paleogene diatomitic clay underlying the basement of hydrolaccolith at the northern West Siberia was studied with SEM and EDX spectroscopy analysis. Samples were prepared by the replica method not to disturb the structure of the frozen sediments. Bacterial colonies were found in the frozen clay at the 30 m depth below ice-core. Bacterial activity is supported by hydrocarbon migration, mostly methane, which is confirmed by seismic survey and geochemical studies of gas content in the ice and deposits. Numerous destructed mineral grains (quartz, feldspars) indicate the cyclic phase transitions of water – ice in the sediments as a result of the pulsating gas microbubbles and pore-water flow through the framework of the plastic-frozen clay. These phase transitions provide the required amount of water and oxygen for the oxidation of hydrocarbons by bacteria to form carbon dioxide or bicarbonate that eventually precipitates as siderite while calcium chloride accumulates in cryopeg. When oxygen is depleted within the sediment or pore fluid, other bacteria reduce sulfate to produce hydrogen sulfide. The formation of secondary sulfides (pyrrhotite – marcasite – pyrite) depends on geology and pore-water geochemistry of the permafrost sequence, and the nature of the bacterial degradation. Sources of iron include colloidal grain coatings, pore-filling clays, and rock fragment inclusions. Authigenic magnetite which is wide distributed in hydrocarbon-induced biogeochemical aureoles in non-permafrost regions was also found in the samples.

Therefore, long-term hydrocarbon seepage can directly or indirectly bring about significant changes in the pH and Eh of the permafrost sequences, thereby result in the precipitation or solution and remobilization of various mineral species and elements.

NUMERICAL MODELLING TECHNIQUE TO PREDICT THE LOAD VERSUS SETTLEMENT BEHAVIOR OF SINGLE PILES IN UNSATURATED COARSE-GRAINED SOILS

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Pile foundations are widely used to transfer significant loads from the superstructure to the soil below the natural ground level to a greater depth. In many scenarios, the piles are either totally or partly above the natural ground water level. Such foundations are however designed using conventional soil mechanics principles assuming that the soil is in a state of saturated condition. The contribution of soil suction, in the unsaturated soil zone above the ground water table, towards the load-settlement behavior is typically not considered in the design of pile foundations. In other words, the presently used procedures are not capable of reliably predicting or estimating both the bearing capacity and settlement behavior of pile foundations placed in unsaturated soils. Recent studies undertaken on model pile tests at the University of Ottawa highlight the significant contribution of suction on the end bearing capacity for coarse-grained soils and shaft capacity for fine-grained soils. Based on these studies, a framework for interpreting the bearing capacity of single piles has also been proposed extending the mechanics of unsaturated soils. However, for the rational design of pile foundations, it is important to obtain the information of the load-settlement behavior. In this paper, test results with respect to the load-settlement behavior of three model piles with 38.3, 31.75, and 19.25 mm base diameter and 200 mm embedded length tested with different capillary suction values of 0, 2, and 4 kPa in a coarse-grained soil are presented. Using the information of the predicted stiffness and the shear strength behavior of unsaturated soils derived from the information of saturated soil properties and the soil-water characteristic curve, the load-settlement behavior is estimated using the finite element analysis (FEA). The commercial software, Plaxis is used in the present study to conduct the FEA. There is a good comparison between the numerical modeling results and the experimental results. The results of the study presented in this paper are of interest for practicing engineers to understand the contribution to capillary suction towards load-settlement behavior of pile foundations in coarse-grained soils. In addition, the proposed numerical modeling methodology is of considerable promise for use in practice.

PREVENTION OF INTERNAL EROSION OF GRANULAR SOILS BY BIOCALCIFICATION

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Bio-minerals are spread out in the nature in the form of corals, bones, and rocs. Based on the observation of such minerals, a new technology of soil improvement has been developed in the beginning of the 21st century. This technology consists of the bio-mineralization of calcium carbonates thanks to the metabolic activity of microbes. It is essentially based on the injection of bacteria, nutriments and calcium, which lead to the formation of calcium carbonates and enhance hydraulic and mechanical properties of soils.

On another part, many studies were carried out on the internal erosion that occurs in granular materials. Many researchers suggested experiments and numerical modeling to evaluate the sensitivity to this phenomenon. As regards dikes and dams, the most important technique of prevention is the introduction of filters as part of the embankment structure. Nevertheless, there is no solution that enables struggling against the internal erosion if the filter is absent or deficient, except expensive and intrusive methods of injection. As a consequence, this study aims to investigate the resistance of granular soils treated by bio-mineralization to internal erosion.

EFFECT OF SALTS ON THE DETERMINATION OF THE WATER CONTENT AND ATTERBERG LIMITS OF EL-HODNA SABKHA SOIL

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Sabkha soils are recent saline sediments widely distributed in Algeria and other countries. As they are characterized by low strength and high compressibility, they are considered to be difficult foundation soils that pose special problems for design and construction engineering.

The inland sabkha of Chott El-Hodna is located in the middle north of Algeria at about 130km from the Mediterranean Sea (Fig. 1). It covers an area of approximately 1100 km² and is relatively flat with an average altitude of about 392m.

The sabkha region is characterized by an arid climate with an average annual rainfall of 172mm, an average temperature of approximately 22°C (-3°C to 40°C) and a rate of evapotranspiration of about 1,330 mm/year. Vegetation is totally absent. During dry periods, the ground water table is located less than 1.0 m below the ground surface, at other times the area becomes a large saline lake with a water depth of up to 75cm. Subsequent evaporation causes salts (mostly NaCl) to precipitate on the land surface.

This study deals with the effect of salts on the determination of the water content and Atterberg limits of sabkha soils. The tests were performed using distilled water, natural sabkha brine and saline solutions with different salt concentrations. The results indicate that the liquid and plastic limits decrease with pore fluid salinity when the conventional water content procedure is used, but increase when the fluid content method is used. Also, the results revealed that the oven drying time of saline soils is highly affected by the size of soil clods and surface salt precipitation.

Keywords: Sabkha soil, water content, fluid content, Atterberg limits, soil clods, saline soils

A CASE STUDY: THE SEISMIC STABILITY OF AN UPSTREAM-RAISED TAILINGS IMPOUNDMENT – EMPIRICAL METHODS AND TREATMENT OF INPUT GROUND MOTIONS

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This paper will present the implications of the phased methodology proposed by the CDA and the different treatment methods of the input ground motions for the seismic stability evaluation of an upstream-raised tailings impoundment currently under construction.

The impoundment, with plan dimensions of 650 m by 1250 m, is used to contain tailings from the processing of niobium ore at a mine near the city of Saguenay in the province of Quebec, Canada. It was constructed by building two parallel starter dikes 60 meters apart along the perimeter and by placing a zone of compacted coarse tailings between the dikes. A shell of compacted coarse tailings is subsequently raised in the upstream direction with a decreasing width with height. Tailings slurry is then placed upstream of the compacted shell. The ultimate height of the impoundment will be 30 m.

The site lies in the seismic zone that produced the 1988 Saguenay earthquake (magnitude 5.9) and is capable of producing earthquakes with magnitudes as great as 7.5. Niobium tailings tend to be cohesionless and vary in gradation from colloidal to sand-size particles and are thus susceptible to liquefaction under seismic loads when loose and saturated.

An extensive monitoring program of the compacted shell, including CPTu and SPT testing, has been implemented to evaluate the compaction methods implemented and for quality control. Based on the recommendations of the CDA 2007 Guidelines, the seismic stability of the impoundment has been analyzed using a phased methodology going from simplified and conservative methods towards more precise and more complex methods. The different methodologies and results are compared and discussed in the light of the empirical liquefaction assessment method. This paper concludes on the implications of the selection and treatment of the input ground motions for sites located in Eastern Canada.

A CASE STUDY: SEEPAGE MODELING AND PROGRESSIVE DESIGN OF AN UPSTREAM-RAISED TAILINGS IMPOUNDMENT USING THE COMPACTION CELL METHOD

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This paper will present the analytical stability evaluation for the progressive design of an upstream-raised tailings impoundment based on survey and instrumentation data.

The impoundment, with plan dimensions of 650 m by 1250 m, is used to contain tailings from the processing of niobium ore at a mine near the city of Saguenay in the province of Quebec, Canada. It was constructed by building two parallel starter dikes 60 meters apart along the perimeter and by placing a zone of compacted coarse tailings between the dikes. A shell of compacted coarse tailings is subsequently raised in the upstream direction with a decreasing width with height. Tailings slurry is then placed upstream of the compacted shell. The ultimate height of the impoundment will be 30 m.

The dam shell is constructed of coarse tailings and progressively raised using the compaction cell method. The coarse tailings are deposited into cells and compacted under a thin layer of water producing a temporary perched water table which after a given duration is connecting to the lower permanent water table. Given the important seismicity of the Saguenay seismic zone where the site is located and the constraints of the operations (wind erosion of dry material, water pond in the center of the impoundment, volume of fine and coarse tailings), operation specifications have to be developed and updated with time as the dam is raised.

An extensive monitoring program of the compacted tailings shell has been implemented to make sure that the water level remains within the limits specified to insure the static and seismic stability of the dam. The modeling of the seepage conditions, that took into account the variable unsaturated zone, was calibrated using detailed piezometric data.

The modeling results shed new light on the observed seepage behavior and enabled the optimization of the tailings impoundment operations. The tailings deposition plan was modified to establish a minimal length of the tailings beach and the duration of the compaction cell method was specified to respect the stability criteria. These implementations are of major importance for the coming period where the dam will reach its most critical end-of-operation conditions.

RÉFLEXIONS SUR L'IMPACT POTENTIEL DES CHANGEMENTS CLIMATIQUES SUR LES GLISSEMENTS DE TERRAIN AU QUÉBEC

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Les rapports 2014 d'Ouranos et du GIEC qui font état des prévisions climatiques obtenues de modèles couplés à des scénarios d'émission de gaz à effet de serres indiquent une tendance au réchauffement pour le Québec et ayant des effets sur l'hydrologie en générale. Des changements sont prévus au niveau de la fonte des neiges et des événements de précipitations extrêmes, qui sont deux phénomènes reliés aux facteurs déclenchant des glissements de terrain. Il y a donc lieu de se questionner sur l'impact potentiel des changements climatiques sur les mouvements de terrain au Québec. Cette article présentera une revue des travaux pertinents associés à l'impact des changements climatiques antérieurs et futurs sur les divers types de mouvements de terrain afin d'amorcer une réflexion sur les impacts potentiels au Québec. Nous évaluerons quels types de mouvements de terrain sont plus susceptibles aux changements climatiques dans le contexte québécois.

METEOROLOGICAL AND GEOLOGICAL INFLUENCES ON ICING DYNAMICS IN SUBARCTIC NORTHWEST TERRITORIES, CANADA

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Icing development, occurring over the winter by freezing successive overflows of groundwater to the surface, has been linked to cold winters, winter warm waves, high autumn rainfall, and low early-winter snowfall. Controlled by local and regional geological and meteorological factors, icings reoccur at the same location, but not necessarily each winter, nor to the same extent. A long-term dataset of icing dynamics and distribution, developed from Landsat data for the subarctic discontinuous permafrost Great Slave region around Yellowknife, Northwest Territories, was used to assess how local and regional factors affect icing dynamics. Hypothesizing that icings vary interannually with identified environmental forcing variables and spatially according to geological conditions, we statistically test the relations between Yellowknife Airport meteorological data and interannual icing dynamics within the study area, which includes four ecologically and geologically distinct ecoregions. Regionally, about 28% of interannual variation of icing density is explained by the frequency of winter warm waves and autumn rainfall. However, interannual icing variation is not coincident among ecoregions, suggesting the differences are related to geological setting and permafrost conditions that influence the hydrological regime. Within the Plain High Boreal, warm waves alone explain 14% of icing dynamics. Limestone and dolomite bedrock create a karst hydrology substantially different than the spill-and-fill hydrology of shield bedrock, likely eliminating the influence of autumn rainfall. Again, within the Lowland High Boreal where icing density is low, warm waves explain 24% of icing interannual variation. Autumn rainfall is not significant, likely due to a diminished a spill-and-fill hydrological regime because of low relief and past basin infilling by sediments, and greater hydrological restriction due to more extensive permafrost relative to the other ecoregions. Shield bedrock, dominates the Upland High Boreal, where warm waves and rainfall explain 31% of icing variation. Rainfall is important likely because of the spill-and-fill hydrology, where autumn rainfall is an important driver of winter streamflow. At Upland Low Subarctic, 34% of icing dynamics is explained by autumn rainfall and early-winter mean air temperature. Hydrologically dominated by several large rivers, low air temperatures may be important because of the greater amount of freezing required to create substantial resistance. As there is no clear mechanical relation between winter warm waves and overflow, it is not apparent why warm waves were not significant. This research establishes a baseline of subarctic icing dynamics, against which future icing conditions under a changing climate regime may be compared.

FACTEURS DE FORME POUR LA CAPACITÉ PORTANTE D'UNE SEMELLE CIRCULAIRE SUR UNE ARGILE NON-HOMOGENE

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La capacité portante d'une semelle filante a fait l'objet de très nombreuses études théoriques et expérimentales. Toutefois, les semelles réelles sont généralement de type tridimensionnel, le plus souvent carrées, circulaires ou rectangulaires. Dans la présente étude le logiciel PLAXIS en éléments finis est utilisé pour l'évaluation des facteurs de forme pour la capacité portante d'une semelle circulaire supposée rigide, sous charge verticale et centrée, sur un sol cohérent avec un gradient vertical de cohésion. Le comportement du sol est régi par une loi élastique-parfaitement plastique et le critère de Tresca a été adopté. Dans cette étude on considère deux types de calcul; premièrement, un calcul en déformation plane pour déterminer la capacité portante d'une semelle filante de largeur B; deuxièmement, un calcul axisymétrique de la capacité portante d'une semelle circulaire de diamètre B et rayon $r = B/2$. Les facteurs de portance obtenus sont utilisés afin de déterminer les facteurs de formes d'une semelle circulaire. Pour calculer les facteurs de portance, une technique de chargement par déplacement est utilisée. Les résultats numériques obtenus par cette étude sont comparés aux valeurs issues des formulations disponibles dans la littérature.

LITHALSAS (PERMAFROST MOUNDS) OF THE GREAT SLAVE LOWLAND, NWT

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Lithalsas are permafrost mounds formed by ice segregation within mineral-rich soil. They are abundant within the Great Slave Lowland of the Taiga Shield, an 11 000 km² low-elevation granitic bedrock plain occupying the north shore of Great Slave Lake, Northwest Territories. The region was glaciated until about 13,000 years ago when it was inundated by glacial Lake McConnell and subsequently by ancestral Great Slave Lake, which declined towards the present lake elevation of 156 m asl. Fine-grained glaciolacustrine and nearshore lacustrine sediments are broadly distributed across the region to an elevation of about 50 m above Great Slave Lake. It has a cold continental climate with a mean annual air temperature of -4.6°C, and permafrost is widespread but discontinuous. Lithalsas are primarily associated with deciduous and mixed forest forests with thin organic cover, and mean annual ground temperatures typically -0.5 to -1.5°C. They have formed as permafrost aggraded into the fine-grained lacustrine sediments following lake-level recession, which has occurred at a rate of about 5.5 mm/year during the last 8000 years. The maximum-limiting age of permafrost and lithalsas in the Great Slave Lowland is therefore elevation-dependent, being youngest near the modern shoreline and older at higher elevations. They are most common within the first few tens of metres above the present level of Great Slave Lake, indicating that many are late Holocene in age and even less than 1000 years.

With an understanding of deglacial and post-glacial history, a conceptual model of lithalsa formation and decay in the Great Slave Lowland is presented. Glaciolacustrine clays were deposited into the deep water basin of Glacial Lake McConnell until about 10,000 years ago. With lake-level recession, ancestral Great Slave Lake reworked glaciolacustrine clays and underlying sediments on bedrock highs by wave action, re-depositing these as shallow-water clays and near-shore silts within low-lying areas. As recession continued, topographic highs were terrestrially exposed with numerous ponds and streams in surrounding low-lying areas. Following emergence, permafrost aggraded into vegetated terrain and the underlying unconsolidated sediments. The combined factors of relatively warm permafrost, fine-grained sediments and available groundwater supply are conducive to segregated ice lens formation and lithalsa formation. Permafrost degradation, due to fire disturbances, hydrological change or warmer climate, induces subsidence of ice-rich terrain, leaving remnant ponds and ramparts that represent former margins of lithalsas adjacent to water bodies.

VARIABILITY AND CHANGE IN PERMAFROST THERMAL STATE IN NORTHERN CANADA

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Change in permafrost temperature is an important indicator of the state of permafrost and a changing climate. Permafrost temperatures have been measured in boreholes across northern Canada for three decades. The permafrost network was significantly enhanced during the International Polar Year (IPY) and consists of over 150 boreholes representing the wide range of vegetation, geological and climate conditions within the permafrost regions. The thermal state of permafrost snapshot developed during IPY (2007-09) provided a baseline for measuring future change. Change in permafrost thermal state since IPY has been evaluated by comparing permafrost temperatures measured in 2012-14 to the IPY snapshot. This change is examined in the context of the longer term record available for some sites.

Current permafrost temperatures at many sites are higher than those measured during IPY. The greatest change is observed in the colder (<-5°C) permafrost of the eastern and High Arctic. In the Baffin region of Nunavut current permafrost temperatures, at 15 m depth, are up to 1°C higher than during IPY. This change is consistent with that observed in the longer record for Alert which shows a general increase in permafrost temperature since the 1980s with a greater rate of increase (about 1.5°C per decade at 15 m depth) since 2000. Some of the highest air temperatures on record at Alert have also occurred since 2000 with 2009-2012 being among the warmest years to date.

Change in permafrost temperatures since IPY has been smaller in northwestern Canada. Little or no change has been observed in the warm discontinuous permafrost of the Mackenzie Valley and southern Yukon while increases in permafrost temperature have generally been less than 0.2°C in the continuous permafrost zone of the northern Mackenzie region. The longer records available for the Mackenzie Valley indicate a general warming of permafrost since the 1980s but temperatures have increased at a lower rate since 2000 partly due to lower air temperatures following a peak in 1998. Where permafrost temperature is close to 0°C, heat energy is largely used to melt ground ice, resulting in degradation of warm permafrost since IPY.

Permafrost warming is generally continuing across northern Canada. These changes in permafrost thermal state and degradation of warm permafrost have implications for ecosystems, infrastructure and communities. The ongoing data collection from the monitoring network provides essential information to plan and adapt to these changes.

CALIBRATION OF GEOLYSIMETERS TO TRACK SHORT-TERM SOIL VEGETATION ATMOSPHERE TRANSFERS

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Tracking a water balance is a foundational component of any evaluation of the hydrologic performance of soil covers used in mine reclamation. In most cases, establishing a water balance requires capital intensive, high frequency, monitoring of soil vegetation atmosphere transfers such as precipitation, evapotranspiration and changes in soil water storage. The costs associated with appropriate instrumentation can limit the spatial density and scale of the monitoring regime.

Geolysimeters (GL) have been proposed as an alternative, low cost, means of long-term monitoring of soil-atmosphere water transfers. To construct a GL, a vibrating wire piezometer is grouted into an aquitard or confined aquifer underlying the site of interest. The pore-pressure record is calibrated using the response to barometric pressure fluctuations and then filtered to remove any extraneous pore pressures responses to earth tides or instrumentation fluctuations. The remaining signal is used to isolate pore pressure responses as a result of soil moisture loading such as rainfall or evapotranspiration. This method has the potential advantage of being able to integrate soil atmosphere transfers over a large contributing surface area and at a lower capital and operational cost than conventional soil cover hydrological monitoring.

This paper summarizes the performance of a set of GLs installed at an oil sands mine site and highlights the methods used to filter and calibrate those GLs. Calibration techniques include manual calibration of loading efficiencies as well as Fourier techniques to analyze earth tide and other frequency based noise. The processed monitoring data is then interpreted to identify key components of the surface water balance on a reclaimed sand tailings dyke. The interpretation is compared to more conventional meteorological and soil monitoring data, as well as more advanced methods such as eddy covariance monitoring of evapotranspiration, to track changes in stored water volumes.

This monitoring enables a long-term assessment of moisture loading to mine landforms, allowing for further hydrological, hydrogeological, and closure interpretation of those landforms. These methods of monitoring may provide an economic alternative for the long term monitoring of reclaimed mine closure landforms.

THE GEOCRYOLOGICAL BIBLIOGRAPHY OF J. ROSS MACKAY (1915-2014)

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Professor John Ross Mackay died on 28 October 2014, just two months before his 99th birthday. For more than four decades he was the Canadian authority in permafrost science, and was internationally recognized for his contributions to geocryology. He published 201 research papers and two memoirs, 175 of which focus on the permafrost environment and development of ground ice. He was the sole or senior author on all but 15 of these papers.

Ross Mackay's Arctic field research began in the Paulatuk area, N.W.T., in summer 1951, and continued without interruption from 1954 to 2011. The permafrost community knows him best for his work on pingos and ice wedges, but his expertise on terrain conditions in the western Arctic was perhaps of most material significance. He was told in the 1970s that his work had saved industry two full years of investigations in preparing for hydrocarbon development in the region.

Mackay's first major contribution to geocryology concerned glacier ice-thrusting of permafrost sediments to account for the deformed beds of Nicholson Peninsula (1956) and Herschel Island (1959). While he based most of his geocryological publications in the 1950s on field observations, in 1962 he published an assessment of talik geometry as part of a seminal paper on pingos. This paper and the Mackenzie delta memoir (1963) were magisterial quantitative statements on the form and function of the landscape. His work developed along with federal and industrial interest and support for research in the western Arctic, so that 1970-1980 provided a series of key papers, e.g., the classical treatment of disturbance to permafrost terrain (1970); segregation as the origin of massive ice (1971); the origin of offshore permafrost (1972); the development of pingos from pore-water expulsion (1973); the characteristics of thermal contraction cracking (1974); experimental demonstration of pingo growth (1977); and the origin of hummocks (1980).

Ross's formal retirement in 1981 was merely a punctuation mark in his research record. From 1982-2011 he published 52 papers, concentrating on tundra lakes, ice wedges, and pingos. In 2005, he published observations on wind-abraded rocks at Paulatuk, including data he had collected in 1951, and in 2011 his last paper discussed a pingo near Paulatuk originally photographed by Stefansson in 1911. His work began and ended at Paulatuk.

The paper will briefly review Ross Mackay's contributions, as above, and present his complete geocryological bibliography.

DESIGN AND CONSTRUCTION OF A GEOSYNTHETIC REINFORCED PAVEMENT ON WEAK SUB-GRADE

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This paper describes the salient features of the design and construction of a geosynthetic reinforced pavement and presents initial assessment of the performance. The project involved rehabilitation of old and damaged roads in the City of Calgary in Canada. At many locations the existing pavement was a full-depth asphalt pavement which was up to 20 years old and was in a distressed state. Poor sub-grade conditions were indicated to be one of the major causes for the distress in the pavement. As part of the city roads rehabilitation program, it was required to reconstruct the pavement. The proposed solution required replacement of the existing distressed pavement with a design comprising of asphaltic concrete, granular base and granular sub-base. This required excavations to accommodate the designed pavement thickness. To minimize the disruptions and inconvenience to the road users, it was desirable to minimize the depth of excavation. Therefore it was necessary to minimize the pavement thickness as far as possible. It is known that reinforcement of the pavement with geosynthetics enhances the strength and stiffness of the pavement and also contributes to the fatigue life of the overlay, hence a reinforced pavement of lower thickness can give the same level of performance as an unreinforced pavement. Alternatives with different types and combinations of geosynthetics were evaluated. A design in which a bitumen coated fiberglass grid was incorporated at the center of the asphalt concrete layer and a biaxial geogrid composite comprising a stiff polypropylene biaxial geogrid bonded to a long fiber nonwoven geotextile incorporated at the bottom of granular sub-base was finally adopted for one section and only bitumen coated fiberglass grid was incorporated for the other section. The pavement was constructed without any significant issues and the initial assessment of the performance seems to be quite encouraging. The paper describes the site conditions and constraints, evaluation of alternative designs, design of the geosynthetic reinforced pavement, construction and the initial assessment of performance.

MACKAY SYMPOSIUM: FROM SCIENCE TO TECHNOLOGY—THE IMPORTANCE OF UNDERSTANDING THE FUNDAMENTALS OF PERMAFROST SCIENCE FOR ENGINEERS PRACTICING IN THE NORTH

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It is an unfortunate reality today that Civil Engineers graduating from Canada's Universities learn little or nothing about the permafrost that covers fifty percent of our country. Even graduate students in Civil/geotechnical are fortunate if they can get more than a lecture or two on how to recognize the unique challenges of design and construction in permafrost regions. Those few of us that choose to practice engineering in Canada's north must learn the tools by working with a mentor and by self-study. That self study component must include a grasp of the fundamental properties of permafrost that affect its distribution and its ability to support the infrastructure that northern Canada needs. We turn to an active scientific group of permafrost geographers currently working in Canada, many of whom can link their mentorship and motivation to the work of Professor J. Ross Mackay.

This paper examines how Mackay's work has directly shaped engineering practice in the north through the 1970's and 80's. The author was assigned a task of planning and executing a helicopter supported, geotechnical drilling program in 1972 that was required for early feasibility assessment of an arctic gas pipeline (Gas Arctic Systems). That program covered the lower Mackenzie Valley and Northern Yukon to the Alaska border. Dr. Mackay took an entire day to educate this neophyte engineer on how to recognize ground ice distribution from surface features and its description when encountered in drill samples. From that time forward, we became friends and shared experiences through his published papers and at the International Permafrost Conferences. The insight into his dedication to the science and desire to help others was an enormous benefit not only to the author but also to those who chose to practice engineering where permafrost is present.

The paper examines a few of the ways that Mackay's work has had a profound effect on engineering practice in Canada, ranging from knowledge of the origin of ground ice to why we encounter permafrost in the near shore sediments of the Beaufort Sea. The paper will attempt to put these and other personal observations into a perspective of current engineering practice. Suggestions are provided to help maintain the legacy of Mackay's selfless knowledge transfer between our science disciplines and engineering practice.

IMPROVING THE SPATIAL SUPPORT OF PERMAFROST MEASUREMENTS

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Permafrost research frequently comprises temperature measurements in boreholes or with sensors otherwise placed in the subsurface. This is usually done in order to investigate how surface conditions, which vary both spatially and temporally, control ground temperature. The surface area that affects the signal of a sensor in the subsurface is thereby proportional to the depth of the sensor. Given that topography, soil properties, vegetation, water saturation, and other factors affecting ground temperature often vary significantly at length scales from tens of centimeters to tens of meters, it is important to pursue a quantification, with adequately dense sampling, of an area of appropriate size. This, we argue, will help to isolate the relationship between surface and permafrost properties much better and reduce the random component due to local variation. Furthermore, the explicit consideration of an area of spatial support is an important step towards more rigorous comparison of field measurements with permafrost models or remote sensing products of surface conditions, both of which are usually grid-based.

Here, we outline a sampling method and protocol for vegetation, soil, micro-topography, and ground temperature based on a review of relevant literature and field protocols used by other researchers. This protocol will be employed in a campaign in the Lac de Gras area, Northwest Territories, in summer 2015.

**GEOTECHNICAL AND GEOPHYSICAL CHARACTERISTICS OF SOILS IN MAHOTIERE AREA
(KENS COFF - HAITI)**

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A geological study based on bibliographic data found on Kenscoff-Mahotiere area revealed that this region is part of a "Massif de la Selle System" and is constituted mainly of two sedimentary dating from the Eocene (ei - limestone) and Paleocene (ep - clay). The geotechnical analysis (physical, mineralogical and chemical identification tests) carried out in the laboratory has allowed to classify the soil samples collected in Mahotiere as calcareous sand and plastic clay, especially in the presence of smectite, chlorite and kaolinite. The geophysical survey carried out in situ (electrical sounding, electrical tomography and refraction seismic) confirms the geological nature of the soil on the site and also describes the geophysical behavior of these soils. A comparative study is made between these two approaches to characterize soil and allowed to find exactly in the area the different soils profiles, plastic swelling clay and limestones.

INTERANNUAL VARIABILITY OF CLIMATE CHARACTERISTICS AND DYNAMICS OF PERMAFROST ON THE YAMAL PENINSULA

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The estimation of the spatial distribution and interannual variability of the climatic characteristics of the Yamal Peninsula on the basis of the analysis of meteorological data from weather stations Marre-Sale, Kharasaway, Bely, Drovyanoy, Tambay, Sejakha, New Port and Salekhard have been carried out. All available materials on climate change on the Yamal Peninsula were collected, checked and corrected. Digital database on daily, ten-day, monthly and annual index of atmospheric pressure, air temperature, surface temperature, direction and speed of wind, precipitations, and snow cover has been collected, verified and corrected. The basic tendencies (trends) changes in climate indices were educed. The average annual temperature varies within wide limits: from -5,0oC in the south of the Yamal Peninsula (Salekhard) to -13,1oC in the North (island Bely). Curve of average annual air temperature is cyclical with periods of warming and cooling. The previous period of warming was observed from mid-1930's to 1950. Then a period of cooling began that reached its minimum by the beginning of 1970. Generally, for the entire region it can be considered that the modern climate warming on the Yamal Peninsula began in the mid 1970 and synchronously for all the area. The average temperature of the last decade has increased with respect to the norm by 1...1,8oC. The maximum increase in interannual air temperature is observed in the Central part of the Yamal Peninsula on the West coast (m/s Marre-Sale), and Eastern (m/s New Port, Sejakha).

The series of cartographic models of climate change show areal distribution of mean annual air temperatures on the Yamal Peninsula.. The last 30 years are characterized by an unfavorable combination of climate change for the Yamal Peninsula: increase in average annual, mid-winter and mid-summer air temperature, precipitation and snow accumulation. This should inevitably lead to dangerous geocryological consequences of raising the temperature of permafrost, partial permafrost degradation and increase the area of taliks, activation of cryogenic processes.

Long-term monitoring on geocryological stations showed that natural ecosystems have a fairly high resistance and inertia. Cryogenic landscapes have different reactions to external influences and have their own protection mechanisms.

The frozen grounds in the area of the typical tundra in conditions of continuous permafrost will remain stable at moderate and medium scenarios of climate warming. At the extreme warming the permafrost temperature will have the temperature of the beginning of the thawing, but, nevertheless, will remain frozen.

THE INFLUENCE OF SHALES ON FLEXURAL TOPPLING IN ANISOTROPIC ROCK SLOPES: A NUMERICAL MODELLING STUDY.

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Toppling of rock columns or layers is one of the most common slope failure mechanisms in rock slopes. Despite the recent advances in numerical modeling, this mechanism of rock slope instability remains one of the most complex to analyze, especially where non-homogeneous anisotropic rock masses are present. The aim of our study is to improve the current understanding of how the presence of weak lithological units affects the toppling behavior of a slope according to their spatial location. Using a numerical modelling approach we investigate the deformations occurring in a 600 m high, anisotropically layered rock slope, comprising two lithologies of contrasting geomechanical parameters dipping steeply into the slope. Several models were realized, in which a thick shale unit within a sandstone rock mass was gradually varied in assumed location from the slope toe upwards towards the slope crest. Toppling rock slope simulations were undertaken using both finite elements (Phase2) and distinct elements (UDEC) methods. Results, interpreted using both recorded shear displacements and a new proposed method considering the numerical inverse-velocity, provide clear evidence that deformation at the base of the slope is followed by the development of a kink zone within which the rotation of the columns takes place, while the rock mass above remains initially undeformed. Surficial deformations initially occur both at the base of the slope and behind the crest, where the kink zone daylights. Tensile failure of the columns was found to occur both along a lower and an upper kink plane. The displacement occurring at the base of the slope provides the space for the columns above to rotate, driving and increasing the deformation upwards along the slope. The deformation rate was found to be higher within the shale layers than within the immediately overlying sandstone resulting in the development of a graben orthogonal to the slope surface and at the boundary between the two lithologies. The proposed numerical inverse-velocity analysis method provides evidence of the occurrence of two discrete successive failure events, related to the portions below and above the shale-sandstone contact. The use of a numerical inverse velocity approach and consideration of the spatial location of weak layers within the slope are shown to have a considerable potential in improving our understanding of complex toppling slope failures which hitherto have been analysed often neglecting the contrasting and varying mechanical stratigraphy of the rock mass.

EFFET DE LA BIOCALCIFICATION SUR L'INTERACTION SOL-STRUCTURE ENTRE UN SABLE ET UNE FONDATION SUPERFICIELLE LORS DE CHARGEMENTS SISMIQUES

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Mon sujet de recherche est axé sur un nouveau procédé d'amélioration des sols : la biocalcification. Le procédé vise à augmenter la capacité portante et à réduire les problèmes de liquéfaction d'un sol granulaire par l'injection de bactéries et d'un sel de calcium menant à la précipitation de calcite. Celle-ci apporte une cohésion et densifie le milieu, ce qui conduit à l'amélioration de son comportement géomécanique. Le procédé est donc relativement simple et peu énergivore, puisqu'il suffit d'injecter la bactérie *Sporosarcina pasteurii*, puis des nutriments, sels et urée. La bactérie va ainsi agir par réaction enzymatique et précipiter les cations Ca^{2+} contenus dans le sel de calcium.

Selon les études menées par Suer et al. (2009), la biocalcification présente plusieurs avantages vis-à-vis la technique équivalente utilisée, le jet-grouting. Celle-ci consiste à solidifier des colonnes de sable en injectant du ciment. Cependant, cette technique nécessite une grande quantité d'énergie, dénature la structure du sol et colmate les pores du sol, ce qui limite l'infiltration d'eau dans le sol pouvant ainsi créer des problèmes d'érosion et d'inondation.

Mon sujet de recherche se concentre sur l'application de cette technique en parasismie. Pour cela, j'évalue les effets de cette technique d'amélioration des sols sur l'interaction sol-structure lors de chargement sismique en trois étapes :

- La première étape porte sur les différents essais réalisés en laboratoire sur des sols traités et non-traités. L'objectif de ces essais est d'observer l'amélioration de différents types de sols, tels que le silt ou le sable, et de quantifier l'augmentation de la portance et de la rigidité du sol après traitement.
- La deuxième étape est de faire la synthèse des modèles de comportement utilisés pour les sols lors de chargements sismiques et des lois de comportement en interaction sol-structure, afin de développer un modèle de comportement pour un sol biocalcifié à partir des modèles existants et des expérimentations faites. Sur ce point, le modèle développé par Fauriel (2012) est un modèle intéressant qu'il conviendra d'améliorer.
- La troisième étape porte sur une modélisation en éléments finis basée sur une structure réelle. Cette étape a pour objectif de simuler un projet pilote sur la plaque sismique du laboratoire de structure de l'école Polytechnique de Montréal, qui fera l'objet d'expérimentations futures.

L'article proposé porte sur l'état d'avancement actuel du projet, à savoir les essais de l'étape 1.

THE THERMO-MECHANICAL BEHAVIOR OF FROST-CRACKS OVER ICE WEDGES: NEW DATA FROM EXTENSIO-METER MEASUREMENTS.

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Tundra polygon networks which result from repeated thermal contraction cracking and ice-wedge growth are among the most prominent features in terrain underlain by continuous permafrost. It has been thoroughly documented that ice-rich frozen soils are affected by thermal contraction when submitted to deep winter cold temperatures, giving way to the opening of networks of cracks. Over the years, the repeated filling of the cracks with percolating surface water in early summer builds up the ice-wedges that delineate tundra polygons. We precisely monitored the timing of cracking and the rates of enlarging and narrowing of well-developed polygonal frost cracks over height years in the Qarlikturvik valley on Bylot Island (N73° 09.028' W80° 00.242'), in fine-grained organic rich permafrost. Specially designed extensiometers were deployed across eight polygon troughs in two distinct networks separated by a distance of 1700 m. The cracking-contraction-expansion data were correlated with atmospheric and ground thermal temperature data acquired by 5 automated stations during this period. A preliminary analysis of the data shows that narrow cracks open abruptly in December as the active layer freezes downward and cools. They enlarge in January up to an average width of 12 mm as the temperature drops to about -10 °C in the permafrost. The cracks fluctuate in size and reach their maximum width in March. Short and small amplitude narrowing events in winter are associated with warmer spells of a few days duration. The cracks narrow by the end of the winter with warming ground and air temperatures but they stay open at about half of their maximum width for several weeks in May-June, at the time of snowmelt. Extensiometer recordings and observations over the summer indicate that some cracks do not close completely near the soil surface until the next freezing season. These results bring new insights on the thermo-mechanical behavior of the active layer and the permafrost; they also help to improve our understanding of the dynamics of ice-wedge growth and tundra polygons morphological development.

HIGH STRAIN DYNAMIC PILE TESTING IN A CHALLENGING SOIL CONDITION – A CASE STUDY IN SOUTHERN ALBERTA, CANADA

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Driven piles are increasingly utilized as foundation elements in challenging geotechnical conditions that are traditionally suitable for drilled shafts. Predicting driven pile performance and capacity is a daunting task. Unique soil conditions or diversity across the subsurface of a project site can add further challenges to predicting performance. High strain dynamic pile testing provides a fast, effective, and economical quality control tool for the installation of driven piles. This paper describes the application of Pile Driving Analyzer® (PDA) in performance evaluation of driven piles installed in a hard ground condition in southern Alberta. The project site is located in the vicinity of Fort MacLeod, Alberta. Site conditions and pile installation process are described. Pile instrumentation, test procedures, and the PDA test result and their relevancy are discussed in detail. Finally, CAse Pile Wave Analysis, performed using CAPWAP® software are discussed comprehensively in order to provide baseline conclusion that can be used in future for analysis of driven piles with similar soil conditions.

Keywords: Driven pile, high strain dynamic pile test, pile driving analyzer (PDA), CAPWAP®.

COMPARISON OF FINITE ELEMENT AND CALCULATION METHODS OF LATERAL EARTH PRESSURE ESTIMATION FOR RETAINING STRUCTURES WITH UNSATURATED EXPANSIVE SOILS

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Lateral earth pressures associated with retaining structures are typically determined by extending the principles of saturated soil mechanics. There is however evidence shown in the literature that the lateral earth pressures for retaining structures associated with backfill soils in saturated and unsaturated conditions are significantly different. More recently, a framework has been proposed at the University of Ottawa, to estimate the lateral pressures extending the mechanics of unsaturated soils for both coarse and fine-grained soils. Such an approach however cannot be applied when the backfill behind the retaining wall is an expansive soil. Significant volume changes occur in expansive soils due to the influence of environmental factors such as the drying and wetting cycles. In addition to the volume changes, the swelling pressure of the expansive soils also varies with changes in water content and can influence the lateral earth pressures behind the retaining wall. In this paper, the framework for estimating the lateral pressures of unsaturated soils has been extended for expansive soils taking into account of both the heave and the variation of swelling pressure with changes in water content due to rainfall infiltration. In addition, the variation of lateral pressures on the retaining wall, were also estimated using the finite element software SIGMA/W. Comparisons are provided between the lateral pressure derived using the proposed calculation method, which was implemented through MATLAB and the one derived using the finite element modeling technique. Finite element methods are comprehensive to introduce any boundary conditions, soil and material properties, and study the influence of various environmental factors. The MATLAB calculation method would be sufficient for simple scenarios that are conventionally encountered in geotechnical practice. The studies presented in this paper are of interest to the practitioners who design retaining walls with expansive soils as backfill material.

INTERPRETATION AND CORRELATION OF CPTU AND VANE SHEAR TESTS FOR VERY SOFT VARVED SILTY CLAYS – A CASE STUDY

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A geotechnical testing program has been carried out for site characterization for the design of an earth dyke at the South limit of the administrative region of Northern Quebec. The preliminary program involved piezocone testing (CPTu) and field vane shear testing (VST) associated with sampling of the very soft varved silty clay foundation. The undrained shear strength profiles estimated from the VST tests were much lower than expected, based on the CPTu tests results. The N_{kt} coefficient used to compare the VST and CPTu results were in the typical range for the clay present on site.

Additional Vane tests were carried out with a manual Vane apparatus in several points; a backhoe allowed testing down to a depth of about 6 m. The results of the second field test program did not correlate with the CPTu results, even if the additional Vane tests seemed to be more representative. As a result, a new testing program has been recommended in order to obtain high quality measurements on the dyke alignment. This third testing program has been made taking into account the difficulties and uncertainties of the previous testing programs: vane tests were carried out with care in order to eliminate any remoulding of the clay and CPTu tests were performed using a lighter probe.

After an introduction describing the generalities of the project site, this paper presents the testing programs and highlights the difficulties encountered in the testing of very soft varved silty clays and in the calibration of CPTu profiles from VST data on such clay.

SUBDIVISION OF ICE WEDGE POLYGONS, WESTERN ARCTIC COAST

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Ice-wedge polygons are characteristic features of the continuous permafrost zone. They commonly have a well-defined surface expression in lowland basins, but are also ubiquitous on hill slopes. J.R. Mackay's long-term field studies on ice-wedge development are critical contributions to our understanding of the genesis of ice-wedge polygons. The ice wedges are found beneath the troughs that lie between the bounding ridges of adjacent polygons. The ridges form as a result of ground displacement due to the growth of the wedges, outward movement of material within the polygon, and ice segregation fed by water from the troughs. Ridges and troughs are not as prominent on hill slopes as in lowlands. Nevertheless, Mackay showed that ice wedges on hill slopes may crack, and he suggested that the ridge-trough-ridge morphology was diminished by downslope soil movement and erosion.

In lowlands, polygons are outlined by the network of primary ice wedges. In places the polygons are subdivided by secondary wedges, and even tertiary features. The smaller secondary and tertiary features are syngenetic and have ridges that are much smaller than the primary wedges. In the 1960s, Dostovalov and Popov proposed that the secondary and tertiary features were the result of winter climate variations, with more wedges cracking in progressively colder winters, thereby relieving increasing thermal tension. Four principal sets of observations suggest that, instead, the development of secondary and tertiary wedges may be due to development of the primary ridges and troughs. (1) Mackay showed that smaller, secondary wedges may crack more frequently than primary wedges. This is contrary to the postulated effects of climate variation. (2) Hill slope polygons are not characteristically subdivided by secondary ice wedges. This suggests that the thermal tension is relieved by the primary network. (3) Recent field data indicate that thermal contraction cracks expand over winter, responding to cooling of the ground as the season progresses. (4) As ridges develop and troughs deepen, snow depths in troughs, which are commonly filled by blowing snow, increase. As a result of (4), cracking decreases in the primary wedges, and we observe (1). The troughs are muted on hill slopes, so cracking of primary wedges there is unrestricted, giving (2). In extreme winters, extension of existing cracks relieves increased tension, deduced from (3).

NUMERICAL INVESTIGATION FOR THE EFFECT OF FRICTION COEFFICIENT BETWEEN PILE AND SOIL ON NEGATIVE SKIN FRICTION

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Pile foundation faces a lot of problems during design and construction. One of these problems is negative skin friction (NSF) or downdrag. Negative skin friction is a common problem if the pile is constructed in a compressible soil. Presence of negative skin friction causes an additional load on the pile, this load is called dragload. Neglecting the effect of negative skin friction may be cause a lot of sophisticated problems either to engineer or to structure itself. Downdrag is a very complex problem influenced by many factors such as pile characteristics, soil shear strength parameters, pile soil relative movement and pile-soil interface properties.

In this study, Numerical work was carried out to study the effect of soil-pile interface friction coefficient on the value of negative skin friction on piles. An axisymmetric finite element model is used to analyze and simulate the pile-soil interaction problem of negative skin friction. An extensive parametric study was carried out to investigate the effect of different factors on neutral plane location, the magnitude and distribution of negative skin friction along the pile length. These factors include pile-soil interface properties, pile-soil limiting displacement, the type of pile material, pile shape and using bituminous coating.

CHARACTERIZING THE TRANSPORT OF THE STABLE ISOTOPES OF WATER IN UNSATURATED MINING WASTE

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The naturally occurring, stable isotopes of water, deuterium ($\delta^2\text{H}$) and oxygen-18 ($\delta^{18}\text{O}$) are often used as tracers for water movement in unsaturated soil profiles. These behave as ideal tracers since they are part of the water molecule and follow water flow paths. In most applications, the isotopes are used to interpret advective transport of bulk water movement, but rarely used to interpret dispersive and diffusive transport.

One reason for this limitation is that the transport of the stable isotopes of water through unsaturated soil profiles is a multiphase process involving the partitioning of the isotopes between the water and vapour phases commensurate with the transport within each phase. The objective of this research is to characterize the dispersive/diffusive transport of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ through the use of large-scale column testing, as well as numerical transport modelling.

A 1.5m high and 0.18m diameter column will be packed with a medium to fine grained sand, saturated, and allowed to drain. A pulse of water, spiked with $\delta^2\text{H}$ and $\delta^{18}\text{O}$, will be applied to the top of the column. Bulk soil samples will be collected along the column to get transient water content, density, and isotope profiles. A numerical transport model will be used to interpret the observed profiles and quantify dispersive and diffusive transport. This work will be then be applied to the design of field experiments to track rates of recharge through unsaturated mine waste.

PERFORMANCE OF A RAILROAD ON DEGRADING PERMAFROST

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Deformations are still actively prevalent along the Hudson Bay Railway line. The railroad line experienced more frequent subgrade failures, heaves, and other similar problems adversely affecting its operation in recent years. The railroad embankment section was constructed on highly compressible peat and near the southern limit of the continuous permafrost zone. The warming climate is contributing to the degradation of permafrost thus reducing the load-carrying capacity of the embankment. A study was conducted to evaluate the reliability and sustainability of the railroad. Samples were obtained near the toe of the embankment and were tested for its compressibility and shear strength properties. Results from laboratory testing were used in numerical modelling to simulate its behaviour and predict future performance.

GEOSYNTHETICS REINFORCED TWO-STAGED CRASH WALL DESIGN AND CONSTRUCTION ON THE 96TH AVE NE EXTENSION ACROSS CP RAIL PROJECT, CALGARY AB

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Geosynthetics Reinforced Two-Stage Crash Wall Design and Construction
on the 96th Ave NE extension across CP rail project, Calgary AB

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Nilex Civil Environmental Group, Calgary, Alberta, Canada
Key Words: Geogrid, Geosynthetics, Crash load, two-stage MSE wall, SierraScape
ABSTRACT

To mitigate the effects of collision of a derailed train, a 450mm thick crash wall was required for a height of 5 meters to protect the bridge abutments for a six-lane bridge cross the CP rail tracks. Behind the crash wall, a SierraScape system was designed to release the lateral load. Above 5 meter, a 7 m high MSE wall faced with 1.5mx1.5m modular panels to support two abutments of the bridge structure.

From Fall of 2010 to late 2012, Nilex was awarded the 1,250 m² MSE wall along 96 Ave NE in Calgary AB. across the CP Railway tracks and Nose Creek, to connect the west end of the Airport Trail / Deerfoot Trail interchange. The paper will discuss the key design factors, construction sequence, and the project management tips on the mechanically stabilized earth reinforcement: Two staged MSE reinforced SierraScape® system was designed to release the pressure behind the 5m-high cast-in-place crash wall, in which the Tensar geogrid was extended as connector to hold the crash wall and the reinforced SierraScape® wall together without void gap between. 6.93m high precast panel wall was set flush above the crash wall for the abutment design.

The Maximum design height is 11.93m for the abutment wall with 20 CSP-cased piles on each abutment spaced at 2979 mm, left an effective coverage ratio of 50% behind the abutment.

RECONSTRUCTING GEOMORPHOLOGY: AN APPRECIATION OF THE CONTRIBUTIONS OF J. ROSS MACKAY (1915-2014)

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Based as they are entirely on his own field experiences, Ross Mackay's geomorphological contributions are commonly regarded as the fruit of solo inspiration. In fact, his work is very much the product of its times. At the outset of his career, geomorphology was entering a radical transformation from interpretive study of landscape history toward quantitative study of landscape-forming processes. Accordingly, Ross's earliest works – including his first essays on the landscape of the western Arctic – are descriptive accounts of regional physical geography. But they already reflected his keen field observation, strict interpretive logic, and deep regard for historical accounts of the landscape.

From 1960, however, his work expresses its dominant character: quantitative measurement in the field and on maps, and the application of physical theory as the basis for interpreting the observations. The theory did not arise with Mackay. He borrowed, but he inevitably improved what he borrowed. The Mackenzie Delta memoir (1963) already indicates the principal sources of ideas and methods that he appropriated. From the American geophysicists Lachenbruch and Brewer came methods of thermal analysis of frozen (and unfrozen) ground and ideas on ice wedges; from early Russian investigators, and from A.E.Porsild and Fritz Müller, came outlines of the theory of pingo formation. More remarkably, the bases for his analysis of the distributary channels of Mackenzie River lie in a little-known monograph by the British civil engineer Claude Inglis.

That his work is based on his own observations again reflects the spirit of his times. Following refocus of the field on process, it became obvious that field measurement should be the basis for advancing the discipline. In this, Mackay emulated other leaders of the period, notably L.B. Leopold of the United States Geological Survey whose career, albeit focused on rivers, bears striking parallels of style with that of Mackay. His long collaboration with William H. Mathews, a UBC field geologist of renaissance abilities, represented a further reinforcement of the preeminent importance of field-based quantitative observation.

The outstanding aspects of Mackay's contributions are his genius for making critical field observations and his ability to use them to develop and rigorously test geophysical theory, often initiated by others, but inevitably improved by him. And his regard for landscape history, learned in his early days, remained an important aspect of his insight throughout his remarkable career.

COMPOSITION AND ORIGIN OF AN ICE-RICH MOUND (LITHALSA) IN THE GREAT SLAVE LOWLAND, NORTHWEST TERRITORIES, CANADA

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Recent recognition of raised mounds in the widespread discontinuous permafrost zone of the Great Slave Lowland, NWT, has prompted questions regarding their internal composition and development. To answer these, fieldwork was undertaken in the summers of 2011 and 2012 at the Boundary Creek Study Area (BCSA, 62° 32'N; 114° 58'W), 30 km west of Yellowknife. This region was deglaciated at about 13 cal kyr BP, after which fine-grained glaciolacustrine sediments were deposited across the lowlands by Glacial Lake McConnell, and subsequently washed into topographic lows between bedrock highs during lake level recession. At BCSA, a prominent mound 700 m long and 4 m high occurs adjacent to a peatland and, from the results of this investigation, is identified as a lithalsa.

Borehole drilling parallel to the short axis of the lithalsa revealed ice-poor conditions within the first 4 m of substrate, with substantial increases in ice content at greater depths within underlying clays. The lithalsa core is composed of layered ice lenses on the order of 0.1 m thick. Stratigraphic records indicate that the sequence of clays, silts and sands are sub-parallel but domed, in accordance with the surficial relief of the lithalsa. Estimated differential heave between the lithalsa and the adjacent peatland is approximately 2.8 m, of which 2.17 m may be directly accounted for by ice lenses within the first 8.4 m of sediment. The $\delta^{18}\text{O}$ values between -18.4 and -16.6 ‰ from ice lenses at depth indicate that the layered ice core formed from modern meteoric waters. The groundwater source is likely from a talik associated with a pond flanking the north side of the lithalsa. A basal peat sample in the peatland indicates terrestrial exposure at approximately 1200 cal yr BP. Within the lithalsa, a detrital organic sample dating to 700 cal yr BP was collected below 3 m of sediment, whereas a 400 cal yr BP sample was recovered under a small peat pocket on top of the lithalsa. These results suggest terrestrial exposure and subsequent permafrost aggradation between 700 and 400 cal yr BP.

The mound at BCSA meets the main criteria for lithalsa formation: a warm ground thermal regime (approximately -1°C) to support water migration to ice lenses, an abundant water supply to feed the ice lenses via cryosuction, and the presence of fine-grained sediment promoting ice segregation and unfrozen water contents at depth.

A NEW APPROACH FOR ESTIMATING THE STRESSES ALONG THE VERTICAL CENTRAL LINE IN VERTICAL BACKFILLED STOPEs

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The backfilling of mine stopes with waste rocks and/or tailings was initially applied to enhance ground stability. It is also considered as an alternative method for mining waste disposal. To ensure a successful application of underground backfill, it is critical to have an accurate estimation of the stress distribution in the backfilled stopes. Over the year, a number of analytical solutions have been proposed. Most of them were based on Marston's approach by considering a horizontal layer element. For vertical backfilled stopes, the vertical and horizontal stresses are the principal stresses along the vertical center line (VCL), but not close to the walls. This suggest that the free differential element is not horizontal. Following a numerical analysis of Sokolovski (1965), Handy (1985) proposed to use arc layer element along which the shear stress is zero. Later, Harrop-Williams (1989) proposed to use circular layer element to represent the shear stress free layer element. In this paper, the approach of Harrop-Williams (1989) was adopted. A new analytical solution has been developed for evaluating the stresses along the vertical central line in vertical backfilled stope. A series of numerical modellings have also be performed to calibrate the analytical solutions. It will be shown that the proposed analytical solution can be used to describe and predict the vertical and horizontal stresses along the vertical central line. An improvement is obtained when compared to numerical results and existing analytical solutions.

CONVECTION MODELLING IN WASTE ROCK PILES IN PERMAFROST REGIONS

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Freezing temperatures in waste rock piles aid sustainable mining practices by minimizing acid rock drainage potential from sulphide bearing waste rock. The GeoStudio 2007 finite element program was used to model natural convection in two waste rock piles located in the permafrost regions of the Canadian Arctic. The GeoStudio 2007 convection module was validated using numerical and experimental examples reported in literature.

Convection modelling of a large scale waste rock test pile and a production waste rock pile is presented in this paper. Convection modelling results were compared to in situ temperatures measured in the two piles. The large scale waste rock test pile was constructed at the Diavik Diamond Mine in the Northwest Territories as part of a multidisciplinary waste rock research project to aid in sustainable mining. Parameters collected during the research project were used in the Diavik test pile model. Modelling results were not comparable to the temperatures measured in the Diavik test pile due to wind forcing air into the test pile. The production waste rock pile is located in the Panda Waste Rock Storage Area (WRSA) at the Ekati Diamond Mine in the Northwest Territories. Convection was modelled in the Panda WRSA using parameters collected during Diavik waste rock research project due to the proximity of the two mine sites. GeoStudio modelling cases could not reproduce the effects of the compacted layers visible in the temperature profiles measured in the Panda WRSA. However, convection effects were observed in the modelling.

DISPUTE RESOLUTION IN GEOTECHNICAL ENGINEERING PRACTICE – SOME LESSONS LEARNED

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The scope of applied geotechnology has increased greatly since it was introduced into modern engineering practice by prominent pioneers in the profession. Geotechnical expertise is increasingly applied in conjunction with other specialty fields and to a broad range of end uses including design, construction and performance. More formal contractual arrangements have evolved together with greater expectations by clients. Notwithstanding significant advances in the state of practice, disputes unfortunately still arise which require resolution by arbitration or litigation. Avoidance of claims and exposure is an important issue. The Authors provide lessons from their experience particularly to benefit younger members of the geotechnical profession.

SOIL-WATER CHARACTERISTIC CURVE BEHAVIOR OF EXPANSIVE SOILS

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The soil-water characteristic curve (SWCC) has been reported in the literature typically as a uni-sigmoidal relationship between the water content (volumetric or gravimetric) or degree of saturation and soil suction for expansive soils. However, in recent literature there is more evidence to highlight the bi-modal nature of the SWCC, particularly for expansive soils. A bimodal curve exhibits two sequent segments of uni-sigmoidal curves in a SWCC, where the two “humps” represent two air-entry values. The bimodal SWCC is believed to be a more efficient tool in the reliable prediction of the engineering behavior of expansive soils. Conventionally, the volume change behavior associated with the suction changes are ignored while measuring the SWCC in both non-expansive and expansive soils. However, the volume change behavior with respect to the applied stress and soil suction can have a significant influence on both the unimodal and bi-modal SWCC of the expansive soils. A comprehensive summary of the various parameters that influence the SWCC behavior of three expansive soils with different clay minerals are summarized in this paper. In addition, both the uni-modal and bi-modal SWCC of a typical expansive soil are used in the numerical simulations of an unsaturated soil slope taking account of the influence of deformation characteristics and other parameters to highlight the differences in the estimated factors of safety. Based on the slope stability analysis results, discussions are provided to highlight reasons associated with the differences in factors of safety and their reliability for various scenarios that are typically encountered in engineering practice.

ON THE EFFECT OF SOPHOROLIPIDS ON THE FRACTIONATION AND SPECIATION OF ARSENIC IN MINE TAILINGS.

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Due to the high toxicity of arsenic, this notorious metalloid is considered a primary pollutant in water in many places in the world, threatening the lives of millions. Exposure to a high level of this component or even long term exposure to lower levels of arsenic is linked to numbers of short term or long term health problems. Among the common valence states of Arsenic in the earth's crust, -III, +III and +V, arsenite and arsenate are the most abundant forms of arsenic. Between these two species of arsenic, arsenite is considered more mobile than its counterpart. Arsenic is found in gold mineral deposits in the form of arsenopyrite. Mine tailings are considered to be one of the main environmental contamination sources. During recent decades, numerous methods have been investigated for the remediation of mine tailings. One of the environmentally friendly approaches for the removal of heavy metals from contaminated soils is using an effective, biocompatible, biodegradable surfactant during the process of soil washing.

The objective of the present study was to investigate the effect of biosurfactants such as sophorolipids, at different concentrations and pH levels, on morphology and composition of mine tailings. Furthermore, the effect of sophorolipids on the speciation of arsenic was investigated. SEM analysis of the samples before being treated with sophorolipids and after treatment with different concentrations of sophorolipids show that that the morphology and homogeneity of the sample was significantly affected by different concentrations of sophorolipids. A comparison between the results from the sequential extraction of untreated and treated sample shows that sophorolipids were able to affect all the fraction of mine tailing and for example a solution of 1% sophorolipids at pH 5 was able to mobilize 44.6% of arsenic associated with water-soluble fraction of mine tailing, 37.4% from exchangeable, 27.0% from carbonate, 60.2% from oxide/hydroxide, 56.4% from organic and 24.2% from residuals fraction of mine tailing. The result from speciation of arsenic showed that that the only water extractable species of arsenic was arsenate [As (V)]. But, speciation of the arsenic in the effluent from batch experiments revealed that washing the mine tailing sample with 1% sophorolipid resulted in the release of both arsenate [As (V)] and arsenite [As (III)] from the mine tailing specimen. The results drawn from these investigations will be used to develop an efficient, environmentally friendly and economically feasible system for the treatment of mine tailings.

OBSERVED DEFORMATIONS OF AN EXISTING HIGHWAY EMBANKMENT ON DEGRADING PERMAFROST

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The integrity of infrastructure in northern regions is negatively impacted by thawing and degradation of the underlying permafrost foundation initiated by changes in both air and ground temperatures. Subsequent deformations due to settlement and lateral spreading can lead to potentially hazardous driving conditions for linear infrastructure such as highways. This paper discusses the deformation of an instrumented highway embankment on degrading permafrost observed since September 2012. The site is located 18 km north of Thompson, Manitoba on Provincial Road (PR) 391. Earlier papers on this site reported results for three years of data collection, but with incomplete instrumentation. Newly-added instrumentation installed in September 2012 has identified a frost bulb in the centre of the embankment. This paper discusses the effect of the frost bulb, which had not been known and therefore not included in previous studies, on the embankment deformation. Lateral and vertical embankment deformations were measured using ShapeAccelArrays installed vertically below the shoulder of the embankment and horizontally at its toe. New instrumentation also included vibrating wire piezometers and thermistors to monitor groundwater and temperatures. Readings from the new instruments provide an improved understanding of the pore pressures and the thermal regime at the site.

OBSERVED AND PREDICTED THERMAL REGIME UNDER AN INSTRUMENTED HIGHWAY EMBANKMENT ON DEGRADING PERMAFROST

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Temperature changes of ground thermal regimes in permafrost regions can initiate thawing and degradation of permafrost and potentially damage existing infrastructure. Subsequent settlements and lateral spreading can lead to hazardous driving conditions on highways. Future changes in climate will exacerbate thermal degradation and negatively impact the long term performance of linear infrastructure like highways, runways, rail lines, and pipelines. The paper will discuss numerical thermal modeling of an instrumented highway embankment on degrading permafrost, both for simulating current conditions and predicting future behaviour. The embankment is located 18 km north of Thompson, Manitoba on Provincial Road (PR) 391. Thermistors were installed beneath the toe, mid-slope, shoulder and centerline of the embankment. Five years of data have been collected. Earlier papers by the authors outlined the instrumentation and development of a first generation of numerical thermal models for the site. This new paper will describe how expected trends in climate change have been used to predict future behaviour.

ESTIMATING THERMAL DIFFUSIVITY IN PERMAFROST USING TEMPERATURE TIME SERIES ON THE QINGHAI-TIBET PLATEAU, CHINA

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The QTP has the largest expanse, about 1.3×10^6 km², of elevational permafrost on earth. During the past several decades, permafrost studies on the QTP have rapidly developed. Since 1980s, an integrated permafrost monitoring network including more than 20 boreholes with depths from 20 to 127m has been set up along the QXHW. Soil temperature data used in this study were obtained from 17 monitoring boreholes during 2006 to 2010. Observation results show that eleven permafrost sites are classified as warm permafrost, which is defined as permafrost temperature at or higher than -1.0°C , and eight of them are warmer than -0.5°C . Based on the observation results, this work indicates that permafrost thermal trumpet curves are generally narrow in warm permafrost regions while they are wide in the low-temperature permafrost regions. In order to analyze the reasons for the difference in the thermal trumpet curves, using the classic algorithms, this work calculated the thermal diffusivity in permafrost at different horizons. Results indicate that the latent heat effects have important implications on the permafrost thermal regime and the most of the permafrost on the Qinghai-Tibet Plateau is undergoing internal thaw. At the same sites, thermal diffusivity is usually small at the active layer bottom since there is an ice layer at this horizon at most sites. It is usually large in the deep permafrost especially when permafrost temperature is low. For the 17 monitoring boreholes, there is a causal relationship between the small thermal diffusivity and the high permafrost temperature. Based on the observation results and numerical analysis, this work suggests that permafrost temperature regimes, whether cold or warm, not only have an important implication on the warming trend of the permafrost, but also have significant impact on the distribution of vertical profile of ground temperature. The latent heat effects that caused by the increase of permafrost temperature will have important implication on the degradation of permafrost under climate warming.

SOIL FREEZING AND THAWING PROCESSES AFFECTED BY THE DIFFERENT LANDSCAPES IN THE MIDDLE REACHES OF HEIHE RIVER BASIN, GANSU, CHINA

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An understanding of soil freezing and thawing processes in seasonally frozen soil is important for many agricultural and environmental issues, especially under different landscapes in terms of land use and climate change. In this study, sandy soil behavior under soil freezing and thawing cycles were investigated under three typical landscapes (i.e., farmland, forest, and desert) in the middle reaches of the Heihe River Basin, Northwest China, from December 2011 to May 2012. Both Neutron Moisture Meter and Time Domain Reflectometry techniques were used to investigate the total soil water content (TSWC) and liquid soil water content (LSWC), respectively, and further based on to calculate soil ice content (SIC) and ice ratio (IR). The partition TSWC into LSWC and SIC at different depths is shown to be corresponded well with soil temperature, frost depth and groundwater dynamics, provided a vigorous basis for augmenting the limited data on soil water redistribution in seasonally frozen soils under natural conditions of different landscapes. The greatest freezing cycles were observed for the farmland, characterized with the deepest frost depths (106 cm), the highest IR (>0.9), and the largest upward heat fluxes (120 W m⁻²), followed by the forest, and then the desert. These differences were primarily attributed to landscape-dependent initial soil water content, soil surface cover and groundwater levels, with marginal effect being attributed to soil physical properties. Profiled water redistribution upon soil freezing and thawing was obviously observed in the moist forest, but neither in the wettest farmland or in the driest desert. The soil frozen processes had a beneficial effect on soil water conservation with reduced evaporation and seepage, and high water content maintained, which could be useful for plant germination in the following spring.

INCORPORATING GEOTECHNICAL INVESTIGATIONS TO SUPPORT RECLAMATION ON RESOURCE PROJECTS

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Integration of geotechnical drill logs and trench data into terrain and soil mapping provides a powerful tool in reclamation planning for resource development. For large resource projects such as pipelines and mines, reclamation planning commonly includes baseline soil and terrain mapping to inform reclamation aspects such as soil salvage and terrain stability planning. Geotechnical drill logs and trench data provide detailed information on soil depths and assist refinement of terrain mapping in terms of depth to bedrock and surficial materials. The geotechnical sample data provided from the drill program also assists in mapping the chemical signature and suitability of material for reclamation to aid in soil handling practices.

Geotechnical drill logs and trench data are imported into geographic information systems (GIS) and cross-referenced to terrain and soil maps. Surficial material depths are modelled across the project development area. The geochemical suitability of overburden derived from drill log and trench samples are also incorporated as part of the soils mapping. In northern regions quantifying permafrost and accurate hazard mapping can rely on geotechnical drill logs to identify areas of potential permafrost geohazards and their potential impact on resource infrastructure and reclamation. Examples of large resource projects that used geotechnical drill logs and trench data for terrain and soil mapping attribution to support reclamation planning are presented.

MONITORING AND MODELING THE THERMAL STATE OF PERMAFROST ON THE TIBETAN PLATEAU

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Permafrost occupies more than half the territory of the Tibetan Plateau (TP). Unprecedented attention has been paid on thermal dynamics and possible changes of permafrost under climate changes due to its effects on land surface, hydrologic and ecologic processes, and further on regional, and even global climate through its influences on heat, moisture and carbon cycles. To evaluate the status and changes of permafrost and its influences on water cycles, ecosystems, climate and infrastructures on TP, monitoring networks on permafrost and its influencing factors have been gradually established since 1960s, and were greatly improved after 2000. It includes more than 200 ground temperatures (GTs) monitoring boreholes equipped with thermistors chains, and part of them connected with dataloggers, more than 20 active layer profiles equipped with thermistor chains, moisture content sensors and soil heat flux plates connected to dataloggers, 10 automatic meteorological stations equipped with sensors of air temperature and humidity, wind speed and direction, both downward and upward radiation of short and longwave, precipitation, etc. Parts of the monitoring sites have been selected as long-term monitoring sites of the Global Terrestrial Network-Permafrost (GTN-P), Circumpolar Active Layer Monitoring (CALM) and Global Cryosphere Watch (GCW). The monitoring data revealed that the thermal state of permafrost was well correlated with elevation, and regulated by annual precipitation, local geological, geomorphological and hydrological conditions through heat exchanges between ground and atmosphere. Generally, permafrost is well developed, and GTs is relatively lower in regions with higher precipitation, wetter surface layer soils as these regions are located at the same elevation and/or are with the same air temperatures. Depths of zero annual amplitude (DZAAs) were well correlated with GTs. Higher in GTs, shallower in DZAAs in permafrost regions, but deeper in non-permafrost regions. It means that the influencing depths of seasonal air temperature variation are smaller in permafrost regions with higher GTs, but higher in non-permafrost regions. Modeling results revealed that the penetrating depth of surface soil heat flux would become shallower accompanied with permafrost temperature increasing induced by climate warming, but be deeper accompanied with GTs increasing in non-permafrost regions. It was said that the buffer layer effect of the ground from ground surface to DZAAs to protect permafrost temperature increasing might become more effective accompanied with air temperature increasing. Furthermore, ground heat flux from the permafrost base might contribute more influence on GTs increasing and thickness decreasing of permafrost.

FROZEN FRINGE THICKNESS ESTIMATION BY X-RAY COMPUTED TOMOGRAPHY

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Frozen fringe is a region between the frozen front and growing ice lens, with characteristics of low moisture content, low hydraulic conductivity and no frost heave. Since the previous studies demonstrated that the phenomena that occur in this area seem to underlie the entire frost heaving process, to determine the thickness of frozen fringe and further learning its physical properties is a necessary condition for developing models about frost heave process. But limited by the current measure technology, the knowledge about the physical properties of frozen fringe is rather lack. The existing research results presented that for the soil column after been frozen, the water content and its distribution will affect the density in different part of tested soil column. The difference in density will influence the variation of CT value definitely. Therefore, this study will analyze the CT value distribution by performing a CT scan on the tested soil columns experienced a one-dimensional freezing process, to determine the thickness of the frozen fringe and its relationship with the top plate temperature, based on combining with the moisture content distribution characteristic and its thermal profile along longitudinal axial of soil column. The results indicated that the X-ray Computed Tomography has a characteristic of high accuracy and easy manipulation in determining the frozen fringe thickness compared with the other estimation methods such as temperature measurement and water content measurement. In the region of the frozen fringe, the water content of soil column will transit from the lowest to the highest level. Accordingly, the CT value of soil column section will have an acute change from the highest to the lowest. By analyzing the CT value of the tested soil column frozen under five different top plate temperatures, it is observed that the thickness of frozen fringe is nearly a constant value and independence of the variation of temperature gradient during its freezing process.

VALORISATION DE SOLS FINS PAR UN PROCÉDÉ DE BIOCALCIFICATION

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Dans un contexte de développement durable, de plus en plus d'études visent à valoriser des déchets industriels dans de nouvelles constructions (remblais, fondations de voiries...). Ainsi, des sédiments, des cendres, des résidus industriels ou encore des sols contaminés peuvent être traités et réutilisés à de nouvelles fins. Parmi l'ensemble des techniques de valorisation, nous nous sommes intéressés à la biocalcification, qui constitue une méthode émergente d'amélioration des sols en place. Son principe repose sur l'injection de bactéries, d'urée et de sels de calcium, qui conduisent à la formation d'un précipité de calcite dans le milieu encaissant.

Les premières recherches menées par des laboratoires australiens, néerlandais, américains, français et canadiens se sont avérées très prometteuses en termes de performances des sols biocalcifiés, mais se sont essentiellement limitées à des sols granulaires grossiers (amélioration de la capacité portante, densification, résistance à la liquéfaction...). L'originalité de l'étude réside dans l'implémentation de la technique hors terre, sur des sols fins et remaniés, à des fins de valorisation en fondation de voiries. À cet effet, nous présenterons les résultats d'essais cycliques de gel-dégel sur des silts biocalcifiés, ainsi que l'évolution de leur capacité portante en fonction du temps pour une éventuelle application au Québec. Le procédé d'injection des bactéries se fera par percolation, à la différence d'une injection plus utilisée par puits car nous ne souhaitons traiter que la surface du sol. Ce procédé est moins demandant en termes de ressources et plus facile à mettre en oeuvre sur de grandes distances. La difficulté réside dans la perméabilité d'un sol fin, bien plus faible que pour un sable.

Pour dégager des résultats concluants, le protocole de percolation sera basé sur celui d'essai avec un sol plus grossier tout en l'adaptant pour que la zone d'effet et l'amélioration de la résistance soit satisfaisante. L'étude se poursuivra avec des tests CBR et triaxiaux pour quantifier l'effet des cycles gel-dégel.

Finalement, nous formulerons des recommandations quant à l'utilisation de cette méthode pour l'amélioration des performances des matériaux de voirie.

VEGETATION IS THE DOMINATED CARBON SOURCE TO SUPPORT GREENHOUSE GAS EMISSION CHANGES IN SUBARCTIC PEATLAND WITH PERMAFROST THAW

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Our study assessed what changes occurred in greenhouse gas emissions with permafrost thaw in subarctic peatland, and the dominated carbon (C) biogeochemical process of these changes. We examined the exchange of CO₂ and CH₄, structure of vegetation, dissolved organic C (DOC) concentration and biodegradability, and other physical & chemical conditions across a complete permafrost thawed gradient from intact palsas, through dry lawn, wet lawn, edge of thawed pond, pond sedges, to several thawed ponds in Quebec subarctic peatland in growing seasons of 2013 and 2014. Permafrost thaw did not caused different peat temperatures among these sites; but lead to water tables decreased significantly, peat pH increased, N supply rates decreased, and K increased (P were similar) along the thaw gradient. These dramatic environmental changes resulted in reduction of vegetation abundance and biomass in shrubs and herbs, and increase in Sphagnum and sedges, and then to the end of pond water along this gradient. Litter decomposition rate also increased along thaw gradient with these vegetation changes. Exudation labile organic C productivities per biomass significantly increased from shrubs & herbs to sedges, which enforced the labile C availability in thaw area. Surface pore water DOC biodegradability may thus fellow the same trend as exudates that significantly increased in more sedges thaw areas. 2 seasons' chamber measurements showed that both CO₂ and CH₄ effluxes strongly correlated with the carbon biodegradability changes along thaw gradient, with significantly higher emissions in wetter and more sedges area. Based on $\delta^{13}\text{C}$ of surface dissolved CO₂ and CH₄, DOC, peat, and plant litter & exudates, we determined that litter & exudates of plant were even the main source of the labile DOC that supporting the production of heterotrophic greenhouse gases in thawed peatland. Therefore, permafrost thawing in subarctic peatland leads to large greenhouse gas emissions, which supported by newly produced labile C from the changed plant communities rather than the old peat.

TEMPORAL AND SPATIAL VARIATION ANALYSIS ON LAND SURFACE TEMPERATURE OVER QINGHAI-XIZANG PLATEAU

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The spatial distribution and multi-year change of land surface temperature over Qinghai-Xizang Plateau was analyzed using MODIS LST products. Firstly the null pixels were reconstructed by integrating temporal and spatial information. The validity ratio was showed to be over 97% after LST recovery. A sine and linear piecewise function was utilized to fit the four instantaneous observations to mean daily LST. Ground observation of 0 cm soil temperature was employed to validate the fitting precision, which was proved to be within 1 K. At last a cosine function model was built to describe the seasonal fluctuation of LST. The mean annual LST, the amplitude and the peak LST date were subsequently extracted by this model. Results showed that the mean annual LST was highly correlated to attitude, latitude and the type of underlying surface. Amplitude was showed to rise from the southeast to northwest. The peak date of water was obviously delayed compared with other types. Slope analysis showed that the mean annual LST over Qinghai-Xizang Plateau was increasing with a velocity of 0.015 K per year. Amplitude was elevated by 0.076K per year, which indicated that the probability of extreme weather was larger than before, due to the greenhouse effect and climate change. The peak date of LST appeared earlier to some extent.

THE BENEFICIAL AND DETRIMENTAL EFFECTS OF ROCKING SHALLOW FOUNDATIONS ON SUPER STRUCTURE DURING SEISMIC LOADING

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Generally, modern seismic design codes prohibit relative movement between the foundation and the soil beneath, which demands the structural elements of the superstructure to dissipate seismic energy. The primary benefit of appropriately reducing the size of the footing in shallow foundation is the partial isolation of the structure from the soil beneath (uplift and rocking). The rocking behavior caused by the seismic loading can occur about the footing base, subsequently reducing the ductility demands transmitted to the superstructure. However, there are concerns and hurdles that hinder the use of foundation rocking in practice, including rocking induced settlement, maximum rotation of the structure (and the corresponding P- Δ effects) and the reliability and predictability of the capacity of the soil-foundation system.

In this study, several centrifuge and shake table experiments on rocking shallow foundations have been analyzed to investigate the reliability and predictability of the moment capacity of the soil-foundation system, rocking induced permanent settlement, the detrimental effects caused by the P- Δ moment (due to rocking induced rotation), and the reduced ductility demands transmitted to the super structure (due to rocking induced seismic energy dissipation). Shear walls and flexible and rigid column structures attached to a deck mass supported by shallow foundations resting on dry sandy soil have been tested in the experiments. These results are correlated as functions of rocking coefficient of the soil-foundation system, critical contact area ratio of the foundation, aspect ratio of the structure, and the intensity of the earthquake.

It was found that, unlike bearing capacity of the foundation, moment capacity of a rocking foundation is reliable and less sensitive to the uncertainty of soil properties and can be predicted with reasonable accuracy. Due to the base-isolation effects and seismic energy dissipation in foundation soil caused by rocking, the maximum acceleration transmitted to the super structure is decreased, reducing the inertia loads transmitted to the structure. The possibility of tipping over failure due to rocking induced rotation has also been analyzed. There exists a limiting lateral displacement of the structure (Δ_{limit}) before tipping over failure could occur and Δ_{limit} can also be predicted with reasonable accuracy. The P- Δ effect is instantaneous and temporary, thanks to the reversing nature of the seismic shaking and the self-centering characteristic of rocking shallow foundation. Finally, how simple ground improvement methods can be used to reduce the settlement of foundation due to rocking is discussed.

DISCUSSION ON HORIZONTAL STRESS RATIO (K_o) FOR TORONTO GLACIAL SOILS

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K_o is one of the important geotechnical parameters required for design of underground structures, especially for tunnels and support of excavations adjacent to sensitive infrastructures. However, the determination of K_o is not an easy task and difficult to evaluate, particularly for glacial deposits. Many factors affect the horizontal stress in soil, including overconsolidation, aging, cementation, etc. Generally, K_o values may widely vary from 0.2 to 2 with some references reporting K_o values as high as 3 to 4. Usually, the retained memory of the horizontal effective stress is less clear in comparison to vertical stress. Deposits of young soils have experienced a relatively simple stress history and therefore, analytical approaches such as reconstruction of vertical stress combined with assessment of basic shear strength parameters such as friction angle may result in reasonable estimate of the K_o. In contrast, this approach is not applicable to glacial soils. The geological history of the Toronto area has included several advances and retreats of glaciers, resulting to a complex stress history which leads to more uncertainty in the results of simple analytical method for estimation of K_o. Apparently, there has not been a consolidated study for the assessment of K_o across the Toronto area. The wide range of possible K_o values and the difficulty in estimation creates problems for designers in assessing and selecting the appropriate values for their projects. The current practice in determining K_o is primarily based on the engineer's previous experience.

The results for determination of K_o values in 20 different sites across Toronto are summarized in this paper, followed with a discussion on the best approximation of stress history for this glacial deposits. The estimated K_o profiles are compared with the results from pressuremeter tests (PMT) and piezocone tests (CPTu), where available. Finally some discussions and recommendations on K_o determinations for transit tunnels in Toronto Glacial soils are presented.

FIELD TESTING OF LARGE SAND-FILLED GEOTEXTILE CONTAINERS USED AS A TEMPORARY FLOOD PROTECTION SYSTEM

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The effectiveness of temporary flood protection is highly variable depending on the location, application, and the nature of flood events. This paper evaluates sand-filled interconnected geotextile containers used as flood protection products within a framework of standardized tests. The products were tested under a variety of flood conditions to quantify seepage rates, stability and durability. This allows informed decisions to be made regarding appropriate applications for each temporary flood protection product, and identifies areas for product improvement and development.

An outdoor testing facility was designed and constructed at the University of Manitoba to administer a modified version of tests outlined in the US Army Corps of Engineers Standardized Testing Protocol for Evaluation of Expedient Floodfight Structures. This testing protocol evaluates the constructability of a flood protection product, as well as its performance under various flood conditions including: hydrostatic loading, wave-induced hydrodynamic loading, overtopping, and debris impact. Two single-layer configurations and two stacked configurations were tested different water levels, while seepage rates and product displacements were measured during each test.

One stacked configuration was found to be unstable and provided insight into stacking requirements for geotextile sand-filled containers. The interconnected chamber design proved to be a stable, durable and effective temporary flood protection product over the range of loading conditions applied. This type of product would be well-suited to situations where stakeholders have a low tolerance for risk, and there is adequate site access for the construction equipment required for installation. An ideal installation would be a long, relatively straight stretch where vertical product/wall and product/product interfaces can be minimized.

REDUCED UNCERTAINTIES IN THE INTERACTION OF PERMAFROST WARMING AND CARBON DYNAMIC BY VERTICALLY RESOLVED SOIL BIOGEOCHEMICAL MODEL

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Air temperatures over the Arctic have indeed increased over the last century. Observations show significant increases in permafrost temperature, enhancing deeper active layer thickness and permafrost degradation. The permafrost degradation has the potential to initiate numerous feedbacks, predominantly positive, in the Arctic climatic, hydrological, and biogeochemical processes. The warming temperature can force the decomposition of organic matter storing within the permafrost, affecting carbon budget. However, uncertainties in the vertical profile and total amount of organic carbon in the permafrost column decrease our understanding about the interaction between the decomposition process and permafrost warming. To reduce the uncertainties, we coupled a cryoturbation process into a land surface model (CHANGE) dealing with heat, water, and carbon processes. The new model includes a vertical dimension to carbon and nitrogen pools and transformations, a more realistic treatment of mineral N pools, and flexible treatment of the dynamics of decomposing carbon. The revised model had applied to the Arctic terrestrial region over the last 20th century. As a result, the model predicted substantially more and older soil carbon in permafrost column than the baseline model. The deepened active layer thickness implicating with the permafrost warming had derived more decomposition of soil carbon in the terrestrial Arctic during the last century.

CHARACTERIZING RELICT LATE PLEISTOCENE PERMAFROST VALLEY FILLS ALONG THE ALASKA HIGHWAY, SOUTHWEST YUKON

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The Alaska Highway through southwest Yukon is located in the Discontinuous Permafrost Zone with many areas of the highway corridor associated with degrading permafrost. Given the strategic value of the corridor, it is critical to have a clear understanding of permafrost characteristics and distribution, particularly in the context of a changing climate. In the Beaver Creek area, the Alaska Highway transverses both glaciated and non-glaciated terrain from the last glacial maximum. Permafrost characteristics are strongly influenced by regional glacial history including the distribution of relict Pleistocene syngenetic permafrost. In this study, we characterize relict Pleistocene permafrost valleys fills along the Alaska Highway between Beaver Creek and the Alaskan border using a multidisciplinary approach. Our surveys include electrical resistivity tomography (ERT), airborne electromagnetic (AEM) geophysical surveys, geomorphological mapping, permafrost drilling, cryostratigraphy, geochemical analyses, and environmental monitoring to define the boundaries and geometry of the valley fills. Using a combination of AEM and ERT data, we are able to map areas of syngenetic permafrost that are preserved beyond the glacial limit near hillslopes, from areas of predominantly epigenetic permafrost within the valley bottoms. Radiocarbon dating and stable isotope analyses of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ combined with detailed cryostratigraphy confirm that much of the ground ice is relict from the late Pleistocene. Ground temperatures are strongly influenced by the valley fill characteristics and geometry. The outcomes from this study will assist with development of future mitigation strategies and maintenance plans for the Highway.

GEOMETRY OF ORIENTED LAKES IN OLD CROW FLATS, NORTHERN YUKON

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During his 60 years of research in the western Arctic, J. R. Mackay devoted considerable attention to thermokarst lakes and examined all aspects of their evolution. An early contribution, in 1956, brought attention to the orientation of thaw lakes in the Liverpool Bay area. He further discussed the morphometric characteristics of these lakes in his 1963 memoir on the Mackenzie Delta Area, indicating that the geometry and orientation of the lakes are in equilibrium with modern wind conditions. In his 1956 paper, Mackay indicated that the lakes of Old Crow Flats (OCF), in northern Yukon, are also perpendicular to the dominant winds. However the morphometric characteristics of the lakes of OCF had not yet been surveyed, nor had their orientation and geometry been compared to dominant wind patterns in the area.

OCF is a 5600 km² Arctic peatland surrounded by mountains and underlain by glacio-lacustrine sediment. More than 2500 thermokarst lakes cover approximately 35% of the surface of the Flats, and many of these lakes have rectilinear shorelines oriented either NE-SW or NW-SE. The origins of these morphometric characteristics are unclear, and have been attributed to the underlying geological structure, wind-generated currents, ice-push, and wave action. We have previously indicated that it is unlikely the orientation of the shores is controlled by underlying faults, as shore recession of up to 3.5 m yr⁻¹ have been measured. In this paper we examine the distribution and characteristics of oriented lakes and basins with rectilinear shorelines in OCF. The objectives are to 1) characterize lake shape and orientation in OCF; 2) examine shoreline recession patterns based on aerial photographs from 1951 and 1996, 3) investigate erosion mechanisms and controls on shoreline form from field observations during the open water season, and 4) investigate the origin of the geometry of the lakes by comparing wind patterns to the shape of lakes of different sizes. In areas where tall shrubs and taiga grow around the lakes, shorelines are irregular and erosion occurs mainly by conduction and thaw subsidence, as the subsiding vegetation creates a barrier protecting shorelines from wave erosion. In areas where low shrubs and grasses dominate the vegetation cover, ponds have irregular shores but become more rectangular as they expand. Small oriented lakes expand most rapidly along a northeast-southwest axis, which corresponds to the dominant wind directions, but no clear trend could be identified for large lakes.

DETECTION OF ROCK SLOPE FAILURE PRECURSORS USING A TERRESTRIAL LASER SCANNER

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In steep mountainous environments, rockfalls are a problematic geohazard affecting linear transportation corridors. These types of hazards tend to occur suddenly and their spatial location and time of failure is often unknown a priori. Advances in the analysis of remotely sensed 3-Dimensional point clouds collected in series, permits the detection of precursors prior to rock detachment, which can allow for the identification of potential rockfall source zones. Precursors consist of deformation, smaller volume rock detachments and opening of tension cracks, and are a result of internal failure processes such as a fracture propagation and/or sliding along pre-existing fractures in the rockmass. To date, the accurate identification of source zone location, potential failure volume and time of failure for rockfalls has yet to be realized in a complex slope environment in an operating rail setting. In this study, an application of remotely sensed data at several high rockfall activity sites along CN rail line in Southwestern British Columbia is used to identify precursors to rockfalls.

To detect rockfall precursors, a geometric comparison of a series of terrestrial laser scanning (TLS) data sets was conducted. The field data collection program was designed to limit sources of uncertainty. This included scanning from multiple view sets to limit data loss from view obstructed areas, limiting high incidence angles, scanning in favorable atmospheric conditions and scanning with a high and consistent point spacing throughout the slope. To reduce the amount of scanner noise, a novel 3D median noise filtered has been developed and was applied to the data. This allows for the identification of discrete block deformation at the millimeter scale. In both back and forward analysis, precursors were identified prior to rockfalls of 1 – 4200 m³ in volume, occurring from one week to over a year preceding failure. For the 4200 m³ event, advance warning of potential source volume and location was given prior to failure. For a 2600 m³ event, a pattern of precursor rockfalls was identified during failure back analysis around the perimeter of the failure and an accelerating trend in surface deformation allowed for the evaluation of several failure forecasting models. In this study, precursor events were shown to be a reliable indicator of potential rockfall sources zones.

The ability to accurately locate rockfall source zones, estimate failure volumes, kinematics, and failure time prior to failure, can provide early warning and will result in safer transportation networks.

THE EFFECT OF FLOW REVERSE ON PERMEABILITY MEASUREMENT IN ROCKS

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This paper presents the results of an experimental evaluation of the alteration of permeability in rock samples subjected to constant flow tests. Cylindrical samples of the rock (Indiana limestone, Stanstead granite and Sandstone (Rudna, Poland)) measuring between 50 mm in diameter and 20 mm in length were tested. The Samples were epoxy coated on the cylindrical surfaces and capped with acrylic disks, allowing only one-dimensional flow. A constant flow rate was applied at the upstream and the downstream was kept open to atmospheric pressure. The fluid pressure response was recorded with time. The Samples were tested at different conditions: initially dry, initially saturated and reversed flow using distilled de-aired water. Although the evolution of permeability was different between rock types as well as with initial saturation condition, a common trend was seen across all tests where the fluid pressure rose to a given value and then decayed, followed by a steady rise to a plateau pressure. Results suggest that previous saturating history strongly influences the permeability measurements. Furthermore, the interpretation of experimental data can be wrongly analyzed and an erroneous permeability obtained due to the pressure gradient not being stabilized or assumed to be stabled at a "pseudo-plateau", in such case, flow reverse had the most significant effect on the Indiana Limestone, in which the pressure did not reach a steady pressure gradient across the sample rock in 18 days.

ROCK GLACIERS IN THE RUSSIAN ALTAI MOUNTAIN AND THEIR PRESENT STATE

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In the course of the reported study, rock glaciers have been detected and assessed in terms of their present state and thermokarst processes, motion of their fronts and surfaces.

Rock glaciers were identified using standard remote sensing and field methods of glacio-morphological analysis and mapping.

The discovered rock glaciers were described according to several parameters: location; type; heights of fronts; activity; slope direction; size (length, width, and surface area); available published evidence. These data made basis for a GIS map of rock glaciers of the Altai and the respective catalog. The map was compiled using LANDSAT images (28 and 14 m/pixel) of the whole territory and ALOS (10 and 2.5 m/pixel) and RapidEye (5-6,5 m/pixel) images of selected areas, as well as published evidence and data collected by our team in the field.

The satellite images shot at different times and in different seasons allow cross checking the flows distinguished in different conditions of vegetation, illumination, and geomorphic expression (the snow cover highlights landforms in winter images).

Rock glaciers are especially abundant in the Russian Altai Mountain – in the South Chuya, North Chuya, Katun, Chikhacheva, Kurai, South Altai ranges, and in the Ukok plateau, where 2700 rock glaciers have been detected, with a total area more than 580 square kilometers. Rock glaciers show a slope-direction dependence because of the predominantly W—E strike of the ranges and mostly western and southwestern wind directions. The greatest number of rock glaciers occur in northern, northwestern, and northeastern slopes (almost 70%), which are more favorable for the existence of permafrost, but they are few in southern, southwestern, and southeastern slopes. Rock glaciers exist at elevations between 2000 and 2600 m above sealevel.

Since 2003 the motion of rock glaciers has been monitored instrumentally (with a geodetic GPS of cm-scale accuracy and a tachymeter) in the Akkol River valley (South Chuya Range) at 2550 m asl (two flows) and at 2300 m asl (three flows). Over the period 2003 through 2013, the marks on the surface of the monitored flows of rock glacier moved 0.32 to 1.79 m downslope at a mean rate of 3-7 cm/yr. For the past two years, the flows have moved 0.9-2.1 cm/yr faster. The reason is that, besides moving downslope by themselves, they experience translation pressure from younger generations of flows up the slope, which also causes their lateral dispersal.

THERMAL MODELLING OF EROSION PROTECTION WITH GESOYNTHETIC CONTAINERS IN COMBINATION WITH LIGHT CLAY AGGREGATE.

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Coastal erosion processes in permafrost regions are usually considered to involve two mass transport processes; thermo-abrasion and thermo-denudation (Günther et al, 2012). Thermo-abrasion is defined as the combined mechanical and thermal action of sea water and sea ice on the coastline. Thermo-denudation is defined as the effect of the surface heat balance causing soil instability and slope failures at the scarp. The analyses presented in this technical note focus on the thermo-denudation processes.

The main objective of the thermal modelling has been to investigate the possibility of using Naue Geosynthetics to insulate the slope to reduce the thickness of the active layer and freeze-thaw action on the slope. In this manner the thermo-denudation process can be slowed down and the erosion of the slope can be reduced to acceptable levels during a coastal structure or landfill service lifetime.

In permafrost engineering applications it is well-known that artificial ground insulation will decrease the thickness of the active layer and decrease degradation caused by freeze-thaw cycles. However, insulation may increase the permafrost temperatures below the active layer. Insulation may, therefore, not be suitable for engineered foundations and slope processes where creep processes dominate the deformation behaviour of the soils. However, the ultimate goal of the analysis presented was to evaluate the capability of Naue Geosynthetics to mitigate thaw depth, i.e. reduce the thickness of the active layer on the permafrost slope.

The baseline case in this study has been a soil profile and geometry similar to the conditions at Vestpynten, Svalbard. Geotechnical investigations and ground temperature measurements have been carried out at this location since 2011 (Finseth and Instanes, 2012).

The numerical model has been extended in order to investigate the possibility of using similar erosion protection techniques in more fine graded soil (silt). The prediction and modelling of coastal erosion in fine-grained, ice-rich continuous permafrost can be more challenging than in coarser soils, due to the presence of ground ice. Under these conditions, the rate and location of erosion can be highly variable from year to year. The results from the analysis must, therefore, be used with care.

MONITORING OF CRYOGENIC GEOSYSTEMS IN THE EUROPEAN NORTH, THEIR CURRENT CONDITION AND DYNAMICS

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There are some results of monitoring of cryogenic geosystems in the permafrost zone in the European North. At the site Boltansky (coast of the Pechora Bay) during the 30 years of observations, mean annual permafrost temperature (MAPT) in different landscapes increased by 0.2...1.0°C C, and the mean annual air temperature (MAAT) at the Bolvansky weather station increased by 3.0°C. Trend of MAAT is 0.07°C/year; trend of MAPT is significantly smaller - up 0.01 to 0.03°C/year. The greatest trend of the MAPT is characteristic for low temperature cryogenic landscapes, and lowest trend - for high temperature landscapes.

The active layer thickness (ALT) within of CALM-site R24 Boltansky for 14 years of regular observations increased in 20 cm, the ALT trend increase is equal to 1.5 cm/year, but the trend in comparison with the ALT in 1983-1993's is only 0.1 cm/year.

After a few unusually warm years, average annual temperature in the active layer increased to 0...-0.2°C in 2011 and ALT increase was recorded in summer 2012. As result, the permafrost table is lowered in local areas. Long-term observations at CALM-site R24 in the continuous permafrost zone showed that formation of closed taliks occur in cryogenic landscapes having low thermal inertia. These include tundra landscapes on the hilltops, presented by ice-poor loam with MAPT of -1...-2°C. Sites with peat on the surface even at a temperature of 0...-1°C remain stable.

The extensive talik has developed on the shrubby slope to the lake depression in the southern part of Bolvansky site. Using seismic methods, it was found that the permafrost table there lowered from 3m in the upper part of the slope to 6-8 m in the bottom of the depression. Seismic studies carried out in a ravine, determined the development of a shallow talik to a depth of 5.5 m.

At the site Shapkina (Central part of the Bolshezemelskaya tundra) over a 30 years, the permafrost temperature significantly increased. The greatest changes occurred in ecosystems tops of peat hills. In 1982-1983, there were observed temperature -1.7°C, and in 2014 - just -0.6°C. In wetland ecosystems has been minimal temperature changes. In 1982-1983, the permafrost temperature was -0.7°C, and in 2014 - only -0.4°C. On disturbed sites (local removal of vegetative cover) the roof of permafrost thawed to 4-5 m due to the change of heat exchange on the surface and soils.

The research was supported by international projects CALM and TSP.

NUMERICAL STUDY OF COOLING EFFECT OF A RUSHED-ROCK INTERLAYER EMBANKMENT WITH PERFORATED VENTILATION DUCTS ALONG EXPRESSWAY IN PERMAFROST REGIONS OF THE QINGHAI-TIBET PLATEAU

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The crushed-rock interlayer embankment with ventilation ducts has been presented to protect permafrost underlying expressway from thawing in China. However, due to the large width and higher temperature of pavement surface of expressway, the cooling technique can have a good cooling effect only when the ventilation ducts are placed on the top of the crushed-rock interlayer with a small space. In this study, in order to increase the cooling effect and make construction easier, the composite embankment structure is improved, namely, the ventilation ducts are perforated, and then buried in the upper part of crushed-rock interlayer, therefore the space between ventilation ducts is extended. To effectively evaluate the cooling performance of the rushed-rock interlayer embankment with perforated ventilation ducts along an expressway in permafrost regions of the Qinghai-Tibet Plateau, a three-dimensional numerical model is developed based on heat and mass transfer theory. The model includes coupled heat transfer between the airflow and duct wall, air convective heat transfer within the crushed-rock layer, and heat conduction with phase change in the soil layer. The numerical results indicated that when the ventilation ducts are perforated and buried in the upper part of the crushed-rock interlayer, the cooling effect of the rushed-rock interlayer embankment can be largely increased. Compared with the crushed-rock interlayer embankment with imperforated ventilation ducts, the similar cooling performance can be obtained even if the centerline space between perforated ventilation ducts is extended twice. The extended centerline space and buried measure of ventilation ducts make construction easier. It is hoped that the crushed-rock interlayer embankment with perforated ventilation ducts can be an effective structure in the expressway construction projects of permafrost regions.

**RESEARCH ON FOUNDATION DESIGN IN ENGINEERING GEOLOGICAL AND GEOCRIOLOGICAL
CONDITION OF PERMAFROST IN MONGOLIA**

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Mongolia is a land-locked country in Central Asia, located between Russia and China. The country's high altitude results in cold, dry, and harsh weather. Permafrost is spread on 63 percent of the territory of Mongolia. This paper emphasizes that the main conditions of permafrost existence in Mongolia are climate and geographical location. Results of the research work indicated that mezo and micro factors of the area determine the formation of permafrost. Recent construction boom in settled areas and extension of rail and highways through the territory pointed on need for detailed research on permafrost condition in Mongolia. Furthermore, optimal alternatives for projecting foundation design on permafrost have been developed according to the characteristics of permafrost in the area and dimensions of the building. Regional classification of permafrost areas in order to select optimal principle of foundation design have been suggested based on the many years' experience and lessons learned from construction works in Mongolian geotechnical and climatic condition.

AGE OF GROUND ICE IN PERMAFROST SEQUENCES OF WEST YAMAL

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To determine the age of ground ice the organic matter inclusions or the enclosing sediments, and oxygen isotope composition are analyzed. Buried massive ice always is overlain by younger sediments. Geological age of the syngenetic polygon wedge ice and enclosing sediments are similar. Allochthonous plant remains, shells, bones, which were reworked from older sequences, can increase the age. Ground massive ice formed during the epigenetic freezing of sequence can be much younger than the enclosing deposits.

Permafrost sequences of West Yamal with massive ice of various geneses were studied. Polygonal wedge ice with vertical bedding contains organic substances, which were supplied with melted water. Correlation of wedge ices with the bedding of enclosing sediments indicates their syngenetic formation. The age of lacustrine deposits is determined between 14000-10500 to 5000 years ago. They are covered by the locally reworked Holocene deposits because the age of the allochthonous residues varies from 7000-3000 years ago.

Lacustrine deposits contain other ice wedges, laccoliths and stocks which are elongation of the horizontal massive ice. These ice bodies are also layered, contain mineral particles and organic remains of the subjacent Late Pleistocene sediments. Ice bodies were formed during epigenetic freezing of the closed taliks about 5000 years ago probably up to 2000 years later than the formation of the polygonal ice wedges. Incorrect definition of the ice genesis can lead to errors in the assessment of their age.

The study has been supported by Russian Science Foundation (Grant 14-17-00131) and Council for grants the President of the Russian Federation (Grant HШ-3929.2014.5)

ROCK GLACIERS IN CHUYA RIVER BASIN (ALTAI MOUNTAINS)

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Rock glaciers are quite widespread in the alpine areas of Altai. They have a significant impact on the dynamics of periglacial geosystems and are reservoir of fresh water as glaciers and permafrost.

The aim of this study was the detection and mapping of rock glaciers in Chuya River Basin (Central and Eastern Altai) for, their classification and features recognition of their distribution.

The morphogenetic approach to the classification of rock glaciers, based on the morphodynamic classification of rock glaciers by D. Barsh (1996), was used in this work. Two main types on study area: debris rock glacier and talus rock glacier were distinguished.

The main difference between these types of rock glaciers is that debris rock glaciers have a direct relationship with the modern glaciation and talus rock glaciers are not related to glaciation and are entirely cryogenic formations (ice is formed during freezing of melt and rain water, and falling snow in pores among stones).

It should be noted that the talus rock glacier are further away from the major centers of modern glaciation (0.7-1.5 km) than debris rock glaciers. Both types of rock glaciers exist at elevations between 1167 and 3970 m above sea level.

The main problem was the mapping of rock glaciers boundaries. In some cases, the boundary between the body of talus rock glaciers and cone of talus, as well as between the covered glacier, moraines complex and debris rock glaciers was highly conditional, and based on the lichen characteristics.

The following parameters for the characterization of rock glaciers: location (geographical coordinates), height above sea level of the front, exposure, type of rock glacier, location in the valley, the surface structures relief, their shape and complexity, area size and dynamic activity were identified. Having this information the basis for GIS "Glacial-permafrost rock formations in the basin of the Chuya River", including the map of the rock glaciers distribution and their catalog was developed. On the territory of the Chuya River basin 1503 rock glaciers have been detected, with a total area more than 352 square kilometers. Expositional confinedness of rock glaciers was calculated using digital elevation model (SRTM). About 50% of rock glaciers are limited to the northern slopes, and about 40% - to the southern, the smallest number of rock glaciers are located on the western and eastern slopes.

THE EFFECT OF DRYING DURATION ON UNCONFINED COMPRESSIVE STRENGTH OF EXPANSIVE SOILS MIXED WITH PORTLAND CEMENT

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The main problem in the foundation of each construction is swell-shrink or settlement of soils. Expansive soils or swell-shrink soils will experience changes in volume by absorbing amount of moisture in the ground. Previous research showed the temperature influenced on some properties of grained soils such as volumetric shrinkage, swelling pressure and shear strength. In other word, stabilizing expansive soils is one of the most important parameters in construction engineering. During the last decades, engineers tried to use different method to reach the specification requirement, from chemical to mechanical stabilization. Most of these methods are expensive and the high expenditure of these methods is an important problem. The best way is to use cheap and local materials. Portland cement is a traditional stabilizer which used in many construction projects as stabilizing such as transportation. Preparation of soil-cement mixture consists of mixed expansive clay with water and Portland cement, placed, compacted, and cured in Accordance with these specifications. Expansive clay soils are extensively distributed worldwide, and are a source of great damage to infrastructure and buildings. Treated soils with cement suggested specifications aegis construction of soil-cement base way, also referred to in a roundabout regions as cement-treated base, cement-treated aggregate base, full depth recycling of flexible pavements. This research evaluated the effect of different percentage of cement mixture with expansive clay on unconfined compressive under different drying time and temperature. The aimed of this laboratory attempt evaluated the effect of drying period and different temperature (30 C° and 60 C°) on expansive soils stabilized with different percentage of Portland cement (2%, 4% and 6%) after 7 days curing. The results revealed that both temperature and period of drying have direct influence on the compressive strength.

ESTIMATING TALIK DEPTH BENEATH LAKES IN ARCTIC ALASKA

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Over 60 lakes located in the continuous permafrost of Arctic Alaska have been investigated over the past several years as the initial phase of the Circumarctic Lake Observation Network (CALON) program, an NSF-funded effort designed to document landscape-scale variability in lake physical and biogeochemical processes. Detailed surveys have been conducted on most lakes using a sonar unit attached to an inflatable boat. High-frequency lake depth measurements were collected along closely spaced nested transects, and interpolated onto a 5 m grid for bathymetric mapping and morphometric analysis. Year-round hourly water temperature records were collected from the near-surface and at the base of the water column from most lakes over the past several years. Meteorological and ground temperature data were also recorded at nearby terrestrial sites over the period. Continuous basal water temperature records and lake bathymetry are currently available for 28 lakes in the study area, extending from the Arctic Ocean southward to the foothills of the Brooks Range. Lakes range in area from 1.3 to 979.9 ha, and lake depths from 0.4 to 7.0 m. Fourteen lakes have a circular plan view, and 14 are elongated with length exceeding width by a factor of two or more; many lakes have well-developed littoral terraces. Lake-specific water basal temperature, ground surface temperature and lake geometric characteristics are used to estimate the nature of taliks or "thaw bulb" beneath each lake using methods developed by A. Lachenbruch and subsequently applied by J.R. Mackay and C.R. Burn in the western Canadian Arctic. Our results suggest that 8 lakes have a talik of less than 18 m because they are very small (<15 ha) or very shallow (<0.8 m). Typically, the mean annual basal water temperature is negative or within a few degrees of the ice point since winter freezing extends downward into the lake bed. The 20 lakes with open, through-going taliks all exceed 1.0 m in depth and typically have average basal temperatures ranging from about 2-5 C because there is a residual unfrozen pool of water beneath the floating ice cover. This method does not account for lake age and assumes steady-state conditions, which may not be valid; there is evidence to suggest that lake ice thickness has been decreasing, the ice-free season is lengthening, and the basal water temperature is warming.

BORED PILE; PERMAFROST; PILE SIDE RESISTANCE; PILE BEARING CAPACITY

Junwei Zhang (1), Junwei Zhang (1), Lei Li (1)
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This paper represents study results of the bearing characteristics and influencing factors of large diameter bored pile under refreezing condition in permafrost region. Principles for designing piles in permafrost on the basis of both ultimate capacity and limiting deformations are reviewed firstly. To solve problems such as pile cap and bridge pier construction, super structure construction, time limit construction, a field experiment was carried out on both the bearing capacity and deformation characteristic of large diameter bored pile in high-temperature fine-granular frozen soil of Fenghuoshan region of the Qinghai-Tibet plateau. Based on ground temperature and in-situ experiment data, pile tip resistance accounted for the entire load is just 2.5% when load on pile top reached 6000kN after frozen soil refreezing completed. In the meantime, it was also obtained that the deformation features of refreezing large diameter bored pile in permafrost. The bored pile is a typical friction pile of the friction pile characterized by the settlement characteristic that pile tip resistance had less loading sharing ratio. The results also indicated that it was very difficult for the permafrost to refreeze to the original state once it had been disturbed due to the bored pile construction. And Pile shaft force and pile side resistance had something closed to do with pile top loading, characteristic of frozen soil around the pile and ground temperature. The study results can be used as some guides and references in the process of pile foundation construction and some guides and references in the process of pile foundation construction.

PHYSICAL MODELLING OF SUBMARINE GASSY SLOPE FAILURES

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This paper investigates the stability of a submarine gassy slope triggered by tidal variations. Under tidal variations on an unsaturated slope, failure may occur under specific combinations of increasing degree of saturation and soil permeability, and decreasing tidal period. A novel physical model test in a geotechnical centrifuge was undertaken of a submarine slope containing gassy sediments. The model preparation techniques, measurement systems and preliminary results are presented. The response observed in the model test is discussed. Existing numerical simulations may provide a basis for verification and validation of future physical model test results.

MEASUREMENT OF THE SMALL STRAIN STIFFNESS OF GLACIAL TILL USING GEOPHYSICAL METHODS AND BAROMETRIC LOADING RESPONSE

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(1) *Queen's University Belfast (Belfast, United Kingdom)*; (2) *Queen's University Belfast (Belfast, United Kingdom)*; (3) *University of Saskatchewan (Saskatoon, Canada)*

Bulk stiffness values in geotechnical structures can range over more than two orders of magnitude for relatively small operational strains. The typical strain levels where soil stiffness changes most dramatically with strain is in the range 0.01-0.1%, however soils do not exhibit linear stress-strain behaviour at small strains, therefore knowledge of the in situ stiffness at small strain is important in geotechnical modelling and design. The stress-strain regime of cut slopes is also complex, with different principle stress directions at different positions along the potential failure plane. For example, loading may be primarily in extension near the toe of the slope, while compressive loading is predominant at the crest of a slope. Cuttings in heavily overconsolidated clays are known to be susceptible to progressive failure, in which progressive yielding propagates from the toe towards the crest of the slope over time.

In order to gain a better understanding of the rate of softening, changes in small strain stiffness is monitored in the field. Seismic geophysical surveys result in very small strains and have been shown to provide estimates of small strain elastic moduli. Loading efficiency uses the pore pressure response of grouted piezometers to barometric pressure fluctuations to estimate the compressibility of the formation.

This paper outlines the techniques used to investigate small strain stiffness in situ in a glacial till cutting in Northern Ireland, using seismic refraction surveys and barometric loading efficiency theory.

SUMMER AND WINTER FLOWS OF THE MACKENZIE RIVER SYSTEM

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The Mackenzie River Basin contains several major hydro-physiographical regions representative of northern permafrost and non-permafrost zones. The environment of different regions exerts influence on the hydrological processes that give rise to variations in the hydrographs of headwater rivers. These environmental imprints are best expressed in the summer and winter flows. Rivers in the Cordilleran mountains are fed by rainfall, snowmelt and, in some areas, glacier melt as well as regulated discharge. Many rivers on the Interior Plains drain extensive wetlands and their basins receive low rainfall but high evaporation. The Canadian Shield with myriad lakes provide abundant storage and the flows are modified by the fill-and-spill mechanism. Compared with summer, the generation of winter flow is less complex. The prevalent presence of an ice cover inhibits vertical water input to and evaporation loss from the rivers. Streamflow is sustained by discharge from groundwater and by the release of storage from lakes. In both seasons, the mountain region contributes the bulk of runoff to the Mackenzie. For winter flows, recent publications have noted a positive trend in the lower Mackenzie basin. This rising tendency has been attributed to the effect of permafrost degradation, though this assertion awaits verification by evidence from the field.

MORPHOMETRIC CHARACTERISTICS OF ROCK GLACIERS OF RIVER BASIN ARGUT (ALTAI REPUBLIC, RUSSIA).

Melnichuk Lyubov (1), Ostanin Oleg (2), Djakova Galina (3)

(1) Vladimirovna (Barnaul, Russia); (2) Vasilevich (Barnaul, Russia); (3) Sergeevna (Barnaul, Russia)

In the course of study, rock glaciers have been detected and assessed in terms of their present state and thermokarst processes.

Rock glaciers were identified using standard remote sensing and field methods of glacio-morphological analysis and mapping. Their principal diagnostic features include: convex flow morphology, U-shaped in map view; a frontal scarp with a debris train at the back and with pressure and impact ridges at the base; flow terraces that produce a characteristic trough-ridge topography; multiple rills and springs in the front part and marginal channels between the bed slope and the side scarp (in some rock glaciers and armored glaciers).

The discovered rock glaciers were described according to several parameters: location; type; heights of fronts; activity; slope direction; size (length, width, and surface area); available published evidence. These data made basis for a GIS map of rock glaciers of the Altai and the respective catalog. The map was compiled using LANDSAT images (28 and 14 m/pixel) of the whole territory and ALOS (10 and 2.5 m/pixel) and RapidEye (5-6,5 m/pixel) images of selected areas, as well as published evidence and data collected by our team in the field.

VALIDITY OF ASSESSMENTS OF LARGE-SCALE THERMO-HYDRAULIC COUPLED GROUNDWATER FLOW SIMULATIONS

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Assessment of future permafrost conditions has been conducted with large-scale 3D models by many nuclear waste management organizations in recent years. These assessments have been conducted in numerical codes traditionally focused on groundwater flow but developed to handle also coupled thermo-hydraulic (TH) processes along with freezing and thawing of bedrock and soil. The lack of validation of these studies is partly attributed to the difficulty in verifying multi-dimensional results produced by the numerical models. In the present study, a number of verification cases are presented along with a code verification study on the performance of two different numerical codes employed in safety assessments, characterization, and phenomenological modeling. The results are in parts addressed within a joint benchmark exercise, within “the InterFrost benchmark”, initialized in 2014 with participants from USA, Canada, Germany, Sweden and France. The InterFrost benchmark includes 13 simulation codes altogether. In addition, an inter-comparison of large-scale 3D models has been conducted. In these types of 3D models not only the coupled processes and constitutive descriptions impose a problem, but also numerical aspects are challenging in these large numerical models with large Peclet numbers.

NUMERICAL INVESTIGATION OF THE INFLUENCE OF DEFECTS ON ROCK STRENGTH

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Estimation of intact rock strength is of paramount importance for deep underground civil and mining projects. This rock strength is influenced by the presence of geological features at various scales; micro-cracks at the grain scale, veins at the laboratory scale, cemented joints at the rock block scale and block-forming joints at the rockmass scale. The determination of the strength of laboratory scale rock specimens is the first step in the process of estimating the rockmass strength. It is well known that the presence of defects at the micro and specimen scales reduces the unconfined compressive strength of rock. In this study, a grain-based distinct element model, whereby a rock specimen is modeled with grains that are allowed to deform and break, is used to investigate the influence of defects at the grain, laboratory specimen, and rock block scales on rock strength. Calibration of the model is conducted on the laboratory properties of intact and granulated Wombeyan marble. The term "granulated" refers to a heat-treated marble where the cohesion of grain boundaries has been destroyed. Once the model is calibrated, it is used to simulate rock specimens with varying damage densities. The damage is simulated by assigning damage properties to the grain boundaries. In this manner, it is demonstrated how defects at the grain scale affects the rock strength. Next, Discrete Fracture Networks (DFN) are used to simulate defects at the laboratory specimen and rock block scales. In this manner, the influence defects and their orientations relative to the applied load on rock strength is investigated. It is demonstrated that the strength of rock blocks can be estimated to be between 50 % and 80 % of that of laboratory scale rock specimen, depending on the orientation of the defects relative to the loading direction.

METHOD OF DETERMINING THE THERMAL CONDUCTIVITY OF DISPERSED GAS-SATURATED SEDIMENTS UNDER CONDITIONS OF HYDRATE AND ICE FORMATION

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Nowadays the world pays a great attention to prospecting and exploration of gas hydrate formations in the bowels of the earth, including in the areas of permafrost. At the same time, a lot of attention paid to the creation and development of technologies for the extraction of natural gas from gas hydrate accumulations. However, the resolution of these issues is impossible without a detailed study of physical properties of gas and hydrate saturated sedimentary rocks, in particular thermal properties. In permafrost gas hydrates formation can take place in subpermafrost (under permafrost) horizons at low positive temperatures and at negative temperatures in permafrost. During the evolution of permafrost gas and hydrate, containing sediments may freeze and cause the permafrost condition, as well as incurring melting processes. In this regard, the investigation changes of thermal conductivity of gas saturated sediments during hydrate formation at low positive and negative temperatures is very relevant.

To solve these problems, the authors developed a method of experimental investigation thermal conductivity of gas-saturated sediments in the process of hydrate accumulation at positive and negative temperatures, as well as during processes of freezing and melting. All experiments were performed on original gas hydrate installation with built-in system for measuring the thermal conductivity of investigated sediment samples under the gas pressure. The determination of thermal conductivity of sedimentary samples is based on the method of stationary thermal regime.

The accuracy of determining thermal conductivity was estimated around 5-7% with a confidence level of 0,95. In this case, the random error of measurement of thermal parameter did not exceed 3-4%.

The object of investigation was a fine-grained quartz sand (mJ3), and multimineral sandy loam (gmQII 2-4).

This technique allows us to investigate thermal conductivity of gas-, hydrate- and ice-bearing sediments under gas pressure up to 7 MPa, and quantify the impact of hydrate saturation and degree of transition pore water in to hydrate form on the thermal conductivity of sediments and trace the influence of hydrate formation conditions on their thermal parameters.

CALCULATION OF SUPERFICIAL TEMPERATURES TO ASSESS THE BENEFITS OF USING HIGH ALBEDO ROAD SURFACING FOR MITIGATION OF PERMAFROST DEGRADATION

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High albedo road surfaces can be used to reduce the amount of heat absorbed by the pavement in order to limit the degradation of the permafrost underlying road embankments. A step-by-step method to calculate the superficial temperature of high albedo surfaces for road built on permafrost is proposed here. It provides an efficient way to evaluate the relevance of using these types of pavement for a specific site based on the radiation index approach. This method is supported by a model based on a simplified energy balance at the surface of the road. Basic equations constituting the model will be presented. Four input data are required by the model: albedo of the surface, incoming solar radiation, air temperature and wind speed. The weather data can be provided as daily, weekly, monthly or seasonal average. The model has been validated using data from a test section built on the Alaska Highway near Beaver Creek, Yukon where the temperatures of four surfaces with different albedo were monitored for a year.

The step-by-step model can be used to evaluate the relevance of using high albedo surfaces for new or existing roads by providing a quick comparison of the superficial temperatures of road pavements with different albedo. First, the test methods to determine the albedo of a road surface material either from small laboratory samples or from existing roads using a pyranometer is described. Second, the method proposes equations and graphical calculation tools in order to calculate the incoming solar radiation as a function of the latitude and cloud cover. Unlike air temperature and wind speed data which are usually readily available for a study site, incoming solar radiation is rarely known. Finally, the radiation index and pavement superficial temperature can be calculated using a simple graphical calculation tool provided in the method.

An example of how the superficial temperatures calculated by the step-by-step method can be used to assess the thaw penetration underneath the pavements having different albedo will be presented. Finally, the effect of the evolution of the albedo due to degradation and aging of the road surface on the long-term efficiency of high albedo surfaces will be discussed.

NUMERICAL MODELING OF GROUND VIBRATIONS FROM A WIND TURBINE

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Wind energy is considered to be an energy source for the future because it is economical, clean and renewable. As of December 2014, Canada has 206 wind farms and 5114 wind turbines installed which provides an installed capacity of 9219 MW. Foundations are a critical part of wind turbines. A wind turbine foundation is subjected to dynamic/cyclic loading due to continuous rotation of blades and the effect of wind loads on the tower and blades. These cyclic loads are transmitted through the foundation to the ground. Prediction of ground borne vibration is therefore very important since it provides information on structural performance and the transmission of vibrations into the environment. Indeed the regulatory requirements for the 'offset' distance between turbines and humans are an important consideration in design. Surface wave interference between adjacent turbines is also of great interest to industry and the public. A multi-disciplinary research project is underway to integrate laboratory testing, field monitoring and numerical modeling of a commercial wind turbine on a shallow foundation. This paper describes finite element modeling of the foundation-soil system to investigate the ground vibrations when various wind loads are acting. This physical problem has been analysed using the commercially available finite element package ABAQUS. The boundary conditions, tractions, models and vibrational states of the soil-structure system will be described. The effect of soil properties on attenuation of vibrations with distance and direction will be demonstrated. Comparison with insitu ground based triaxial accelerometers data from the site will also be made.

SPATIAL VARIABILITY OF THE HOLOCENE THERMAL MAXIMUM IN NORTHERN YAKUTIA, NE RUSSIA, INFERRED FROM LAKE SEDIMENTS

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Although thermokarst activity is a widespread arctic feature, the relationships between limnogeological processes, periglacial features and climate change in the Siberian Arctic are yet not sufficiently understood. To gain insight into the local to regional spatio-temporal climate variability in Arctic Russia we investigated diatoms and pollen, grain-size distributions, organic contents, elemental and mineralogical compositions from different lake sediments in the Lena Delta area and its hinterland. Multiple proxies revealed the Younger Dryas cold and dry period 12 cal. kyr BP associated to a prolonged seasonal lake ice cover and the formation of framboidal pyrite in the oxygen-depleted bottom waters. The transition from cooler periods with dominant small benthic alkaliphilous fragilarioid diatom taxa to moderately warmer climates with initial diatom diversification occurred already in the early Holocene.

The thermokarst lakes Sysy-Kyuele (N 69.4°; E 123.8°) and Kyutyunda (N 69.6°; E 123.6) in the subarctic zone exhibit a direct link between the limnological, ecological, and sedimentological development and the regional climate variability. Our results show that the Holocene Thermal Maximum (HTM) in the lower Lena River area reveals a temporal delay from north to south of about 3000 years. This pattern of the occurrence of the HTM in Siberia can be linked to regional environmental features that influence the global climate system, providing evidence of teleconnection between the North Atlantic region and north-eastern Russia. The spatial and temporal variability of the HTM in the Lena Delta area and its hinterland is caused by the westerlies, which brought cold air from the north Atlantic region where deglaciation processes still influenced the climate until the Laurentide ice sheets vanished about 7 kyr BP.

MINE BACKFILL POREWATER PRESSURE DISSIPATION: NUMERICAL PREDICTIONS AND FIELD MEASUREMENTS

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Cemented paste backfill (CPB) has gained popularity in underground mining operations over the past decade. Fresh CPB is being held in the stope by means of a barricade until it cures and can be self-supportive. Therefore, the barricade safety is crucial in mining industry. The pressure acting on the backfill barricade is dependent on the amount of dissipated pore water pressure in the CPB and thus its degree of consolidation. The problem of self-weight consolidation of an accreting material was first studied by Gibson (1958). Fahey et al. (2010) applied Gibson's solution to the consolidation of CPB and introduced lower and upper bound solutions for different coefficients of consolidation. Shahsavari and Grabinsky (2014), based on the in-situ measurements, introduced a new boundary condition and studied its effect on the pore pressure variations with time and height as CPB was deposited. However, the effect of the weight of the non-consolidating slurry layer on the pore pressures was not considered in the previous study. In the current study, the same boundary condition as Shahsavari and Grabinsky (2014) is being applied and the gravity force due to the presence of a non-consolidating slurry layer is considered. The process of consolidation is modeled in FLAC3D using Terzaghi's consolidation theory assumptions. 1D, 2D and 3D analysis are performed and the effects of the filling rate, slurry layer height and weight, and stope geometry on pore pressure are studied. At the end a sample comparison between numerical analysis results and field measurements is made.

COMPARISON OF CLIMATE AND PERMAFROST RELATIONS DURING RECENT YEARS IN CENTRAL ASIA

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The links between climate and permafrost were well documented in lots of previous literatures, however the responding mechanisms of permafrost to climate change and the feedback of permafrost changes on the climate system were still kept poorly understood until now, especially in the Central Asian regions including on the Qinghai-Tibet Plateau, the Loess Plateau in China, and the Mongolian Plateau. Three typical permafrost sites in above-mentioned three plateaus were selected to perform the comparison analysis. The related meteorological elements and ground temperatures at different levels were continuously measured during the last several years. The difference of the impacts of climate on the permafrost was demonstrated in details in this study. The surface offset, the thermal offset, and the air and ground surface freezing/thawing indices were calculated according to the observation data. The possible impacting mechanism of climate conditions on the ground thermal regimes were quantified and compared. This study will enhance our understanding on the response of permafrost to recent climate changes in Central Asia. The strengthened observations at those sites were suggested in the following work.

HYPER-SALINE SPRING DYNAMICS AND SALT DEPOSITS ON AXEL HEIBERG ISLAND, NUNAVUT

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On Axel Heiberg Island in the Canadian High Arctic, many low temperature perennial saline springs occur despite cold polar desert climate conditions marked by a mean annual air temperature of -18°C . Associated with 2 groups of hyper-saline springs are distinctive landforms resulting from winter deposition of salt minerals. The presence and deformation of salt deposits and saline groundwater could contribute to elevated geothermal gradients that help sustain groundwater circulation. Perennial spring activity is also sustained because of depressed freezing temperatures. These deposits resemble tufas structurally, but unlike true tufas which are composed of carbonate minerals, these landforms are formed mainly of salt. This study hypothesizes that the extreme cold winter air temperatures cool water temperatures triggering rapid precipitation of various salt minerals [mainly hydrohalite ($\text{NaCl}\cdot 2\text{H}_2\text{O}$)]. These newly formed salt minerals subsequently alter the flow hydrology by obstructing summer flow paths. The tufa-like appearance of these salt deposits reflects the interaction between changing water temperature, chemistry and flow. This research characterises the geomorphology and geochemistry of two hyper-saline springs on Axel Heiberg Island: the first is located at Wolf Diapir ($79^{\circ}07'23''\text{N}$; $90^{\circ}14'39''\text{W}$), the deposit at this site resembles a large conical mound (2.5m tall x 3m diameter). The second is located at Stolz Diapir ($79^{\circ}04'30''\text{N}$; $87^{\circ}04'30''\text{W}$). In this case a series of pool and barrage structures staircase down a narrow valley for approximately 300m (several pools are up to 10 m wide x 3 m deep). The springs have very different seasonal surface hydrologic regimes and topographic settings which influence the pattern of mineral precipitates. This presentation will focus on results from four periods of fieldwork (two in spring for winter conditions and two in summer) including results from time-lapse photography, air and ground monitoring, mineralogy and water chemistries. Many Polar Regions contain evaporate sequences as part of their geological foundation that could result in similar processes. Understanding these interactions may provide insights into a number of natural systems and potential impacts of climate change. Another interesting application of this research pertains to the search of liquid water on Mars. These features offer a potentially unique indication of groundwater activity in areas of cold permafrost and thus may aid in the site selection for future Mars missions.

THE NEUMANN PROBLEM WITH SINUSOIDAL SURFACE TEMPERATURE

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In permafrost regions the seasonal variation of the ground surface temperature causes a layer of the soil to freeze and thaw as the temperature fluctuates around the phase-change temperature of soil water. Understanding the active layer behavior is vital for safe design of cold-regions structures.

The input for calculating thaw depth is the seasonal variation of the ground surface temperature, rarely available, but air temperature is widely monitored. The relationship between air and surface temperatures can be estimated using n-factors at a site.

The most common method to predict the active layer depth at a site is the Neumann solution, which requires that the initial, surface, and phase-change temperatures are all constant. Actual problems usually have surface boundary conditions that are periodic in time, often assumed to be sinusoidal. The choice of the initial conditions and the surface temperature to use with the Neumann solution is not obvious. The predicted active layer depth is sensitive to these somewhat arbitrary choices. This paper develops a rational method to make these choices.

An analytic solution for the soil temperature at the moment when thaw starts is also developed and it clearly shows that the initial temperature which gives correct thaw depths using the Neumann solution is not the same as the value that really exists due to sinusoidal surface temperatures.

NUMERICAL SIMULATION ON THE SAFE WATER CONVEYANCE DISTANCE OF UNDERGROUND PIPELINES IN THE SEASONALLY FROZEN AREAS

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The maximal freeze-free water conveyance distance of underground water pipeline in seasonally frozen areas in winter is called safe water conveyance distance. A good knowledge of different-condition-based safe water conveyance distance of water pipeline will offer theoretical reference to the reduction in the depth of underground water pipeline, prevention against freezing damage to water pipelines and cutting down engineering costs, and is of practical significance to the advance of existing centralized water supply project in suburb and rural areas. With the adoption of quasi-three dimensional numerical method, the paper established the model used for calculating water pipeline temperature and safe water conveyance distance, and simulated the effect of six major factors, for example water content of topsoil, mean annual surface temperature and the depth of underground water pipeline, on safe water conveyance distance of underground water pipeline in seasonally frozen areas in winter. The results proved that the rate of temperature fall of water pipeline was on continuous decrease with the rise in mean annual surface temperature, the depth of underground water pipeline, water pipeline diameter, water content of topsoil and the flow rate of water in the pipe, and was on continuous rise with the increase in inlet water temperature; the safe water conveyance distance of water pipeline increased in exponential relationship with the rise in mean annual surface temperature, the depth of underground water pipeline and water pipeline diameter, increased in logarithmic relationship with the rise in topsoil water content and inlet water temperature, and increased in linear relationship with the rise in flow rate of water pipeline.

INVESTIGATION OF CHANGES THE THERMOKARST LAKES AND RISK ASSESSMENT FOR DIFFERENT ENGINEERING STRUCTURES USING METHODS OF MATHEMATICAL MORPHOLOGY OF LANDSCAPE AND REMOTE SENSING DATA

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As a rule, frozen ground processes including those in a stage of stabilization or attenuation become more active under technogenic intervention and climatic changes, receiving a new impulse. It is especially important in rapidly changing natural conditions of the Northern regions. One of the important problems is to find principles of distribution and dynamics of thermokarst development with the purpose of forecasting environmental changes. A lot of researches are dedicated to risk estimation of engineering structures damaging. With statistic approach to risk estimation, a researcher faces certain problems due to the fact that statistics gathering requires significant time which often equals the structure's functioning time. Methods of mathematical morphology of landscape were suggested as another approach allowing to avoid aforementioned problems.

Mathematical morphology of landscape is a branch of landscape science studying quantitative principles of mosaic structures formed by natural territorial complexes on the Earth's surface as well as these mosaics mathematical analysis methods.

This work aims at trying to develop and substantiate the quantitative risk estimation procedure for linear, areal and point objects with the help of remote sensing and methods of mathematical morphology of landscape.

The theoretical basis of mathematical morphology of landscape is formed by mathematical models – the quantitative dependences describing the basic properties of morphological structures.

Researches demonstrate that basic equations do not depend on a lot of particular conditions, for example, the material structure of surface sediments, annual sum of precipitation, etc. Thus, the model allows us to examine the problems in general, i.e., obtaining a solution applicable to a broad spectrum of natural geographical conditions.

After data analysis, the probabilistic mathematical dependences reflecting the most essential geometrical properties of a pattern for territories with thermokarst processes have been developed by A.S. Viktorov. The obtained expressions include:

- probabilistic distribution of the number of thermokarst lakes;
- probabilistic distribution of changes of thermokarst lake areas.

We performed the model approval in several test districts: Siberia, Canada, Alaska. We selected them based on morphological homogeneity and availability of remote sensing data. The districts must be similar in terms of microstructure and background phototone as well as lakes location and shape. The analysis shows that a number of deductions from the proposed mathematical model for thermokarst lake plains are generally corroborated by empirical data. Equation for the estimation of different engineering structures damage probability was verified too and analysis shows general correspondence of calculated and empirical data.

APPLICATION OF ANALYTICAL METHOD IN THE ANTI-FROST DESIGN PARAMETER OF UNDERGROUND PIPELINE IN THE SEASONALLY FROZEN AREAS

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Numerical simulation on the safe water conveyance distance (abbr., SWCD) of underground pipeline in the seasonally frozen areas showed that quasi-three dimensional numerical method involves many parameters, such as mean annual surface temperature, water content of soil, buried depth, pipeline diameter, inlet temperature and water velocity. Applying this method to optimize the anti-frost design parameter of underground pipeline, it means heavy numerical calculation. According to the relationship between the SWCD and several primary factors, the interaction among various factors, and calculation results based on quasi-three dimensional method, with reference to the current widely used anti-frost design idea of underground pipeline in the seasonally frozen areas, the paper first analyzes the feasibility of adopting the maximum seasonally frozen depth instead of the mean annual surface temperature, moisture content and soil property, and the feasibility of adopting quantity of flow instead of pipeline diameter and water velocity to calculate the SWCD. Second, an equation about the SWCD is established, which involves the maximum seasonally frozen depth, buried depth, pipeline diameter, water velocity and inlet temperature. Based on the existing numerical simulation results, two unknowns in the equation are solved and an analytic solution is obtained for the SWCD of underground pipeline. Finally, through comparing calculation results by analytic solution with the quasi-three dimensional numerical method, it is found that the both method are in good agreement. Under the condition of safety factor of 1.5~2.0, the analytic solution can be used to optimize the anti-frost design parameter of underground water pipeline in the seasonally frozen areas.

EXPERIMENTAL STUDY OF FREEZING POINT AND WATER PHASE COMPOSITION OF SALINE SOILS CONTAMINATED WITH HYDROCARBONS

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Gas and petroleum deposits are located mainly in the northern regions, and most of them - in permafrost. There are a lot of saline frozen soils

Hydrocarbon pollution of soils can happen in various ways: during the deposit development, also there are leakages during the transportation of petroleum and hydrocarbon products. Sometimes at the same time hydrocarbon pollution and salinization of soil can happen. The sources of salts in this case are the formation fluid and other geochemically active substances used for the hydrocarbon extraction and desalting. In addition, joint salinization and hydrocarbon pollution can occur on areas of distribution of saline soils, where are roads of transportation.

Hydrocarbons are the priority pollutants of the environment. When they hit the ground profound changes of all components of the environment happen.

Geocryological prediction assumes knowledge of all the characteristics of the environment, determining the laws of formation of spatial and temporal variability of permafrost and its processes. It is necessary to study the influence of various factors on the properties of frozen soils, which are largely determined by the water phase composition.

Studies of the influence of salinization on soil properties in different years were engaged. According to their data is well known that the presence of salts in the soil lowers the freezing point if compare it with nonsaline rocks and increases the content of unfrozen water in the soil. Effect of hydrocarbon pollution on soil properties is not so widely studied. However, according to existing research hydrocarbon pollution has no significant effect on the unfrozen water content and temperature of freezing start.

If joint salinization and hydrocarbon pollution happen salt and hydrocarbons penetrate into the soil and form their own areols that usually divergent with each other. This work shows the modeling of the spatial distribution of salt and hydrocarbons. But not carried out yet a study of their joint influence on soil properties. Therefore, the aim of our research is studying of the combined effects of salinization and hydrocarbon pollution on soil properties, particularly on thermal properties, temperature of freezing start and the water phase composition in the frozen soil. This report presents the results of experimental studies of the unfrozen water content in the soil and the processes of freezing and thawing.

PERMANENT DEFORMATION OF UNBOUND GRANULAR MATERIALS: DEVELOPMENT OF A TESTING METHODOLOGY

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Flexible pavements deterioration through structural rutting may lead to costly rehabilitation operations because it is typically associated with the accumulated permanent deformation in the subgrade soil. However, when thick pavement structures are built to mitigate the effect of frost action, the contribution of the unbound granular materials (UGM) encountered in the base and subbase to structural rutting may be significant. Over the last decades laboratory research efforts were mainly focused on the characterization of UGM and soils resilient modulus required for pavement design. Much less attention was given to damage accumulation and permanent deformation behaviour. With the evolution of pavement design methods towards sophisticated mechanistic-empirical procedures, the permanent deformation behaviour of pavement materials is now becoming useful and important information in order to predict pavement performance. In this context, while few testing methods are available for permanent deformation characterization of UGM in comparison with resilient modulus standards, the Ministry of Transportation of Quebec has undertaken research efforts to develop a testing standard for the characterization of UGM permanent deformation behaviour. The paper will describe the proposed 5-steps research methodology, the main results and a description of the preliminary test method. First, the paper summarizes the more important literature information. Secondly, the paper presents a summary of the review of the available instrumentation and of the procedure followed to select adapted measurement techniques for the testing method. Thirdly, a comparison of the results obtained using some important testing standards identified is presented. Fourthly, prior to propose an adapted testing method, stress modelling was performed with two different softwares for typical heavy vehicle loading on Quebec pavement structures in order to quantify the typical stress conditions in Quebec's flexible pavement structures. Finally, the collected information was used to propose an adapted preliminary testing methodology. The paper presents the first results obtained with the proposed test method, which allows quantifying the effect of stress conditions and water content on the permanent deformation performance of UGM.

GEOPHYSICAL IMAGING OF PERMAFROST CONDITIONS ALONG THE NORTHERN YUKON ALASKA HIGHWAY

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The Yukon Alaska Highway is a vital transportation route connecting the resource rich Yukon to southern Canada and serving as a commercial trade and tourist route between Canada and Alaska and between the lower US and Alaska. The construction and maintenance of transportation infrastructure in permafrost regions presents challenges and costs that do not exist in other areas due to sensitivity of the engineering properties of the substrate to temperature. For the Yukon Alaska Highway, road surface and embankment damage are believed to be associated with the prevalence of warm, ice-rich permafrost. Geophysical surveys can provide valuable information on permafrost and ground-ice conditions. However, geophysical images can be complex functions of many variables including soil type, temperature, and ground-ice occurrence. Three sections of the northern Yukon Alaska Highway (23 km) have been identified for testing the usefulness of geophysical surveys for understanding permafrost degradation and assisting with highway management. We examine results from capacitive resistivity and ground-penetrating radar surveys along with surficial maps, records from geotechnical borehole investigations, and surface observations of highway distress such as roughness, longitudinal cracking, embankment failures and differential settlements. Several relationships are observed: linear settlements are the most frequent and severe type of observed damage often affecting both the road surface and the embankment; high degrees of roughness tend to occur over areas mapped as till, however, identified problem areas are largely associated with fluvial and glaciofluvial map units; there is no obvious correlation between roughness or observed damage and borehole observations of ice-rich sediment or massive ice; observed damage appears to be associated with other types of ground ice. The associated geophysical signatures are subtle and complicated. Modelled electrical resistivities can be highly non-unique and the combination of soil type and thermal state can render interpretation equivocal. Nevertheless, both observed highway damage and near-road thermokarst may be associated with moderately conductive anomalies attributed to frozen silt-rich material. These anomalies are distinguished from the conductive signature of unfrozen silt-rich material and the resistive signature of the embankment or unfrozen sand and gravel. The geophysical images also allow for identification conductive portions of the embankment which may result from the presence of groundwater which will play an important role in the thermal evolution of the permafrost.

CYCLIC FREEZE-THAW EFFECTS ON ATTERBERG LIMITS OF CLAY SOILS

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Freezing induced pore water migration and ice crystal growth may have a myriad of effects on the physical and mechanical properties of fine grained soil. Atterberg limits are often viewed as inherently unchangeable soil properties as they are based on interactions between the clay minerals and pore water. Several studies in the literature, however, suggest Atterberg limits are not unalterable but may change as a result of mechanical disruption such as that caused by freezing and thawing. The purpose of this study was to test the hypothesis that soil consistency, as measured by Atterberg limits, may be altered by the freeze-thaw process. Four soils with different clay contents and varying Atterberg limits were studied. In one group of samples the initial structure of each soil was maintained throughout freeze-thaw cycling up until the point of Atterberg determinations. A second group of samples had any initial structure destroyed by mechanical mixing at a high water content before freeze-thaw cycling. Both groups had their water contents adjusted to 25% gravimetric and equilibrated overnight before freezing at -15°C for 12 hr and thawing at $+15^{\circ}\text{C}$ for 12 hr. Liquid and plastic limits were determined initially before freeze-thaw cycling and subsequently following 1, 5, 10, 30 and 50 cycles. Liquid limits tended to remain essentially unchanged for both the high and low plasticity soils regardless of the number of freeze-thaw cycles while the plastic limit measurements showed some change after freezing and thawing. Concomitant changes to the plasticity index (the difference between the plastic and liquid limits) were therefore also noted in the case of the higher plasticity soils. Changes in soil consistency as measured by Atterberg limits were more profound in soils where initial structure was destroyed prior to freezing and thawing than those retaining their initial structure. The initial state of aggregation in the soil, which affects the pore water dynamics during freeze-thaw, best explained the changes.

WATERSHED DELINEATION OF PERMAFROST DISTURBANCE ON EASTERN BANKS ISLAND, NWT: A GEOMATIC APPROACH FOR PREDICTING WATER QUALITY IMPACTS

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Retrogressive thaw slumps (RTS) are a form of permafrost disturbance that can develop on sloping terrain underlain by ice-rich permafrost. These disturbances are often initiated alongside coastlines, lakeshores, and rivers/streams and can liberate large amounts of sediment and solutes that alter the chemistry and turbidity of surface water and ultimately water quality and aquatic structure. Increasing numbers of disturbances have been observed across the Arctic reflecting changes in landscape stability resulting from a warming climate and increasing summer thaw depths. The objective of this work is to examine the impact of disturbance on water quality by examining varying sizes of watersheds with different magnitudes of disturbance. This detailed mapping of a region on eastern Banks Island, NWT will provide us with knowledge of specific watersheds that are being impacted by permafrost disturbance to allow us to develop detailed field sampling strategies for water quality assessment.

A disturbance inventory for eastern Banks Island was acquired through a partnership with the Northwest Territories Government and a Cumulative Impacts Monitoring Program. In total 637 active RTS were digitized using SPOT and Quickbird imagery and ranged in size from 300 to 224 000 m². Watersheds were derived from the Canadian CDED DEM and NHN stream network data sets using ArcGIS with ArcHydro and Spatial Analyst extensions. Watersheds were created based on stream order (e.g., 4th order and higher, 5th order and higher) to produce a hierarchy of nested watersheds. The impact of disturbance on water quality will be examined in a number of different research questions: 1) does watershed size impact downstream water quality where there is the same magnitude of disturbance; 2) is water quality impacted more by a large areal extent of disturbance or increased frequency of disturbance; and 3) does the connectivity or distance to a water source affect downstream water quality. Results of this study will provide a framework for evaluating the relationship between watershed and disturbance and its impact on water quality, and provide information suitable for researchers, communities and decision makers to assess the impact of permafrost disturbance on surface water.

GESTION DES RÉSIDUS – MINE DE FER DU MONT-WRIGHT

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Le parc à résidus de la mine du Mt-Wright, actif depuis 1976, est opéré par ArcelorMittal Exploitation Minière. Il se situe dans la région de Fermont. Sa superficie de 20 km² en fait l'un des plus grands en Amérique du Nord. L'accumulation de résidus atteint par endroit plus de 100 m d'épaisseur. Depuis 2014, le parc accueille près de 30 Mm³ de résidus par an. Plusieurs méthodes de construction de digues et de barrages de parc à résidus sont utilisées pour ériger les huit kilomètres d'ouvrages de retenue qui ceinturent le parc. Le plus grand barrage à noyau étanche mesure 1 500 m de long et 50 m de haut tandis que la plus grande digue construite selon la méthode de construction amont s'étend sur 4 km et atteint 100 m de haut.

L'article aborde les stratégies mises en œuvre pour gérer de façon efficace, sécuritaire et économique l'eau et les résidus miniers malgré les conditions climatiques subarctiques et le tonnage élevé de résidus produits. Il présente également le choix des différentes méthodes de construction ou de rehaussement en fonction des conditions du terrain, des contraintes environnementales et de la disponibilité des matériaux de construction. Il introduit les différents systèmes de suivi des ouvrages. De plus, il rend compte de la gestion des réserves d'eau qui doit satisfaire les besoins hivernaux du concentrateur mais garantir l'accueil de la crue printanière.

En hiver, les conditions climatiques rigoureuses limitent les possibilités d'intervention et de suivi. Les résidus, fins et grossiers mélangés, sont donc déposés dans la portion centrale du parc. Ce choix permet de minimiser le déplacement des points de déposition.

Durant la période de construction, les résidus les plus fins sont déposés dans la portion Nord du parc. Les résidus grossiers servent alors à rehausser les digues grâce à un système breveté de distributeurs à côtés ouverts. Ce système favorise la décantation des plus grosses particules. Il permet ainsi d'obtenir des pentes de déposition plus raides et plus hautes qu'avec la déposition par spigots multiples. La plage déposée sert ensuite de zone d'approvisionnement pour le rehaussement par boteur de paliers intermédiaires.

Afin d'assurer la sécurité des ouvrages du parc, plusieurs d'entre eux ont été équipés de divers instruments. La banque de données pour certains de ces instruments dépasse 25 ans. Leur analyse représente un outil fiable de suivi du comportement des infrastructures et illustre leur évolution dans le temps.

CYCLIC SWELL-SHRINK BEHAVIOR OF EXPANSIVE CLAY STABILIZED WITH AQUEOUS POLYMER

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The swell and shrink behavior of highly plastic clays or Expansive Clays is well documented in the literature and various stabilization methods are proposed. Most of the available stabilization methods for Expansive Clays employ pozzolanic or cementitious binders creating a chemically bound soil with significantly reduced plasticity, hence swelling potential and compressibility. Shear strength is likely to be improved considerably as a result of the improved particle interaction and soil structure. Despite of this well documented and commonly used approach to stabilization of Expansive Clays, there is ongoing research about the use of new stabilization products such as the use of polymers. Aqueous Polymers can be easily diluted in water and mixed with Expansive Clay on site during the compaction process reducing the need for use of pozzolanic or cementitious materials which commonly require a curing period after compaction. A polymer adhesive or polymer emulsion solution can be used to produce a stabilized soil mix with larger agglomerations contained in a matrix of continuous polymer chains and soil grains and it doesn't require a curing period simplifying the construction process. The matrix of polymer chains and soil grains provides flexibility to the stabilized soil and has significantly greater impact resistance, shear strength, and reduced swelling potential and compressibility. In this paper, an aqueous polymer solution namely Styrene/Acrylic with concentrations varying in the range of 0.5g/lit to 10g/lit is utilized to stabilize a set of expansive clay samples reconstituted on the dry side of the compaction curve, at -5%, -3% and -1% from the optimum water content. The cyclic Swell-Shrink behavior of the treated samples is studied and compressibility tests carried out after each cycle to study the effect of swell-shrink history on the compressibility. The preliminary results indicate that the effectiveness of the Aqueous Polymer is comparable to the other forms of pozzolanic or cementitious stabilization agents, hence due to the simplicity of its application it is a viable stabilization solution.

Keywords: swell, shrink, expansive clay, aqueous polymer, stabilization.

HYDRAULIC PROPERTIES OF POSIDONIA OCEANICA ASH AND SILICA FUME TREATED EXPANSIVE SOIL

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Expansive soils cause crucial damages to light structures in semi-arid climates. They are well known for their swell-shrinkage and over-consolidation characteristics, which are highly influenced by variation in suction due to seasonal changes. The water retaining capacity of a soil that is subjected to different suction can be described by soil-water characteristic curve (SWCC) which can be related to hydraulic conductivity, shear strength and volume change of soils in unsaturated state. The importance of this curve led researchers to develop several laboratory methods to establish SWCC, one of which is the application of osmotic method. This technique has been used by soil scientists since early 1970s as an alternative method to measure suction mainly due to its ability to attain high suctions in conditions that are close to reality. The fact that no air pressure device is used makes it one of the inexpensive and simple methods for determination of SWCC. In this study an expansive soil is treated with a natural (Posidonia Oceanica ash) and an industrial (Silica fume) waste. Posidonia Oceanica (PO) is common seaweed of the Mediterranean Sea, which grows all along the coastal areas forming widespread meadows. Silica-fume is an industrial waste produced from the smelting process of silicon metal and ferrosilicon alloy production. In this research osmotic technique is used to determine the water retention properties of treated expansive soils, implemented by placing samples in semi-permeable membrane tubing and plunging in a container with Polyethylene Glycol (PEG), placed on a magnetic stirrer. SWCC of untreated and treated specimens are obtained on both wetting (adsorption) and drying (desorption) paths and the effect of the mitigation with different materials on the hysteresis of the adsorption and desorption curves are studied, the conclusions of which will be included in the final paper.

RESILIENCE AND SUSTAINABILITY OF CIVIL INFRASTRUCTURE SYSTEMS

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Resilience is the ability to bounce back from a change or disturbance. Unlike "fail-safe" design philosophy, the concept of resilience presents a different perspective in designing infrastructure systems, called "safe-to-fail" design. A resilient infrastructure system has an ability to absorb, recover from, and adapt to external shocks. As the limit states of a resilient infrastructure system are more flexible, catastrophic consequences following "failure" of the infrastructure system can be reduced when subjected to unforeseen or unavoidable disturbance, such as natural hazards. Despite the significant attention to resilience in civil engineering, there is lacking literature which provide an overview on engineering resilience and on methodologies of resilience analysis. This paper provides a literature review on resilience with the focus on engineering and infrastructure perspective. Due to diversity and complexity of resilience definition, various approaches to analyze or assess resilience of a system are developed. A general framework of resilience assessment is proposed in this paper by integrating various methodologies of quantitative analysis of resilience. Possible applications of resilience concept to geo-structures are also identified for future research work. Geo-structures and infrastructure are essential to serve the society and economy, and also have high demand in natural resources, which can impose significant impacts to the environment. Application of resilience concept to geotechnical projects can play a significant role in achieving sustainable development.

A MULTICRITERIA BASED QUANTITATIVE FRAMEWORK FOR ASSESSING SUSTAINABILITY OF GEOTECHNICAL PROJECTS

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Geotechnical engineering can play a significant role in sustainable development due to its high potential impacts to the society, economy, and environment. Geotechnical projects involve high demand of natural resources, and critical geotechnical structures can be essential to serve the society and economy. In order to assess sustainability of geotechnical projects, a robust and comprehensive assessment framework with quantitative approaches and practical application to geotechnical projects are in need. In this paper, a sustainability assessment framework is adapted and applied to selected geotechnical projects for demonstration purpose. The framework is comprised of life cycle analysis (LCA), cost-benefit analysis, and multi-criteria analysis. The life cycle analysis is a well-established tool which quantitatively analyzes environmental impacts of a project. The cost-benefit analysis is performed to address the socio-economic benefits. The results of analysis are then integrated by multi-criteria analysis in which certain weight are assigned to each criteria based upon the significance towards the objectives of the project. In this paper, the sustainability assessment framework is applied to evaluate sustainability of foundation piles, mechanically stabilized earth (MSE) walls, and tire-derived aggregates to demonstrate its practical and universal application of the framework.

TEMPORARY SLOPE STABILIZATION AT THE AIRPORT TRAIL UNDERPASS EXCAVATION, CALGARY INTERNATIONAL AIRPORT

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The Calgary International Airport is currently undergoing its single largest expansion in its history. The expansion includes a \$640 million runway development program which addresses a 14,000 foot runway along with aircraft aprons, taxiways and other infrastructure. In conjunction with the runway addition is the City of Calgary's 36 m wide by 600 m long underpass beneath the runway to accommodate the city's Airport Trail route.

Construction of the Airport Trail Underpass (ATU) required excavating over 440,000 cubic metres of soil and rock using the cut-cover method of tunnel construction. The 15 m deep by 50 m wide excavation exposed about 3-5 m of soils and 10-12 m of bedrock. The ATU structure was built with cast-in-place reinforced concrete which required various trades to work in a confined area between near the toe of the 15 m high rock slopes and the vertical concrete tunnel wall. The side slopes of the temporary excavation were exposed for several months between December 2011 and October 2012 during which the concrete structure was built and the excavation backfilled. Although large scale slope instability was demonstrated to be a very low risk, smaller scale rock topples and slips caused by undercutting were observed during excavation. Freeze-thaw cycles, drying-wetting cycles, alternate shale-sandstone and groundwater seepage all contributed to soil and rock weathering and detachment.

Following initial excavation of the rock slopes to the design angle (63°), a small volume rock failure occurred on the south wall. Although the rock fall caused no damage / injury, construction was interrupted until mitigation measures could be selected and implemented. Alternative solutions included rock slope angle reduction, shoring system or rock slope stabilization measures such as mesh anchor system, systematic inspection / monitoring and supplementary rock bolting. The latter approach based on lowest costs, was adopted. This paper demonstrates the selected geotechnical mitigation program.

The City of Calgary turned over the ATU section under the taxiways of the new runway to the Calgary Airport Authority on schedule (October 31, 2012).

THE AGE AND EVOLUTION OF CRYOGENIC MICROFORMS IN SUBARCTIC MOUNTAINS

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The age of cryogenic microforms covering the surface of Subarctic mountains has yet been discussed and a little is known about its evolution. However, subarctic mountainous landscapes are very sensitive even to slightest changes in the environment, and the smallest landforms those appear due to alternate freezing and thawing of the sappy ground are the first to receive the impact. Understanding space-time patterns of cryogenic microrelief development in different combinations of natural conditions allows us to reveal the tendencies of landscape transition.

Based on the vast amount of field data gathered at several regions of the Russian North (Kola Peninsula, Polar Urals, Central Kamchatka) we mark out three stages of cryogenic microrelief development (growth, stable functioning, degradation) characterized by specific changes in outward appearances and internal structures of landforms. They are controlled by local conditions those determine the thermic regime of the ground. For the first time, we widely used grain-size and chemical analyses of ground samples, radiocarbon dating, large-scale mapping and profiling. A bulk of morphometric data for cryogenic forms (length, width, height and composition of its elements) and respective environmental conditions (altitude, angle and exposition of the sites) was processed; typical limits for each parameter and region were found.

Radiocarbon analysis of buried organic material provides the range of dates (10 dates from 3500 to 150 radiocarbon years BP) those correspond to the age of cryogenic forms' elements (turf ramparts of medallions and polygons, peaty interlayers and buried sod in solifluction terraces, basis of turf hummocks, etc.). The appearances of those biogenic elements mark the transition from one stage of evolution to another (from one type of cryogenic form to another). Hence, corresponding dates can be used to estimate the duration of different stages.

Resting upon the radiocarbon data and space-time analysis the duration of each stage varies from first decades up to several hundreds of years while the age of the particular form can reach up to the first thousands of years. The stages naturally replace each other in time, i.e. evolve, and form genetic sequences. The direction of evolution defined by the combination of initial conditions is then influenced by self-development of forms due to local redistribution of temperatures and moistening in the ground. This secondary differentiation of local conditions causes cyclic development of the cryogenic microforms. The smaller the form is the lesser time it needs to complete the cycle from growth to degradation.

DESIGN AND CHALLENGES OF RESIDENTIAL FOUNDATIONS ON EXPANSIVE SOILS IN BRAZIL

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The design of foundations of any structure requires a good geological investigation on site construction and its surroundings. So it is essential to identify the behavior of the soil in order to obtain the maximum design parameters. Then if this information is not taken into account, there are the pathologies and ruptures and collapses. When we find a kind of expansive soil undoubtedly the design conditions should be more careful and the engineer of foundations be prepared to solve this problem. Often in Brazil not made the correct identification of expansive soil due to the costs involved in the process, but it has been causing many trouble, especially in slabs-on-ground foundations. The buildings in which the designers make the recognition of expansive soils has helped in map creation for this type of soil in Brazil that has been cataloged regions since 1989. Even so, the information is basic and preliminary. This paper presents three case studies where expansive soils were identified in Brazil in different regions and was applied to different methodologies for projects individually. The projects were for residential foundations of up to 5 floors where the scheme is composed of structural masonry concrete blocks. Were used mostly reinforced slabs-on-ground and post-tensioned slabs-on-ground without piles, but there were cases of using piles (piled raft foundation). It is important to comment yet Brazil does not have a specific standard for projects of slabs-on-ground foundations on expansive soils, so there was an adaptation of different calculation methods for Brazilian conditions, because the climatic conditions of Brazil are different from other countries, and is a country of continental dimensions, providing an even greater challenge.

THE EXPERIMENTAL STUDY OF ELECTROKINETIC DEWATERING OF OIL SANDS TAILINGS

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Electrokinetic (EK) treatment has shown to be successful in dewatering and strengthening of fine oil sands tailings (mature fine tailings (MFT)). In this study the lab scale experiments are performed on MFT to generate horizontal EK flow and consolidation via two vertical installed electrodes. The coefficient of electroosmotic (EO) permeability, k_e , is measured in EK cell under different tailings void ratios generated under different consolidation pressures (1, 2, 5, 10 kPa). The MFT water contents after different period EK treatment are measured and recorded at anode side, center and cathode side in EK dewatering cell during EK treatment. Two voltage gradients, 50 V/m and 100 V/m, are used in this study. The water content at anode reduced quickly at the beginning of treatment, then reached constant after 100 to 150 hours, depending on the applied voltage gradient. The regression analysis shows that the relationship between the post-treated water content of MFT, w , and treatment time, t , can be expressed as an exponential decay function at anode and center, i.e. $w(t)/w_0 = Y + Ae^{(-B \cdot t)}$ (Y can be zero), where $w(t)/w_0$ is the ratio of the post-treated water content to the initial water content. On the other hand, the water content at the cathode remains constant during all tests. The undrained shear strengths, S_u , of MFT are measured at different treatment time to assess time dependent shear strength gain. For EK treatment under 100 V/m, a significant strengthening effect is observed after 50 hours treatment at the anode of the MFT sample. On the other hand, for EK treatment under 50 V/m, the shear strength gain is much less and noticeable only after 70 hours treatment. The analysis of the experimental data after EK treatment also include the compressibility, material index properties and power consumption.

IMPACTS OF FOREST FIRES ON SEASONAL THAW AND PERMAFROST THAW, SCOTTY CREEK, NORTHWEST TERRITORIES, CANADA

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Permafrost marks the vital ecological structure of northern ecosystems. Permafrost thawing is constantly increasing due to the climate change, and increased forest fires as well as preventative measures around established communities. Studying forest fires in relation to the thawing of permafrost environments is vital to northern ecology and changing hydrology; since, our northern Canadian landscape is being drastically altered.

The main purpose of this research is to improve the understanding of forest fires on the ground thermal regime of permafrost thawing terrain by modeling the surface-energy-balance after a partial forest fire on a peat plateau at Scotty Creek (61°18'5.15"N; 121°17'58.87"W) in the Lower Liard River Basin, 50km south of Fort Simpson, Northwest Territory, Canada. Previous studies on energy modelling and forest fires show increasing permafrost thaw due to; increase incoming solar radiation from the loss of the canopy, and decrease in albedo from the blackened surface. However, in the case of a partial forest fire, where the forest has not been completely removed, will the models still predict accurately the permafrost thaw? Instruments of measurement have already been placed on the burn site and have been recording data since the end of summer 2014. Two ten-foot tripod tower stations have been installed on the affected peat plateau. One on the burnt area and the other across in the unburnt forest zone. These tower stations have multiple measuring instruments to record the following values: incoming and outgoing short- and long-wave radiation; air temperature and humidity; wind speed and direction; soil temperature and snow depth. Soil temperature was also measured along a transect line at equidistant intervals crossing the burnt/unburnt interface. This upcoming March, a field survey will provide snow transect measurements, such as snow depth, density and snow water equivalent during winter and the snowmelt period leading to spring.

CHARACTERIZATION OF PERMAFROST THERMAL STATE IN THE SOUTHERN YUKON

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The Alaska Highway Corridor traverses the discontinuous permafrost zone of the southern Yukon. Although permafrost characteristics were investigated in the corridor over 30 years ago to support a pipeline proposal, little information was available on current ground thermal conditions. Since air temperatures in the region have increased 0.4-0.5°C per decade since the 1970s, it is essential that updated information on permafrost conditions be available to support design of resource development infrastructure and climate change adaptation planning for the existing highway.

To address the lack of information on ground thermal conditions for the section of the corridor west of Whitehorse, nineteen boreholes up to 10 m deep were instrumented between 2011 and 2013, with temperature cables. These boreholes complement those instrumented during the International Polar Year (2007-09) elsewhere in the central and southern Yukon.

The data acquired has enabled a description of the ground thermal regime in the northwestern portion of the corridor. Permafrost is generally warm in this section of the corridor with temperatures generally higher than -1.5°C. However, permafrost can be at temperatures as low as -3°C in the immediate vicinity of the Alaska border. A comparison of the recent ground temperatures with those measured in some of the boreholes by the Geological Survey of Canada in the late 1970s indicates that some warming of permafrost has occurred. Continued ground temperature measurements will facilitate assessments of changes in permafrost thermal state and the impact of a changing climate.

The ground thermal data collected from these new monitoring sites have been compiled into a digital database along with data obtained from other instrumented boreholes in the central and southern Yukon. These data facilitate a better understanding of current regional permafrost conditions. These publicly available data can also inform climate change adaptation planning and support infrastructure design in the region.

ANALYSIS OF FREEZING INDUCED SOIL SHRINKAGE WITH IMPLICATIONS REGARDING STRUCTURAL CHANGE

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The approximately 9% volumetric expansion during freezing suggests that at high water contents, above 91.7% saturation, the total soil pore volume cannot accommodate ice growth thus resulting in an increase in bulk soil volume. However, when soil is viewed as a non-rigid porous media comprised of both solid particles and the enclosed void spaces, freezing induced bulk volume increases may not always occur. Previous research has shown that at lower water contents, below approximately 75-90% saturation, freezing induced bulk soil shrinkage can occur in non-rigid soils.

The freeze-thaw process has also been cited as being alternately responsible for either soil structural improvement or degradation. Structural improvement has been attributed to freezing induced desiccation of intra-aggregate pore space while structural degradation has been linked to both the effects of freezing at high initial water contents and freezing induced moisture redistribution upon thawing.

In terms of soil moisture retention, the freezing process has many similarities to the drying process to the extent that the soil freezing characteristic has been compared to the soil moisture characteristic or water retention curve. The shape of the freezing induced bulk soil shrinkage curve of void ratio versus moisture ratio can thus theoretically be used to delineate structural changes in the soil during freezing induced shrinkage. Such analysis may lead to elucidation of the effects of the freezing process on soil structure that have until now yielded seemingly conflicting results. A constitutive shrinkage equation developed from basic equilibrium thermodynamics is fitted to freezing induced volume change data using an unbiased least-squares curve fitting procedure. The resultant equation is differentiable thus allowing precise estimation of the different regions of the unsaturated shrinkage curve. The range of water contents associated with these different regions may then be related to both independently determined soil properties and the observed changes in soil structure resulting from freezing. This analysis is performed on a data set of freezing induced soil shrinkage in a clay soil.

THE GUIDING HAND OF J. ROSS MACKAY IN WESTERN ARCTIC PERMAFROST RESEARCH AT THE GEOLOGICAL SURVEY OF CANADA: THE EARLY DAYS

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As interest in oil and gas development increased in the western Canadian Arctic in the late 1960s, the Geological Survey of Canada (GSC) began a program of permafrost terrain mapping in the region. Dr. J. Ross Mackay of the University of British Columbia was central to these research activities; GSC financial, personnel and logistical support was provided by the Terrain Sciences Division (Dr. John Fyles, director).

Ross's (and GSC's) interests included mapping and interpreting the origin of massive ground ice, pervasive at shallow depths throughout the Western Arctic. In addition, the origin, shape, growth and distribution of pingos were of continuing interest to him.

To examine the lateral extent of segregated ice, combined UBC-GSC mapping and interpretation of industry boreholes was undertaken on the Tuk Penninsula. A GSC research site "Involute Hill" was established 10 km east of Tuktoyaktuk. For several years, permafrost conditions in this area were studied with various geological and geophysical techniques.

Ross's landmark paper predicting the occurrence of seabottom permafrost in the Beaufort Sea shelf, and the hypothesis of possible widespread ice-bearing conditions, triggered the development of specialized engineering-geophysical techniques in the early 1970s. In 1972 he was on board the GSC survey vessel "North Star" when ice-bearing permafrost was detected during early marine seismic refraction tests 50 km seaward of Pullen Island. Such work led to GSC offshore geotechnical drilling, sub-seabottom temperature measurements as well as a co-operative GSC – industry reanalysis of seismic records throughout the Beaufort Sea to provide regional maps of ice-bonding.

Ross Mackay's interest in installing non-heave bench marks for pingo elevation surveys led to collaboration with GSC staff to develop hydraulic jet drilling methodologies. By 1973, the GSC-UBC teams were routinely deploying thermistor arrays to 60+ m depth in terrestrial and marine environments.

Ross firmly believed in the value of long-term field experiments, and the UBC-GSC team planned the "Drained Lake" project to examine the development of permafrost in the exposed lake bottom. Of the six candidate lakes carefully examined for geological and geophysical suitability, Illisarvik on Richards Island was selected and drained. The experiment began in 1978 and continues today, yielding perhaps the longest continual set of combined permafrost observations of its kind.

SOIL FAILURE MECHANISM FOR LATERAL AND UPWARD PIPELINE-SOIL INTERACTION ANALYSIS IN DENSE SAND

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Pipelines are routinely used to transport oil and gas between offshore production plants and the mainland, or between remote subsea well-heads and a centralised production facility or in onshore. The pipelines may be placed on the soil surface but it is more usual that they are placed into trenches, which are subsequently backfilled. The response of these buried pipeline due to lateral and upward relative displacements is one of the major concerns in pipeline design. Both physical modeling and numerical analyses have been performed in the past to understand pipeline-soil interaction mechanisms. The numerical analyses are generally performed using finite element modeling (FE) techniques. In the present study, FE analysis of buried pipelines in dense sand is presented. The analyses are performed using a modified Mohr-Coulomb model where pre-peak hardening, post-peak softening, density and confining pressure dependent friction and dilation angles are considered. The FE analyses are performed using the Arbitrary Lagrangian-Eulerian (ALE) approach available in Abaqus/Explicit FE software. The modified Mohr-Coulomb model is implemented in Abaqus FE software using a user defined subroutine. The main focus of the paper is the mechanism of soil failure due to lateral and upward pipeline-soil interaction. A detailed correlation of load-displacement response with the mechanisms of failure is shown. Shear band formation due to strain concentration and failure patterns for both lateral and upward pipeline-soil interactions are discussed from the simulations with modified Mohr-Coulomb model. FE results show that the modified Mohr-Coulomb model used in the current study can simulate the load-displacement behavior and soil failure pattern. Also proper understanding of soil failure mechanism aids the interpretation of pipeline-soil interaction analysis.

THE INFLUENCE OF SEGMENTAL LINING IN DEEP TBM TUNNELLING.

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For long deep tunnels, such as the ones going through the Alps, mechanized excavation using tunnel boring machines (TBMs) contributes significantly to savings in construction time and costs. However, severe conditions may be encountered during the excavation process. A major geological hazard is the squeezing conditions usually met at high depths within weak rockmasses. Squeezing conditions do not only cause difficulties during excavation, and sometimes even termination of a tunnelling project, but due to the increased stresses applied on the final liner, liner damage may be possible post-construction. Therefore, the investigation of the influence of the in-situ conditions on the final lining employed is rather important.

However, a mechanized tunnelling process is far more demanding in terms of computational cost when compared to conventional tunnelling simulation, as it involves a more complex interaction between the structural components and the surrounding rockmass. In order to fully simulate mechanized tunnelling a three-dimensional (3D) analysis has to be employed, but two-dimensional analyses can also be proven useful at a preliminary stage. 2D analyses can provide an initial estimation of the expected response of the final lining when pressure is transferred from the surrounding rockmass to it. This can provide an evaluation of the influence of the different factors affecting the final lining and the developed structural forces, which can be proven rather important at the early stages of the design process.

The mechanized tunnelling process is usually incorporated into the construction sequence with regards to the use of pre-cast concrete segments (segmental lining). However, one of the usual assumptions of the conducted analyses is the continuous lining approach, leading to a different response than the one expected in reality. Therefore, it is of great significance to examine the two different lining approaches, their estimated response and the impact of different factors on the structural forces of the final lining.

For the purposes of this paper, two different types of final liners are adopted in order to investigate the influence of the in-situ conditions on the structural forces developing in the liner after the construction of the tunnel has been completed and the material properties of the structural components.

GEOPHYSICAL MONITORING OF ENGINEERING CONSTRUCTIONS IN WESTERN YAKUTIA AND STUDY OF COUPLED PROBLEM OF TEMPERATURE AND SEEPAGE FIELDS IN PERMAFROST NEAR HYDRO UNIT

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In permafrost areas stability of many engineering structures, including hydraulic objects, open-cast mines, associated with thawing - freezing process. The basic danger during construction and operation of open-cast mines in permafrost zone is degradation of frozen rocks. The last leads to instability of open-cast mine boards and landslips development. Emergency situation of the hydro unit we have when seepage occurs in originated permeable talik zone adjoining to reservoir. We present original results of long-term geophysical study on hydro technical objects and open-cast mines of Western Yakutia analyzing problems associated with use of geophysical methods for the study of rocks in permafrost area. Geophysical methods allow predicting dangerous sites on which occurrence of sliding processes is possible. The leading geophysical method allowing operatively finding out and tracing the presence of potentially dangerous sliding activity sites of frozen rocks adjoining to edge the open-pit a mine, the electric tomography certainly is. In a complex with others ground surface and borehole geophysical methods it can be used for working out of actions for maintenance of stability of slopes of open-cast mines in conditions long-term frozen rocks. For Hydro Units the primal problems of studies were focused to I) eliciting and checking of a position of talik zones and places of filtering of water in a body of foundation and coastal contiguity of constructing and operating reservoirs dams; II) estimation of dynamics of seepage progressing processes for a development of a complex of measures, directional on exception of losses of water from reservoir and supply of stability of a body of a dam. From ground-level methods of studies in composition of operations were included high frequency electric profiling, electric profiling on a method of a natural field, georadar, seismic profiling and seismic sounding. Down-hole observations on dams included long-term regime temperature measurements and complex of logging studies (resistance, flow meter survey, gamma logging, neutron gamma logging, caliper measurement, radio wave cross-borehole testing). Alongside field studies, numerical evaluation of permeable talik zone (thawing) origination and development in a broad zone around a dam was made. The non-steady problem of heat-mass transfer in fractured-porous saturated frozen media, inter-bedded in frozen impermeable strata is discussed. The model takes into consideration the main conditions causing initiation and development of talik near a reservoir: annual temperature and snow cover, seasonal water temperature distribution in the storage basin and evolution of permeability in rock due to thaw-freeze processes.

LATERAL TRANSPORT THROUGH WETLANDS IN THE DISCONTINUOUS PERMAFROST REGION

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The wetland dominated basins in the headwaters of the Mackenzie River, which lie within the discontinuous permafrost zone, present an opportune location to study rapid change as the region warms. Understanding and characterizing the processes and pathways of water flows through these systems and how they change with permafrost degradation is crucial to accurate modelling and forecasting for downstream basins. Though much research has been conducted to improve our understanding of the processes contributing to runoff generation in this landscape, little work has been done to understand the unique land cover type responsible for lateral flow transport in the headwaters of the region, channel fens. As a result, channel fens are difficult to incorporate into large scale hydrological models and are often misrepresented as open water channels. A representative channel fen in the Scotty Creek research basin, Northwest Territories, was divided lengthwise into hydrological response units (HRUs) for processing in the Cold Regions Hydrological Model (CRHM). Detailed characteristics of the water and energy balance of the channel fen were measured over the snowmelt period, the most hydrologically important event of the year in these environments. This analysis will result in a conceptual model of the dominant processes involved in lateral transport through the system, with the aim of improving parameterization of channel fens for large scale hydrological modelling in Modélisation Environnementale Communautaire – Surface and Hydrology (MESH).

DEVELOPMENT OF A NEW CSA STANDARD FOR MODERATING THE EFFECTS OF PERMAFROST DEGRADATION ON EXISTING BUILDING FOUNDATIONS

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The Canadian Standards Association (CSA) published a new national standard in December 2014, entitled “Moderating the Effects of Permafrost Degradation on Existing Building Foundations” (CAN/CSA-S501-14). It is one of a suite of new standards being developed as part of the Standards Council of Canada’s Northern Infrastructure Standardization Initiative (NISI).

The degradation of permafrost in Canada’s North poses a significant problem for many types of infrastructure. The desire of northern governments and communities to build larger, more complex infrastructure, coupled with the observed and projected impacts of climate change, results in an increased need for a standardized tool for moderating the effects of permafrost degradation on foundation stability.

The expert working group, which developed the Standard, included engineers, design consultants, permafrost experts, government managers and northern infrastructure owners. The working group was largely made up of northerners whose long-standing experience added to the effectiveness of the process.

Permafrost degradation can be caused by many factors. When degradation occurs, buildings or structures constructed on permafrost can suffer distress or damage. The Standard covers both shallow and deep foundations and is organized according to the progression of steps that should be undertaken in order to moderate the effects of permafrost degradation on existing buildings or structures. The strategies available depend heavily on site-specific conditions so use of the Standard requires a flexible approach.

The paper reviews the need and usefulness of such a specifically targeted northern standard, its basic elements, and recommendations within the standard that are intended to help the user with decision-making.

CATHEDRAL MOUNTAIN 2014 ICE FALL AND DEBRIS FLOW

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Cathedral Mountain is located in the southern Rocky Mountains of British Columbia, 7 km east of the community of Field. Its northern slopes are situated in Kicking Horse Pass, the most traveled route across the Continental Divide of the Canadian Rocky Mountains. The higher elevations of the mountain are occupied by the Cathedral Glacier, which includes a supra-glacial lake that drains north towards the Kicking Horse River through a valley known as Cathedral Gulch. Since 1925, 16 debris flows have been recorded down Cathedral Gulch including several that buried or washed out one or more levels of the Canadian Pacific railway mainline and TransCanada Highway. The debris flow activity at Cathedral Gulch caused by large volume releases from reservoirs within and adjacent to the glacier, glacial down-wasting, loss of stagnant ice and the subsequent entrainment of colluvial sediment have been larger and more frequent than other similar, small steep watersheds in the Rockies. At 0630 on July 10, 2014, approximately 40,000 cubic meters of ice collapsed from Cathedral Glacier allowing the supra-glacial lake to drain. The ice and water flowed down Cathedral Gulch and transformed into a debris flow that buried the uppermost CP tracks. Analysis of the event included: an initial rapid assessment and safety plan for workers who had the track functional by 1420 the day of the incident, a qualitative assessment using detailed 3D surface models from oblique aerial photos taken during the days following the incident, the analysis of the stability of the remaining glacier and supra-glacial lake, and a magnitude frequency analysis of Glacial Lake Outburst Floods (GLOF) and debris flows that have occurred down Cathedral Gulch. This case study highlights the key results of the analyses and reports on some of the innovative techniques available for rapid Geohazard assessments in similar terrain.

ÉTUDE DU COMPORTEMENT STATIQUE ET CYCLIQUE DES ARGILES SENSIBLES DE L'EST DU CANADA

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Les méthodes traditionnelles de calcul des fondations profondes, utilisées dans les bureaux de génie-conseil, ont fait l'objet de révisions et d'améliorations pendant plusieurs années. Toutefois, la rupture des fondations profondes observée lors des derniers tremblements de terre a révélé la mauvaise performance de ces méthodes. La conception inadéquate des fondations a entraîné plusieurs effets néfastes sur la superstructure tels que l'effondrement, la perte de leur état de service ou de leur capacité de résistance à d'éventuels événements sismiques. C'est pourquoi, au cours de ces dernières années, des efforts ont été déployés pour identifier et analyser les causes des dommages de fondations profondes, et ce, afin de développer des techniques de mitigation pour préserver l'intégrité des superstructures durant ces événements.

Ainsi, les méthodes de calcul dynamique suscitent actuellement beaucoup d'intérêt à travers le monde, car elles permettent de mieux tenir compte de l'interaction sol-fondation-structure. Ces méthodes, dont les nombreux avantages seront décrits dans la revue de littérature, jouent un rôle déterminant dans l'analyse de la réponse dynamique des fondations profondes. Cependant, les quelques travaux de recherche proposant des procédures de calcul très performantes délaissent l'aspect des conditions sismiques et géotechniques particulières de l'est du Canada.

De plus, dans le Code canadien sur le calcul des ponts routiers (2006) et dans le manuel canadien des fondations (2006), on ne retrouve pas de méthodes de calcul approfondies pour le dimensionnement des fondations profondes sous sollicitations sismiques. L'ingénieur praticien ne dispose d'aucun outil de conception convenable pour ce type de calculs. Ce problème prend d'autant plus d'importance sur le territoire québécois puisque sa partie méridionale est sismiquement active. Un autre volet, et non des moindres, concerne la méconnaissance du comportement cyclique de l'interaction sol-structure des dépôts d'argiles sensibles et de silts d'origine glaciaire.

CONSIDERING PERMAFROST IN THE DESIGN OF LINEAR INFRASTRUCTURE THROUGH MOUNTAINOUS TERRAIN

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This paper presents an assessment of permafrost in mountainous terrain during the routing and design of linear infrastructure. Traditionally, only a small corridor width is considered and assessed when linear infrastructure, such as a road, pipeline or transmission line is planned. As such, hazards that originate from the periglacial belt at high elevations outside the corridor, which are often controlled by climatic parameters, may therefore not be considered. Rapid climate change and variations in climate extremes can have a significant impact on the permafrost degradation and deglaciation in mountainous terrains of the Canadian Rockies and the Coastal Mountain Range and change the geohazard potential with time. In order to assess such potential hazards for a linear infrastructure project through northern British Columbia, a probabilistic permafrost distribution model was developed. The permafrost distribution model was based on the mapping of periglacial landforms in the vicinity of the corridor. In addition, information from site investigations within the corridor were included in the validation of the model. Even though the actual corridor only intersects with the lowest probability zone, the map helped in the assessment of potential hazards that originated outside, at higher elevation.

RÉSISTANCE MÉCANIQUE ET PRESSIONS DE FRACTURATION DE QUELQUES MATÉRIAUX ROCHEUX SÉDIMENTAIRES TYPIQUES

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Des essais de compression et de microfissuration hydraulique ont été réalisés au Laboratoire de mécanique des roches de CanmetMINES, situé à Ottawa (Ontario), pour déterminer la résistance mécanique, les modules de déformation élastique et les pressions de fissuration et/ou d'injection de quelques matériaux rocheux sédimentaires typiques. Ces travaux ont été entrepris pour caractériser les matériaux soumis aux essais dans un premier temps, et dans un deuxième temps, pour étudier la faisabilité des projets d'extraction et/ou d'enfouissement éventuels associés soit à la production et/ou à la séquestration de gaz, ou encore à l'entreposage à long terme de résidus nucléaires à l'intérieur de ces mêmes matériaux et/ou formations rocheuses. Les matériaux visés par les essais sont un matériau de shale à être identifié plus tard (re : autorisation de divulgation en cours) et un matériau de calcaire provenant de la Formation de Cobourg, dans la région du Niagara (Ontario). Un matériau de ciment fréquemment utilisé pour procéder à l'injection et à l'imperméabilisation des forages et des formations rocheuses (aussi utilisé pour compenser les échantillons de shale soumis aux essais en laboratoire) a également été testé pour compléter le programme d'essai. Les essais réalisés ont donné d'excellents résultats, autant en ce qui concerne leur homogénéité que leur dispersion relative autour des moyennes mesurées. Les écarts observés s'expliquent par les conditions de mise en place et/ou de prélèvement des matériaux. Les essais de microfissuration ont également permis de vérifier les théories usuelles de pressurisation, applicables à la fracturation (hydraulique) et/ou à l'ouverture des fissures dans les matériaux rocheux intacts ou fissurés, de faible porosité et/ou perméabilité. Les méthodes de prélèvement des échantillons et/ou des matériaux en chantier, et les méthodes d'essai utilisées au laboratoire seront exposées. Les résultats obtenus seront présentés. Leur signification et leur utilisation éventuelle dans le contexte des applications visées seront alors discutées.

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NWT HIGHWAY 3 TEST SECTIONS NEAR YELLOWKNIFE

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Highway 3 is the only all-weather road connecting southern Canada to the City of Yellowknife, the capital of the Northwest Territories. The last 100 km of the highway is located in an area of extensive discontinuous permafrost within the Great Slave Lowlands. Ground temperatures are typically warmer than -1°C and extensive permafrost degradation has been noted in recent years. The highway was originally constructed as a gravel road in 1968 and was straightened and reconstructed between 1999 and 2006. Since reconstruction, sections of the highway have experienced significant sagging in soil-covered areas and requires considerable maintenance efforts to keep the road in a comfortable and safe driving condition. The embankment deformations have been attributed to the degradation and associated thaw consolidation of the ice-rich permafrost foundation. In the fall of 2012, four test sections were constructed to evaluate potential mitigation techniques for road embankments on permafrost foundations. The focus of these techniques is not to aggrade permafrost and stop permafrost degradation per se, but to reduce maintenance requirements. The test sections included partial to full replacement of road embankment fill with geotextile-reinforced fill; replacement and re-location of existing culvert with an open-arch culvert; partial replacement of road embankment fill with geogrid-reinforced fill; replacement of embankment shoulder fills with clean cobbles intended to create a passively-cooled, ventilated shoulder; partial replacement of embankment fill with a layer of cellular concrete; and replacement of existing rock drain with an open-arch culvert in geosynthetic-reinforced fill. Thermistors were installed in the test sections and biannual inspections carried out to monitor the thermal and structural behaviour of the embankments. The paper presents data and findings from the first 2.5 years of monitoring. Even though the test sections have been operational for only a short period, one that is too short to draw major conclusions, preliminary trends can be observed, which are discussed.

[KEYNOTE] COLD REGIONS ENGINEERING IN A CHANGING CLIMATE

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Considering climate change is an integral part of any infrastructure design that has a design life of more than 20 years and is of particular importance with respect to perpetual designs. Various technical guidelines indicate that global warming should be addressed in the design but often details on how to do this are missing. Also, climate projection models have seen significant improvement over recent years, but the biggest challenge in terms of designing for climate change are not changes in air temperature, but second and third order effects, together with changes in climate extremes. Non-linear changes in precipitation, adjustments in vegetation and/or related geohazards are of relevance rather than average changes in air temperature alone, which are typically the products with the lowest uncertainties available from climate models. The keynote presentation will present these challenges, provides a summary of latest climate change modelling products available and introduces a systematic, risk based approach for cold regions designs considering climate change.

RE-ACTIVATION OF AN INACTIVE TAILINGS IMPOUNDMENT

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One of AMECFW's major clients operates several active and inactive tailings impoundments in the Abitibi Temiscamingue area (QC). Their primary tailings impoundment called Q2 was last raised in 2009 and is expected to reach maximum storage capacity by the end of 2016.

A new site needed to be identified for the continuation of the tailings operation once the life of Q2 would be attained. With this objective in mind, an assessment for other potential tailings impoundment areas was carried out. It has been noted that the re-activation of one of the dormant tailings impoundments, known as N5, offered some very attractive potential advantages. It was felt that N5 had some considerable, previously untapped, potential storage capacity. As N5 is an existing facility, its re-activation will have very minimal new environmental impacts and no additional permits will be required for another effluent discharge. Low investment and construction costs are also expected as the site is fairly close to the mills with nearby available borrow pits for construction material and several existing access roads that could be used during construction.

However, redeveloping N5 presents several challenges; the site footprint foundation consists of very soft clay; thus large settlements are anticipated and can be problematic during construction and operation. The site is located at the edge of a city with several homes and businesses downstream so dust emission from the tailings operation will be an issue, and in case of dyke's failures, the impacts to local residents needs to be considered.

A concept for the re-activation of N5 has been proposed in this paper, which takes into account the above-mentioned issues. Staged construction has been planned over several years with an instrumentation program to mitigate the effects of settlement and guide the staged construction. An appropriate sequencing of the deposition operation has been established in parallel with usage of dust suppressant to minimize emissions. This concept prioritizes the beaching of tailings at sensitive areas, moving the free-water pond away from the embankment and operates the water-pond at lowest operational level. This will decrease hydraulic head and minimize seepage, increase stability and lower the risk of dyke failures.

In support of the above concept, the geotechnical and hydro geological studies were performed in 2014. The re-activation of the site and the construction of the required tailings management infrastructures are planned to commence in 2015.

THE KUUJJUAQ AIRPORT: A CASE OF CLIMATE INTERACTIONS ON INFRASTRUCTURE STABILITY IN THE DISCONTINUOUS PERMAFROST ZONE.

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Remote airport infrastructures in northern communities are an essential link to major cities in the South for the transportation of persons, goods, and supplies. The impact of climate warming on their stability is of even greater concern for those located in the discontinuous permafrost zone because of its higher sensitivity to thawing. The Kuujuaq airport is underlain by warm permafrost and the principal runway consists of a paved surface. The initial goal of this study was to assess the stability of the infrastructure in the context of warming since very little information was known on permafrost distribution and its characteristics for this area. The surface geology was studied and the properties of the permafrost under the runway were determined using several methods, which include excavation with machinery, ground penetrating radar surveys, drilling, groundwater monitoring in the active layer and sediment analysis. Thermistor strings were installed in boreholes to depths ranging from 4 to 8 meters both under the paved runway and in the gravel shoulder and automated data logging since 2006 has provided valuable information on the ground thermal regime.

The soil under the runway is dominated by till and coarse glacial drift that varies in thickness from about 1.5 m to over 9 m over bedrock. The active layer has a thickness of about 3 meters and its yearly freezing and thawing rates vary depending on ground surface conditions and the surface drainage regime which are particularly affected by the sharp contrast between the paved runway surface and the unpaved shoulders and the natural terrain. This spatial and temporal variability of the active layer influences the ground water flow near and under the paved runway. The number of freeze-thaw cycles varies on a yearly basis but they are more pronounced under the paved runway than under the shoulders. This phenomenon is more important in spring and hence has a direct influence on the infrastructure stability and renders the pavement sensitive to heavy loads such as large aircrafts. The impact of recent climate warming in the region which has resulted in a deeper active layer than previously measured seems to have a greater impact on the local groundwater regime than on thaw settlement. This affects runway sensitivity to heavy loads, therefore impacting aircraft traffic. Some remedial works such as drainage trenches alongside the runway are currently being tested as a mean to address the new drainage conditions.

QUANTITATIVE ASSESSMENT OF "ORE AT RISK" WITH DIFFERENT STOPE SEQUENCE STRATEGIES

Shahe Shnorhokian (1), Hani Mitri (1), Lindsay Moreau-Verlaan (2)
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In steeply dipping tabular orebodies with fairly competent rockmass properties, several stope sequence strategies may be technically feasible. Deciding on a particular scenario depends on a number of factors such as the proximity to problematic geological structures, shape and spatial extents of the orebody, economical considerations, and ground control issues emanating from the redistribution of mining-induced stresses. Numerical modelling is a widely used analytical tool in the mining industry and it can be very useful in assessing different stope sequence strategies and their associated stress redistribution patterns within the rockmass. In this paper, mining-induced stresses are evaluated for two stope sequence strategies at a deep Canadian metal mine within an orebody immediately west of a brittle dyke intrusion. In the first case, mining is simulated as originally planned, whereby stoping activities progress from both the eastern and western sides of the orebody towards the center, resulting in a diminishing ore pillar that is eventually extracted. In the second case, an alternative sequence strategy is tested, whereby the mining fronts are reversed and made to advance from the center towards the sides, thus moving towards the brittle dyke in the east.

The authors have recently published a method to enable a quantitative assessment of instability in the diminishing pillar as a result of implementing the planned stope sequence (Shnorhokian et al 2015). The method, which is based on combining volumetric analysis with the brittle shear ratio (BSR) as an instability indicator, is also used in this study to evaluate the viability of the alternative sequence strategy. The volume of rockmass with a BSR – the ratio between the differential stress and the unconfined compressive strength – exceeding 0.7 is designated as "ore at risk" and compared amongst the two sequence strategies at every mining stage. In addition to the total BSR for the orebody, the BSR values for only stopes next to an opening at a given stage are also examined since these would realistically present the ones at risk of rock ejection.

The results of the combined numerical-volumetric analysis for the original and alternative stope sequence strategies are analyzed and discussed in detail.

INFLUENCE OF ROCKMASS PROPERTY VARIATIONS ON PRE-MINING STRESSES: A CASE STUDY

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Variations in rockmass properties are commonly encountered in underground mines. Samples from a single rock formation could produce appreciable differences in laboratory test results and borehole log entries. When these are combined to derive input rockmass properties required for numerical models, a wide range of possible values could be obtained. Depending on the number of geological formations, a large number of combinations of rockmass properties need to be numerically simulated to assess pre-mining stresses at locations of interest. In this paper, a conceptual mine-wide model of a deep Canadian metal mine is constructed in FLAC3D to study the influence of rockmass property variations on pre-mining stresses at two drift locations 1500 m below ground surface. Boundary tractions are applied to the model and calibration is conducted using results from an in-situ stress measurement survey at the same depth. Laboratory results and borehole log data for key formations are analyzed to determine their minimum, average, maximum, and most likely categories in terms of rockmass properties used as input for the numerical model. In the initial phase, calibration is conducted with all formations at similar property categories. In the second phase, formations are individually assigned maximum and minimum values, while the others are kept constant, to evaluate their impact on the results.

The vertical boundary traction applied to the model coincides with the minor principal stress (s_3) and is due primarily to overburden weight at this depth. It is calculated analytically and used for the selection of rockmass property combinations for key formations that are realistically possible. It is observed that pre-mining stresses plotted for the drift locations follow regular patterns that depend on the rockmass properties of the influential formations. The s_3 value is used once again to narrow the wide range of possible readings to a more realistic one. In the third phase, five models are set up with key formations being assigned properties that are selected randomly from their respective ranges. The predicted s_3 boundary tractions required for calibration, and pre-mining stresses at the drift locations are first read from the previous plots. The models are then simulated and the actual tractions and pre-mining stresses are compared to predicted ones. It is shown that the two sets show a good correlation and thus allow for the assessment of expected stress ranges for any combination of rockmass properties with a small number of simulations.

A PRACTICAL GUIDE TO PERMAFROST VULNERABILITY FOR YUKON'S NORTH ALASKA HIGHWAY.

Fabrice Calmels (1), Louis-Philippe Roy (1)

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The Northern Climate ExChange (NCE) of the Yukon Research Centre has partnered with Government of Yukon's Highway & Public Works (HPW) to map and classify extensive discontinuous, warm ($> -2^{\circ}\text{C}$), and potentially ice-rich permafrost underlying the northwestern 200 km of the Alaska Highway in Yukon. Thawing permafrost impacts road beds, leading to significant increases in hazards and maintenance costs. The highway is vital for distributing food, supplies and medical necessities to multiple Yukon communities as well as Alaska. Thus, it was imperative to examine the potential impacts of climate change on permafrost underlying this stretch of the road.

The objectives of this project were to identify and characterize permafrost underneath the Alaska Highway, to establish future climate scenarios for the region, and to evaluate the potential effects of climate change on the area's permafrost. The project will provide a user-friendly field guide to be used by HPW's personnel and engineers during their everyday work along the highway. This will develop an understanding of the impacts of climate change on highway infrastructure and will facilitate the development of appropriate maintenance and remediation strategies, ensuring the highway's continued viability.

The current presentation will focus more specifically on a case study from the field guide. It was created using a combination of geophysical data, geotechnical reports, Highways and Public Works maintenance records, air photos and field investigations including including permafrost coring, geocryological analyses, ground temperature and climate monitoring, ERT (Electrical Resistivity Tomography), and remote sensing techniques. We present here the results obtained for the case-study, as well as an example of how results were conveyed to HPW as the end user.

EFFECT OF DENSITY AND MOISTURE CONTENT ON THE POTENTIAL COLLAPSE OF SOILS IN SEMI-ARID AREAS

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In the present investigation, discusses the Hydro-mechanical behavior of sandy- clay soils of the semi-desert areas that are most abundant in the Laguna region. The study of soils was done under different moisture content and weight to determine their influence on the response of collapse. Allowing this limit with the problems that are due to settlement of structures when the ground on which they are cemented changes it's moisture condition. To this end, oedometer tests on statically compacted soil samples with different moisture content and different densities in order to find the coefficients of collapse. The tests were carried out on specimens fabricated using soil variables of specific density and moisture content. The first test group was carried out with different densities depending on their dry unit weight and constant moisture, while the second group the dry unit weight remained constant and specimens with different moisture contents. The results show the different effects that the density and initial moisture have on the trajectories for collapse in soils of semi - desert areas.

DESCRIPTION OF INHERENT AND INDUCED ANISOTROPY IN GRANULAR MEDIA

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Many naturally occurring geomaterials are anisotropic at the macroscale, which is strongly related to their microstructure. Sedimentary rocks (like shales), for example, display an inherent anisotropy, which results from the presence of bedding planes. In granular materials, the anisotropy may originate from the shape of the grains. It is well known, for example, that the strength properties of sand with elongated angular-shaped aggregates are strongly affected by the direction of loading in relation to the direction of deposition. But even if the skeleton itself may be considered as isotropic, e.g., sand with nearly spherical particles, there is usually a bias in the distribution of void space, due to initial compaction, which also triggers the anisotropy that may evolve during the deformation process. Whether inherent, induced or a combination of both, the anisotropy in microstructure may have a significant effect on both the strength and deformation characteristics of the material and should be accounted for in the context of analysis and design of geotechnical structures.

The primary objective of this study is to demonstrate that a significant degree of anisotropy may occur in particulate materials that have nearly spherical aggregates (i.e. are typically considered as isotropic) provided there is a bias in the distribution of pore space due to the initial densification process. The study includes both an experimental and theoretical component. An experimental program is conducted on dynamically compacted samples of Ottawa standard sand (C109), and incorporates a series of tests performed at different orientation of the specimens. A plasticity formulation based on the critical plane approach is employed. A systematic procedure for identification of material parameters is proposed and some numerical simulations of a series of triaxial tests are conducted. The mathematical framework is enhanced by an evolution law for the material fabric.

NEAR-SURFACE GROUND ICE CONDITIONS IN UNIVERSITY VALLEY, MCMURDO DRY VALLEYS OF ANTARCTICA

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The distribution and nature of ground ice is of importance to our understanding of polar environments. In the Arctic, the ground ice content of permafrost is fairly well characterized. By contrast, the ground ice content of permafrost in Antarctica is largely unknown. In the McMurdo Dry Valleys (MDV) of Antarctica, three types of permafrost have been advanced: i) dry permafrost; ii) ice-cemented permafrost; and iii) ground ice or buried ice. The prevalence of dry permafrost in areas of the MDV known to also contain ground ice has steered several studies related to subsurface ice conditions. However, only a limited number of studies determined the ground ice content in the MDVs' permafrost and none have described the soil's cryostructures.

The objective of this research project is to describe the cryostructures in permafrost, quantify the ground ice content and determine the origin of ground ice in University Valley, McMurdo Dry Valleys of Antarctica. Methodologies include: i) sampling of fifteen shallow permafrost cores (<1 m); ii) determining the ice content of the permafrost cores; and iii) using computed tomography scanning and imaging of the permafrost cores to determine the cryostructures in permafrost. Additionally, relations between permafrost, ground ice and environmental factors (e.g., soil surface temperature, potential incoming solar radiation and soil texture) will be investigated.

This contribution will help advance our current understanding of ground ice conditions in cold-dry environments and will evaluate the applicability of Arctic-centric cryostratigraphic classification schemes to Antarctic permafrost. Moreover, due to the similarity between the MDV of Antarctica and the Martian landscape, results from this study may enable comparisons between Antarctic and Martian permafrost.

NON-DESTRUCTIVE INSPECTION OF THE SURFACE OF UNDERGROUND STRUCTURES BASED ON THE PROPAGATION OF SURFACE WAVES

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Underground structures play a vital role in places where the space available at the surface of the soil is limited. As time passes, these structures degrade and must be maintained in order to remain fully functional. The planning of the maintenance of underground structures will vary depending on their state of degradation which may be difficult to evaluate due to their location. The use of non-destructive techniques (NDT) for the inspection of these structures is becoming increasingly popular due to the advantages they may offer over destructive techniques. When it comes to the inspection of an underground structure located in an urban environment where direct access to the structure is limited, the use of an NDT that can be performed rapidly and with minimal disturbance to the population is advantageous. Although several NDT's are available to estimate the location of such structures, none of them have so far shown the potential to evaluate their state of degradation without requiring a direct access to them. This article presents a new NDT based on the study of the propagation of elastic waves that is intended to evaluate the state of degradation of an underground structure directly from the surface of the soil. With this new technique, the variation of the vertical acceleration of the soil following a mechanical impact is recorded along the surface of a given profile. The variation of the acceleration of the soil in time, space and frequency is then studied in order to determine the surface condition of the underground structure. In previous work, the behavior of elastic waves propagating in a soil profile containing an underground concrete structure was modelled using 2 dimensional numerical models. One of the drawbacks of using 2D models to represent 3D structures is that 2D models neglect the effect that out of plane discontinuities may have on the propagation of elastic waves. In the case of underground concrete structures, the underground profile may however show important discontinuities in the out of plane directions. This paper therefore uses 3D modelling to show how the condition of the surface of an underground concrete structure affects the propagation of elastic waves and how this can be used as part of an NDT.

Key words: Underground structures, numerical modelling, NDT, elastic waves, Rayleigh waves.

REMEDIAL MEASURES INCORPORATING JET GROUTING AND MICROPILES FOR THE CONSTRUCTION OF A NEW BACKFLOW PREVENTER

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A new backflow preventer was constructed as part of Toronto's West Don Lands redevelopment in preparation for the 2015 Pan Am Games. Movement of three adjacent existing bridge piers early during conventional construction necessitated an embargo on dewatering, a change from conventional to innovative techniques as well as remedial measures to construct the new backflow preventer.

The site is located within the flood plain of the Don River and is underlain by over 30 metres of weak organic deposits. Overlapping jet grouted columns were installed using the double fluid process to create both a low permeability base plug and a vertical cut-off. Jet grouting parameters were verified by conducting a full-scale pre-production test program. Rock-socketed micropiles were installed through the jet grout base plug to support and tiedown the new chamber. Several challenges were encountered during remedial works, namely revisions to the method and sequence required to mitigate further movement of the adjacent bridge piers. Eventually additional micropiles were installed as part of a foundation retrofitting scheme to permanently transfer the foundations of the three existing bridge piers to rock.

Jet grouting was successfully applied to construct a base plug and vertical cut-off to stabilize the ground and enable excavation works to be performed in the dry. Micropiles were successfully applied to construct a foundation through the jet grout base plug as well as replacing the compromised existing bridge pier foundations. Full scale pre-production test programs were conducted for both jet grouting and micropiles. Details of the jet grouting, backflow preventer micropiles and bridge micropiles, including test programs and challenges encountered during construction are outlined in this paper.

PRELIMINARY DATA FROM 2014 GEOTECHNICAL INVESTIGATIONS OF A LARGE LANDSLIDE SITE AT QUYON, QUÉBEC

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A large landslide has been identified from a recent study near Quyon, Québec. The landslide covers an area approximately 14 km long and up to 4 km wide along the Quyon River, and is situated within Champlain Sea glaciomarine deposits. It has previously been interpreted to have been triggered by an earthquake about a thousand years ago. Geotechnical studies were conducted to investigate the minimum earthquake magnitude required to trigger the landslide. This paper presents the field and laboratory data collected from the 2014 geotechnical investigations. Ambient (noise) vibrations were measured to estimate the thickness of the Champlain clay deposits at 180 locations across the landslide zone. The data indicate that the fine sediment thickness (or depth to the bottom of the fines layer) ranges from near surface to 68 m. Cone penetrometer tests (CPT) were conducted at seven locations both inside and outside the landslide zone. The depth of the CPT ranged from 20 m to 40 m at refusal. Shelby sampling and vane shear testing (VST) were carried out to a 30 m depth at a CPT location outside the landslide scarp to calibrate the CPT data. The CPT cone tip resistance (Q_t) to undrained shear strength (S_u) factor (N_{kt}) was calibrated to be $N_{kt} = 10.5$. The CPT pore pressure (σ_u) to S_u factor ($N_{\sigma u}$) was calibrated to be $N_{\sigma u} = 10.0$. The VST and the calibrated CPT results of the undrained shear strength showed remarkable consistency. Soil sampling and handheld vane shear testing were also conducted at seven shallow boreholes along the Quyon River and its tributaries. The shallow test holes were drilled at the toe of the river banks to a maximum 4.5 m depth below river level. Laboratory tests were carried out to determine the geotechnical index properties of the soil samples collected from both the deep and shallow boreholes. The fine sediments encountered are classified as either silty clay or clayey silt with plasticity index ranged from 7.7% to 68.6%. The undrained shear strengths of the fine sediments from both the deep and shallow boreholes ranged from 22 kPa to about 300 kPa. The sensitivity of the soil samples ranged from 2 to 51.

LARGE DEFORMATION FINITE ELEMENT MODELING OF SOME FACTORS AFFECTING PROGRESSIVE FAILURE OF SENSITIVE CLAY SLOPES

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Many landslides in sensitive clay slopes near the riverbank in Eastern Canada and Scandinavia have been reported in the literature. Some of them extended over a large horizontal distance from the river bank. Traditional limit equilibrium methods cannot explain such failure because the failure surfaces develop progressively. Numerical modeling of such failure is very challenging because significant strain concentration occurs along the failure plane (shear band) and therefore huge mesh distortion occurs if typical finite element modeling technique is used. Moreover, the failed soil mass could move a significantly large distance.

In the present study, simulation of sensitive clay slopes failure using a large deformation finite element modeling technique will be presented. The post-peak degradation of shear strength and its effects on progressive failure surface development will be examined. Various factors such as the amount of toe erosion, height and angle of the slope, initial stress conditions will be examined. It will be shown that toe erosion could result in formation of horsts and grabens; however, it depends upon soil properties and geometry of the slope.

FOUNDATION DESIGN IN WARMING SALINE PERMAFROST IN LONGYEARBYEN, SVALBARD

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Longyearbyen, Svalbard (N78°13', E15°38') has experienced warming air temperatures during the last 25 years. The 30-year average mean annual air temperature has increased from -6.7 °C in 1988-1989 to -4.8 °C in 2014. Unusual warm winter temperatures have been observed especially during the last 10-15 years. This includes above 0 °C in January and February with rainfall. Ground temperature measurements indicate that the permafrost temperature at depth show an increasing trend as well. This paper discusses the consequences for existing pile foundations and shallow foundations in Longyearbyen. Mitigation techniques are discussed. In addition a methodology for foundation design in warming permafrost is presented.

STRUCTURAL AND DEFORMATION CHARACTERISTICS OF A ROCK GLACIER ON NORTHERN SLOPE OF KUNLUN MOUNTAIN, QINGHAI-TIBET PLATEAU, CHINA

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A large rock glacier in the cold mountain areas bordering the northern Qinghai-Tibetan Plateau was investigated. The composition, structure, thermal condition and ice (water) content were detected. This rock glacier has a relatively gentle slope and flows slowly downslope. It mainly consists of rock boulders and sandy silt. This rock glacier has a poorly sorted structure. The rock blocks immerse randomly in the finer-grained sandy silt matrix. The large boulders in front of and embodied in the rock glacier block the downslope flowage of the finer material. The ice (water) content increases with depth. In June, the water content in the active layer increases from 2.9 percent at the surface to 10.3 percent at the depth of 45 cm, while temperature ranges from 9.4 centigrade degree to below zero degree. The ice content may be higher than 50 percent at the bottom of the rock glacier.

The prediction of mechanical behavior of rock glacier has always been a problem, especially when the impact of ice and temperature should be considered. Numerical modeling technique and laboratory tests are utilized to study the mechanical behavior of rock glacier deposit. Laboratory geotechnical tests on the field collected samples were carried out to study the mechanical behavior of the deposit. Based on the laboratory tests results, a series of numerical simulations were conducted to obtain the mechanical parameters of the deposit. A four-phase mechanical model considering the interaction of ice, blocks, unfrozen water and finer grains was established. The influence of blocks and ice content on mechanical parameters was also studied. On the basis of the results of tests and simulation, the stability and the deformation feature of the rock glacier were simulated.

EFFECT OF CHEMICAL GROUTING ON THE SHEAR BEHAVIOR OF ROCK JOINTS

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Grouting of rock joints improves the characteristics of rock mass in various ways. It increases the shear strength of joints and enhances the deformation modulus of rock mass. Grouting of joints also results in decrease in permeability of rock mass. The joints can be grouted using either cement grouts or chemical grouts. In this article, the effect of chemical grouting on the shear behavior of rock joints is studied using laboratory direct shear test. The tests are carried out on different types of rocks under constant normal load (CNL) conditions. The effect of various parameters including joint aperture, type of rock and chemical grout on the shear strength of the joints are evaluated.

PRÉDICTION DES TASSEMENTS D'ESSAIS DE PLAQUE SUR DES ENROCHEMENTS DE ROMAINE-2 À PARTIR DES RÉSULTATS D'ESSAIS TRIAXIAUX ET ŒDOMÉTRIQUES

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Un total de 10 bancs d'essai d'enrochements de calibre 0-600 à 0-1800 mm ont été construits lors de la phase de conception des ouvrages du projet hydroélectrique de Romaine-2 en vue d'établir l'influence du calibre et des conditions de la mise en place sur leur déformabilité. Des essais de chargement ont alors été effectués sur une plaque circulaire de 750 mm de diamètre jusqu'à des charges pouvant atteindre de près de 450 kN. D'autres essais ont aussi été effectués durant la construction du barrage et de la digue F2. Des tassements compris entre 3 et 9 mm ont ainsi été mesurés sous une telle charge selon le type d'enrochement. De plus, des essais de cisaillement en cellule triaxiale et de compression en cellule œdométrique ont également été effectués sur des granulats issus de fragments de roc prélevés au site. Les résultats de ces essais ont servi à l'ajustement des paramètres de la loi de comportement de Nohari-Duncan implémentée dans le logiciel FLAC pour la conception des ouvrages de Romaine-2. Par la suite, la même loi de comportement a été utilisée dans cette recherche pour prédire les tassements mesurés lors des essais de chargement de plaque. Bien que la loi de comportement permette de reproduire l'essentiel du comportement des enrochements lors des essais de plaque, les tassements calculés sont nettement plus importants que ceux mesurés en chantier. Par conséquent, l'ajustement des paramètres de la loi de comportement comme celle de Nohari-Duncan à partir seulement des essais en laboratoire n'est pas aussi robuste qu'espéré, d'où la nécessité de valider de telles lois par des essais in situ.

VIRUSES IN ANCIENT ICE WEDGES IN CENTRAL YAKUTIA

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As part of microbial study of permafrost system were found viruses. In fact, viruses of bacteria play key role in the microbial life. Realizing transfer of genetic material, viruses regulate a population and variety of bacteria and involve in the cycle of organic material.

The study of the viral component of ancient microbial communities from permafrost is important for the understanding many fundamental questions. Such as evolution of microbial communities, possibility of their variations due to climate change, changes in the physical-chemical state of permafrost and practical questions of biosafety.

For the first time ever was discovered the virus particles in native samples of ice wedges Mammoth Mountain. Defined morphological diversity of viruses that can be attributed to five main types: miovirus, sifovirus, podovirus, spherical and filamentous.

Specific characteristic of these viruses are small size and fever genome. The addition to the bacterial genome ancient unknown genes of virus particles give a new unpredictable properties to bacteria and change the microflora's composition. Permafrost thawing due to the climatic change may lead to a possibility for these microorganisms and viruses to be expose to the existing Earth ecosystems. It cannot be excluded that occur a dangerous viral infection unknown origin from melting glaciers and permafrost ice accumulations of the Arctic and Antarctic as a result of climate change on the Earth.

Finally, microbial communities, including viruses, are an important component of permafrost and have stratigraphic and paleogeographic significance.

GEOTECHNICAL INVESTIGATION AT THE LONG LAKE CONTAINMENT FACILITY, EKATI DIAMOND MINE, NT

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The Long Lake Containment Facility (LLCF) at the Ekati Diamond Mine (Ekati) is the primary containment area for processed kimberlite generated during diamond ore processing. Processed kimberlite slurry is pumped to the LLCF where it is deposited in subaerial beaches. Ekati is located in an area of continuous permafrost terrain. The LLCF closure design comprises surface stabilization through vegetation and rock cover. Permafrost is expected to aggrade into the processed kimberlite, stabilizing the subsurface material.

In the winter of 2013 a geotechnical investigation was completed in the LLCF to investigate the in situ conditions of the deposited processed kimberlite and to evaluate permafrost aggradation in the facility. Boreholes were advanced at seven locations using a sonic drill rig and CRREL barrel, to obtain continuous core samples through the processed kimberlite and underlying foundation soils. Cone penetration testing was also completed where unfrozen soil was encountered, and ground temperature cables were installed to monitor ground temperatures. Index geotechnical testing and x-ray diffraction testing was completed on recovered samples to characterize the processed kimberlite and assess if notable differences, corresponding to varying deposition periods and ore sources, could be observed. Geochemical testing was also completed to evaluate the degree to which solute expulsion was occurring in the LLCF.

Investigation results indicate significant permafrost growth in the LLCF. Subsurface conditions at the borehole locations comprised layers of processed kimberlite and ice overlying lake bed materials and till. The soil stratigraphy was predominantly frozen in 6 of the 7 borehole locations, with unfrozen material encountered at the southern limits of the investigation area where the most recent processed kimberlite deposition had occurred. Geochemical testing on recovered samples suggest some expulsion of solutes during the freezing process.

This paper provides an overview of the investigation and summarizes the geotechnical and geochemical test results. Comparison with previous investigation results are also made to evaluate historical permafrost growth and material variations within the LLCF.

DESIGN PRINCIPLES FOR RIVER CONTROL STRUCTURES IN PERMAFROST AREAS

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Perennially frozen grounds within the channels of permafrost rivers are mostly confined to the large alluvial bars, where they reside either as newly formed lenses or remnants of the floodplain permafrost patches. In both cases, the largest alluvial forms are affected which influence the channel pattern and fluvial dynamics during the low-flow period. Surface and central parts of such bedforms show increased stability while the marginal parts experience intensive deformations.

Channel development pattern in presence of the frozen sandbars is well-studied and effectively reproduced in computational (model) experiments. This process introduces specific cryogenic constraints on the water management procedures for the Arctic rivers, causing the increase in both gross operating costs and waterways maintenance costs. Moreover, the hydraulic effectiveness of the river control structures can be significantly reduced whence the frozen state of the channel bed is ignored in the structure design. Within-channel permafrost, in our view, should thus be considered as a natural control over the fluvial activity of the Arctic rivers.

Most river control structures in the Arctic regions are implemented to reduce the risks of direct hydrological impact, e.g. flooding or bank erosion, for which purpose dykes and spurs are constructed. Dredging is frequently used to increase a waterways capacity during low flows. In both cases, design of those structures should account for a frozen state of channel bed and related fluvial activity, also with respect to potential geotechnical modifications to the thermal state of the channel alluvium.

Three design principles for water control structures can be implemented in the Arctic water management. Principle 1 ('frozen state' principle) requires the intentional freezing of certain channel bed areas to be used as a part of design projects. This principle is used, though sporadically, on the Lena River mostly for the dredging operation plans, when the pulp sinks are considered as subjects to subsequent freezing. In case of the control structures directly adjacent to

Principle 2 ('thaw state' principle) requires the initially frozen channel parts to be intentionally thawed as a part of the structure design. Permafrost degradation brings the channel section in compliance with the flow hydraulic structure.

Principle 3 ('as-is' principle) can be implemented when no intentional (artificial) changes in the thermal state of channel bed are planned, but the state of the ground (frozen/thawed) is explicitly accounted for in the hydrotechnical design. Numerous successful examples from Sakha (Yakutia) Republic will be demonstrated.

EXPERIMENT SETUP FOR SIMPLE SHEAR TESTS IN A TRIAXIAL CELL: TSS

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This paper documents the development of a new combined triaxial simple shear (TSS) apparatus. The TSS system consists of a simple shear apparatus incorporated in a triaxial cell for the measurements of static and dynamic characteristics of soil samples. Loading systems, mechanical parts, pressure transducers, and data acquisition systems are detailed described. The key application of TSS is the evaluation of liquefaction potential of soil under uniform or random motions. Sample results in terms of effective stress and excess pore pressure obtained using the new device on different soil samples and extracted from different sites are presented to illustrate its capabilities, and compare these results to those obtained using traditional liquefaction charts.

Keywords: TSS, triaxial, simple shear, liquefaction.

IS SUBMARINE GROUNDWATER DISCHARGE A CONTROL ON ARCTIC PERMAFROST-ASSOCIATED GAS HYDRATE FORMATION ON THE BEAUFORT SHELF?

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Methane hydrate is an ice-like solid that can sequester large quantities of methane gas in marine sediments along most continental margins where thermodynamic conditions permit its formation. Along the circum-Arctic shelf, relict permafrost-associated methane hydrate deposits formed when non-glaciated portions of the shelf experienced subaerial exposure during ocean transgressions. Gas hydrate stability and the permeability of circum-Arctic shelf sediments to gas migration is closely linked with relict submarine permafrost. Heat flow observations on the Alaskan North Slope and Canadian Beaufort Shelf suggest the movement of groundwater offshore, but direct observations of groundwater flow do not exist. Submarine groundwater discharge, an offshore flow of fresh terrestrial water, can affect the temperature and salinity field in shelf sediments, and may be an important factor in submarine permafrost and gas hydrate evolution on the Arctic continental shelf. Submarine groundwater discharge may also enhance the transport of organic matter for methanogenesis within marine sediments. Because it is buoyancy-driven, the velocity field also has a vertical (upward) component as it flows offshore. This combination of factors makes submarine groundwater discharge a likely mechanism for permafrost-associated gas hydrate formation on the Arctic continental shelf.

In this study, we quantitatively investigate the feasibility of submarine groundwater discharge as a control on permafrost-associated gas hydrate formation on the Arctic continental shelf, using the Canadian Beaufort Shelf as an example. We have developed a shelf-scale, two-dimensional numerical model based on the finite volume method for two-phase flow of pore fluid and methane gas within Arctic shelf sediments. The model tracks the evolution of the temperature, salinity, methane, pressure, hydrate, and permafrost fields given imposed boundary conditions, with latent heat of water ice and hydrate formation included. The permeability structure of the sediments is coupled to changes in the permafrost and gas hydrate deposits, and the model can be run over several glacial cycles. Model development and preliminary results will be presented.

INSAR MONITORING OF TRANSPORTATION INFRASTRUCTURE IN PERMAFROST REGIONS

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The combined effect of climate change and accelerated economic development in Northern regions increases the threat of permafrost related surface deformation of transportation infrastructure. Satellite based Synthetic Aperture Radar Interferometry (InSAR) provides a means for monitoring deformation over remote and spatially extensive areas and hence is potentially well suited for monitoring Northern roadways.

However, permafrost poses challenges for InSAR monitoring due to complex deformation patterns caused by both seasonal active layer fluctuations and long-term changes in permafrost thickness. These dynamics suggest a need for InSAR methods which provide deformation estimates with high spatial and temporal resolution. To address this requirement we have developed an InSAR method that 1) optimizes spatial resolution through adaptive filtering of both persistent and distributed InSAR scatterers, 2) provides high temporal resolution by combining multiple InSAR datasets.

Data for this work have been collected and analysed for a number of permafrost affected areas in Northern Canada including the Québec communities of Salluit and Umiujaq. Surface deformation estimates decomposed into long term linear deformation and seasonal active layer fluctuations are presented and compared to in situ data collected by project partners from the Centre d'Études Nordiques.

The proposed InSAR method is demonstrated to provide deformation estimates over the study areas with high spatial and temporal resolution and shows potential for mapping risks to infrastructure posed by both seasonal active layer deformation and long term changes to permafrost state.

INVESTIGATION ON THE BEHAVIOR OF ROCKFALL FLEXIBLE BARRIERS BY NUMERICAL SIMULATION

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One of the commonly protective measures against rockfall in roads and railways is flexible barrier kits. In this paper, the finite element method is used to study the behavior of this kind of barriers. The effect of various parameters such as rock block shape, angle and location of impact on mesh, number of spans, and use of energy dissipaters is presented. Based on the results of this research, some recommendations for cost-effective and safer protection of flexible barriers are made.

A CASE STUDY OF A LANDSLIDE ON HIGHWAY 20 NORTH OF CRAVEN, SK

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Saskatchewan's climate is classified as a semi-arid zone. However, the occurrence of rainfall events and the intensity of rainfall/day have increased significantly in recent years. An increased frequency and intensity of rainfall events results in more water infiltration and a subsequent increase in groundwater elevations and reduced soil suction in the side slopes. Higher groundwater levels and reduced soil suction are contributing to destabilizing marginally stable natural slopes and manmade fills across many valleys throughout Southern Saskatchewan.

Two such failures were observed on Highway 20 North of Craven, SK. Highway 20 has a number of high fills across ravines that feed into the Last Mountain Lake Valley just a few kilometer north of Craven where the highway starts to climb out of the valley. The fill at the location of the failure is more than 15 m, and a tension crack in the shoulder was observed in August 2014.

This paper documents the results of geohazard risk assessment, terrain analysis, site investigation, instrumentation monitoring, numerical slope stability and seepage analysis and evaluation of remediation options.

EFFECT OF CEMENTITIOUS AMENDMENT ON THE GEOCHEMICAL BEHAVIOR OF A SURFACE PASTE TAILINGS DISPOSAL

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Surface paste disposal (SPD) was a recently developed technique proposed as an alternative to the conventional tailings disposal. The main principle of this technique consists in removing up-stream water from tailings (thickening) and in depositing them at the surface in a pasty state. Thus, SPD may favour water recycling and the control of free water during deposition, reduces the need for costly retaining dikes, and also facilitates the mine site progressive rehabilitation. However, there are only a few studies on the environmental behavior SPD stacks. The objective of this paper aims in studying the geochemical behavior of a sulphur paste tailings deposit by using laboratory physical model (midsize box 2 m x 0.5 m). Paste tailings were prepared and deposited inside the physical model in nine layers. In a first stage, only the first two bottom layers were amended with cement (2wt. % of CP10 Portland cement). The tailings stack was wetted every four weeks with 40 L of water, followed by a drying period (wetting/drying cycle). The collected water was analysed for its chemistry and its volume measured. Wetting/drying cycles were performed for a long period (27 months). After that, a 10th layer of cemented tailings was deposited on top of the tailings stack to ensure encapsulation. Further testing was run until the 34th cycle. The results showed that the pH of the water remained around neutrality along the whole testing, although some diffuse oxidation that progressed along the preferential pathway was observed from surface before encapsulation. The evolution of leachates chemical quality over the time confirm the oxidation of sulphides (release of sulphate and metals as Zn, Cu, etc.) with a well correlated neutralization response by carbonates contained in the wastes. After the tenth cemented layer deposit, the evolution of metals concentration in the leachate collected after each wetting cycle has not much varied. However, the release of sulfate as well as magnesium slowed in the course of time demonstrating sulphide oxidation inhibition (decrease of the oxygen diffusion through the cement top barrier). While calcium concentration increased slightly due to limited cement dissolution.

Keywords: Surface paste disposal, cement amendment, sulphide oxidation, neutralisation, oxygen diffusion

IMPROVING WATER CONTENT DESCRIPTION IN SATURATED PERMAFROST SOILS

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The water content of permafrost soils is an important property with implications for engineering and permafrost processes. In soils with substantial excess ice, where water content approaches 100% (by volume), the gravimetric water content, typically expressed on a dry-weight basis (mass of water per unit mass of dry soil), becomes extremely high. This may make interpretation difficult. For this reason, despite its widespread use, dry-basis gravimetric water content is poorly suited to expressing the water content of ice-rich soils. Volumetric water content is the best representation of water content for most purposes, but volumetric water content determination requires samples of known volume that are difficult to obtain on a routine basis.

Some recent innovations that address this issue include the use of photogrammetric methods combined with dry-basis gravimetric methods to estimate volumetric water content (Kanevskiy et al. 2013, 2014), and the use of CT-scans to determine volumetric water content (Calmels and Allard 2008). However, these new methods require specialized training, equipment, and software. In addition, samples must be kept frozen before and during analysis. These conditions may be difficult to meet during summer fieldwork in remote locations, or expensive when numerous samples are required (e.g. Morse et al. 2009). We suggest that expressing water content using a wet-basis gravimetric method (mass of water per unit mass of field-moist soil) is useful for the routine reporting of water content in permafrost soils.

Samples from several locations in the western Canadian permafrost region, including alluvial, till, glaciolacustrine, and organic deposits, are used to illustrate the value of reporting wet-basis gravimetric water content. Comparison of different methods of expressing water content for the same samples shows that wet-basis gravimetric water content has better agreement with volumetric water content than does dry-basis gravimetric water content. Moreover, wet-basis gravimetric water content better represents the ice content of ice-rich soils, approaching a value of 100% in a pure ice layer. Our analysis shows that there is value in reporting wet-basis instead of dry-basis gravimetric water content when a cheap, simple method must be applied due to field constraints.

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MONITORING GEOHAZARDS NEAR PIPELINE CORRIDORS WITH AN ADVANCED INSAR TECHNIQUE AND GEOMECHANICAL MODELLING

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Pipeline owners and operators face numerous operational challenges from geohazards in pipeline corridors including landslides, tension cracks, slope creep, subsidence, and permafrost degradation. Current monitoring solutions used by industry include borehole instrumentation, manual inspections, and conventional surveys. Key challenges of these methods include obtaining high accuracy measurements over a broad geographic area including outside the pipeline right-of-way, and early and accurate identification of emerging geotechnical risks.

In this paper we present surface displacement results derived from Interferometric Synthetic Aperture Radar (InSAR) for the monitoring and risk assessment of geohazards near pipeline corridors. InSAR is a remote sensing technique that allows simultaneous high accuracy, fine spatial resolution (several metres) and broad spatial coverage (tens of kilometres) measurements of surface deformation. Our analysis uses a novel InSAR method, termed Homogenous Distributed Scatterer (HDS)-InSAR, which reduces the noise of low-backscatter areas such as asphalt and bare ground while optimally preserving the spatial resolution to increase both the accuracy and geographic precision of the deformation result.

Our analysis investigates how the InSAR results can be enhanced through integration with geomechanical models. Two and three-dimensional continuum and discontinuum numerical models can yield additional important insights into landslide failure mechanisms; InSAR-derived displacements both in space and time provide an excellent constraint for the geomechanical models.

Geohazard monitoring is demonstrated using InSAR and geomechanical modelling results over the Fels Glacier in Alaska. High-resolution InSAR stacks using the RADARSAT-2 sensor were acquired over Fels which is located next to the Trans-Alaska Pipeline and Richardson Highway. The area contains active deep-seated gravitational slope deformation (DSGSD) and has the potential for generating long-runout avalanches that could severely damage the pipeline and highway below. InSAR surface displacements coupled with geomechanical modelling results can be used to improve our understanding of landslide geohazards along pipeline corridors and provide a significant improvement compared to current monitoring practice.

THE ROLE OF LATERAL STRESS COEFFICIENT (K0) ON SHEAR WAVE VELOCITY CORRELATIONS FOR CANADIAN CLAYS

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The shear wave velocity, V_s , is a key parameter involved in the dynamic analysis of a soil deposit. It is related to the soil stiffness under very small-strains (G_{max}), only involving the soil density. Also, V_s is a fundamental parameter allowing characterization of a soil in the elastic range ($\gamma < 10^{-3}$). Several empirical correlations have been suggested in order to estimate V_s for a given soil based on its geotechnical properties. Most correlations are based on void ratio, overconsolidation pressure, plasticity and mean effective stress. The latter is significant, but moreover, one requires two parameters to obtain its value, namely the effective vertical stress and the lateral stress coefficient at-rest. While the effective vertical stress is readily available, using the correct value of K_0 is more challenging and may limit the use of such correlations. The coefficient K_0 represents the anisotropy under no lateral strains conditions. Nowadays, several methods are proposed to measure K_0 in laboratory, in-situ and via empirical correlations. However, several researches show an important scatter between the different values of K_0 depending on the adopted method of measurement. In the present paper, a database of various deposits of Canadian clays is presented and used for this analysis. Chosen sites are well characterized in terms of water content, plasticity, void ratio, and preconsolidation stress. For these sites, K_0 was quantified using one or more techniques. Then, the range of V_s calculated from various values of K_0 for different forms of V_s correlations is presented. The results show the magnitude of V_s values revealed from correlations by using the available values of K_0 . This paper allows to appreciate the impact of K_0 on the mean effective stress and therefore on shear wave velocity correlations.

NEW TECHNIQUES FOR MAPPING PERMAFROST CONDITIONS

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Mapping changing permafrost conditions such as thawing soils, ground ice melt out and terrain instability is crucial to northern development. Unfortunately, until recently the remote hostile arctic environment made it difficult and costly to undertake detailed and in-depth site investigations prior to construction. In today's rapidly changing climatic conditions it is even more important to quantify the terrain sensitivities before disturbance.

By utilizing emerging remote sensing technology, terrain mapping and monitoring can now be accomplished in greater spatial and temporal detail than ever before. In this presentation we present the results of our recent work on the application of SAR interferometry, unmanned aerial vehicle remote sensing, ground-based time-lapse photogrammetry and object-based image analysis. These data sources are used to generate ultra-high resolution maps, digital terrain models and ground motion calculations at the millimetre scale on as frequent as a daily basis. The added advantage of these emerging techniques is an order of magnitude cost savings for data acquisition.

PREDICTION OF GROUND TEMPERATURES FOR A PIPELINE ROUTE FROM ALBERTA TO QUEBEC AND OKLAHOMA

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Prediction of the ground temperature at depths of 0.9, 1.2, and 1.5 m was carried out for 4 seasons (winter, spring, summer, and autumn). A one-dimensional version of software SIMTEMP developed in-house by AMEC Foster Wheeler with various boundary conditions (temperature, heat flux, Newton Law) and Stefan conditions within freezing zone were used for the predictions. The entire length of the pipeline is approximately 5,800 km. The pipeline route crosses various soil types, various climate and vegetation zones and agricultural lands with various planting and harvesting dates. For this study, the following main tasks were completed: 1. Review of mean annual and mean monthly air temperatures, wind speed, snow depth, net solar radiation, and evaporation. The climate parameters were used to calculate the upper boundary conditions of the geothermal model. 2. Determination of typical soil types based on soil composition, density and moisture content. The soil type identification was based on available surficial geology maps published by the Canadian and U.S. Geological Survey, and on archival data available from Enbridge Pipelines Inc. 3. Identification of vegetation zones and agricultural fields. The majority of the pipeline route crosses undeveloped grasslands or cultivated fields. The insulating influence of the ground vegetation (agricultural crops and perennial grasses) on ground temperature was assessed as a thermal resistance during growing period (for crops) or year around (for grasses). Various vegetation maps and information available from web sites which describe planting and harvesting dates were used for assessment of ground vegetation conditions. 4. Outlining geotechnical districts. Each geotechnical district was characterized by a specific set of climate, vegetation type and soil parameters. 5. Assessment of soil thermal conductivities and volumetric heat capacity. These soil thermal parameters (frozen and unfrozen values) were either calculated with the use of empirical relationship from literature or were based on published data. 6. Conducting geothermal modeling.

Based on the results of modeling, graphs of the predicted ground temperatures at various depths for the 4 seasons of a year are presented for the identified geotechnical districts. Sensitivity analyses were conducted to evaluate the impact of soil volumetric heat capacity, soil thermal conductivity, climate parameters and various agricultural crops on the predicted ground temperature from Alberta to Oklahoma.

EVIDENCE IN FAVOR OF THAT OVER THE PLEISTOCENE CRYODIVERSITY IN NORTHWESTERN SIBERIA DEVELOPED AS INTERACTION OF PERMAFROST AND MOUNTAIN GLACIERS BUT NOT OF ICE SHEETS

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Originating in the Early Pleistocene, permafrost in Northwestern Siberia exists so far and includes such indicators of strong freezing as repeated ice wedges. The permafrost area fluctuated in size but always occupied a vast space. Nevertheless, some researchers suppose giant Pleistocene ice sheets covering all terrain of Northwestern Siberia, though to explain their combined development with permafrost is impossible. The sheets must transform their frozen bed and ground ice thereof, whereas the latter occur in the fair preservation.

For a long time study of glaciation in Siberia was carried out on the base of the Alpine concept defining high snow supply and ice turnover to form the glaciers considered then as so-called warm ice which is, for the most its part, on the ground outside the permafrost area. They must grow quickly under a cooling, since the snow supply is firstly enough against sharp ablation decrease yielded by the cooling. Such a process will go until the humid and cold stage of the cooling will change by the dry and cold stage. Under initial high moistening the glaciation reached the sheet form over geologically short, relatively, Pleistocene cryochrones. This model is suitable to explain forming the past ice sheets in Northern Europe moistened from the Atlantic; however it is not suitable in Siberia where cold and enough dry environments prevailed over the Quaternary as an effect of cryoaridization (permafrost promoting under cold and arid conditions). Therefore the glaciation in Siberia was denied for a long time, whereas use of the Alpine-type rules yielded reconstructions of giant ice sheets alien to Siberia.

In spite of low snow supply and active ablation (an attribute of continental climate) the glaciers in Siberia exist due to big cold storage in their bodies: it keeps additional ice feeding, when thawed water repeatedly freezes on their surface. Being under the initial developed cold and dry stage, the glaciers reacted to the cooling by slow growth. Their snow supply decreased as the cryoaridization was stronger, and during the cryochrones they, gradually absorbing scanty supply, reached the valley form only.

Continental climate in Siberia made conditional on the particular environments to form glaciers interacted with permafrost. They become a new element of cryodiversity (a set of objects and phenomena produced by cold), and differ from those considered as of the Alpine glaciation model, and obtain properties which are more characteristic for permafrost objects, than for the Alpine-type glaciers.

RATIONALIZING THE DESIGN OF ADFREEZE STEEL PIPE PILES WITH LIMIT STATES DESIGN

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Adfreeze steel pipe piles are a commonly used foundation type in permafrost areas and are well suited to relatively light loads. The strength of the permafrost into which the piles are installed is time-dependent. Permafrost has higher resistance to short-term loads than sustained loads, all else being equal. Adfreeze piles are designed by assuming that they will settle in creep under load, over the life of the structure being supported.

The capacity of adfreeze piles is dependent on the pile configuration, the nature of the load being applied, the characteristics of the permafrost, and the allowable deformation of the structure being supported. Pile capacity can be optimized by taking into account the duration of the various types of loading be imposed on the pile. It is proposed that this be done by considering long-term and short-term loading separately. Long-term loads would be dead load and sustained live load, such as occupancy live load. Short-term loads would typically environmentally imposed live loads.

In the context of Limit States Design, allowing for deformation is analogous to Serviceability Limit State (SLS). It is not practical to think of adfreeze pile capacity in terms of an Ultimate Limit State (ULS). Consequently, it is proposed that piles should be designed by referencing service (unfactored) loads. Designing for factored loads may be unnecessarily conservative. An approach to maintaining appropriate conservatism under SLS is proposed.

**ADFREEZE PILE DESIGN FOR BRIDGES ALONG THE INUVIK TO TUKTOYAKTUK HIGHWAY,
NORTHWEST TERRITORIES**

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The Inuvik to Tuktoyaktuk Highway (ITH) consists of 140 km of two-lane, gravel surfaced, roadway that is currently under construction, and will provide an all-weather connection to the community of Tuktoyaktuk, NT and the Arctic Coast when the highway is completed in 2017. The route will include eight bridges.

The route is underlain by continuous permafrost, much of it ice-rich. Bedrock is generally too deep to be accessed for foundation construction. Mean annual ground temperatures ranged from about -1.8°C to -4.3°C in boreholes drilled in the vicinity of proposed bridge locations. Adfreeze steel pipe piles were selected as the foundation type for the bridges, considering the site conditions.

Adfreeze steel pipe piles are generally suited to relatively light loads, particularly in relatively warm permafrost (-2°C and warmer). Bridge loads tend not to be light. There is not much precedent for the use of adfreeze steel pipe piles as bridge foundations. There were two particular challenges for the designs in this application:

The strength of permafrost is time-dependent. Adfreeze piles are designed by assuming they will settle in creep under load. The capacity of adfreeze piles is dependent on the pile configuration, the nature of the load being applied, the subsurface conditions, and the allowable deformation of the structure. For these bridges, traffic live load was a high proportion of the overall foundation load. Permafrost has higher resistance to short-term loads than sustained loads, all else being equal. The short duration of individual traffic load events was taken into account to justify correspondingly high capacities for this component of the loading. This contributed to adfreeze piles being a practical foundation alternative for this application.

The bridges are required to have a design life of 75 years. The potential impacts of climate change over this interval needed to be considered in the design. Considering ground temperature response to projected air temperatures alone, it is likely that permafrost will approach the onset of thaw over the design life of the bridges. While some factors, such as snow clearing and shading at pier locations, may mitigate the impact on ground temperatures, overall warming of the permafrost should be anticipated. A strategy is being implemented to monitor ground temperature response and implement mitigative measures to the bridge foundations, if pile capacity is determined to be compromised in the future.

FIELD MEASUREMENTS OF PERMAFROST CONDITIONS BESIDE THE DEMPSTER HIGHWAY EMBANKMENT, PEEL PLATEAU, NWT

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Permafrost degradation caused by climate warming is already affecting northern infrastructure construction and maintenance. These problems may be exacerbated because infrastructure may trap snow, limiting ground heat loss in winter. In addition, linear infrastructure commonly crosses natural drainage networks, causing water to accumulate, and increasing the amount of latent heat that must dissipate during active-layer freezeback.

The objectives of this study were: (1) to characterize permafrost conditions at the toe of the Dempster Highway road embankment on Peel Plateau, NWT, (2) to assess the thermal influence of snow and moisture accumulation along the roadway, and (3) to compare ground thermal conditions at the embankment toe with undisturbed tundra. Permafrost on Peel Plateau is ice-rich and within a few degrees of 0 °C. Significant road maintenance has been necessary to address permafrost-related issues.

Permafrost temperatures were measured in 2012-14 at five tundra sites at the toe of the embankment on Peel Plateau using shallow thermistor cables, with sensors at 0.05, 0.2, 0.5, and 1 m, and with cables to 8-m depth. Control sites were located in undisturbed tundra away from the road. Active-layer thickness was estimated from temperature profiles for the sites at the road, and by probing at the control sites.

Mean annual ground temperature near 5-m depth at the road sites ranged between -2.2 and -0.02 °C. At three of the five sites, the temperature was >-1 °C. Temperature profiles indicated that permafrost is degrading at four of the five sites, whereas conditions were near equilibrium at control sites. Active-layer thicknesses at the four degrading sites were between about 2 and 5 m, but commonly < 1 m in undisturbed tundra. Probing in August 2014 identified taliks at some locations beside the road. The high ground temperatures at road sites are associated with enhanced snow and moisture accumulation along the embankment. Given the current thermal state of permafrost beside the embankment and the ice-rich substrate throughout the study region, active snow management should be considered to reduce ground temperatures in the areas most susceptible to thaw subsidence.

DEW LINE THERMAL LANDFILL MONITORING DATA

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The DEW Line Clean Up project remediated 21 military sites across the arctic. The clean up included remediating existing landfills and constructing new landfills for contaminated soil. Construction was from 1996 to 2014.

Thermal and geochemical monitoring at the sites is ongoing. The thermal behavior in 28 landfills are being monitored by 103 vertical ground temperature cables (GTC). Data loggers record temperatures twice a day. Up to 16 years of data from the sites is now available.

The landfills are constructed using a combination of geomembrane liners and sufficient granular soil cover to maintain the majority of the landfill waste in a frozen state.

Data from across the Arctic is presented. The thermal data has been synthesized to examine correlations with active layer and mean annual ground temperatures to the thawing indices and mean annual air temperature. The data shows that three or four years are required for the ground temperature to stabilize. Following stabilization, the annual variation in active layer and mean annual ground temperature follows the expected pattern. The variability in soil conditions and other climate factors make it difficult to develop a definitive multi-site correlation.

ALTITUDINAL ZONATION OF MOUNTAIN FROZEN GROUNDS IN SOUTHERN PATAGONIA

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South end of the Southern Patagonian Ice-Field is a geographically active area with several glaciers on fast retreat. The area of study, Paso John Gardner (PJG) at 1.200m a.s.l, is a periglacial environment presenting several features of cryogenic activity. PJG is located; 2km East, 3km Northwest and 7km South from Grey, Los Perros/Olguín and Olvidado glaciers respectively, inside the Paine Towers National Park, Chile. The area presents diffuse polygonal grounds and a scarce vegetal cover limited to lichen and moss. Snow cover is mostly wind-blown during winter and absent during warm season. The site was visited during both warm and cold season.

1.5 kilometers westward down from PJG, Grey glacier's moraine diffuses enough to become a terrace with a consistent vegetal cover, having 30cm of thickness. This is also the lower limit of the tree line for a *Nothofagus antarctica* and *Nothofagus pumilio* forest, which ranges between the 200 and 1.000 meters of altitude. Differential frost action by altitude lapse rate effect should account for the absence of shallow geocryological features in this terrace, regardless of the glacier's proximity. Both sites are located at the same latitude, 1.500m from each other.

Altitudinal lapse rate accounting for the differentiation of these two seasonally frozen areas was assessed by studying PJG's MAAT, ground temperature and comparing the soil profiles of both areas.

Temperatures above 0°C were evidenced down to 1.8m depth during winter of 2014 in PJG, ruling out the existence of permafrost at that lower limit. PJG presented winter ground temperatures even lower than some historical measurements from Tierra del Fuego, 500km south from PJG, but its mean annual temperature is higher.

The area of PJG shows a decreasing geocryological activity and part of its periglacial features are considered to be due to past events of higher influence, such as highly present snow hydrology which is now restricted to mere patches in the area. Wind-blown snow is considered an important factor avoiding snow accumulation and insulation during winter months, in contrast to the lower altitude terraces which remain snow-covered during cold season.

PJG's grounds suggest the future lowering of frost and snow action on its surface. This is to be further verified by inter-annual monitoring of the area.

The present work is part of an ongoing monitoring network along South America that intends to fill the gap between tropical Andes and the Antarctic Peninsula.

THE INFLUENCE OF A CAVITY AIR FRACTION ON THE INTERPRETATION OF RESULTS FROM HYDRAULIC PULSE TESTS

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This paper presents results that are supplemental to material that will be presented in a forthcoming paper [1] dealing with the use of hydraulic pulse tests for the estimation of the fluid transport characteristics of a granitic rock. The laboratory estimation of permeability can be performed using either steady state or transient tests. Hydraulic pulse tests offer the quickest approach for estimating fluid transport characteristics of low permeability materials but requires attention to other peripheral properties including the porosity of the rock, the deformability characteristics of the porous skeleton, the compressibility of the grains and degree of saturation of the fluid cavity that is being pressurized. While all these parameters and their variability can influence the estimated permeability, the present investigation examines the influence of the air fraction in the pressurized cavity on the estimated permeability.

A cylindrical sample of granite containing a sealed fluid-filled cylindrical cavity was used. The sample measured 15.24 cm in diameter and 30.48 cm in height containing a cylindrical cavity partially drilled along the central axis of the sample with a diameter of 2.54 cm and a depth of 15.24 cm. The permeability of the sample was first estimated using steady a state technique. A series of hydraulic pulse tests were then conducted on the same sample at three different initial cavity fluid pressures ranging from 100 kPa to 750 kPa. It was observed that the rate of water pressure decay was pressure-dependent which cannot be explained by piezo-conduction equation, based on the assumption of full saturation of the cavity. Also, the permeability values were 1 to 3 orders of magnitude less than the permeability obtained from steady state testing technique. It was seen that the assumption of having de-aired water in the pressurization cavity and using the fluid compressibility of de-aired water in the analysis of hydraulic pulse tests can lead to an underestimation of the permeability parameter since air voids can exist in the cavity and increase the compressibility of the fluid significantly. A technique was suggested to take into account the influence of air voids in the pressurization cavity on the interpretation of hydraulic pulse test results, with only saturated flow within the porous region. COMSOL MultiphysicsTM was used to analyse the test results.

[1] Selvadurai, A.P.S. and Najari, M. (2015) Laboratory-scale hydraulic pulse testing: Influence of an air fraction in the fluid-filled cavity on the estimation of permeability, *Geotechnique* (in press).

NUMERICAL MODELING OF A DEEP EXCAVATION BEHAVIOR IN OVERCONSOLIDATED CLAY: THE IMPACT OF SOIL MODEL

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To simulate the behavior of a deep excavation under service loads, usually a linear-elastic coupled with perfect plasticity criterion model is assumed to be representative for the soil behaviour. In order to accommodate the excavation strains, adjustments are made to the elastic soil modulus. This, can be sufficient to predict wall deflections but usually leads to imprecise estimation of soil settlements.

In this paper, an instrumented, 20 m depth excavation in Taipei (Taiwan) is simulated. In addition to linear elasticity, three more sophisticated models have been adopted: The Hardening Soil (HS), the Hardening Soil with Small-Strains (HSS) and the Hypoelasticity. These models can accurately represent the overconsolidated Taipei clays behaviour.

The work presented in this paper shows that using a nonlinear model for the overconsolidated Taipei clay, leads to a satisfactory simulation of the wall deflection and the soil settlement.

KEY WORDS: Deep excavations, Numerical modeling, Overconsolidated clay, Soil models.

DÉVELOPPEMENT D'UN MODÈLE MÉCANISTE-EMPIRIQUE DE PRÉDICTION DE L'UNI DES CHAUSSÉES FLEXIBLES

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L'uni est la distorsion à la surface de la chaussée qui affecte la qualité de roulement, la sécurité et le coût d'utilisation des automobiles. C'est un phénomène représenté par l'Indice de Rugosité Internationale (IRI), développé par la Banque Mondiale en 1982. Bien que la représentation de l'IRI par le modèle « quart de voiture » fait consensus à cause de sa reproductibilité et sa stabilité dans le temps, mais sa prédiction est empirique et reste un axe qui demande encore d'amélioration.

L'état empirique des modèles de prédiction de l'uni est dû aux complexités qui caractérisent le processus de la dégradation de la chaussée et du phénomène de l'uni lui-même.

Le modèle que nous avons développé part de cette conscience de complexité en proposant un modèle mécaniste-empirique. Un modèle mécaniste-empirique suppose que la dérivation de la forme mathématique est basée sur la physique et la mécanique du phénomène d'une part et d'autres part des régressions statistiques pour la calibration et la précision du modèle.

Quatre hypothèses ont été posées en vue établir le modèle : la variation de l'uni est due à la déformation permanente et du soulèvement au gel du sol d'infrastructure, 1 à 9m sont les longueurs d'onde qui induisent le phénomène d'uni, les fissures transversales sont considérées comme des facteurs aggravants et le modèle n'est valable que pendant la durée de vie utile d'une chaussée.

Des modèles de prédiction de la déformation permanente (Développé dans le cadre du projet) et du soulèvement au gel (Konrad,1999) considérant les propriétés des sols comme le pourcentage des fines, le pourcentage d'argile, le coefficient de courbure, la surface spécifique, le degré de saturation et la densité sèche ont été adoptés pour tester la sensibilité du modèle. La variabilité spatiale des ces propriétés entraîne une variabilité spatiale des phénomènes de déformation permanente et du soulèvement au gel et d'où l'uni.

Pour valider le modèle, des bases de données des chaussées en service du Ministère de Transport du Québec et de la Chaire i3c de l'Université Laval ont été exploitées. En plus, des essais de caractérisation ont été complétés sur des échantillons des sols d'infrastructure prélevés à 4-5m sur les bordures de ces chaussées en service.

ÉTUDE NUMÉRIQUE DE LA POUSSÉE DYNAMIQUE DES TERRES SUR LES MURS DE SOUTÈNEMENT RIGIDES

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La détermination des pressions dynamiques des terres en présence d'eau est l'un des problèmes les plus compliqués en géotechnique. Les secousses sismiques violentes, induisent souvent la rupture des structures de soutènement accompagnée par la liquéfaction du sol soutenu particulièrement dans le cas des sols saturés. Avec peu de comparaison avec des ouvrages auscultés et observés, les méthodes de calcul théorique disponibles en littérature restent incapables de résoudre les problèmes envisagés. Dans cette étude, l'interaction sol-structure est prise en compte. Des divergences sont notées dans l'estimation des pressions des terres et les mécanismes de rupture générés par les tremblements de terre. La modélisation numérique de cette étude est réalisée en utilisant le code PLAXIS 2D basé sur la méthode des éléments finis. Les valeurs numériques obtenues par cette étude sont comparées avec ceux disponibles dans la littérature .

Mots clés : Soutènement, poussée, séisme, modélisation numérique, PLAXIS.

THE CALCULATION OF LANDSLIDE SLIDE THRUST LOAD AND LENGTH OF ANTI-SLIDE PILE IN WULONG LANDSLIDE TREATMENT ENGINEERING USING NUMERICAL LIMIT ANALYSIS METHOD

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Wulong county of China is located on a large-scale landslide. The monitored data shows that there is a deformation trend and still under development, which threatens the live of 400000 residents. The large-scale landslide is 340 m long and 35 m thick. Landslide thrust is up to 8600 kN/m. A row piles cannot resist such a huge landslide thrust. So four row anti-slide pile are used in this landslide treatment. According to the traditional design method, the anti sliding length is up to 50 meters. The moment and section area of anti-slide pile are very large, high cost, and difficult to construct. Can we shorten the length of the pile ? The first problem is how to calculate the length of the pile. The second problem is how to calculate the landslide thrust load acting on the four row pile? A new design method was adopt. That is called numerical limit analysis method. The stability safety factor with different length of ant-slide pile are calculated by strength reduction method. According to Chinese landslide design code, the slide stability safety factor need to be up to 1.4 for the first safety grade treatment engineering. Through a series of calculation using c-tan ϕ reduction algorithm, the economic pile length are obtained when the stability safety factor reach to 1.4. Using this method the landslide thrust load acting on the every pile are calculated at the same time. It is found that landslide thrust load proportional coefficient between the four pile was unchanged even the design safety factor and strength parameters changed. As a result ,the length of piles was reduced by about 1/3. Project costs was saved. After the completion of the project, the surface displacement and deep hole displacement and steel bar tensile force were monitored for 2 years. The monitored data showed the landslide keep stability with the ant-slide pile. It also indicated that it is feasible to use the numerical limit analysis method to calculate the length of pile and landslide trust load.

**SIMULATION OF HYDRO-MECHANICAL BEHAVIOR OF ROCK DURING BRITTLE FAILURE
CONSIDERING THE GRAIN-SCALE HETEROGENEITY OF REAL ROCK MATERIAL**

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This paper presents a grain-based discrete element model for simulating the quasi-brittle failure of rocks under hydro-mechanical loading. In this approach, the development of crack along grain boundaries controls the degree of damage and the associated permeability alteration in rock. As a result, the overall permeability of the model, which is a function of degree of micro-cracking and crack connectivity, can be calculated at each stress state. A cohesive crack model is implemented into the UDEC distinct element numerical code to define the constitutive behavior of grain interfaces in both tensile and compressive states. The influence of micro-scale heterogeneity of real rock due to the contrast in mechanical properties of constituent minerals of rock is introduced to the model by assigning material. The rock heterogeneity, due to the presence of different mineral grains, is introduced to the model by considering the mineral composition of real rock and contrast in mineral mechanical properties. The elastic properties of the grains and the strength properties at grain boundaries are extracted based on the experimental data. Then, the capability of the model to replicate the hydro-mechanical behavior of Lac du Bonnet granite under compression and tension is evaluated. To do so, a series of uniaxial and triaxial compression and Brazilian tests is simulated. In addition, the relation between macro-properties such as strength, friction and cohesion of the model and input micro-mechanical properties assigned to grains and interfaces is investigated.

The numerical experimentations demonstrate the capability of this micro-mechanical model to mimic the pre- and post-failure response of polycrystalline geomaterials and corresponding rock permeability. The calibrated model very accurately predicts, in a quantitative sense, the macroscopic properties of real granite such as elastic properties, damage thresholds (crack initiation and interaction stresses), peak strength (tensile and compression strengths), triaxial strength envelope (friction angle and cohesion) and dilation angle. Calculated permeability evolution of the model in pre- and post-failure states compares well with experimental observations, in which the permeability decreases by 2 orders of magnitude from its non-stressed permeability (5×10^{-20}) prior to rupture of rock, while interaction of cracks leads to an additional 3 orders of magnitude increase for post-failure permeability. It is also demonstrated that coupling between the pore fluid pressure and solid constituents of rock plays an important role on cracking-driven failure process and resultant permeability of brittle materials.

BENCHMARKING AND SPEED IMPROVEMENTS IN A 2D/3D GEOTECHNICAL STRESS/DEFORMATION SOLVER

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Economic growth in developing countries has resulted in an increased focus on construction activities. These activities have increased the focus on solving 2D/3D stress/deformation foundation-related problems. SoilVision Systems Ltd. has been performing research on new related technologies in an internal research program over the past four years. The research is implemented in a finite element stress/deformation solver which is capable of solving large 3D models with speed improvements. This paper presents the benchmarks related to the 2D and 3D performance of the solver and demonstrates speed improvements. The new technology is suited for the solution of larger 3D models in reduced time periods.

A LONGITUDINAL SURVEY OF EXPERIENTIAL FIELD-BASED LEARNING IN GEOLOGICAL SCIENCES AND GEOLOGICAL ENGINEERING (GS&GE) AT QUEEN'S UNIVERSITY USING STUDENT ASSESSMENT OF LEARNING GAINS (SALG)

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A basic tenet of professional programmes is that experiential learning is critical to practice. Our hypothesis is that field-based learning, specifically engineering site investigation and geological mapping, is essential because it develops the habit of mind of integrating sparse, disparate observations into meaningful conceptual models and helps students transition from learner to expert. Queen's GS&GE currently offers up to 17 courses with a field component, beginning with two concentrated courses in 2nd year; fall term field methods (6 half days in the field) followed by the 12 day spring field school. In these and other upper year courses students learn and integrate basic principles and skills and demonstrate the ability to 1) make reliable field measurements, 2) identify and recognize engineering characteristics of earth materials and structures, and 3) display spatial and temporal reasoning. While our belief is that field-based learning is transformative, and enhances theoretical learning, there is a need for quantitative evidence of its effect on, and importance to, geological engineering students. In order to investigate the nature of student field experiences and their perceptions of learning gains, we have completed a pilot study and initiated a longitudinal survey of current students in YRs 2 to 4. The SALG survey instrument consists of demographic queries and 4 parts each consisting of 10 Likert-like items to assess gains in the areas of: 1) thinking and working like a geoengineer, 2) skills development, 3) confidence and comfort in fieldwork, and 4) changes in attitudes and behaviour. The response rate for the pilot study was ~20%, and broadly representative of the three years. The reliability was good on the basis of alphas greater than 0.7 for each of the four subsections and overall. Scores for individuals correlate well with their written comments. Although the YR3 median scores for the four subsections of the survey are greater than those for YR2, the differences are not statistically significant possibly because students spend less time on concentrated field-work in YR3. The much higher median scores in each subsection for students nearing graduation indicates that major gains occur in all areas in the latter half of YR4, probably owing to their work in the capstone design project. Most individual item scores show a year-to-year increase that we interpret as indicating a progression of skills development and an evolution from emerging to mastery of the stated learning outcomes for course-related field-work.

IMPROVEMENT OF EXPANSIVE CLAY SOILS USING LIQUID POLYMER STABILIZER

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The clay soil deposits of high plasticity and high swelling potential behavior have a great impact on structures built-in, built-on or built through such deficient soils. Moisture variation in such expansive soils results in a corresponding volume change in different seasons. The restriction to free swell of such soils under an existing structure causes significant distress which may eventually result in some geotechnical hazards. Therefore, it is necessary to evaluate the swelling potential of the foundation soils and take suitable measures to mitigate such challenges. In the present study, the effects of liquid polymer stabilizer to control swelling/shrinkage characteristics of expansive soils were investigated. For this purpose, different tests, including Atterberg Limits, standard compaction, swelling potential and consolidation test, were conducted on the control and treated soil samples using different proportions of Polymer. Also Linear shrinkage test and temperature tests were also conducted on the control and treated samples. For proper evaluation of these tests, the treated samples with polymer in different percentages were allowed for curing periods of 7 and 15 days. The results showed that soil treated with the polymer, caused improvement of the soil behavior with significant reduction in plasticity, shrinkage, swelling potential and pressure. The results also indicated that the temperature had a relatively significant effect on the plasticity and swelling properties of the treated samples.

EVALUATION OF DSS TEST RESULTS ON GRANULAR SOILS BASED ON TSS RESULTS

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Although dynamic simple shear (DSS) tests represent quite well the soil conditions subject to shakings; one of its drawbacks is its lack to reflect the change of soil confining pressure. This defect is in turn altering the test results that are traditionally used to construct liquefaction potential charts. In this paper; the new combined triaxial simple shear (TSS) apparatus has been employed to evaluate the DSS test results on granular soils. The TSS system consists of a dynamic simple shear apparatus incorporated in a triaxial cell for the measurements of dynamic characteristics of soil samples under control stress and drainage conditions. Two series of TSS tests without (DSS) and with varying confining pressures have been conducted and the results demonstrated that the TSS results should replaced the DSS results in evaluating liquefaction potential of granular soils.

REMOVAL OF ARSENIC FROM CONTAMINATED WATER AND ITS STABILIZATION IN SOIL USING IRON/COPPER NANOPARTICLES

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Heavy metals contaminated soils and waters pose a major environmental and human health problem. Arsenic as a metal is causing a global epidemic of poisoning and has been associated with skin lesions, cancers and other symptoms. Contamination of water by arsenic has become a crucial water quality problem in many parts of the world considering the fact that the source of pollution is mostly the contaminated soils. Several remediation methods have been tried to stabilize or remove arsenic from polluted soils. Although most of these methods are effective for arsenic removal, the associated high cost makes them prohibitive to use in many circumstances. In order to overcome this problem many new technologies are being developed, among them using nanoparticles as a new class of adsorbents has received a great deal of attention. Because of their high specific surface area and higher surface reactivity due to their extremely small sizes, nanoparticles provide a large number of active sites for adsorption. Moreover, due to their smaller sizes, nanoparticles can easily be transported to the target zone of contaminated aquifer for in-situ remediation. In this research, iron/copper bimetallic nanoparticles were synthesized to remove arsenic from aqueous solutions as well as to stabilize arsenic in a soil matrix. In order to determine the effectiveness of Fe/Cu nanoparticles for arsenic removal, sorption tests were performed with aqueous arsenic solutions of three different concentrations: 100, 500 and 1000 $\mu\text{g/L}$ (typical of contamination in polluted aquifers) with varying doses of nanoparticles (10, 50 and 100 mg/L).

Detailed characterization of synthesized nanoparticles through XRD, XPS, TEM and BET analyses confirmed the successful formation of hybrid Fe/Cu nanoparticles with the mean diameter of 13.17 nm. These hybrid nanoparticles were found to be effective in removing arsenic from aqueous solutions. Arsenic removal in the range of 69 to 85% and 93 to 96% were observed for As (III) and As (V), respectively (with dosage of 100 mg/L of nanoparticles). To evaluate the efficiency of Fe/Cu hybrid nanoparticles in stabilizing arsenic in contaminated soils, several batch and column experiments are being performed and the result will be presented.

MISE EN ÉVIDENCE EXPÉRIMENTALE DU DOSAGE OPTIMAL DES CIMENTS COMPOSÉS (LIANTS) UTILISÉS DANS LA FABRICATION DE REMBLAIS EN PÂTE CIMENTÉS

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Le remblai en pâte cimenté (RPC) est un mélange de résidus miniers filtrés, d'un agent liant et d'eau de mélange. L'agent liant peut être soit du ciment Portland seul ou composé avec un ajout minéral (slag, cendres volantes, autres réactifs pouzzolaniques). Généralement, la résistance mécanique des remblais augmente avec l'augmentation de la quantité de liant. Cependant, les coûts du remblayage minier représentent une part importante des coûts d'exploitation d'une mine souterraine, soit entre 10% et 20% du coût total et le liant détient la plus grosse part budgétaire (~80%). Ce coût pourrait être réduit avec la substitution partielle du ciment par des ajouts minéraux moins chers. Mais il peut arriver qu'un ajout minéral coûte plus cher que le ciment; d'où la nécessité du choix d'un liant alternatif à performance équivalente des liants conventionnels. Aussi, lors des phases d'études de préfaisabilité de systèmes de remblayage, une estimation préliminaire de la résistance mécanique du RPC potentiel est requise. Mais, le choix d'un liant alternatif adapté et la prédiction de sa résistance nécessitent l'usage d'un modèle mathématique. Ce dernier pour être robuste doit se baser sur les principaux paramètres physico-chimiques reliés à la formulation de RPC. Un tel modèle a déjà été développé à l'UQAT en 2010 à cet effet.

Cette étude vise à vérifier expérimentalement la cohérence des paramètres physico-chimiques du modèle existant, afin de le valider pour une prédiction conservatrice de la résistance mécanique des RPC, et donc de la performance relative des liants. Un des paramètres clé de ce modèle est l'indice d'hydratation relative qui permet de quantifier l'activité hydraulique du liant utilisé. Une fois validé, ce modèle pourrait servir d'outil de prédiction et d'aide à la présélection d'agents liant optimaux pour le RPC. Pour atteindre l'objectif visé, différentes recettes de mélanges de RPC ont été préparées avec trois types d'ajouts minéraux (slag, cendres volantes de classes F et C) et deux pourcentages fréquents dans les mines de liant (4,5% et 7%). La résistance à la compression uniaxiale (UCS) des éprouvettes de RPC a été déterminée à quatre temps de cure (14, 28, 56 et 90 jours). Les résultats préliminaires montrent que les recettes de mélanges ayant un indice d'hydratation relative équivalent à celui du liant de référence (20% ciment Portland GU et 80% slag), ont développé les UCS les plus élevés dans leur catégorie de recette. Ainsi donc, ces recettes fournissaient l'optimum de résistance mécanique dans leur catégorie.

INVESTIGATIONS OF DISCONTINUOUS PERMAFROST IN COASTAL LABRADOR WITH DC ELECTRICAL RESISTIVITY TOMOGRAPHY

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In the Labrador region of northeastern Canada, isolated patches of permafrost are found in localized coastal environments as far south as 51°N but become more frequent northwards. Investigations of permafrost conditions within the coastal Labrador communities of Cartwright and Nain revealed patches of discontinuous permafrost at low elevations. The characteristics of this permafrost were examined using a combination of standard field methods and DC electrical resistivity tomography (ERT). The local climatic conditions in Cartwright are unfavourable for permafrost with a mean annual air temperature exceeding 0°C in recent years. Consequently, permafrost is restricted to mineral cored palsas in raised bogs at exposed coastal locations. These palsas are numerous but permafrost is thin, with a maximum thickness measured to date of 3.5 m. In the more northerly field sites in Nain, permafrost was inferred at numerous sites within the community boundaries under both fine and coarse surficial covers. Permafrost thicknesses up to 18 m occur in marine deposits at the coast and permafrost thicknesses up to 10 m were inferred at an upslope forested site. Localized permafrost thaw at several sites was shown by building subsidence and was correlated with low near-surface resistivity values in the ERT profiles, inferred to be the result of talik formation. The identification of permafrost bodies in Nain is challenging due to the lack of obvious links to geomorphic features, the area's coarse surficial cover, deep active layers, and anthropogenic disturbance, all of which complicate interpretation of geophysical results. However, a combination of standard field based methods and ERT can discriminate between seasonally and perennially frozen ground at most sites in coastal Labrador, especially where supplementary borehole information is available.

A PRELIMINARY ANALYSIS OF PROTECTIVE EFFECT ON PERMAFROST OF TYPICAL EMBANKMENT ALONG GONGHE-YUSHU HIGHWAY

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Gonghe-Yushu highway is the first high-grade highway in permafrost regions of Qinghai-Tibet Plateau, and is playing an important role in China Western Development. The occurrence of permafrost makes it difficult to maintain the well-functioning of the highway. Learned from the successful experience of Qinghai-Tibet railway, the idea of actively cooling embankment is adopted, and various measures have been taken to protect permafrost from thawing. Along the highway, dozens of monitoring sections have been set up respectively depending on the permafrost conditions and roadbed structures to learn the thermal regime of the roadbed as well as the underlying permafrost. In this paper, data collected between 2012 and 2014 from 3 nearby sections with different roadbed measures, namely insulation board embankment, block-stone embankment and ventilated embankment, is analyzed. It is worth noting that the chosen sections have a similar underlying permafrost condition. The result shows that at the initial stage after the construction of the embankment,

(1) The temperature of the underlying permafrost for all the three kinds of embankment structure rises, not obvious.
(2) There is a uplift of artificial permafrost table for insulation board embankment and ventilated embankment, showing a continuing uplift trend. As for block-stone embankment, it is not so significant.

(3) The uplift of artificial permafrost table for the shady side of the high is greater than that of the sunny side.

The result shows that all the three measures are effective in protecting permafrost from thawing. However, it is just a short time since the construction of the highway, whether the measures are efficient to protect permafrost in the future is unknown, and further study is still ongoing.

A PRELIMINARY ROCK GLACIER INVENTORY FOR THE TORNGAT MOUNTAINS OF NORTHERN LABRADOR, CANADA

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The Torngat Mountains of northern Labrador are located at the southern limit of the low-Arctic in Canada allowing for the existence of small mountain glaciers and permafrost. However, apart from site-level descriptions undertaken during archeological investigations, there is almost no baseline information to assess the regional distribution of permafrost. Previous observations of permafrost features (e.g. rock glaciers and ice-cored moraines) in the Torngat Mountains imply that mountain permafrost is present and may be widespread at high elevations, but to date, no comprehensive inventory of permafrost features in the region has been completed.

This study maps and characterizes the spatial distribution of rock glaciers in the Torngat Mountains using a combination of satellite remote sensing and terrain modelling. Rock glacier outlines were iteratively mapped in a three-stage process by multiple operators to reduce uncertainties in manual delineation of features. Each rock glacier was then classified based on origin and interpreted level of activity by each of the operators. Results show that both talus-derived and glacier-derived rock glaciers are present throughout the region, with talus-derived rock glaciers encountered more frequently in the northern part. Rock glaciers are found across a wide swath of elevations ranging from ~50 to ~1200 m a.s.l.. Comparison with regional climate data suggests that the threshold for rock glaciers in the Torngat Mountains is below the -4.5°C mean annual air temperature isotherm. The interpretation of local permafrost distribution is challenged, however, by complications in discriminating between relict and active rock glaciers. Furthermore, the complex glacial history of the Torngat Mountains increases the uncertainty in utilizing glacier-derived rock glaciers as regional permafrost indicators. Considering only talus-derived rock glaciers, the lower limit of widespread permafrost shows a strong latitudinal trend across the entire Torngat Mountains region.

TEMPERATURE FIELD INVESTIGATION OF SUBGRADE FOR WIDE PAVEMENT IN PERMAFROST REGION

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With the rapid development of economy and road construction, building of expressway in Tibetan Plateau of China is becoming more and more urgent. However, wide pavement used for expressway has much higher heat absorption area and volumetric heat capacity than current pavement used in the permafrost regions of Tibetan Plateau. It can cause severe temperature rising and permafrost thawing problems leading to pavement failure. Therefore, this study focused on the temperature field of subgrade with wide pavement in permafrost region based on numerical simulation analysis. Based on the characteristics of climate and permafrost in Tibetan Plateau, the basic controlling equation for numerical simulation analysis of temperature field was built and the thermal physical parameters of permafrost as well as boundary conditions were determined. Finite element modeling for wide pavement was built and carried out by ABAQUS software. Firstly, the influences by the width and height of subgrade on the temperature field of subgrade and permafrost were analyzed. Then the influences of insulating layer embedded in subgrade on the temperature field of subgrade and permafrost were evaluated. Its influences on the pavement structure under vehicle load were also considered. At last, the combining effects of insulating layer and crushed rock layer in subgrade on the temperature field of subgrade and permafrost were investigated. Based on the findings in this study, the reasonable height of subgrade for wide pavement was calculated. The embedded depth and optimal thickness of insulating layer in subgrade were determined. Composite subgrade based on insulating layer and crushed rock layer was recommended.

INVESTIGATION OF ASPHALT MIXTURE WITH LOW THERMAL CONDUCTIVITY FOR PERMAFROST REGION

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This study focused on the design of asphalt mixture with low thermal conductivity and the evaluation of its cooling effect for asphalt pavement in permafrost region. Vermiculite with low thermal conductivity was mainly used to modify the thermal conductivity of asphalt mixture. Based on gradation design of the original asphalt mixture and gradation analysis of vermiculite, vermiculite was used to replace the fine aggregates passing 2.36mm sieving by the same quality. Different mass contents of vermiculite including 4, 6, 8 and 10% were used to prepare asphalt mixtures. Thermal conductivity test was conducted to investigate the lowering effect of vermiculite on the asphalt mixture. Wheel tracking test, low temperature bending beam test, freeze-thaw splitting test and bending beam fatigue test were also conducted to evaluate the influences by vermiculite on the performances of asphalt mixture. Based on pavement structure design, the influences of asphalt mixture with low thermal conductivity on the temperature field of subgrade and permafrost were analyzed by finite element numerical simulation. It is found that, with 10% vermiculite in asphalt mixture, the thermal conductivity of asphalt mixture can be lowered by 45% and the performance of asphalt mixture can still be guaranteed. With the same pavement structure, 4cm asphalt layer with low-conductivity asphalt mixture can lower the temperature by 2°C than 4cm asphalt layer with normal asphalt mixture at the same spot of subgrade. And the low-conductivity asphalt mixture can improve thaw depth in permafrost very well.

THE INFLUENCE OF TUNNELING ON SLOPE STABILITY

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Tunneling projects usually involve the design and construction of two adjacent (twin) tunnels with respect to underground infrastructure projects for road, railway or subway systems. Currently, there is limited investigation associated with the interaction generated between the excavation of two adjacent tunnels within geotechnical engineering. One of the major drawbacks with regards to such an investigation (i.e. a precursor to design) is the increased computational cost required to model the detailed three-dimensional (3D) excavation process utilizing 3D numerical analysis tools. However, through the use of rough approximations, two-dimensional simulation can be employed in order to draw selected preliminary results with respect to the impact of the interaction between twin tunnels. Added complexity is introduced when such twin tunnel projects are constructed within or adjacent to slopes. Despite of being conservative, these slope stability problems can be satisfactorily simulated in two dimensions.

With respect to design for a tunneling project, factors such as the in-situ stresses and the quality of the soil / rockmass are of great significance. However, within twin tunneling, the distance and positioning of the tunnels (with respect to one-another as well as within a slope) is an additional factor that must be taken into consideration as this affects the stress redistribution around the excavations and consequent deformations. This may also result in more complex failure modes, thus reinforcing the necessity for specific investigations and design procedures associated with the impact of an underground excavation on the stability of the slope especially in weak rockmass and shallow conditions.

In this particular paper, twin tunneling excavation interaction is investigated for tunnels close to the ground surface of slopes within weak rockmasses. The effect of the excavation on the stability of the slope is examined in order to illustrate under which conditions a slope can fail due to the existence of underground excavations. The factors investigated for their impact on the slope stability are the transverse distance between the twin tunnels, which have a circular cross-section, and their overburden. Rockmass properties and in-situ stresses are considered constant in order to isolate the effect of the geometrical features of the design.

A case study utilizing data amassed from twin tunnels constructed near slopes within the European Alpine Region that affected the slope stability of the mountainside they were excavated within will also be utilized in order to validate numerical models and highlight the importance of such construction.

THE EUREKA SOUND LOWLANDS: AN ICE-RICH PERMAFROST LANDSCAPE IN TRANSITION

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This paper presents recent observations concerning the distribution, stratigraphy and chemistry of ground ice, thermokarst and landscape changes in the Eureka Sound lowlands on central Ellesmere and Axel Heiberg Islands in the Canadian high Arctic. At 80°N the Eureka area is characterized by cold polar desert conditions (a MAAT of -19.7°C), cold permafrost up to 600 m thick and a dynamic landscape where rapid changes linked to melting ground ice dominate. Even though recent data from the Environment Canada weather station at Eureka show a slight increase in mean temperature and thaw indices, the past 5 years are marked by a sharp increase in thermokarst activity. Massive ground ice and ice-rich sediments are widespread below the Holocene marine limit (150 m asl) where its distribution, content, and stratigraphic character are closely related to the nature of a marine sediment veneer. Cryotextural and hydrochemical analyses confirm rapid epigenetic ground ice formation synchronous with post glacial emergence. The water source is a combination of brackish seawater and melt water from local ice caps. With only a few exceptions these marine sediments contain excess ice. The main variables influencing the stratigraphic character of the ground ice, and thus its geomorphology, are sediment thickness and the underlying geology. Since 1990 approximately 470 different natural exposures of massive ice have been mapped including more than 100 that were studied in detail. Most of these exposures are in the head wall of retrogressive thaw slumps. GPR surveys and data from 50 boreholes ranging in depth from 2-17 meters is also presented. Extremely pure, horizontally foliated massive ice ranging in thickness from 2.1 to 8.4 m was documented in most of the detailed profiles. Repeated GPS surveys of head wall positions have provided both short and long-term rates of retreat. Since retreat rates vary across the head wall of every slump; maximum retreat from a single point can be misleading so we took the average of the most active 10m section. Over 25 years of observation the average retreat for all sites is 6.9 m/yr., but in the past 5 years the average is 7.5 m and the highest annual retreat is 23.9m. Since 2005 many of the ice wedge polygons have exhibited significant thaw degradation and in many cases a measurable subsidence along their troughs. Numerous new thaw ponds have also formed within ice wedge troughs and at trough intersections.

HYDROTHERMAL REGIME ANALYSIS OF SHALLOW LAYER OF A SOIL SLOPE UNDER SHORT-TERM FREEZE-THAW CYCLES

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This paper is to reveal hydrothermal regime on a shallow layer of soil slope in one of Chinese short-term frozen zones. In China, there are about 1.9 million km² of short-term frozen zones, which account for about 19 percent of the total land area of China. Short-term frozen soil has the characteristics of a high frequency of short-term freeze-thaw cycle and a high moisture content under the condition of snow infiltration. The results of field investigation show that stability issue of shallow layer of residual soil slope occurs frequently.

This paper takes typical short-term frozen zone in Fujian province of China as an example, a hydrothermal regime on shallow layer of soil slope in short-term freeze-thaw cycles is analyzed based on the combination of meteorological monitoring method and numerical simulation.

Based on measurement from December 2013 to February 2014, there were a total of 18 times of freeze-thaw cycles of air temperature: 16 times of one-day, one time of two-day, and one time of six-day cycles. During the short-term freeze-thaw cycles of air temperature, the minimum and maximum of air temperature can reach -4.4°C and 10.8°C, respectively. The peak of daily radiation ranges from 41 to 827 W/m², and an average wind speed is between 3.5 and 3.7 m/s. During the one-day or six-day freeze-thaw cycles of air temperature, the maximum duration of the soil freezing is between 5 hours to 32 hours, the maximum frozen depth from 5 cm to 12 cm, an ice content of frozen soil is from 0.14 to 0.16. During one-day cycle, the soil freezing time is between 3 a.m. and 8 a.m. The initial freezing time of soil depends on the minimum air temperatures and the freezing time of soil depends on intensity of daily radiation. The shallow layer of soil slope is not easy to be frozen when air temperature below soil freezing temperature and solar radiation is in coexistence or when the duration of air temperature below soil freezing temperature is less than 1.5 hours.

IMPACT OF SALINITY AND LOW TEMPERATURES ON THE FLUIDITY AND RHEOLOGICAL PROPERTIES OF FRESH CEMENTED PASTE BACKFILLS

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The design of pipeline transportation of cemented paste backfill (CPB) to targeted mine stopes requires determining the head losses from pipe pumping loop tests. Rheological properties of CPB can also be used to estimate the head losses as preliminary procedure. To date, most investigation addresses CPB transportation in temperate and semi-arid climates in Canada and worldwide. However, backfilling is a viable option for underground mines projected in cold regions (e.g. Meliadine Mine project owned by Agnico-Eagle Mines (AEM) Ltd. in Nunavut, Canada). Under such cold climates, the preparation and transportation of CPB may occur at relatively low temperatures, even during the summer. Although heat can be generated by CPB-pipeline wall frictions and CPB shearing along the flow distance, pipelines must be thermally isolated to avoid local CPB freezing. Antifreeze admixtures may also be used. In addition, pore fluids in permafrost are naturally saline and deicing salts are added during ore processing to decrease the freezing temperature on the site. Consequently, the salinity becomes a new factor to be taken into account, and which is not considered yet in previous studies related to CPB recipe formulation and transportation. For example, it is expected that backfill at Meliadine site contains 0.5% w/w of dry tailings of NaCl, KCl, MgSO₄ and MgCl₂. This paper aims to study the impact of temperature and salinity on the rheological properties of fresh CPB. For that purpose, different CPB mixes were prepared at different solid contents (ranging between 75 and 81 % w/w) using two types of aggregates: tailings from the Goldex Mine (AEM) and aggregates obtained from pilot processing of drill cores coming from Meliadine site. Types GU and HE cements were used at dosages of 3 and 5 % by dry weight of aggregates. Mixing water with and without salt was used. Artificial water with salt mimicking that one expected on the Meliadine mine site was prepared by adding various salts to tap water. The CPB materials (tailings, water, binder) were stored at the targeted testing temperature (from the CPB freezing point to 45°C) in a temperature-controlled room where the CPB preparation and testing were performed. Rheological analyzes using the AR2000 rheometer and slump tests were performed. This rheometer is equipped with an efficient Peltier temperature control. Preliminary results on the effects of temperature and salinity on slump, yield stress, and dynamic viscosity of CPB are presented and discussed.

RELATIVE IMPORTANCE OF GEOLOGICAL VERSUS ECOLOGICAL CONDITIONS ON PERMAFROST ICE CONTENT OF FINE-GRAINED SEDIMENTS IN THE BOREAL FOREST NEAR YELLOWKNIFE, NWT

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The climate is warming most rapidly in the high northern latitudes. This temperature rise is causing increased rates of permafrost degradation (thawing of ground that has remained frozen for two or more years). If degradation occurs where there is high ground ice content in the permafrost, ground subsidence will ensue. Subsidence can damage infrastructure, alter landscapes, and affect the well-being of people living in the area; therefore, it is imperative to understand the distribution of ground ice for use in future planning. Additionally, permafrost degradation can lead to the alteration of entire ecosystems by releasing water stored as ice, altering groundwater flow pathways, and causing soil disturbances and mass wasting. There has been some work to model the distribution of ground ice in areas of discontinuous permafrost. However, there have been few in situ studies in mineral soils of the boreal forest which compare the relative importance of the multitude of factors which influence ground ice content. A field study is being conducted to compare hypothesized important variables and their relative effects on the occurrence of ground ice content of the mineral soil permafrost in the Yellowknife area of the Northwest Territories. Specifically, geological factors (age of the land and sediment type) are being compared against ecological factors relating to successional stage (age of a forest stand, canopy cover, and organic layer thickness). Permafrost is being cored to ascertain the amount of ground ice present at each site. Field data collection is planned to be completed by the end of summer 2015. In addition, soil samples retained from permafrost coring are being analyzed for particle size, organic and inorganic carbon, C/N ratios, salinity, and metals. The objective of this research is to gain a better understanding of the drivers of ground ice in boreal forests with fine-grained mineral soil. A secondary objective is to be able to better estimate ground ice content from only land classification and surficial geology information, which is considerably more cost and time efficient than direct measurements of ground ice and can be done over large spatial extents. Our results will provide new insights into the key drivers of near-surface ground ice content.

FREQUENCY-MAGNITUDE OF ROCKFALL EVENTS FOR HAZARD ANALYSIS: A COMPARISON OF DATA OBTAINED THROUGH TERRESTRIAL LIDAR SCANNING WITH TRADITIONAL METHODS OF REPORTING

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Canadian railway corridors that are built along natural slopes are exposed to frequent rockfall hazards, which may cause disruption to service and damage to infrastructure. A thorough understanding of the characteristics of these hazards is an important component of risk assessment, which can assist with the management of tracks in these settings. The frequency-magnitude of rockfall events is an important input to risk assessment, which can be evaluated from a rockfall database. Traditional rockfall inventories have been collected by railway personnel, and while they may contain estimates of event volumes, event dates, track mileage, and possible source zones or triggering mechanisms, many of these inventories are incomplete. Events can also be recorded using slide detector fences; however these reports only contain information on the time and location of the event, and are lacking volume estimates and information about source zone locations or characteristics.

Three years of high resolution LiDAR data has been collected for a section of railway track along the Thompson River valley near Lytton, British Columbia. Analysis of change from sequential LiDAR scans has provided detailed data that can't be obtained from traditional databases, including the magnitude, spatial and temporal distribution of rockfall events, and useful information regarding rockfall source zones and structural controls. High-resolution photographs collected simultaneously with the LiDAR data provide us with visual confirmation of the failure events.

A comparison between the two datasets is made in order to understand how each may contribute to establishing a complete rockfall hazard inventory for this section of vulnerable railway track. Once sufficient information is collected, the frequency-magnitude data will be evaluated for use in risk management analyses.

DATA QUALITY IN FIELD SAMPLING: A CASE STUDY

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Laboratories receive environmental samples in small jars and vials, extract an aliquot under strictly controlled conditions, and report results in units of milligrams or micrograms. In the field, we deal in units of hectares, tonnes, and cubic metres. How do we reconcile these vast scale differences so that analytical results – reported and compared to regulatory standards at parts per billion/trillion – are truly representative of the site characteristics for a particular property? The consequences of misrepresentation or inaccurate interpretation can be measured in millions of dollars or lifelong health impacts. The answer lies in adequate knowledge of site characteristics in order to design an appropriate sampling program that accounts for variability due to site conditions and sample collection methodologies.

This case study reviews a municipal development project where a property had previously been used for placement of undifferentiated fill by third parties. The fill materials exhibited evidence of construction debris – minor amounts concrete & asphalt – that are typical in many urban settings. The site was located in an area of mixed use with potential for off-site sources of contamination, as well as sensitive species habitat on an adjacent woodlot. Previous sampling had identified exceedances of MOE allowable standards that would render the construction budget untenable. A supplementary sampling program designed to better define the fill and groundwater characteristics on the property and the variability of these media helped to establish an improved remediation program that met the budget constraints for the project, while also demonstrating protection of nearby sensitive species.

INVESTIGATION OF DISCONTINUOUS PERMAFROST AT MULTIPLE SCALES, IN WESTERN AND EASTERN CANADA

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This paper reports on more than a decade of field investigations and modeling across the zones of discontinuous permafrost in western Canada (Yukon and B.C.), and more recent research in Labrador. Broad patterns of permafrost distribution across latitudinal and elevational gradients can be described using empirical-statistical modeling based on climate data derived from networks of simple air and ground temperature monitoring stations. Finer scale determinations within the region require physical modeling but are limited by a lack of baseline information on substrate characteristics, snow and the surface organic layer. New techniques, such as the use of electrical resistivity tomography and low level aerial imaging using an unmanned aerial vehicle have proved critical to site-level investigations, allowing field observations to move from a single point to examine local spatial variability in two or three dimensions. However, traditional ground probing and temperature measurements in boreholes continue to meet many information needs, especially concerning temporal trends.

CLIMATE CHANGE AND ITS ADAPTATION STRATEGIES IN THE PERMAFROST REGION OF MONGOLIA

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Mongolia has a typical continental climate, which is dry throughout the year with marginal precipitation during the summer. Annual precipitation ranges from less than 100 mm in the south to 300 mm in the north, and that in Ulaanbaatar, the capital of Mongolia, is approximately 200 mm. Because of the dry and cold weather, approximately 60% of the land is underlain by permafrost.

During the 20th century, the global surface temperature has increased by about 0.74°C (IPCC, 2007), but the annual mean air temperature in Mongolia has increased by 2.10°C since 1940. However, annual precipitation has decreased by 7.5% in summer and 9% in winter. Because a significant part of the country's population depends on climate-dependent sectors for livelihood, especially on pastoral livestock husbandry, Mongolia is one of the countries vulnerable to climate change.

In this study, we used several indices, such as Permafrost Index (PMI), Water Deficit Index (WDI), Net Primary Production (NPP) and the Carrying Capacity of Grassland (CCG) to describe the vulnerabilities of ecosystems caused by climate changes, such as the degradation of permafrost, desertification of grassland and reduction of carrying capacity. The results show that global warming might exacerbate the land-surface evapotranspiration (ET) and the degradation of permafrost, and then cause the water deficit over land surface, and finally lead to the degradation of grassland and its carrying capacity.

We also found that different regions are burdened with different vulnerabilities. Water-related changes associated with climate change will affect people in the arid and semi-arid regions in southern Mongolia. Droughts may have more obvious effects in northern regions and desertification is a major challenge in southern regions. Northern Mongolia is also vulnerable to permafrost degradation. To against the above-mentioned climate-related vulnerabilities, we put out some recommendations for climate change adaptation, i.e. training herders to keep suitable livestock number; improving pasture use by creating more wells and water points in remote areas; developing and transferring renewable energy technologies and so on.

30 YEARS OF GEOTECHNICAL MONITORING OF THE NORMAN WELLS TO ZAMA PIPELINE: OVERVIEW AND LESSONS LEARNED.

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Between 1983 and 1985, a 12-inch oil pipeline was constructed from Norman Wells, NT, to Zama City, AB through discontinuous, ice-rich permafrost in Northern Canada. Due to the construction activities along the right-of-way and the oil flowing at ambient temperatures, the permafrost was expected to degrade. In order to monitor the impact of the pipeline on the permafrost thermistors and piezometers were installed on many of the larger slopes where the factor of safety might be below the design. By monitoring thaw depth and pore water pressure, these variables could be used to further refine the factor of safety and provide ongoing monitoring. Slope inclinometers were installed to monitor movement rates and depths.

New monitoring instruments are added based on the stability assessment or as older instruments require replacement due to damage from wildlife, excess deformation, aging or maintenance operations.

Installation of geotechnical instruments in a remote setting with permafrost requires special consideration for drilling, instrumentation installation methods and instrument type. Site access and ground conditions require that these instruments are installed in the winter when air temperatures are commonly -40°C and the days are short.

Some of the traditional challenges include: drill advancement in frozen ground, preventing grout from freezing, choosing the correct piezometer type, installing piezometers at a valuable depth where it will not freeze, ice and frost accumulation inside of slope inclinometer casing, anchoring slope inclinometers in frozen ground, and water seepage through frozen backfill.

Advances in remote monitoring have removed some of the traditional challenges, but they have presented others, such as: maintaining power in extreme cold and short winter days and testing the technology in extremes of their design.

There will be a presentation and discussion on the specialized techniques developed to install instruments in the extreme northern conditions, the limitations of traditional instruments, new real-time satellite systems, an update on the data monitoring program, and the lessons which could be applied to future projects in the north.

NUMERICAL INVESTIGATION OF THE BEARING CAPACITY OF RING FOUNDATIONS ON CLAY

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Although the bearing capacity of ring foundations has been addressed in the literature, this is limited to drained soil behavior only. Ring foundations are commonly used for supporting cylindrical structures such as oil tanks, bins, hoppers, bridge piers and silos. With more construction of very large cylindrical structures, the use of ring foundations has become a very economical solution. The time and construction cost reduction of ring foundations compared to circular footings has motivated engineers to look for more guidance on the determination of the bearing capacity of ring foundations. This paper presents the results of a numerical investigation of the performance of ring footings on soft clay soils with increased shear strength with depth. The study includes investigation of the effect of the footing diameter ratios and soil strength density on the undrained bearing capacity factor N_c . The research has been conducted using finite element analysis with the software PLAXIS. The variation of N_c will be shown with varying geometry and soil properties. The research has both practical application to design and academic interest related to the interaction of closely spaced foundations.

UPLIFT OF SINGLE-HELIX SCREW-PILES IN SAND AND CLAY FOR SOLAR PANEL FOUNDATIONS

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: Round shaft helical piles (Screw-Piles) are being used increasingly as economic foundations to resist uplift loading on solar panel arrays and other structures in a wide range of soils. A Screw-Pile consists of a round central pipe shaft and a single lead helical plate that is installed by rotation or screwing into the ground using a hydraulic torque head mounted on conventional construction equipment. In many situations, support can be derived within the upper soils. This means that Screw-Piles are being installed at relatively shallow depths. Traditional methods of analysis for estimating the uplift capacity of shallow plate anchors which are based on microscale testing generally assume that the failure occurs as an inverted truncated cone or wedge of soil that is mobilized to resist uplift. Recent full-scale uplift tests in clay and sand which represent macroscale behavior indicate that a soil wedge does not really develop for many installations and failure is a combination of local bearing capacity immediately above the lead helix and side resistance along the pipe shaft. The contribution of these two components to the total uplift depends on the specific geometry of the Screw-Pile. i.e., diameter of the lead helix and length and diameter of the pipe shaft as well as the soil type and depth of embedment of the helical plate. Results of full-scale uplift tests conducted at two sites are used to illustrate the behavior of shallow single-helix Screw-Piles in uplift. Companion uplift tests on plain pipe piles with the same length and diameter as the Screw-Pile shafts were performed and were used to provide an estimate of the contribution of the pipe shaft from the total capacity. The site characteristics and load test results are presented and a proposed design procedure for estimating uplift capacity based on the test results is suggested.

INSTALLATION TORQUE STUDY OF HELICAL PILES IN CLAY AND SAND

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Helical piles and anchors have become popular elements for a wide variety of geotechnical problems. Measurement of installation torque is an important quality control practice for evaluating the installation quality of helical piles and anchors. Torque is also used by some engineers to estimate the load capacity. However, a number of factors can influence the measurement of installation torque and a number of measurement methods are available. A field study was conducted to evaluate different methods for measuring installation torque at two sites. Both direct methods using in line digital commercial torque indicators and indirect methods using the hydraulic pressure from the torque head were used. Different combinations of hydraulic torque head, installation machine and measurement device were compared. In addition, some operator variables were also investigated to determine the influence on installation torque. All of the measurements were made on a single geometry triple-helix pile. A brief summary of the site conditions is presented along with the results of the field trials. The results demonstrate that all of the measurement methods do not give the same value of torque. The reasons for this and suggestions for proper torque measurement are discussed.

STRESS STRAIN BEHAVIOUR OF SILTY SOILS IN TRIAXIAL TESTS

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Frost heave and thaw settlement are two major issues in the design of pipelines in cold regions. The pipelines generally traverse through a variety of soils. Among the different types of soil, silt has been identified as highly frost susceptible soil. In the design of chilled gas pipelines, the stress-strain behaviour unfrozen silt significantly influences frost heave and thus the response of the pipeline subjected to heave. In the current research program centrifuge physical modeling and finite element modeling will be performed for frost heave effects on chilled gas pipelines. While a large number of laboratory test results on different sands and clays are available in the literature, available tests on silt are very limited.

In this paper, laboratory test results on silts will be presented. A number of triaxial tests have been conducted to understand the constitutive behaviour of silt. The soil used in triaxial tests is same as the soil used for centrifuge physical modeling. Comparing the test results with available constitutive models for sand and clay, the improvement/modification required for modeling of silt will be highlighted. Finally, the improved model will be implemented in FE program for frost heave analysis.

PROGRAMME D'INVESTIGATION POUR L'ANALYSE DYNAMIQUE D'UN REMBLAI FONDÉ SUR L'ARGILE DE LA MER DE CHAMPLAIN

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Le canal de Beauharnois s'étend sur une longueur d'environ 25 km au sud de Salaberry-de-Valleyfield, à une quarantaine de kilomètres de Montréal. Il permet de transiter la majeure partie du débit du fleuve Saint-Laurent entre les lacs Saint-François et Saint-Louis en passant par la centrale de Beauharnois. Le remblai rive droite (digue), qui assure la fermeture du canal en rive droite, s'étend de l'embouchure du canal jusqu'à la centrale. Une partie importante de cette digue a été construite sur une fondation naturelle d'argile molle, ce qui s'est traduit à la conception par un élargissement considérable de l'ouvrage. Bien que l'ouvrage se comporte très bien depuis sa mise en eau, une revue de sa sécurité incluant une analyse de sa stabilité dynamique advenant un séisme d'une récurrence 1 : 2500 ans a été complétée. Les connaissances sur les propriétés dynamiques de l'argile de la mer de Champlain étant actuellement limitées, une campagne d'investigations géotechnique et géophysique a été réalisée. Cet article présente les caractéristiques de la digue, fait un bref rappel des connaissances actuelles sur les propriétés dynamiques de cette argile et détaille la planification et la réalisation du programme d'investigation géotechnique. L'article expose toutes les activités mises en œuvre pour déterminer les propriétés dynamiques de l'argile de Beauharnois afin de confirmer la stabilité de l'ouvrage sous sollicitations sismiques.

EFFECT OF FIBRE REINFORCEMENT ON TRIAXIAL SHEAR BEHAVIOUR OF CEMENTED SAND WITH DIFFERENT CEMENT TYPES

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The present study used conventional triaxial tests to investigate the effect of the addition of polypropylene fibres on the mechanical behaviour of sand cemented with Portland cement, hydrated lime or gypsum plaster. The cement content was 3% dry weight of the base soil and fibres were added at 0.0%, 0.5% and 1.0% dry weight of the sand-cement mixture. All samples were prepared at 70% relative density. Samples containing the different cementing agents were cured under different conditions. The results indicate that, although samples containing Portland cement showed the highest shear strength, the effect of fibre inclusion on shear strength was higher for samples cemented with hydrated lime. It was also shown that the width of the shear band induced during triaxial shear tests differed by type of cement. Samples containing Portland cement showed the greatest deformability, which conforms to its higher energy absorption potential from among the tested cements.

THE ICE AGE GEOLOGY OF THE MACKENZIE DELTA AREA, CANADA

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J.R. Mackay's stratigraphic observations in the Mackenzie Delta area have provided a rich source of information about the litho- and cryostratigraphy in this region, a framework for understanding the history of ground ice and permafrost development, and a reconstruction of Quaternary landscape evolution. In particular, Mackay recognized long before most other earth scientists the importance of interactions between glacial ice and permafrost, not only in terms of glaciotectonic deformation but also of groundwater supply and massive-ice formation. The chronology of events Mackay reconstructed in the Mackenzie Delta area and elsewhere is based on radiocarbon dating, and despite the pitfalls of old carbon being well preserved in permafrost and often redeposited, he made important insights into the timing of geological events, which can now be tested by other dating methods.

Optical stimulated luminescence (OSL) dating of sand provides another valuable method of investigating the ice age geology of the Mackenzie Delta area, and extending the record back beyond the 40,000 or so year limit of radiocarbon dating. We have applied OSL dating of quartz sand grains to a series of stratigraphic sections around the coast of northern Richards Island, Hadwen Island and Summer Island. We trace the development of the landscape from the deposition of river sands of the Kidluit Formation between 76 and 34 ka and through windblown sands deposited in large dunes and sandsheets of the Kittigazuit Formation between 26 and 12.9 ka. Glaciation during the Toker Point Stade interrupted aeolian activity at about 16.5 ka, consistent with Mackay and S.R. Dallimore's (1992) suggestion that glacier ice advanced to Tuktoyaktuk sometime between 17 and 15 cal. ka., based on radiocarbon dating of massive ice. Catastrophic meltwater flooding near the end of the ice age curtailed widespread aeolian activity and caused widespread erosion of the terrain.

ADVANCED INSAR FOR PERMAFROST RELATED GROUND MOTION

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The Arctic is an especially challenging environment for measuring ground motion with InSAR. Persistent ice and snow cover during the winter months and widespread surface water during summer greatly affect InSAR quality. Seasonal ground deformation through the freeze-thaw cycle of the active layer, combined with large variations in soil moisture and atmospheric water vapour dominate the InSAR signal; these phenomena make it difficult to extract long-term trends of ground motion needed to identify and monitor unstable ground. Ongoing climate change is expected to lead to widespread permafrost changes, leading to more unstable ground, affecting both the natural Arctic environment and the spread-out settlements within it. Therefore despite the technical challenges, InSAR, with its unmatched spatial coverage, make it an attractive choice to provide ground motion information for vast landmasses such as the Canadian Archipelago for communities and climate change scientists.

Measuring permafrost related ground motion using InSAR is well established, and the authors have taken part in five separate projects, monitoring over 20 communities in permafrost related areas. This study focuses on the town of Inuvik, in Canada's Northwest Territories, which has presented the largest challenges to InSAR processing of the communities monitored.

Previous attempts using traditional InSAR methods did not yield useful results. In addition to the seasonal change problems, vegetation (which also diminishes InSAR quality) is more abundant than for the other communities, and the size of Inuvik is too small to rely solely on buildings for stable 'targets'. However, considering Inuvik's large dataset of 37 very high resolution RADARSAT-2 Spotlight images, this provided a unique opportunity to develop a novel approach to Arctic InSAR monitoring of ground motion. Several new methods, such as temporary target selection, advanced atmospheric error correction, coherence sharpening, and spatio-temporal adaptive filtering combined with a parametric seasonal model of the active layer, have been incorporated into the Arctic InSAR process.

This paper discusses the initial failures to monitor Inuvik and the subsequent efforts towards developing a new strategy, resulting in eventual success. These innovations are applicable to all such areas, and offer new possibilities for measuring change in the permafrost regions.

A NEW INDIRECT DIAMETRAL TENSILE TESTING SETUP TO DETERMINE STIFFNESS MODULUS AND POISSON'S RATIO OF LIGHTLY STABILISED GRANULAR MATERIALS

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This paper presents a new indirect diametral tensile (IDT) testing setup for determining the stiffness modulus and Poisson's ratio for the characterisation of lightly stabilized granular base materials required for pavement design. In a traditional IDT testing setup, only the deformation along the horizontal diameter is measured and stiffness modulus is determined using the elastic theory equation based on an assumed value of Poisson's ratio for the tested material. However, an inaccurate Poisson's ratio with a difference of 0.1 from the actual value may increase/decrease the stiffness modulus by up to 25% resulting in an uneconomical and conservative pavement design. With the objective of addressing this limitation, a new internal test setup for measuring the deformations along both the horizontal and vertical diameters of IDT specimens is proposed in this study so that both the stiffness modulus and Poisson's ratio can be determined analytically. The experimental program included the determination of IDT strength, stiffness modulus and Poisson's ratio for a typical freshly quarried granular base material stabilised by the addition of 0.5-3% cement-flyash and 1.5-3% slag-lime slow-setting binder. The samples, prepared using a gyratory compactor, were cured for 28 days and then tested in the IDT testing machine. Details of the new IDT testing arrangement with on-sample deformation measurement for performing monotonic testing to obtain reliable data are discussed. This study indicates that the proposed IDT testing setup could be used consistently for determining the tensile properties of a lightly stabilised granular material.

ENVIRONMENTAL DYNAMICS IN PERMAFROST REGIONS OF CENTRAL AND NORTHERN YAKUTIA: GEOLOGY AND HYDROLOGY EVIDENCE

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Recent Quaternary geology and hydrology field studies in central and northern Yakutia (the Lena and Yana River basins) performed at selected locations in summer 2014 have produced new evidence on a regional climate and environmental development, geological contexts and enclosed biotic manifestations of the Late Pleistocene to Holocene in age. The integrated geo-hydrology research focused on: 1) mapping of environmental settings in terms of riverine system dynamics in the active permafrost zone (the Yana-Bytantay valleys); 2) a regional thermocarst lakes' development (central Yakutia); 3) identification of key stratigraphic sites that provide peer multi-proxy information on the past climatic evolution and environmental transformations; 4) cryogenic context definition of potential occurrences of the Last Glacial palaeontological and cultural records; Mapped sequences of organic and anorganic (silty-slay) strata within active permafrost geological contexts from the central Yana basin document in detail high-resolution (palaeo)climate variations in northern Yakutia during the Final Pleistocene-Holocene time period. Well-preserved and taxonomically rich fossil fauna assemblages sealed in intact geological positions in the frozen Late Pleistocene colluvial formations point to a very high biotic potential of the Last Glacial (MIS 3-2) northern (forest-)tundra. Humanly modified large fauna (horse, mammoth, rhinoceros and bison) bones indicate a co-existence of early people and the Pleistocene herbivores in the ice-Age ecosystems. The uncovered archaeology finds (stone and bone industries) released from the formerly frozen alluvial and colluvial formations due to the progressing permafrost degradation, show, in accordance with the analogous finds from the Arctic Siberian coast, that parts of the central and northern Yakutia were inhabited by the last glacial hunters exploiting the tundra-forest and tundra-steppe periglacial habitats.

Geo-hydrology studies performed at a series of thermokarst ponds (alases) focused on near-banks fine clastic and organic deposits (0-70 cm stratigraphic depth) for palaeoecology analyses (diatoms, pollen and spores). The bulk sediment samples (depositional facies, lithology and other environmentally indicative and diagnostic proxies) from geological and geoarchaeological locations expand the existing database on reconstructions of the regional central and north Yakutian Late Pleistocene-Holocene climate history. The modern meteorology records confirm the empiric field observations on increasing annual temperatures in the Yana River basin and an accelerated permafrost degradation visible in both the river floodplains as well as on mountain plateaus. This knowledge has a fundamental bearing for an increased visibility of encountered occurrences of fossil fauna finds released from the local permafrost grounds.

PERMAFROST DEGRADATION AND INFRASTRUCTURE – SETTLEMENT RISKS IN CENTRAL YAKUTIA

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Permafrost degradation is causing major environmental and engineering problems in cold regions. Negative effects of present melting of permafrost in Yakutia (Sakha Republic, Siberia) were observed in urban areas, as well as nearby of rural settlements. Except for building constructions, this is particularly evident in the local road infrastructure. Indices of progressing permafrost degradation were observed during expeditions in Central and Northern Yakutia in summer 2013-2014. The monitored ground-defreezing processes pose risks to safety of road transport and development of settlements. Road transport in addition to water and air transport is important for Yakutia. Particularly sensitive to permafrost degradation processes are the edge zones of the southern and the south-west oriented exposures. Effects of collapses of deconsolidated grounds were observed along the principal as well as subsidiary unpaved roads and nearby human settings, particularly in the lowland areas with lakes (alases) formation and on slopes of the main river valley. One of the most prominent positions of degrading permafrost was documented next to the M56 regional road near to Nuoragana located in the east of Yakutsk. Significant permafrost degradation progresses are seen on the southern slopes and around the local lake systems will a clear tendency of further development. Hazardous places linked to permafrost degradation were also located in the Amga River basin in the village Myndagay, where the progressive permafrost thawing is causing large changes in the relief by slope slumps and ground sinking. The loci of collapsed land masses directly adjoin residential buildings and present an acute threat to local inhabitants. Effects of permafrost degradation were also detected near the village Tyungulyu about 50 km east of Yakutsk and in another sites. Although the buildings are positioned above gently slopes of the northern and NW exposure, they are at risk of seasonal permafrost melting. Above the shoreline of the lakes, there are several terrace generations and erosional sections dissecting the thermokarst terrace levels. Thermokarst (alase) lakes experience enhanced water level fluctuations, presumably due to global climate, but also human influence (pastoralist practices and forest logging). The lakes are also the main source of mineralogically depleted drinking water for the local inhabitants residing on elevated geomorphic positions (mostly old thermokarst terraces). Anthropogenic factors, apart of presumed global warming, thus also presumably apply to some measure to acceleration of local permafrost degradation. A regular monitoring of ground ice decay is essential for both regional settlement and infrastructure security.

ISOTOPE GEOCHEMISTRY OF PERMAFROST: TRACERS OF PALEO-THAW UNCONFORMITIES AND POTENTIAL BIOGEOCHEMICAL CHANGES TO ECOSYSTEMS UNDER FUTURE WARMER ARCTIC. EXAMPLES FROM GLACIATED TERRAIN IN NORTHWESTERN CANADA.

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Knowledge on the extent of permafrost degradation to past warm climate intervals (i.e., Medieval Warm Period, early Holocene thermal maximum) is of importance to assess the potential magnitude of changes that permafrost and its environment may experience as a result of climate warming or disturbance. One approach to infer past permafrost conditions is through the identification of paleo-thaw unconformities that result from an increase in active layer thickness followed by the aggradation of permafrost. Paleo-thaw unconformities can be identified by a change in cryostratigraphic observations along natural exposures, it has been suggested that geochemical and isotopic anomalies in permafrost may be recorded above and below a paleo-thaw unconformity. Although it has been suggested that changes in the isotope geochemistry of ground ice may be used as a tracer of paleo-thaw unconformities, little is known on the extent to which the isotope geochemistry composition of permafrost (H₂O: stable water isotopes, soluble ions; organic and inorganic carbon, nitrogen) can be used to identify permafrost degradation during past warm climate intervals. Can the isotope geochemistry composition of permafrost register high frequency – low magnitude permafrost degradation (i.e., inter-annual/decadal change in active layer thickness) or only low frequency – high magnitude permafrost degradation events (i.e., maximum depth of thaw encountered during the thermal maximum)? Can the concentration and isotope composition of any molecules or elements (H₂O: 18O-D, soluble ions; concentration and 13C of organic and inorganic carbon; concentration and 15N of nitrogen) be used as tracers of permafrost degradation?

To assess the extent to which paleo-thaw unconformities may be identified from the isotope geochemistry of permafrost, this study investigates the ground ice content, 18O-D of ground ice, concentration and total soluble ions, concentration and 13C of organic and inorganic carbon; concentration and 15N of nitrogen in the uppermost 5m of permafrost at 12 sites in the northwestern Canada. The sites are situated across the glaciated terrain of the Richardson Mountains and Peel Plateau and eastern Mackenzie Delta region. In addition to assessing the potential magnitude of permafrost degradation through the use of cryostratigraphy and permafrost isotope geochemistry, the results will provide the necessary context for assessing potential biogeochemical impacts of future permafrost thaw on terrestrial and aquatic ecosystems.

THE MONITORING OF PERMAFROST DEGRADATION AND EXPRESSWAY EMBANKMENTS DEFORMATION IN LESSER KHINGAN MOUNTAINS REGION OF CHINA

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The northwest of Lesser Khingan Mountains in China belongs to the high latitude permafrost regions in the discontinuous zone, also belongs to the degradation of patchy permafrost regions. The permafrost under the expressway embankment decline gradually due to the effects of the global warming and human activities. Thus, most of expressway diseases induced by thaw settlement come into being. The research area located in the region between K160 section and K182 section of the Bei'an - Heihe expressway reconstruction project in the northwest Lesser Khingan Mountains of China. We layout some temperature sensors and the soil pore water pressure sensors in the soil of expressway embankments in permafrost underlying sections, to continuously monitor the soil temperature and the soil pore water pressure during 2009-2014. At the same time, we use settlement gauge to monitor the subgrade deformation, and use the high density electrical method meter to detect the resistivity variation of permafrost. The melting thickness of permafrost at the position of the subgrade in road central position during the period of construction (during July 2009 to August 2011) was up to 1.9m, the subgrade settlement was up to 26.9cm. While during August 2011 to October 2014 (after the expressway construction was completed) the melting thickness is up to 1.0m, the subgrade settlement was 13.4cm. Permafrost melting at widening subgrade slope toe was more intense. The melting thickness of permafrost during the construction period from July 2009 to August 2011 was up to 2.5m, the subgrade settlement was 31.4cm. And during August 2011 to October 2014 the melting thickness was 1.3m, the subgrade settlement was 20.1cm. The results showed that, the velocity of permafrost melting thickness under subgrade was fast during the period of expressway subgrade construction, and the position of widening subgrade slope toe and road central position present large settlement. After the expressway construction was completed, the velocity of permafrost melting thickness under subgrade decreases gradually, and the subgrade settlement velocity decreases. However, the widening subgrade slope toe position of the permafrost melting velocity is still large after the expressway construction was completed, and the velocity of subgrade settlement is also large. The top and bottom of permafrost present seasonal changes. The melting at permafrost bottom lead the pore water pressure of soil increase, the pore water pressure decreases as the drainage consolidation of soil. Meanwhile, the permafrost temperature changes lead the resistivity changes significantly.

UAV-BASED HIGH RESOLUTION MAPPING OF GEOMORPHOLOGICAL PROCESSES AND VEGETATION COMMUNITIES IN THE SOUTH SHETLANDS (ANTARCTIC PENINSULA).

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The West Antarctic Peninsula (WAP) is one of the Earth's regions with a fastest warming signal since the 1950's with an increase of over +2.5 °C in MAAT. Significant changes have been reported for glaciers, ice-shelves, sea-ice and also for the permafrost environment. Mapping and monitoring the ice-free areas of the WAP has been until recently limited by the available aerial photo surveys, but also by the scarce high resolution satellite imagery (e.g. QuickBird, WorldView, etc.) that are seriously constrained by the high cloudiness of the region. Recent developments in Unmanned Aerial Vehicles (UAV's), which have seen significant technological advances and price reduction in the last few years, allow for its systematical use for mapping and monitoring in remote environments. In the framework of projects PERMANTAR-3 (PTDC/AAG-GLO/3908/2012 - FCT) and 3DAntártida (Ciência Viva), we complement traditional terrain surveying and mapping, satellite remote sensing (SAR and optical) and D-GPS deformation monitoring, with the application of an UAV. In this communication, we will present the results from the application of a Sensefly ebee UAV in mapping vegetation communities and geomorphological processes (e.g. sorted circles, rockglaciers), as well as for digital elevation model generation in Hurd (Livingston Island) and Barton peninsulas (King George Island). The UAV is a lightweight (ci. 700g) fixed-wing model, with 96 cm wingspan, portable and easy to transport. It allows for up to 40 min flight time, with RGB or NIR cameras. We have tested the UAV successfully with winds up to 10 m/s and obtained aerial photos with a ground resolution of 3-4 cm/pixel. The digital orthophotomaps and high resolution DEM's together with field observations have allowed for deriving geomorphological and vegetation community maps with unprecedented detail and accuracy. The automatic classification of the vegetation communities derived from UAV imagery will be compared with that obtained with IKONOS and QuickBird imagery. Vegetation shows a clear control of topographical variables, especially those related to wind exposure and snow accumulation and therefore, UAV-derived DEMs allow for very accurate identification of conditioning factors. Models of potential vegetation community distribution will be presented and discussed.

LE CANAL DE BEAUHARNOIS: UN PROJET AMBITIEUX POUR LES ANNÉES 1920

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Le canal de Beauharnois constitue un ouvrage civil unique au Canada. D'une longueur de plus de 25 km, ce dernier a été excavé pendant les années 1930 au cœur d'un dépôt d'argile molle de la mer de Champlain dans le but d'y dériver la presque totalité des eaux du fleuve Saint-Laurent et ainsi en exploiter le potentiel hydroélectrique. Ce canal intègre des digues totalisant environ 45 km de longueur et il sert à alimenter la plus grosse centrale hydroélectrique au fil de l'eau du parc d'équipement d'Hydro-Québec. Ces digues exceptionnelles par leur étendue incorporent des concepts de construction avec et sur de l'argile molle totalement novateurs pour l'époque.

Le présent article regroupe trois volets. Le premier volet détaille l'histoire de ce projet. Le deuxième volet présente une synthèse des conditions géotechniques dans l'emprise du canal, les méthodes de construction mises de l'avant spécifiquement pour ce projet afin de réaliser les travaux d'excavation du dépôt d'argile molle et la conception des digues longeant le canal. Le troisième volet consiste en une analyse du processus de consolidation dans le temps de l'argile naturelle constituant la fondation des digues à partir de données géotechniques récentes de travaux d'exploration dans l'emprise des remblais et de terrains naturels en périphérie de cet aménagement. Également dans ce volet, une comparaison sera également effectuée entre des mesures récentes de la résistance au cisaillement de ce dépôt d'argile à l'aide du piézocône et des mesures du Pr. K. V. Terzaghi impliqué à titre d'expert sur ce site en 1946 pour une problématique géotechnique.

"BAHA". SYSTEME DE GESTION DES RISQUES ASSOCIES AUX CASTORS LE LONG DES ROUTES ET DES CHEMINS DE FER. BEAVER RISK MANAGEMENT ALONG TRANSPORTATION CORRIDORS.

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Le resume en francais suivra. L article sera dispo en Francais et en Anglais. (Peut etre classe dans Glissement de terrain)

Activities of nuisance beaver in mountain areas along transportation corridors present a real and constant threat to the stability of infrastructures and can be a concern for safety of the public and of the environment. Every year, there are hundreds of occurrences of catastrophic ground collapses and landslides caused by the presence of beaver dams in the vicinity of highways, pipelines, power lines and railways. Some of these instabilities, if not detected in time, pose a direct danger to the users and to the public as they may occasionally results in severe accidents and even derailments. Although it is not possible to stop all instabilities and eliminate all risks, a large proportion of the problems can be prevented with the implementation of a risk management system related to the beaver activities. The author presents the first steps of implementation of a system to reduce such risk; the " Beaver Activity Hazard Assessment" (BAHA). The BAHA methodology provides a consistent evaluation of the level of danger of each beaver dam and each watershed which can impact the railways infrastructures. As a second step, by considering the potential consequence of different failure scenarios, the system determines where risk control measures are needed and provides risk based priorities for field interventions. This system has been used successfully for over 15 years along one Canadian Railways as hazard assessments of over 10,000 beaver dams are being performed twice/year during helicopter patrols.

1 ou 2 autres co auteurs suivront.

SPATIAL ANALYSIS, GEOSPATIAL TECHNOLOGY, AND THE EVOLUTION OF THE CIRCUMPOLAR ACTIVE LAYER MONITORING PROGRAM

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CALM (Circumpolar Active Layer Monitoring) was the first international permafrost global-change observation program, and has been operating since the early 1990s. CALM incorporates well over 200 observatories in the Arctic, Antarctic, and mid-latitude mountains. More than 250 peer-reviewed publications have resulted from the program. A review of this literature demonstrates significant and increasing emphasis on mapping and other forms of spatial analysis in the program, as well as in the larger realm of permafrost science.

From a spatial-analytic viewpoint, active-layer thickness (ALT) has much in common with topography. Both are represented by a linear, ratio-scale metric with an elevation-based datum, and can be represented as continuous spatial fields. Several studies have demonstrated that terrain geometry exerts an important influence on ALT, in large part through its influence over climatic and hydrological properties and processes. Others have shown that, through various feedback mechanisms, ALT can act as an important control over the intensity and rate of mass-wasting and fluvial processes, as well as affecting vegetation patterns, wildlife distribution, and the sustainability of human land uses.

. From its inception, the CALM program has used spatial-analytic methods and geospatial technology to assess ALT variability and active-layer dynamics over geographic space, across a broad range of scales. CALM has been effective in testing hypotheses about the behavior of ALT over space, and instrumental in developing new hypotheses and theory. This paper provides a retrospective view of the CALM program's evolution, with emphasis on spatial-analytic methodologies and geospatial technologies. Important elements of these efforts include spatial sampling, spatial autocorrelation analysis, geostatistical methods, mapping and validation across scales, spatial interpolation, digital elevation models, spatial derivatives, geographic information systems, ground-penetrating radar, LiDAR, and differential global positioning systems. Remote sensing is playing an increasingly important role in permafrost science. CALM is contributing to these efforts, as well as providing crucial validation data for spatial modeling.

DEFORMATION OF THE RAILWAY EMBANKMENT AT THAWING PERMAFROST

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Railway embankment significantly changes the soil conditions of heat exchange with the atmosphere. In this case, the main site of embankment enhances the cooling of the ground in the winter due to the artificial removal from the surface of the snow, and the slopes reduce it due to the accumulation of snow on them and as a result of wind transport of snow.

Summer heating of soil on slopes is also increasing due to the radiant energy. The arrival of this energy is increased due to decrease reflectance of the surface of the slope and its inclination to the horizontal.

At a certain ratio embankment surfaces (slopes and the main site) the balance of thermal energy supplied to the ground through the ground surface becomes positive, and at the base of the roadbed is lowering the upper boundary of permafrost. This is accompanied by draft of embankment under its own weight and the train load. If the first after the termination of thawing practically stops, the second lasts a long time in the presence of the base of the roadbed instability zones.

Under the zones of instability is understood such field in the base of embankments in which the shear stresses in the soil exceed the limits defined by the cohesion of the soil and angle of internal friction.

Sediment embankment under load can occur due to bulging out under embankment of unstable soil volume, and by squeezing water from the unstable ground and the subsequent decrease in porosity.

If the unstable zones are ground in a stable environment, then the deformation process proceeds in two stages: the first stage, the water is squeezed from the soil under the influence of the pore pressure. In the second stage the load is transferred to the soil skeleton and its porosity decreases.

Consequence of reducing the porosity is to increase the strength properties of the soil (cohesion and angle of internal friction) and reduction of zones of instability before their extinction.

Based on these ideas, we propose a model taking into account additional deformations in weak thawed soil of embankment foundation.

The model was verified by calculations for embankments on the line Chum - Nikita Northern Railway.

The check results concluded that the calculation of the settlement should be taken into account deformation occurring under the embankment in the area of unstable soil thawed soil. Value of these strains is comparable to precipitation due to the thawing of frozen soils.

THE MONITORING OF SOIL PORE WATER PRESSURE AND SOIL TEMPERATURE IN CUTTING SLOPE BEFORE AND AFTER SALIVA FLOW ICE

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In northeast China, the cutting slope in road segments of Bei'an to Heihe Highway often occur the phenomenon of saliva flow ice. In winter, the water pouring from the cutting slope and was frozen as its flowing. There was a huge ice from slope to road surface, which destroyed the slope surface and threaten road traffic safety.

Ground temperature and pore water pressure monitoring points were set up on the cutting slope where saliva flow ice ever happened. The results show that, in same depth, soil temperature where saliva flow ice ever happened is higher than those never had saliva flow ice. When soil temperature dropped below 0 °C, the soil pore water pressure rised rapidly to a maximum value. With the water outflow, soil pure water pressure declined slowly. Saliva flow ice had the characteristic of seasonal and uncertainty location.

ISOTOPIC EVOLUTIONS OF GROUND ICE IN PERMAFROST REGION ON QINGHAI-TIBET PLATEAU AND ITS CLIMATIC-HYDROLOGICAL SIGNIFICANCE

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The Qinghai-Tibet Plateau (QTP) is the highest permafrost region in elevation which is extremely sensitive to the climate and hydrology on the plateau, numerous instructive messages that were useful for the environmental and hydrological research on the QTP contained in the permafrost. As the unique feature of the permafrost, the ground ice enriched in the permafrost on QTP, it is one of the convenient tools to explore the climatic and hydrological process on QTP. In this paper, the first record of stable isotopic composition through a complete sequence of ground ice collected from a deep borehole in Kunlun Mountain Pass on the QTP is presented. The results reveal the depth deviations in the whole borehole which can be divided into four sections according to the isotope variations. The isotopic evolution of each section may be indicative of different climate conditions and hydrological effect during the ice formation. Between 2.5m to 10m, the isotope variation shows the truth that the ground ice is mainly originated from the water of active layer and precipitation. From 10m to 16m, the gradually positive isotopes give an evidence of aggravated-origin of ground ice in the positive geothermal gradient. And the nearly stable isotope contents of ground ice in the range of 16m to 50m are indicative of relative stable climatic conditions and single source water during ground ice formation. Finally, the variability of d-excess in the depth of 50m to 92m certifies that the unstable ice-formation conditions induced the alteration of fractionation factors and yields the variable isotope composition. Totally, the isotopes in different depths mean the different climatic conditions and hydrological processes during the ground ice formation which can be used to infer the paleo-climate and paleo-hydrology in the permafrost regions.

CONSTRUCTION POTENTIAL MAPS IN SUPPORT TO CLIMATE CHANGE ADAPTATION AND MANAGEMENT STRATEGIES: CASE STUDIES FROM NORTHERN QUEBEC

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The sensibility of permafrost conditions to climate warming in northern Quebec raises concerns regarding existing and future infrastructures. As the Inuit communities are facing this challenge in their community planning work, the rapid population growth in Nunavik (increase of 25% between 1996 and 2006) has also led to a severe housing crisis. A better understanding of the spatial variability of permafrost conditions and its geotechnical properties at the community scale is crucial to guide the development of site specific optimized adaptation and management strategies, particularly building foundations.

An integrated and multi-technique approach has been developed to map geotechnical properties of 13 Inuit communities in Nunavik. This approach includes extensive surficial mapping using pre and post construction aerial photographs and recovery of drilled frozen cores of the communities. Laboratory and cryostratigraphic analysis allowed a detailed characterization of permafrost in terms of geotechnical properties of the different units encountered. Thereafter, a multicriterial analysis combining the geoscience information was achieved in GIS software to produce based risk index maps. These maps index integrate four layers of information: surficial deposits, permafrost conditions, slopes, and identified zones of severe constraints for construction.

The results of the multicriterial analysis are presented as construction potential maps where, for any given terrain category, the suitable foundation types according to the existing engineering solution guidelines are proposed. These tools are essential to land use planning since the permafrost conditions vary within each community as well as between them. For instance, Akulivik, located on continuous permafrost, has thaw-stable ground which could allow the development on the western section of the village, while the eastern part is built on ice-rich and thaw sensitive sediments. As for Kangiqsualujjuaq, located on the east coast of Ungava Bay on discontinuous permafrost, the community is built in a valley made of thick glacial deposits (>2m) which are potentially ice-rich and thaw sensitive. In that latter case, further characterization of the permafrost properties is still necessary.

As surficial geology and permafrost conditions maps provide regional decision makers with a better understanding of the challenges posed by permafrost and climate warming, the construction potential maps are a useful tool in support of decision making in land management and community issues.

AN IMPROVED METHODOLOGY FOR MESHING 3-D EARTH DAM STRUCTURES

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The design of earth dams has sometimes been subjected to finite element flow or deformation numerical models. Such numerical models can improve designs and allow for the relatively inexpensive identification of potential flaws in designs prior to construction. A difficulty that has been traditionally encountered in practice is that many earth dams are 3-D in nature due to the valley in which they are typically placed. A 2-D numerical model is often inadequate or unable to represent the flow or deformations encountered close to the intersection of the earth dams with the valley walls. Another complication is that there are significant pinch-out issues with the intersection of the earth dam with the valley. Many earth dams may be made up of complex low-conductivity cores or drainage sections which ultimately result in fairly complex and highly 3-D geometries with many pinch-out zones. Such geometries are extremely difficult to model with existing software tools.

This paper presents a new methodology for the quick creation of 3-D numerical models for the purpose of ultimately creating a 3-D flow or stress/deformation numerical model of an earth dam. The methodology allows geotechnical engineers to work off of readily available cross-sectional designs and allows for quick calculation of pinch-out zones as the earth dam intersects the valley walls. The methodology presents a fast process which can be carried out in a consulting time frame and allows the building of numerical models to the creation of the mesh.

SEISMIC RESPONSE ANALYSES AND STABILITY OF TAILINGS IMPOUNDMENT DIKES BASED ON CASE STUDY

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Two tailings impoundment dikes failed at the Mochikoshi gold mine in Japan in 1978 due to earthquake loading. The failure of Dyke No. 1 occurred during shaking and was attributed to the liquefaction of the retained tailings and the tailings used to construct the dike as well as the lateral loads applied by earthquake shaking. The failure of Dike No. 2 occurred several hours after the end of shaking and was attributed to the post-shaking dissipation of excess porewater pressures through the dike. This study deals with the seismic response of the tailings impoundment including liquefaction, seismic deformation and development of excess pore water pressures.

This paper presents numerical analyses performed based on Dike Nos. 1 and 2 during and following the seismic event that caused their failures. The analysis was conducted using Plaxis 2D 2010 with the dynamic and flow options. The results indicate that numerical analysis can be used to evaluate the stability of tailings impoundments during and after shaking.

Analytical and numerical methods were used to establish a correlation between the output of the numerical method and the current state of practice to evaluate the seismic stability of impoundments.

PRELIMINARY RESULTS OF THE INVESTIGATION ON THE EFFECT OF PERMAFROST ON EARTHQUAKE-INDUCED GROUND MOTION AMPLIFICATION IN THE MACKENZIE DELTA, NWT.

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The Geological Survey of Canada is working towards improving the understanding of earthquake geohazards in the Mackenzie-Beaufort region through their Public Safety Geoscience Program. To adequately design infrastructure and undertake emergency preparedness, industry, regulators and northern communities require information on seismic hazard at both regional and local scales.

The primary source of regional information is the National Seismic Hazard Model, which is part of the National Building Code of Canada. Ongoing work undertaken as part of the 2015 revision of this model suggests that an increased seismic (earthquake) hazard exists in the Mackenzie-Beaufort area. Specifically, seismologists have recently included earthquake sources for this area that could produce large earthquakes of up to magnitude 7.8. Events of this size have the potential to generate significant ground shaking, and depending on the nature of sea bottom deformation, a significant tsunami.

It has long been recognized that the intensity of ground motion during earthquakes and the associated impacts to infrastructure and landscape are greatly influenced by local geology and soil conditions (Seed and Schnabel, 1972). A local condition that is not well understood is the influence of permafrost properties on this ground motion amplification. In the Mackenzie-Beaufort area there is substantial variability in both onshore and offshore permafrost distribution and geotechnical properties. For instance, permafrost is very thin or sometimes absent in parts of the modern Mackenzie Delta where the sediments are Holocene in age and ground surface temperatures are relatively warm. Meanwhile, in older terrain on Richards Island, only a few kilometres to the east of the modern Delta, more than 400 m of permafrost may be present.

To address the effects of permafrost on earthquake ground motion amplification, reconnaissance field surveys were conducted in August 2014 to measure resonance effects in areas with varying permafrost conditions. A portable, low-cost engineering seismology instrument (Tromino) was used to passively record ambient vibrations at the surface. Field measurements were carried out at locations with less than 100 m of warm permafrost beneath the modern Mackenzie Delta to more than 600 m of cold permafrost in the northern Richards Island area. Substantial variability in the site response characteristics was observed. Field work to expand on these initial results is expected to take place in summer 2015.

MEASUREMENTS OF PERMAFROST THERMAL CONDUCTIVITY THROUGH CT-SCAN IMAGE ANALYSIS: A NEW TECHNOLOGY FOR PERMAFROST CHARACTERIZATION

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Structural and thermal design considerations when building in the Arctic require precise knowledge of the thermal and geotechnical properties of permafrost. Property values are also necessary as input for the parameterization of heat transfer models and thaw settlement prediction. Previous studies showed the great potential in using X-ray computed tomography for volume measurements of permafrost components and visualization of the cryostructure. We developed a new approach to measure permafrost thermal conductivity. It combines proven thermal conductivity models and computed tomography analyses. The aims of this study are to (1) present the application of an innovative and non-destructive approach using CT-scan to estimate thermal conductivity of undisturbed permafrost samples and (2) validate the results computed from CT-scan image analysis with experimental thermal conductivity tests. Our model applications take into account the soil type, the porosity of ground ice and the cryostructure in the samples to assess the potential of the proposed method. To do so 20 permafrost samples with different textures and cryostructures ranging from homogeneous fine-grained soils with stratified ice lenses to coarse-grained diamictons well-bonded with pore ice, were extracted from various sedimentary environments in the Nunavik and Nunavut regions. The core samples were scanned using a Siemens Somatom 64TM scanner at the Institut National de la Recherche Scientifique (INRS) in Québec city. Given the core diameter (100 mm), a voxel resolution of 0.19 x 0.19 x 0.6 mm was obtained. By selecting a range of Tomographic intensity (TI) values corresponding to each of the soil components (sediments, ice, and gas), voxel classification and quantification of the sample components were achieved using ORS Visual © software, therefore providing fractional volumetric contents of the frozen cores. The thermal conductivity tests were conducted inside a cell surrounded by an insulated box at a constant temperature of about -8 °C. The results show that the ice plays a key role on permafrost thermal conductivity and are consistent with laboratory results by Slusarchuk (1975) and field measurements by Leblanc (2013). Generally, high ice content samples tend to have a lower thermal conductivity because of the high porosity and air content in the ice fraction. This observation stems from the use of CT scan to evaluate the porosity of the ice is statistically validated by the excellent relationship between the measured and modeled conductivity of a core of buried glacier ice.

STEEP BANK RIVER VALLEY GEOMORPHOLOGICAL AND GEOLOGICAL CATEGORIZATION

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Natural terrain hazard assessments require the development of geomorphological and engineering geological maps to understand the past and current performance of the natural river valley slopes. This paper outlines the approach for the hazard assessment and the geomorphological and engineering geological inventory maps developed for the natural riverbank slopes along the Steepbank River Valley escarpment in Fort McMurray, Alberta.

The inventory maps document the location and spatial distribution of the observed major slope instabilities and geological features and the current physical conditions of the River Valley escarpment slopes. These maps provide an understanding of the nature and magnitude of the various potential instability hazards in the natural slopes and are considered to be representative of baseline conditions against which future conditions can be compared.

The dominant geomorphological and hydrogeological key features in the study area include crest retrogression, talus slopes/sloughing, fallen/inclined trees, erosional gullies, large-scale historic failures, seepage, and signs of oily sheen/bitumen. The available aerial photographs and surveys indicate that on-going regression of the escarpment slopes is occurring as a result of natural processes.

The dominant geologic structural feature observed in the study area is the high-angle joints (dips greater than 40°) and small-scale faults in the Clearwater Formation. Dipping clay beds and localized collapse structures with slumped McMurray Formation sediments were also identified.

DETECTION AND INVENTORYING OF SLOPE MOVEMENTS IN THE BROOKS RANGE, ALASKA USING DINSAR: A TEST STUDY

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This study investigates the detection of slope movements using Differential SAR Interferometry (DInSAR) in a continuous permafrost and mountainous Arctic setting near the Dalton Highway in the northern Brooks Range, Alaska. Previous DInSAR studies have been conducted in temperate mountainous regions in discontinuous permafrost, and analysis here was conducted using similar techniques, acknowledging that vegetation, seasonality, snow, and other factors differ between these two environments [1].

A surficial geological map of the Chandalar quadrangle was produced by Hamilton (1978) and previous quantitative ground studies have focused on the rapid movement of a frozen debris lobe (FDL-A) towards the Dalton Highway [2], but a regional slope movement inventory has not previously been conducted and could contribute to understanding the nature of movements in this region.

In the first part of this study, a systematic analysis was performed on two approximately 7 by 7 km areas located near the Dalton Highway. Datasets of ERS, TSX, and ALOS interferograms were used to detect movements in sparsely vegetated and non-glaciated areas. For the 100 detected moving objects, the main mass wasting processes identified were FDL, rock glacier, landslide, and solifluction, with velocities ranging from cm/day to cm/year. This initial inventory derived from DInSAR appears useful and shows correlation between detected movements and the geomorphology on the digital elevation model (DEM). It also provides a comparison tool for future inventories to monitor changes in detected movements.

The second study focuses on detecting fast moving FDLs along a 45 km stretch of the Dalton Highway to investigate whether accurate velocities of these landforms can be detected using DInSAR. Velocities determined using ground based measurements and DInSAR for FDL-A were categorized into the same velocity class (cm/day) [2]. Of the 23 mapped FDLs, almost 70% were detected with a cm/day velocity rate using the ERS 1-day interferograms.

Major limiting factors include the quality of the InSAR data and orthoimages, as well as the presence of snow, moisture, and vegetation, which contribute to a loss of coherence in signal.

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[2] R. Daanen, G. Grosse, M. Darrow et al. (2012) Rapid movement of frozen debris-lobes: Implications for permafrost degradation and slope instability in the south-central Brooks Range, Alaska, 1521-1537.

TERRASAR-X courtesy of LAN1145 (©DLR); ERS SAR (©ESA) and ALOS PALSAR (©JAXA) courtesy of ESA CP1.6817.

DIFFERENCES IN THE HEAT-MOISTURE PROCESS OF ACTIVE LAYER AMONG DIFFERENT ECOSYSTEMS IN THE QINGHAI-TIBET PLATEAU

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The heat moisture process of the active layer over permafrost plays a significant role in surface energy balance, carbon cycle, ecosystem and hydrological cycle. Over a period from 2010 to 2014, soil temperature and moisture measurement sites of 10 sites at different ecosystem were established along the Qinghai-Tibet Highway. In this study, we investigate the difference in the heat-moisture process of active layer among different ecosystem. The results show that difference ecosystems have a large difference in freezing and thawing process, moisture distribution and active layer thickness. For alpine steppe, soil moisture is mainly enriched in the bottom of active layer during the thaw process. For alpine meadow, soil moisture is mainly enriched at the bottom and subsurface of active layer during the thaw process. For alpine swamp, soil moisture is mainly enriched over the active layer. However, the feature of moisture enrichment is influenced by soil properties. For alpine steppe at Kunlun Pass basin, a slight amount moisture at the bottom can be found in subsurface of active layer due to subsurface clay layer. The differences of heat moisture process of active layer among different ecosystem may affect ecosystem stability and the response of permafrost to climate change.

FINITE ELEMENT SIMULATION OF PROPAGATION OF ULTRASONIC WAVE ALONG A SOIL NAIL

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This paper presents a numerical simulation of the propagation of ultrasonic waves along a soil nail using ABAQUS. Reinforcing existing infrastructures or building new ones demands innovative and cost-effective construction techniques. Soil nail wall, one of these techniques, has been widely used for supporting excavations or reinforcing existing slopes. Soil nail walls are constructed in-situ and built in stages from the top down without excavation soil behind. The drilled and grouted method is the most popular construction technique for soil nailing where a hole is drilled first in the ground followed by insertion of a soil nail and then grout of the annular space between the nail and the drill hole. Since the drill hole can be 10 or 20 m deep, soil collapsing or necking will appear during construction which will inevitably influence the quality of soil nails. Currently, the success of soil nail walls depends mainly on the quality control of the soil nails during construction through destructive pull-out tests. Therefore, it is highly necessary to develop a non-destructive testing (NDT) technique to replace these tedious and costly destructive testing.

Based on some preliminary studies in Hong Kong and the United States, ultrasonic NDT provides a promising technique for field quality control of soil nailing. In order to fully understand the ultrasonic wave propagation in the nail, this study will investigate the propagation of ultrasonic waves along a soil nail and develop the dispersive curve and its related parameters, for example frequency of excitation, geometry of nails, and attenuation rate, etc. The finite element program ABAQUS will be used to simulate the wave propagation. The results will improve the understanding of the wave propagation along a soil nail and help develop an efficient ultrasonic NDT technique for soil nailing technique.

LABORATORY STUDY OF CREEP BEHAVIOUR OF ANCHORS IN FROZEN SILTY SOIL

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The objective of this project was to study the pull out creep behavior of anchors of different geometries embedded in a frozen silty soil. A cylindrical steel rod of 16 mm of diameter and a hybrid anchor having a coned-shaped enlarged base were tested at temperatures of $-1,2^{\circ}\text{C}$ and $-0,6^{\circ}\text{C}$. Good agreement of creep behavior on cylindrical anchors with field data reported in the literature was observed. Important attenuations of the creep rates in time were recorded on enlarged base anchors, particularly at $-1,2^{\circ}\text{C}$. Also, an important reduction of creep rate was observed after rest periods with alternating temperatures.

CONSTANT-HEAD PERMEABILITY TESTS PERFORMED IN MONITORING WELLS AT LABORATORY SCALE

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Field permeability tests are regularly done in wells monitoring hydraulic conditions in aquifers. Variable-head tests are usually preferred for low values of the aquifer hydraulic conductivity, K , and constant-head tests for high K values when the hydraulic response is short, typically a few seconds, which yields inaccurate test data and thus an inaccurate K value. The two types of permeability tests have been performed in twenty wells monitoring a confined aquifer, correctly installed in a large sand box. Electronic transducers have been used to register water pressure and atmospheric pressure versus time. The paper presents first the method used to calibrate the sensors, in order to assess their zero offset and its influence on the test data. Then, it presents the results of the variable-head tests, which have been performed as either falling-head or rising-head tests, and the results of constant-head tests performed using a peristaltic pump, thus as constant flow rate tests until stabilization of the water level in the monitoring pipe. In addition, several types of constant-head tests have been used: (i) single flow rate as for groundwater sampling; (ii) different steps, with or without rest periods between the periods of constant flow rate. The paper presents and discusses the correlations that have been obtained between the K values extracted from the field data for each type of permeability test. The paper will briefly examine the more frequent case of incorrectly installed monitoring wells, considering that over 2/3 of all monitoring wells are poorly installed according to Nielsen and Scalla (2006) in the Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring.

KEYWORDS: permeability tests, monitoring wells, aquifer, transducers.

A STUDY ON PARTICLE BREAKAGE USING A GYRATORY COMPACTOR

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A study on particle breakage of crushed rock of three different mineralogies was conducted using a gyratory compactor. The gyratory compactor (also called Texas gyratory press) combines a vertical stress applied to a sample placed in a 150mm diameter mold with a kneading effect caused by a plane strain shear induced by mold inclination in a gyratory movement. The crushed rock particles had an initial size varying from 10 to 14 mm. The objective of the project was to observe the evolution of the particle breakage in terms of particle size distribution using long duration solicitations (up to thousands gyrations) seeking for an ultimate curve size distribution that would be in accordance with a fractal distribution.

FINITE ELEMENT ANALYSES OF BURIED PIPELINE SUBJECTED TO CYCLIC LOAD USING ABAQUS

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In this paper finite element method (FEM) is applied to analyse soil stiffness degradation and pipe-soil interaction of a buried pipeline subjected to traffic load. The two-dimensional plane strain finite element is used for the analysis and computations are carried out using finite element software, ABAQUS 6.13. Soil behaviour is represented by the elasto-plastic Drucker-Prager model and pipe material is assumed to be isotropic and linear elastic.

For whole system, geometric and geotechnical effect of backfill materials, pipe and pipe-soil interaction properties are investigated. In addition, the effect of traffic pressure with magnitude varies from 200 to 550 kPa in both terms, static and cyclic at different pipe burial depth, changing between 1-3 times of pipe diameter is assessed on pipe-soil deflection. A non-linear model is also developed to predict soil settlement on soil surface and pipe deflection based on variation in abovementioned parameters. The Abaqus results are compared with those predictions achieved through numerical and experimental researches in existing literature and for some cases the model is simulated using Plaxis to check the analysis.

DRAINAGE CONDITION AND ITS EFFECT ON NONLINEAR SEISMIC SITE RESPONSE ANALYSIS

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Conventional engineering practice has often used one-dimensional equivalent linear total stress procedures to carry out seismic site response analyses. Equivalent linear procedures use traditional parameters such as modulus reduction and damping curves. Nonlinear analyses can provide a more accurate representation of soil behaviour in response to the propagation of seismic waves, however their use has been limited in practice due to the perceived complexity in parameter selection and usage. Moreover, both total and effective stress nonlinear analyses can be conducted to evaluate seismic site response. It would be insightful from a practical point of view to explore the difference in results when either of these approaches is used. In this paper the critical state bounding surface plasticity constitutive model SANISAND is used to investigate the nonlinear response of a site subjected to seismic loading. The importance of correctly modeling the porous solid-pore fluid interaction is explored, along with effect of drainage condition on seismic site response. Conclusions are drawn with respect to the relative differences in seismic site response when undrained, drained and coupled drainage conditions are used in nonlinear analyses.

MEASURING THE SMALL-STRAIN ELASTIC ANISOTROPY OF A CARBONATE CLAY TILL WITH THE RESONANT COLUMN APPARATUS.

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It is well accepted that the small strain stiffness (0.001% - 0.01%) of most natural soils is anisotropic to a certain degree. Hence, elastic moduli $G_h \neq G_v$ and $E_h \neq E_v$, where the subscripts h and v relate to horizontal or vertical directions in which the stiffness is measured. It is also acknowledged that measuring the cross-anisotropic properties of soils is very difficult due to the complexity of determining the five independent parameters needed to describe a transversely isotropic soil. These parameters are the associated Poisson's ratios (ν_{vh} and ν_{hh}) and the stiffness parameters (G_{vh} , E_h , E_v).

Despite a range of different methods being available for estimating small strain stiffness; through in-situ tests (e.g. down-hole and cross-hole profiling) or laboratory tests (e.g. bender element and triaxial test), studies have shown a wide variety of results due to multiple factors that play important roles during the execution of each technique. In addition, the spatial variability of the ground can lead to difficulties interpreting the data.

The resonant column method has been used widely to analyze the dynamic soil behaviour, specifically to measure torsional stiffness (G_{vh}) and damping ratio (ξ). Improvements to the standard Stokoe apparatus have enabled the additional measurement of Young's modulus and Poisson's ratio through axial oscillation and from flexural excitation. At present, resonant column testing method is considered to be one of the most reliable, effective, and practical laboratory test methods for testing shear modulus and material damping ratio of soils (ASTM-D4015-92).

Very little work has been done to data on using the technique to investigate the anisotropy of elastic moduli. This paper reports on a study of a series of tests conducted using a resonant column device to examine the degrees of anisotropy of a carbonate clay till deposit located in Southern Ontario. Comparisons of the results have been made with measurements done using bender elements (BE) and the results are discussed in light of the applications of this data to practical geotechnical engineering.

EFFECTS OF GALLING HERBIVORY ON GROUND THAW THROUGH SHRUB-SOIL HEAT TRANSFERS IN CANADA'S NORTHERN BOREAL FOREST

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Canada's northern boreal forest has faced significant climate warming over the past 100 years. This temperature change can have both direct and indirect effects on forest dynamics, including altering the disturbance patterns of herbivores and changing the abundance of natural enemies, competitors and mutualists. Warmer air temperatures can impact the distribution and overwinter survival of arthropods, both novel species and resident natural enemies. There is thus a need to better understand the effects of these arthropods on the plants and their environment to predict future impacts. Gall-inducing mites are a resident natural enemy in high latitude forests and have been shown to drive dramatic reductions in photosynthetic carbon uptake and transpiration rates of infested plants. Warming air temperatures could lead to increased overwinter survival rate for these galling mites. Most previous research of galling impacts have focused on the physiological implications of galling herbivory for the plant, this study will examine the potential impacts the gall-inducing eriophyoid mite, *Vasates oldfieldi*, has on *Betula* shrub energy inputs to the underlying ground surface. Two hypotheses will be tested: 1) a positive feedback to permafrost thaw through a reduction in evaporative cooling on the leaf surface which will increase the canopy temperature of the *Betula* shrubs. This will increase the incident longwave radiation to the ground surface, leading to an increase in the active layer thickness; 2) a negative feedback on permafrost thaw through a compensatory response in the shrub which will lead to an increase in leaf area index to offset the loss of photosynthetic function. This reduces the amount of incident solar radiation at the ground surface resulting in a cooler soil surface temperature and a shallower active layer. To test these hypotheses, we measured soil moisture and surface temperature, leaf temperature, active layer thickness, transpiration, shortwave radiation and leaf area index. Our initial findings have shown an increase in active layer thickness and soil temperature beneath ungalled shrubs compared to galled shrubs of similar size for both the 2013 and 2014 field seasons. The results from this experiment are of great significance as the potential for a positive feedback of warming at a very local scale can potentially influence ground thaw in the northern boreal forest, which is currently being amplified by increasing global temperatures.

STATISTICAL CORRELATIONS BETWEEN PRESSUREMETER MODULUS (EPMT) AND STANDARD PENETRATION TEST N-VALUE FOR GLACIAL TILLS

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Abstract: Standard Penetration Test (SPT) is a quick, simple and cost-effective testing method, which is intensively used to assess the properties of soils throughout the world. The SPTs often reach refusal, i.e. blow count (N) value greater than 50 for 150 mm increment when the SPT sampler hits a cobble or boulder within the glacial tills. As the distribution of cobble or boulder within the glacial tills is random, the high SPT's N-value may not reflect the real density or consistency of the glacial tills. The soil parameters estimated from the SPT N-value may be overestimated when the sampler hits cobbles/boulders or underestimated when the samples hits smaller soil particles between cobbles/boulders. In order to recognize a real changeability of glacial till properties, relative expensive test methods such as pre-bored Pressuremeter Tests (PMT) are often used for big projects.

The comprehensive site exploration programs for the Eglinton Crosstown LRT Project in Toronto involved various in-situ and field testing methods. This offers an excellent opportunity to conduct statistical correlations and a great amount of useful information can be derived from these tests. Among many testing methods, SPT and PMT tests were used in this project.

In this paper, the correlation between the PMT modulus (EPMT) and SPT N-value was investigated for glacial tills in the Greater Toronto Area (GTA). This study focused primarily on the statistical correlation between SPT N value and EPMT for glacial tills with different textures, such as silty clay, clayey silt, silty sand, sandy silt, sand, and silt. The literature review shows that there is only very limited information available about EPMT and no correlation available between EPMT and SPT N value for glacial tills. Therefore, the new development of correlation between those parameters is needed and necessary. In this paper, a new correlation will be suggested between SPT N-value and EPMT. In addition, the statistical analyses of physical properties of various glacial tills in the GTA are also presented and discussed. These findings will help Geo - technical community in evaluating and interpreting Geo - technical parameters for their clients.

GROUND ICE DETERMINATIONS ALONG THE YUKON COAST USING A MORPHOLOGICAL MODEL

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Permafrost often contains significant amounts of ground ice, and the Canadian western Arctic is an extremely ice-rich area. The ice content of the region's soils is high due to the presence of pore ice and thin segregated ice lenses, abundant ice wedges, and beds of massive ice. Pingos are also quite common in the region. A geomorphological model is used to estimate ground ice content at the landscape level, which is important in order to properly assess how the region will respond to changes in the environment, whether natural or anthropogenic. The Yukon coastline was divided into 44 different terrain units, ranging from 0.8 to 33.2 kilometers in length, based on geology, coastal morphology, and the presence of different types of ground ice. The different types of ground ice within each terrain unit were then quantified and the overall volume of ground ice within a terrain unit was assessed based on the stratigraphic relationships between the different ice types. Massive ice was documented in 15 units and had an average thickness of 4 m. Ice contents due to pore ice and thin lenses were measured in shallow cores for upper soil layers, and from bluff exposures for lower layers. The percentage of pore ice and thin segregated lenses ranged from 10 to 95%, with the higher values in fine-grained material. The amount of wedge ice was quantified by using average wedge volumes and estimating the length of wedges in a terrain unit based on the size of the polygons and therefore the spacing of the wedges. Ice wedge depths ranged from 3.0 to 7.0 m, with a mean of 5.3 m. The width of the wedges was between 1.5 and 2.3 m, averaging 2.0 m, while the mean spacing was 13 m. Ice volumes in the various terrain units ranged from 0 to 74% and are a function of surficial material. When considering the breakdown of ice types, pore ice and thin segregated lenses account for 76% of the total ground ice, wedge ice accounts for 3%, and massive ice for 21%. Model results show that over 180 million m³ of ground ice is present in sediments along the Yukon Coastal Plain, representing 46% of all earth materials.

2D AND 3D FEA COMPARISON TO SOLVE A 3D PROBLEM: IMPACTS ON A NEARBY SHALLOW FOUNDATION FROM A PILE AND SHEET PILE EARTH RETAINING STRUCTURE

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Modeling is always an issue for engineers, as the problems they face need to be conceptualized in order to be satisfactorily solved. Many hypotheses need to be made to do so and these can greatly affect the modeling results as well as the engineer's interpretation.

Numerical modeling can be used to estimate settlement of an existing footing due to nearby excavation in clay provided the earth retaining system is included in the model. If this system is made up of regularly spaced tubular piles fill with concrete and sheet piles, this problem appears as though it can only be solved by means of a 3 dimensional (3D) numerical analysis. A 2 dimensional (2D) analysis would assume that the geometry width of the modeled section is infinite. However, in reality, the geometry, the stiffness and the inertia of the retaining system will vary with the section considered.

First, results from triaxial tests on the clay subsoil were modeled using the following softwares: RS3 2013 by Rock Science (a 3D finite element software) and Sigma by the 2012 GeoStudio suite (a 2D finite element software). The linear-elastic model and the Cam-Clay modified model were used. Both model parameters were adjusted in the software in order to achieve an identical material behavior. The retaining system was then modeled in both 2D and 3D.

This paper describes the methodology and the interpretation of 2D results in order to model a 3D problem by means of 2D analyses. The impact of the selected model (linear elastic vs Cam-Clay Modified) was also evaluated in both 2D and 3D and the differences between the two types of analyses are compared.

DINSAR DISPLACEMENTS IN BUILT AND NATURAL PERMAFROST ENVIRONMENTS, IQALUIT, NUNAVUT

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Monitoring permafrost dynamics over large areas is challenging. In recent years, interest in the use of Interferometric Synthetic Aperture Radar (InSAR) as a source of ground surface displacement information for permafrost environments has increased considerably. Among the available InSAR methods, conventional differential InSAR (DInSAR) makes it possible to detect very small ground surface movement, on the order of centimetres, for every pixel over large coverage areas, providing a way to assess permafrost dynamics. In order to evaluate the information content of DInSAR maps, data were acquired over consecutive summers between 2011 and 2013 for the Iqaluit area, Nunavut. RADARSAT-2 spotlight scenes with a resolution of approximately 1 m were used to create maps of seasonal ground surface displacement. In this paper, we examine inter-annual DInSAR results along with surficial units, permafrost and climatic data, and compare results from built and natural environments. Quantitative analysis of displacement per surficial geology unit agrees well with the associated sediment type and ice content. Low displacement is associated with bedrock and coarse sediments, while finer sediments, more likely to be ice-rich, show higher values of displacement. In general, displacement seen in seasonal data sets is caused by thawing of the active layer. For a given surficial geology unit, displacements were generally lower in built areas than in the natural environment. Granular fill or pads and construction methods could play a role in reducing the amount of settlement, especially for surficial geology units showing higher displacement values. Within the same surficial unit, local surface and subsurface conditions can lead to different amounts of displacement. This can be explained by ground ice distribution and may be related to water flow within the active layer. Increased spatial detail in surficial geology could also explain variability in the DInSAR results. Higher displacement values are often associated with flooded vegetation. Our previous research findings indicate that DInSAR accuracy varies according to surface condition (dry areas versus flooded vegetation). In spite of that, the results so far have shown a good correlation with our observations and certainly have the potential to provide useful geoscience information to support decision-making for existing or new infrastructure.

AN EXPERIMENTAL STUDY OF CONTACT EROSION BETWEEN A TILL CORE AND COARSER CREST AND FILTER MATERIALS

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Contact erosion is an internal erosion process found in embankment dams and dikes which can lead to failure. It is defined as the pullout and dragging of fines from a base material through an adjacent coarser material under seepage parallel to the interface. This process can take place, for example, during a core overtopping (i.e. the reservoir level is situated above the core elevation but below the crest of the dam). This study intends to understand and to identify the mechanisms that control contact erosion with materials used for the construction of Romaine 3 dam.

To study the erosion process, a new experimental setup and a methodology have been developed. It consists of a rigid wall permeameter in which the soils studied are placed with a horizontal interface. A controlled parallel flow to this interface is then applied. Velocity, water pressure, eroded mass and vertical deformations are measured for each test. The experimental program consisted of combining different base soils and coarse soils. The base soil is a glacial till with a fines content of about 30%.

The experimental results confirmed the risk of erosion is minimum provided that the filter criteria are met. The results also showed that the critical velocity for the till is a little underestimated by models proposed in literature. This observation may be explained by the difficulty to choose the characteristic grain size of the soil. An analysis of the evolution of the erosion process as a function of time and hydraulic solicitation indicates that, for a well graded material, there is a stabilisation and in some cases a stoppage of erosion, even if the discharge velocity is higher than the critical value. This is due to the formation of a coarser layer at the interface between the materials that slows down the erosion process. Clogging of the filter was also observed in some cases.

GEOTECHNICAL AND GEOENVIRONMENTAL CHARACTERIZATION OF BENTONITE-ENHANCED SAND MIXTURES

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Bentonite-enhanced sand (BES) mixtures are usually used in buffers, slurry walls, and contaminant barrier systems in solid and radioactive waste disposal sites, due to their relatively high strength and low hydraulic conductivity. The efficiency of these insulated barriers depends largely on their hydraulic and mechanical behavior. A laboratory investigation was conducted to examine the geotechnical and geoenvironmental characteristics of selected BES mixtures. The laboratory experiments consisted of hydraulic conductivity tests, direct shear tests, unconfined compression tests and pure diffusion tests. Four BES mixtures with 10, 20, 30 and 40% bentonite content were selected. The results of hydraulic conductivity tests showed that with increasing bentonite content, the hydraulic conductivity of BES mixtures decrease substantially. In direct shear tests, bentonite had negative effect and caused decrease of the shear strength of the BES mixtures. The results of unconfined compression tests showed that increasing bentonite content up to 30% in BES specimens increased the unconfined compression strength. Diffusion tests showed that diffusion coefficient of BES specimens decreases as the bentonite content increases. Based on the results of conducted tests it was concluded that the BES mixture with 20% bentonite and 80% sand could be selected as an optimum mixture for the material to be used in contaminant barrier systems.

NUMERICAL SIMULATION OF PRESSUREMETER TESTS IN GLACIAL TILL

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The analysis of soil response in a pressuremeter test can be performed using either numerical simulation or the cavity expansion theory. These current analyses are based on an assumption of a homogeneous soil. This assumption is not true for the glacial till which contains cobbles and boulders. As the distribution of cobbles and boulders within the glacial till is random, the glacial till is generally heterogeneous. The newly developed discrete element method (DME) provides an opportunity to simulate a heterogeneous soil such as the glacial till.

This paper presents a numerical analysis of prebored pressuremeter test (PMT) in the glacial till using the DEM. In the analysis, the soil is modeled as the glacial till with different textures of silty clay, clayey silty, sandy silt, sand and silt, and silty sand and different percentages of cobbles and boulders. The analysis results are compared with the PMTs conducted in the Greater Toronto Areas, Ontario. Use of the PMT measurements such as the limit pressure and modulus in the geotechnical design is discussed and recommended based on the numerical analysis.

MASSIVE ICE STRUCTURE IN PERMAFROST AND ITS IMPLICATION FOR DEVELOPMENT IN THE CANADIAN NORTH

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According to Mackay (1973), massive ice structures are generally found above remarkably uniform sand and gravel deposits. The origin of these massive icy bodies is not yet fully understood, but Mackey proposed that the mechanism of massive ice formation is analogous to that of pingo growth, where the water source is generated by pore water expulsion resulting from freezing of adjacent coarse-grained sediments over a considerable large area.

After reviewing different mechanisms of massive icy beds formation, the paper analyses the implication of massive ice in an esker for the development of a reservoir in a northerly environment. Numerical thermal simulations were performed with FROST-2D to evaluate the influence of reservoir level on the stability of the esker over time. Links between permafrost science and engineering are emphasized, illustrating Ross Mackey's influence on the engineering community.

FROST HEAVE PARAMETERS OF FINE-GRAINED SOILS OBTAINED FROM SHELBY TUBES AND FROM RECONSTITUTED SAMPLES

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Frost heave parameters are usually represented by the segregation potential defined as the ratio of segregational frost heave rate and temperature gradient in the frozen fringe near the frost front. Segregation potential may be determined in the laboratory using one-dimensional freezing tests, from field data or inferred from empirical correlations. Freezing tests can be conducted on reconstituted samples or high quality samples obtained from adequate samplers. This paper presents the results of a study conducted at two sites in the province of Quebec, one at Cap Santé located on HYW 138 and the other one at St-David located on HWY 122. Samples were collected at both sites using 70 mm diameter Shelby tubes. Laboratory freezing test were conducted on 10 cm high samples extruded from the Shelby tubes and compared to reconstituted samples obtained by consolidation of a slurry mixed at an initial water content of about 1.3 times the liquid limit. The results indicate that there is a marked difference in SP values, most likely associated with a different soil fabric and water content. The soil fabric also influences the ice lens morphology. The empirical relationship proposed by Konrad (1999) was also compared to the laboratory derived parameters and found to be adequate for both soils tested.

**DESIGN, CONSTRUCTION AND PRELIMINARY RESULTS ON TWO INSULATION COVERS
EXPERIMENTAL CELLS AT THE MEADOWBANK**

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An important challenge for the mining industry is the reclamation of tailings storage areas, especially when tailings can generate acid mine drainage (AMD). For mine sites located in Nordic conditions, integrating tailings within the permafrost by the use of an insulation cover can represent an interesting reclamation option. The objective of the insulation cover is to maintain the tailings in a permanently frozen state below the active layer cover made of inert material. Low temperature in the reactive tailings will slow down both chemical and biological oxidation reactions and reduce the generation and migration of pollutants. This study focuses on one reclamation option at the Meadowbank mine (Nunavut, Ca) for the tailings impoundment which consists in an insulation cover made of inert waste rocks. Two cover scenarios are tested in field experimental cells built to validate the reclamation technique. Two cells ($\approx 10\text{m} \times 10\text{m}$) with cover thicknesses of 2 m (cell 2m) and 4 m (cell 4m) respectively are tested. Volumetric water content suction and temperature sensors were installed into the cells in order to assess the thermo-hydraulic behavior of the tested covers. Oxygen consumption (OC) tests were also performed below the cover and in the tailings impoundment to estimate the reactivity of the Meadowbank tailings with or without cover on top. Results indicate that the covered mine tailings remain nearly frozen during the warmest period of the year for the two cells. Indeed, during the first months of the experiment, temperature at the tailings-waste rocks interface shows an average value of 0.3°C and -0.7°C for the 2m and 4m-thick covers, respectively. The oxygen fluxes remain low with values below $10 \text{ moles.m}^{-2}\text{.year}^{-1}$ (detection limit of oxygen consumption test) for the tailings below the two insulation covers while the tailings reactivity can reach values between 20 and 80 moles of $\text{O}_2\text{.m}^{-2}\text{.year}^{-1}$ when exposed to Meadowbank summer climatic conditions.

THE EFFECTS OF DRAINAGE CHANNELS ON COLLAPSE SCAR BOGS IN DISCONTINUOUS PERMAFROST TERRAIN

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Flows from river basins in the lower Liard River valley in northwestern Canada have been rising in the last two decades as a result of climate warming. Changes in precipitation account for only about 30% of this increase. In the wetland-dominated basins that characterise the southern margin of permafrost, permafrost thaw and disappearance, and resulting land-cover change, is occurring at an unprecedented rate. Permafrost thaw has the potential to fundamentally alter the processes giving rise to streamflow in this region by altering the type and relative proportions of biophysical terrains. Field studies were conducted at the Scotty Creek Research Basin, a 152 km² watershed, located about 50 km south of Fort Simpson, NT. Scotty Creek is typical of other basins in the region and is underlain by discontinuous permafrost. There are three major land-cover types in the basin, each exhibiting a distinct hydrological function. Channel fens convey water to the basin outlet, while permafrost plateaus are runoff generators. Collapse scar bogs have been shown to be primarily storage features, however ephemeral channels have been observed to cut through permafrost plateaus and allow for hydrologic interaction between bogs. These channels create series of bog cascades that drain adjacent peat plateaus and ultimately flow into the channel fen. This study suggests that these drainage channels are created as the relatively warm water in the bogs slowly erodes the intervening permafrost-cored peat plateau. It is shown that the transmission of water through bogs and into the fen via these drainage channels is a mechanism that changes the effective contributing area. Field data indicates that the dynamic contributing areas are controlled by storage thresholds. Sharp crested v-notch weirs and flume boxes were installed in the channels to create a continuous stage-discharge relationship to gauge runoff entering the channel fen through the bog cascades. In this study we attempt to quantify the amount of runoff produced from bog cascades and determine how the contributing area varies in time and space. We will use the hydrological model Raven to simulate this response under different degrees of connectivity resulting from permafrost thaw.

COMPRESSIBILITY OF ROCKFILL USING A LARGE DIAMETER OEDOMETER, CENTRIFUGE TESTING AND FIELD DATA FROM ROMAINE-2 DAM

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The Romaine-2 dam is a 112 m high asphalt core rockfill dam located in northern Quebec, Canada. Dam construction occurred in 2012 and 2013. During the design stage, laboratory testing was conducted on crushed rock particles (max size of 25 mm) to determine the relevant parameters for modelling the behaviour of Romaine-2 dam. The compressibility of rockfill was a key parameter for the prediction of dam settlement during construction. Laboratory one-dimensional compression tests and 2-D centrifuge tests were conducted on the same material with a grain size distribution parallel to the specified average distribution for the rockfill material used at Romaine-2. The compressibility obtained from each testing device was compared to field data collected during the construction. The results indicate that actual field behaviour is close to that observed in the centrifuge tests provided that the material densities are close. One-dimensional compression appears to result in slightly smaller compressibility values. Nevertheless, the large oedometer remains an excellent device to determine the best material to be used at a given site to minimize dam settlements.

HIGH ARCTIC HILLSLOPE-WETLAND LINKAGES: TYPES, PATTERNS AND IMPORTANCE

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High Arctic wetlands are lush areas in an otherwise barren landscape. They help to store and replenish water and they serve as significant resting and breeding grounds for migratory birds. In addition, they provide rich grazing grounds for arctic fauna such as muskox and caribou. Arctic wetlands can be characterized by lakes, ponds, wet meadows, and, often times, they are inter-mixed with areas of dry ground. While seasonal snowmelt continues to remain the most critical source of water for recharging ponds, lakes, and meadows in these environments, less is known about the role of lateral inputs of water into low-lying wetlands, namely water flowing into these wetland ecosystems from adjacent hillslopes, which often surround them. This paper will review the different modes of hillslope runoff into both patchy and regional-scale wetlands including late-lying snowbeds, snow-filled creeks, and both small and large (>1st order) streams. It will draw upon field results from four Canadian Arctic islands (Ellesmere, Cornwallis, Somerset and Bathurst) and a research period which spans from the mid-90's until the present. This study will evaluate seasonal and inter-seasonal patterns of snowmelt driven discharge (initiation, duration), timing and magnitude of peak flows, in addition to stream response to rainfall and dry episodes. The impacts of these lateral water sources for a range of wetlands (ponds, wet meadows) will include an analysis of water level fluctuations (frequency, duration), shrinkage/expansion rates, and water quality. Finally, this study will surmise how these types of lateral hillslope inflows might shift in the future and suggest the impact of these changes on the sustainability of High Arctic wetland terrain.

ASSESSMENT OF PERMAFROST CONDITIONS UNDER AIRPORTS AND ACCESS ROADS USING AN INTEGRATIVE APPROACH TO SUPPORT ADAPTATION STRATEGIES TO CLIMATE WARMING: CASE STUDIES FROM NORTHERN QUEBEC.

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The Nunavik community airports were built between 1984 and 1992 using thick embankments of rock fill placed on the undisturbed ground surface to prevent thawing of the underlying permafrost. However, since around 2000, many of the runways have shown signs of permafrost disturbance as some localized differential settlements have begun to take place. With further climate warming, the vulnerability to permafrost degradation of the runways, aprons and access roads raises concerns. A precise assessment of the spatial variability of permafrost geotechnical properties underneath infrastructures was needed in order to plan adaptation strategies to climate warming. A geomorphological and geotechnical investigation campaign, including surficial geology mapping using pre-construction air photographs and recovery of drilled frozen cores, was carried out at eight airports. The impact of the runway embankments on surface drainage, snow drift accumulation and permafrost thawing was also determined. Stratigraphic information from drilling was used to reinterpret CCR and GPR surveys done in previous studies. High resolution cross-sections of the stratigraphy and permafrost conditions were drawn. Lab testing of undisturbed frozen samples was performed to determine the geotechnical properties of the different stratigraphic units encountered, particularly thaw consolidation ratios. Field measurements of ground temperatures and numerical modeling of the thermal regime of the embankments and subgrades were also performed to assess the potential impacts on permafrost thawing alongside and beneath embankments under different climate change scenarios. Localized damages on some embankment shoulders such as cracks and settlements confirm that the permafrost beneath the shoulders is greatly degraded. In fact, thermal measurements and drilling information reveal that unfrozen layers (talik) reaching up to 6 meters deep are now present at the toe of many embankments. This accelerated degradation of permafrost is due primarily to snow and water accumulation bringing ground temperature towards warmer conditions. According to our numerical modeling, as the climate warms up, active layer in the centerline of the runway will slightly increase resulting in limited thaw settlement. On the other hand, embankment toe will keep degrading rapidly according to the combined effect of snow and water accumulation. For this reason, the proposed adaptation plans focuses on minimizing snow and any potential heat input through summer-warmed water seepage by using specific designs such as gentler slopes (1:7), air convection embankments or heat drain embankments with improved drainage systems. These mitigation techniques are now being applied at many sites in Nunavik; current monitoring indicates that they are efficient.

FIBER OPTICS LINEARLY DISTRIBUTED TEMPERATURE SENSING FOR MONITORING ROAD PERFORMANCE ON PERMAFROST IN SALLUIT, NUNAVIK

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We used fiber optics Distributed Temperature Sensing (DTS) to monitor the temperature regime under a newly reconstructed road on permafrost. In DTS systems, as pulses of light emitted by a laser travel in a fiber optics cable, a small fraction of the signal is reflected along its course back to the source with a slight frequency shift that is temperature dependant, thus allowing to measure temperature along the cable by measuring two-way travel time. The permafrost beneath the road consists of very ice-rich silt that puts the road at high risk of deterioration by permafrost thawing following any input of heat that may occur anywhere along its length, the most feared heat sources being snow insulation on shoulders in winter and water seepage underneath the structure in summer. About 900 m long of embankment were rebuilt: specially designed heat drains were buried under one side of the road to cool the embankment under snow in winter. On the other side of the road, the geometry of ditches and culverts was redesigned so as to reduce heat advection by water infiltration in summer. A total length of 3.4 km of DTS cable was buried under the embankments slopes on both sides of the road. On one side, the cable is buried at two depths (0.3 and 0.8 m) to detect heat carrying water seepage in the ground whereas on the other side it is buried under the heat drain to assess its efficiency in cooling back the permafrost under the roadside. The cable also runs in loops across the road under four culverts. A section is buried 0.25 m in nearby natural terrain as reference. The linear resolution of the system is 0.25 m and the temperature measurement precision is 0.1 °C. The datalogging system was programmed to take readings every 3 hours year round. Results show the different timing of freeze back of the embankment under the roadside in relation with wet and dry sections of terrain on which the road is built. At spring time, heat intake in the ground by water flowing through the culverts and the warming impact of some seepage under the road at a few points could be detected. Fiber optics DTS allows detection of sensible spots anywhere along its length and to accurately measure temperatures variations both in time and space.

SIMPLE SHEAR LOADING RESPONSE OF UNDISTURBED AND RECONSTITUTED SILT

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The mechanical behaviour of natural silt specimens (Plasticity Index = 7), along with reconstituted specimens prepared from the same material, were investigated using monotonic and cyclic constant-volume direct simple shear test methods. Natural silt, retrieved using thin-walled sharpened-edge tube sampling from selected deltaic deposits located within the Lower Mainland of British Columbia, Canada were used for the study. Reconstituted specimens were prepared from the slurry deposition method. It was noted that the void ratios observed from the reconstituted specimens, after consolidation to a given vertical effective stress, were consistently lower than that determined for natural (relatively undisturbed) specimens. Monotonic loading tests were performed on both relatively undisturbed and reconstituted silt specimens at three different confining stresses, whereas cyclic loading tests were performed at a selected confining stress with the application of different cyclic stress ratios. The initial vertical effective confining stress levels were selected such that shearing phase of all tests would commence on specimens that are normally consolidated. During monotonic shear loading, reconstituted specimens exhibited slightly higher shear strength than that of undisturbed specimens. Cyclic resistance was assessed from the number of uniform sinusoidal loading cycles that were required for the specimen to attain shear strain of 3.75%. In these cyclic direct simple shear tests, all reconstituted specimens displayed higher rate in strain accumulation and pore-water pressure development compared to those observed for relatively undisturbed specimens. Accordingly, despite the relatively denser state of reconstituted specimens in comparison with relatively undisturbed specimens at the start of cyclic simple shear loading, the reconstituted specimen possessed a weaker cyclic shear resistance in comparison to the relatively undisturbed specimens. Typically, lesser void ratio (denser particle arrangement) results an increase in shear stiffness and strength, whereas destructuration of natural fabric could cause a decrease in shear stiffness and strength. It appears that in the observed monotonic shear loading response of reconstituted specimens, the effect of change in void ratio has over-shadowed the influence due to the change in fabric and micro-structure whereas in cyclic loading, the changes in fabric and micro-structure seem to have affected the shear behaviour more than that arising from the changes in void ratio.

JOHN ROSS MACKAY—THE GREATEST TUTOR AND BEST FRIEND OF CHINESE PERMAFROST RESEARCHERS

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In 1982, Dr. Ross Mackay visited China for the first time. His six professional and inspiring presentations amazed Chinese geocryologists, and they immediately adopted him as the greatest master in permafrost research.

Dr. Mackay has the highest esteem among the Chinese permafrost scholars not only because of his great achievements in the studies on permafrost and ground ice, but also his devotion to science, unique research methodologies and painstaking attitude for research. For a half century, his unquenchable curiosity for mysterious permafrost phenomena and insatiable thirst for learning new things, and his devoted, tenacious research on arctic permafrost while fighting with an extremely harsh environment, have impeccably exemplified for Chinese researchers what a true geocryologist should be. In addition, Mackay was talented for seamlessly integrating the three key elements for fieldwork: theories/hypotheses, simple and effective instrumentations, and proficient and meticulous observations. In particular, the draining of the Illisarvik Lake for an all-scale field-experimental study on the growth of permafrost has been a unique and classical example for project design in Chinese minds. Because of his scholarly attitude on pursuing the science, the data and conclusions based thereupon in his voluminous papers are generally trusted with the utmost confidence.

Although Dr. Mackay is no longer with us, he will always be the best friend of Chinese researchers. He attentively arranged and catered, with the greatest hospitality, batches of Chinese visiting scholars to and in Canada; he tirelessly helped revising and editing the English papers for Chinese scientists; he volunteered to helping reviewing and editing the English abstracts of the Journal of Glaciology and Geocryology; he helped China in all international activities, and; there are just too many to exhaust all his greatness and generosity.

The 1980s was a critical and trying period for China in opening and reforming, and the fledgling Chinese geocryologists were actually faltering out to see the world, when Mackay timely lent a helping hand and the tutorship. What Dr. Mackay gave us, in a badly needed time, will forever be cherished by numerous Chinese researchers. Maybe, also because of the Chinese blood in Mackay, in addition to admiring him with a great awe, Chinese colleagues also feel an unspeakable kinship to Mackay.

John Ross Mackay, the greatest mentor and best friend of Chinese permafrost scholars, will live forever in China and beyond.

THE FIRST FINDINGS OF THE LATE PLEISTOCENE PALEOSOLS IN NORTHWESTERN SIBERIA, IN THE BASIN OF THE MIDDLE OB' RIVER

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Permafrost history of Northwestern Siberia is hotly discussed. Our discovery of the well-developed Late Pleistocene paleosols, in the bodies of the Middle Ob' 30-35m terrace, contributes valuable information for this matter, especially as it is the first finding of paleosols here.

The study area is in the South of the modern permafrost extension (headwaters of the Vakh-River, a right-hand tributary of the Middle Ob'), where the recent soil is a well-developed Podzol in sandy alluvium. The first paleosol occurred at a depth of 4 m on the parent substrate of a half-meter thickness with alternating clayey, loamy and sandy-loamy layers. It consists of a grey strongly gleyed horizon in a loamy stratum underlain and overlain by sandy sediments. Its calibrated radiocarbon age is 25,000-27,000 yrs. BP (MIS-3a). In the middle and basal parts of the 30-35m terrace (its surface is at a height of 120-140 m a.s.l.) other paleosols occurred. Defined as Gleysols, they also formed in loamy sediments; their profiles consist of well-developed grey A- and G-horizons. In thin sections the gleyic horizons demonstrate compact packing with practically no voids, few ferruginous pedofeatures – mottles and stripes, sometimes – poorly decomposed fragments of plant tissues. Under higher magnifications frequent opaline biomes – sponge spicules, diatoms and phytoliths were observed. Radiocarbon dating indicated these paleosols as older than 40,000 yrs. BP (MIS-3c?). All paleosols were traced along the terrace over long distances.

The terrace body is not frozen. At a background of absence of glacial deposits, no evidence of strong freezing revealed itself in all terrace sediments; residual post-cryogenic textures yielded by segregation ice occurred sometimes only. It means that over the Late Pleistocene, permafrost, southwards of its modern limit, formed as of high-temperature and middle-temperature modes. Also the continuous well-preserved MIS-3 paleosols, together with absence of glacial sediments between the paleosols, and between them and the modern soil, prove that the studied area was not both deep freezing and covered by ice sheets. Strong gleying of paleosol points to its development under poorly drained water-saturated conditions. Taking into account little development of macro- and microscopic features of cryogenic processes in the studied paleosols, we suppose that a contrasting evolution of pedogenesis, from gleyic during MIS-3 to podzolic in the Holocene, is related to the terrace tectonic uplift that changed drainage conditions provided by river geological work in the modern and ancient Ob' basin and sea regression-transgression activities from the Arctic.

FIELD-TESTING STUDY ON FROST-HEAVE PREVENTION OF HIGHWAY ROADBED IN VALLEY REGIONS OF SOUTH GANSU PROVINCE, CHINA

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Abstract : Roadbed problems related to thawing and freezing process occur widely in seasonally frozen regions in China, frost-susceptible soils can generate severe frost heave and frost boiling under certain environmental conditions such as shallow water table and abundant water recharging. The new constructed Tanchang-Diebu highway (TDH) is located in valley regions of south Gansu Province in China, due to damp and rainy climate, thick layers of humus and silty clay, higher water content and snow cover in winter in this area, frost heave and thaw settlement are still the bottle-neck issues in the highway construction. To solve such problems, several testing sections were constructed to investigate the effectiveness of mitigation measures including replacement method with crushed rock layer and lowering groundwater table. Because the distance from testing sections to a nearby tunnel, named Lazikou tunnel, is about 8 kilometers, the mucking debris from the tunnel was used as crushed rocks. Monitored temperature and displacement results indicate that a certain thickness of crushed rock layer played a roll of adjusting the ground temperature field, the 2.0 m thickness of crushed rock layer has much better abilities in adjusting the temperature field than the 1.0 m thickness of crushed rock layer has. And the maximum relative frost heave observed at a shoulder and at the center during the period between October 2013 and March 2014 are 5.6 mm and 10.6mm, respectively. The maximum amounts of frost-heaving are no more than 60 mm, which is admissible value of frost-heaving in the Guide for highway engineering anti-frost design and construction technology. Furthermore, the analysis of groundwater table observed during the period between June 2013 and October 2014 shows that the table is consistently located below the original water table. The mitigation measures were successfully applied in the TDH construction and now the highway is under well service. All these state that the replacement method with crushed rock layer and dewatering are the effective measures to mitigate frost damage in valley regions of south Gansu Province. This research can provide a useful reference for future projects in similar areas.

SECONDARY CONSOLIDATION OF A COHESIVE SOIL IN NORTHERN ONTARIO: A CASE STUDY

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Long-term field settlement data and short-term and long-term laboratory consolidation test data provide a comparison of typical values used in the assessment of secondary consolidation (creep) of a cohesive soil beneath a Highway 69 embankment crossing a swamp south of Sudbury in Northern Ontario. Design of the approximately 10 m high embankment with surcharge over an approximately 22 m thick clay deposit was based on the standard Terzaghi primary and secondary compression concepts. The secondary consolidation design, which is the focus of this paper, was based on standard 24 hour load increment consolidation tests (i.e. total test time of 14 days or less) and embankment construction included wick drains, staged construction and a surcharge. Regular monitoring of the compression of the cohesive layer using a settlement profiler was carried out during embankment construction and surcharge period and annual readings have been taken following completion of the highway and opening to traffic in 2009. Secondary compression indices back-calculated from the long-term, post-construction field data are compared to values derived from the short-term (standard) laboratory consolidation tests as well as from long-term laboratory consolidation tests that have been running for more than 1 year. This paper presents a summary of the site and test conditions, a summary of the properties of the cohesive soil as well as a summary and comparison of the field measured and laboratory test results including magnitude of settlement and estimates of secondary compression index/strain ($C\alpha(e)$ and $C\alpha(\epsilon)$).

CRYOGENIC PROCESSES AND FEATURES IN PERMAFROST-AFFECTED SOILS.

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Permafrost-affected soils are dominated by cryogenic processes. The mechanisms driving these cryogenic processes are the increase in volume when water freezes, turning it into ice, and the migration of water from warm to cold parts in the soil, feeding and growing the ice bodies. These processes increase the ice volume in the soil, resulting in differential frost heave, compaction, rotation, sorting of particles and pore formation. These processes are eventually responsible for the formation of unique macro and micro features in these soils.

The most common cryogenic macro features are irregular or broken soil horizons and transfer of soil materials into lower soil horizons as a result of cryoturbation. Platy, blocky, granular structures are due to ice lensing and rolling of soil aggregates while oriented coarse particles have resulted from rotation and frost heave. Massive and amorphous structures develop as a result of desiccation during freeze-back. Development of frost cracks and ice wedge formations are also common features in these soils. Although these macromorphological features occur primarily in the active layer of the soils, they can also be found in the near-surface permafrost.

The most common micro features generated by cryogenic processes are orbicular (skeletal grains organised into circular patterns), susitic (skeleton grains oriented in a linear pattern), conglomeric (structural units enclosed by finer matrix), lenticular or platy (resulting from ice lensing and vein ice) and granic (granular or blocky microfabrics resulting from cryodesiccation). These micro features are very useful indicators for determining present or past cryogenic processes in the soil.

The water moving along the thermal gradients (warm to cold) also moves soluble salts, organic acids and Fe Al-gels. A major concern is the various contaminants, such as persistent organic pollutants and mercury concentrated by cryogenic processes, especially in perennially frozen organic soils. These soils, when thawing, are then these toxic contaminants move into the groundwater.

Cryoturbation is one of the processes that not only produces irregular soil horizons, but are also responsible for the translocation of organic materials from the soil surface into the deeper soil layers. Due to the low soil temperature and, in some cases, the acidic conditions, this organic material accumulates and is preserved in the subsoil for thousands of years. However, there would be much concern if this carbon were released from these soils as carbon dioxide and methane, further increasing climate warming.

SIMPLIFIED ANALYSIS METHOD FOR A BLAST SOLLICITATION NEAR SENSITIVE CLAY SLOPE

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Blasting is a construction device used in many fields of engineering especially for transportation and mining and it is also “the most challenging and least understood source of construction vibrations” (Dowding, 2000). As the main purpose of blasting is to excavate rock by fragmentation, it also has an effect on surrounding soils and structures which depends mostly on the blast design. Blasting operations may be a triggering factor for landslides in sensitive clays. A large slide in sensitive clay occurred on August 1st 2009 in La Romaine village on the North Shore of the St-Lawrence, triggered by blast during the construction of the road. The soil investigations revealed the presence of sensitive clay overlaid by a layer of 3 m of peat (Locat et coll., 2010). As several rock outcrops were found on the site, blasting operations were needed for the future alignment of the road. All the fragmented rocks resulting from blasting operations were planned to be used for the purpose of road construction and have been projected on the clay. When workers went back to the field after blasting, they noticed that a large landslide (175 m by 300 m) had occurred. Two types of loading may have affected the slope: the blast loading and the impact loading of fragmented rocks. It’s necessary to characterise those particular physical phenomenon to understand their influence on the slope stability. This article focuses on the blast loading. It presents a literature review on vibrations control during construction, peak particle velocity generated during blasts and landslides cases implying blasting operations. The objective of the article is to understand the influence of this particular blast on sensitive clay slope with a simplified method. The blast design of La Romaine is going to be detailed, the associated peak particle velocity, stresses and deformations are going to be determined with theoretical and empirical equations.

DEFORMATION MODULI OF ROCKFILL EMBANKMENT DAMS DERIVED FROM FIELD MEASUREMENTS DURING CONSTRUCTION

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Rockfill deformation parameters are required for the design of embankment dams as well as specification of compaction procedures during their construction and safety assessment during their operation. These parameters are often determined by laboratory testing and used in stress deformation modelling. Based on modelling results, precedents and engineering judgment, construction procedures are specified as well as expected dam displacements.

However, laboratory testing cannot fully reproduce in situ conditions affecting rockfill moduli such as the presence of large particles as well as layering and anisotropy due to placement methods and segregation. Significant scale effects are almost always present when testing dam fill materials in laboratory. To circumvent some of these difficulties, this paper presents an approach to compute rockfill deformation moduli based on in situ construction settlement measurements by inclinometers. A number of large rockfill dams are examined to assess the effects of various material gradations and compaction procedures on deformation moduli.

The presented practical approach allowed a representative synthesis of field rockfill properties to be used in modelling. It can also be used to assess rockfill properties for future projects by relating computed moduli for existing dams with expected rockfill characteristics of dams to be constructed.

CASE HISTORY OF STATIC AND HIGH STRAIN DYNAMIC TESTING OF DRIVEN STEEL PIPE PILES PERFORMED AT AN INDUSTRIAL SITE NEAR EDMONTON, ALBERTA

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This paper describes a case histories involving static load testing and high strain dynamic testing (HSDT) of driven steel pipe piles at an industrial plant site near Edmonton, Alberta.

The site geology consisted basically of thin discontinuous deposits of glaciolacustrine clay and discontinuous deposits of aeolian sand overlying a thick glacial clay till stratum containing sand layers.

A pile load test program was carried out prior to construction to assist with the design of the piles. The testing program consisted of four static load tests on driven steel pipe piles and included static compression and tension testing. In addition, High Strain Dynamic Testing (PDA tests) were conducted on all test piles at the End of Initial Drive (EOID) and at Beginning of Restrike (BOR), after a period of at least 7 days. The pile diameters ranged from 508 mm to 762 mm, with pile embedment of approximately 20 m.

As part of the quality control during construction, high strain dynamic tests (i.e. PDA tests) were performed on approximately 190 piles, representing about five percent of the installed driven steel piles. The PDA tests were conducted on pile sizes ranging from 254 mm to 762 mm and depths ranging from 10 m to 24 m, and were performed at EOID and at BOR.

This paper will provide the results of the static load test program and a comparison with the results obtained by the PDA testing performed at EOID and BOR at each test pile. In addition, a summary of the PDA testing performed in the production piles will also be presented including a discussion of the PDA test results. The dynamic test results indicated considerable scatter in pile capacities and the importance of "set-up", or increase in capacity with time which is an important component for pile design optimization and acceptance.

A CASE STUDY ON FAILURE OF ROCK SLOPE UNDER VERTICAL CUT

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Deep vertical cut of rock slopes are often encountered in engineering projects of densely populated urban areas. A recent development required the excavation and vertical cut of a rock slope in Western China, which might cause large deformation or failure of existing buildings above the slope. The minimum horizontal distance between the buildings and the cut edge of the slope was 3 meters and the maximum excavation depth was 20 meters. The rock slope was composed of soil, weathered mudstone, sandstone and a set of bedding planes inclining outward was observed. Stabilizing piles strengthened by a series of tie-back anchors were designed to protect the cut slope. It was observed that the construction sequence had a significant impact on the stability of the slopes. At the slope section where staged construction was followed, the slope remained intact based on the monitoring data of slope displacement. At the section where the slope was cut at a single stage after installation of stabilizing piles, considerable deformation was observed to cause evacuation of existing buildings. Numerical modeling was conducted that showed the slope vertically excavated to 20 m deep was under factor of safety of 1.0.

THE EFFECT OF SNOW: HOW TO BETTER MODEL GROUND SURFACE TEMPERATURES

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We present an inverse modeling approach for reconstructing the effective thermal conductivity of snow on a daily basis using air temperature, ground temperature and snow depth measurements. The method is applied to four sites in Alaska. To validate the method we used measured snow densities and snow water equivalents. The modeled thermal conductivities of snow for the two interior Alaska sites have relatively low values and reach their maximum near the end of the snow season, while the conductivities at the two sites on the Alaskan North Slope are higher and reach their maximum earlier in the snow season. We show that the reconstructed daily thermal conductivities allow for more accurate modeling of ground surface temperatures when compared to applying a constant thermal conductivity for the snow layer.

CHANGES IN PERMAFROST AND ACTIVE-LAYER TEMPERATURES ALONG AN ALASKAN PERMAFROST-ECOLOGICAL TRANSECT

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The impact of climate warming on permafrost and the potential of climate feedbacks resulting from permafrost thawing have recently received a great deal of attention. Ground temperatures are a primary indicator of permafrost stability. The monitoring network of the Thermal State of Permafrost (TSP) program established during the Fourth International Polar. In Alaska, two major permafrost temperature measurement networks exist. One of them is operated by the U. S. Geological Survey predominantly within the North Slope of Alaska. The second network was established in the late-1970s and early-1980 by Professor Emeritus T. E. Osterkamp and has been supported since then by the Permafrost group at the Geophysical Institute University of Alaska Fairbanks. Most of the research sites of this network are located along an Alaskan Permafrost-Ecological Transect. This transect spans all permafrost zones in Alaska from the southern limits of permafrost near Glennallen to the Arctic coast in the Prudhoe Bay region. In this presentation, the results of more than 30 years of the permafrost and active layer temperature observations along this transect will be presented. Most of the permafrost observatories in Alaska show substantial warming of permafrost since the 1980s. The magnitude of warming has varied with location, but was typically from 0.5 to 2°C. However, this warming was not linear in time and not spatially uniform. A short warmer period in the very early 1980s was followed by a relative cooling in the mid-1980s. Since the late-1980s, the permafrost and active layer temperatures were increasing up to the late-1990s. During the first half of the 2000s, permafrost temperatures were not changing significantly at almost all of the sites in Alaska, except for the sites in the Brooks Range and at its southern foothills where the temperature was still increasing. Interesting dynamics in permafrost temperatures have been observed in Alaska since the mid-2000 until the present. While permafrost warming resumed on the North Slope of Alaska with a rate between 0.2 to 0.5°C per decade, permafrost temperatures in the Alaskan Interior started to experience a slight cooling that have continued during the first half of the 2010s. The observed climate warming triggered permafrost degradation in Alaska, especially at the locations which were affected by human activities. The combination of thawing permafrost and erosion is damaging the local community infrastructure such as buildings, roads, airports, pipelines, water and sanitation facilities, and communication systems.

LOAD TRANSFER OF HELICAL PILES IN FROZEN GROUND

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Load Transfer of Helical Piles in Frozen Ground

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Helical piles (also known as screw piles) are often used in industry to minimize the frost heave normally generated in frozen ground. However the performance of these piles in frozen ground has not been well understood. Most of the existing literatures discuss the performance of this type of piles in unfrozen soils. Therefore, the present paper is dedicated to investigate the performance of helical piles in frozen ground when temperature is below freezing point. Pile-load tests are conducted to investigate the bearing capacity of helical piles in both frozen and unfrozen conditions. The obtained results are also compared to the pile-load tests conducted on conventional open-ended steel piles under similar conditions.

OPTIMIZING DESIGN OF ROCK SOCKETS USING BIDIRECTIONAL TESTING OF PRELIMINARY TEST PILES - A CASE HISTORY

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Piles with longer rock sockets (and high L/D ratios) are typically designed as friction piles due to limited mobilization of end bearing at serviceability limit states. The unit skin resistance (f_{max}) is usually estimated from unconfined compressive strength (UCS) of the intact rock and other rock mass/interface properties. The initial estimate of f_{max} is based on assuming certain design parameters in addition to representative UCS which can yield conservative capacities. Significant savings and high design reliability could be achieved where large number of piles are involved by conducting bidirectional load testing on preliminary test piles. This paper presents a recent case history of design evolution for rock socketed piles (around 2000 piles) from results of bidirectional testing of instrumented preliminary test piles (PTP) as part of the geotechnical investigations. The diameters of six PTP range from 900 mm to 1500 mm with maximum rock socket length of about 23 m. Instrumentation consists of strain gauges at eight levels and an O-Cell located within the rock socket. The maximum bidirectional test load is determined from initial theoretical estimates based on concrete's compressive strength (50 MPa) for each pile diameter. Mobilized average unit skin friction at each depth interval is calculated from strain gauge data of different loading and pile movement stages. The results indicated close matching of mobilized skin resistance within the same stratigraphic unit irrespective of the pile diameter and location suggesting consistent and homogeneous character of geological units across the site. For each test, simulation analysis is conducted to establish equivalent top loaded pile behavior using the obtained representative t-z curves of different depth intervals of rock socket and maximum measured unit skin friction. This method indicates more accurate assessment of the equivalent top loaded pile behavior than the simple estimates of adopting simple (linear) load transfer functions. In addition, the analysis could be extended to establish the failure load and ascertain the overall safety factor. Selected representative f_{max} for different depth intervals are subsequently used to back calculate the rock socket design parameters. The results have indicated savings of 20-25%, in addition to minimizing the potential uncertainties and maximizing the level of confidence. The capacities and settlement behavior of the working piles will be further verified by conducting static pile loading tests during the construction stage.

DIMENSIONNEMENT DES FONDATIONS PROFONDES - COMPARAISON DES RÉSULTATS OBTENUS À PARTIR DE L'EUROCODE 7 ET DU MANUEL CANADIEN D'INGÉNIERIE DES FONDATIONS

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Une nouvelle version du Manuel canadien d'ingénierie des fondations est en préparation. En parallèle, le Comité Européen de Normalisation (CEN) a lancé la révision de l'Eurocode 7, calcul géotechnique en vue de produire la nouvelle génération des Eurocodes. Ces deux référentiels fondent les dimensionnements des fondations sur l'approche aux états limites. Les résultats obtenus avec ces documents de référence vont être comparés, à partir de l'exemple du dimensionnement des fondations profondes de l'ouvrage de franchissement de la rivière Garonne à Saint Béat, dans le Sud-Ouest de la France. Une attention particulière sera apportée à la définition des valeurs caractéristiques à partir des essais pressiométriques ainsi qu'à la détermination de la résistance des pieux selon l'approche du « pieu modèle » et du « modèle de terrain » décrite dans l'Eurocode. Ces paramètres seront confrontés aux valeurs que l'on obtiendrait en utilisant le Manuel canadien.

STRESS EVOLUTION WITH TIME IN STOPES FILLED WITH A HYDRAULIC BACKFILL

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While paste backfill is gaining its popularity across the world, hydraulic backfill still remains commonly used to fill large underground voids created during the mining operations. It is produced and distributed as a slurry at a pulp density $P = 65 - 75\%$ (solid content) which contains a substantial amount of water. Compared to paste backfill that contains full tailings, the removal of a portion of fine particles ($\leq 10 \mu\text{m}$) in hydraulic backfill can significantly increase its hydraulic conductivity. As a result, the water in hydraulic backfill drains quite quickly after placement and becomes free water. When the drainage system is not efficient, ponding of water can occur on top of the backfill and generates high pore-water pressure, threatening the stability of barricade. Therefore, a good understanding of the evolution of the total and effective stresses within such backfilled stopes is critical for improving the design of barricades. To date, most existing analytical solutions for assessing the stresses in backfilled stopes were developed for the case of a fully drained (zero pore water pressure) or a hydrostatic (equilibrium) state. To the authors' knowledge, there is no analytical solution available to describe the stress evolution from the placement to the full drainage of the backfill. In this paper, the authors present an analytical solution that can be used to estimate the total and effective stress evolution with time in stopes with hydraulic backfill. Sample calculations are presented using typical hydraulic backfill properties to analyze the key influencing factors. A discussion follows on some particular features and limitations of the proposed solution.

A SUGGESTED PROCEDURE FOR APPLICATION OF PROBABILISTIC SEISMIC HAZARD ASSESSMENT RESULTS IN LATERAL SPREADING MODELS

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Liquefaction induced lateral spreading is a major concern for design of infrastructure in liquefiable ground. Empirical regression models such as Youd et al. (2002) and semi-empirical models such as Zhang et al. (2004) are widely used by practitioners to estimate lateral spreading displacements. These models were developed from case histories with defined seismic hazard in a deterministic fashion, including magnitude and distance of the seismic event and peak ground acceleration (PGA) at the site. A difficulty arises when using the regression models with results from a probabilistic seismic hazard assessment (PSHA) since the result of a PSHA is made up of contributions from a range of magnitude and distance combinations. Direct application of these models with PSHA parameters, may result in significant under-prediction of lateral spreading displacement and misunderstanding of probability of occurrence of the estimated displacement values. Moreover, there can be significant differences in estimated lateral displacement between empirical models that use magnitude and distance as input parameters (e.g. Youd et al. 2002) and semi-empirical models that use PGA and magnitude as input parameters (e.g. Zhang et al. 2004).

This paper introduces a procedure to use lateral spreading regression models with conventional PSHA output. The procedure differentiates between small and large lateral spreading displacements (i.e. greater than or less than 30 cm) and provides an indication of the likelihood of lateral spreading displacement exceeding the threshold value of 0.3 m as well as likely value of large lateral spreading displacement. Examples from recent projects are provided and discussed in this paper. Application of this procedure results in a reasonable agreement between the Youd et al. (2002) and Zhang et al. (2004) models. This procedure can be used as a framework for performance-based design of structures subjected to lateral spreading.

DETERMINATION OF SHEAR STRENGTH PARAMETERS OF DAM BODY MATERIAL USING DISTURBED SAMPLING

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INTRODUCTION: Shear strength parameters determination is the most important part of stability analysis of geotechnical structures. Cohesion and internal friction angle obtained from direct shear tests are generally referred to as shear strength parameters of soil. Although undisturbed samples being used commonly for the determination of soil strength parameters, undisturbed sampling might not be held in certain circumstances. In this study, shear strength parameters of a tailings dam which was constructed without compaction is evaluated. Due to coarse grain size and looseness of the dam material, undisturbed sampling was impossible. Density of the direct shear test specimen was determined according to standard compaction test results.

EXPERIMENTS:In the context of this study, standard compaction test and direct shear tests were performed on disturbed soil samples. A 30x30cm square shear box was used for shear tests and the sample was reconstituted in the laboratory. The required compaction for earth structures is generally denoted between 90% and 95% of the maximum dry unit weight obtained from compaction test. Because no compaction was applied to the dam material at the construction stage, a systematic approach was developed for specimen preparation. The dam was divided into three layers according to their elevation from surface; and each layer was assumed to have dry density values of 70%, 80%, and 90% of the maximum dry density values.

In order to inspect the effect of compaction on shear strength the sample is tested under the same normal stress and shearing rate. The sample was compacted at a dry density 80% of maximum dry density obtained from proctor was failed at 466.65 kPa, whereas the sample with 90% dry density was broke down at 470.19 kPa. Therefore, it can be concluded that compaction assumption made in this study does not affect the stability analysis results much.

CONCLUSION: Typical friction angle values for medium-dense sand is given in the range of 32° to 38°, while typical friction angle values for medium-dense sandy gravel can range from 34° to 48° (Das, 1983). Obtained results are within the range of values given in the literature. Therefore, this approach may be used whenever undisturbed sampling is impossible.

EVALUATION OF COMPATIBILITY OF EXISTING LIQUEFACTION CHARTS FOR EASTERN REGIONS OF NORTH AMERICA

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Soil liquefaction is a crucial issue in the design of foundations or structures to sustain dynamic. Since 2005, the National Building Code of Canada (NBC 2005) requires a systematic analysis of liquefaction potential of soil strata. This achievement has an important impact on civil engineering projects in the cost related to the treatment of the soil and choosing the type of foundation. The liquefaction problem is known in the regions of the world with high seismicity (United States, Japan and China), but remains poorly documented for the eastern regions of North America, because of the lack of historical events. In practice the evaluation of liquefaction potential is generally based on the charts established from observations made after earthquakes in the United States, Japan and China, and, using the parameters derived from sounding (N: standard penetration test (SPT) or qc: cone penetration test (CPT)) or Vs measurement). In eastern Canada there is a need to evaluate the applicability of seismic chart used by practitioners. In this paper, a series of seismic loading (cyclic or arbitrary loading) tests on granular soil samples have been conducted using the new combined triaxial simple shear (TSS) apparatus. The TSS system consists of a simple shear apparatus incorporated in a triaxial cell for the measurements of dynamic characteristics of soil samples. With TSS, it is possible to conduct simple shear tests under control confining pressure, undrained conditions and by applying arbitrary seismic loading. As a part of this study, different sample of soils are subjected to seismic loading obtained from group response analysis of soil deposit subjected to earthquakes compatible with Eastern seismicity. The results are compared to those subjected to earthquake consistent to those used to establish the existing charts. The ground responses are obtained using the computer code, FLAC. The comparison confirmed the accuracy and reliability of the TSS test results and demonstrated that liquefaction charts based on traditional tests should be revisited for the eastern regions of North America.

EFFECTS OF VARYING MODULUS OF SUBGRADE REACTION ON STRUCTURAL DESIGN OF MAT FOUNDATION

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Geotechnical engineers are normally requested by structural engineers to provide "modulus of subgrade reaction - k_s " for the design of mat foundation or slab-on-grade. From the results of geotechnical investigation, field tests and/or laboratory tests, the geotechnical engineers will provide the values of k_s which are deemed applicable to the planned sizes of mat foundation to the structural engineers, who will subsequently use the k_s as elastic springs underneath the mat foundation in typical analytical models, e.g., slab on elastic foundation, to determine contact pressure distribution under the mat foundation, settlement, bending moment, etc.

From the previous paper on the k_s by the same authors (i.e., "Matching modulus of subgrade reaction and elastic modulus for equal foundation settlement" presented in GeoMontreal 2013), the values of k_s , which depend on mat foundation sizes/stiffness and soil profiles/properties, will not normally lead to the same foundation settlements when comparing the analyses by geotechnical engineers (using elastic modulus) and structural engineers (using k_s). Such discrepancy can be resolved by repetitive analyses to be performed between geotechnical and structural engineers until both analytical results agree by satisfying a common criterion (e.g., similar foundation settlement). However, such a procedure is not normally followed, particularly for a small project, since it is time consuming and increases design cost.

This paper presents the analytical results of the structural design of mat foundation using various "modulus of subgrade reaction - k_s " values and the Finite Element Method. The effects of varying k_s values on mat foundation design (e.g., thickness, settlement, bending moment), if used without the benefit of repetitive analyses between geotechnical and structural engineers to match the same foundation settlement, are presented. The results will be useful for geotechnical engineers when working on a small project which requires modulus of subgrade reaction values for the design of mat foundation and slab-on-grade.

APPLICATION OF ANALYTICAL SERIES IN SEEPAGE RATE AND COMPARISON WITH FINITE ELEMENTS

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The study of seepage in porous media soil environment is very important. This issue important regarding to hydrology point of view, estimated of ground-waters amount under different hydraulic conditions, the of drainage during construction implementation inside of underground water aquifers, study of earth dam stability and structures retaining soils under the seepage forces, Consolidation of clay soils, Production of runoff, erosion processes and solute transport. In this study, a classic method is used for obtaining analytical solutions of seepage in the saturated zone of the homogeneous mountain foot with arbitrary geometry. In order to solve analytical series the method of separation of variables has been used. That its priority to numerical methods is that it can be obtained faster and are more accurate and with the most accuracy, the total error can be obtained at the border. The upper and impermeable lower boundary have been declared by spline or linear equations using a criterion and the static water level which was unknown at first can be determined by using numerical methods. The method of least squares is used to determine the coefficients of the series expansion of the Laplace's equation. Numerical methods based on analytical techniques that provide reliable solutions that are valuable. Therefore in order to analyze obtained results from a series of analytical methods, we use thoroughly numerical finite element scheme to examine the validity of the answers. Through using of similar conversions for other simple geometries, analytical solutions can be provided, but for extensive range of geometric borders, the appropriate transformation can not be found easily.

CORRELATION BETWEEN ELASTIC MODULUS AT LARGE STRAIN AND SHEAR WAVE VELOCITY

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Geotechnical studies on large projects need constitutive relations for modeling deformation behavior of soil foundation or construction materials. Modeling is particularly important for zoned dams to examine the compatibility of deformations between pervious and impervious zones, generally made of different materials. The determination of the deformation behavior of granular materials, especially coarse granular soils, requires special equipment's and remains complex. For this reason, the small strain shear modulus (G_{max}) is an interesting parameter, because it can be measured in the field under the true in-situ conditions without intrusion (MMASW). However, the exploitation of these measures requires the establishment of relationship between this module (G_{max}) and soil parameters at large deformations (E , E_{oed} , ν). This can be achieved by measuring simultaneously the oedometric module and the shear waves velocity (V_s) in the laboratory on materials having a similar gradation to that used for the construction of the geotechnical structure. This paper presents the results of experimental work carried out at the soil mechanics laboratory of the University of Sherbrooke in different granular materials varying from sand to gravel. The purpose of this study is to establish relations between the large deformation modulus measured in oedometer (E_{oed} , large deformation) and the shear waves velocity or shear modulus measured at low strains (G_{max}) on similar granular materials (in terms of gradation) to those used for the construction of rockfill dams. These relationships can be used to predict, from in-situ shear wave velocity (MMASW), the modules at large deformations required for numerical modeling of various soil materials.

HOW TO BRING IN-SITU TERRESTRIAL PERMAFROST DATA INTO EARTH SYSTEM MODELLING

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(Contribution to the GTN-P thematic session)

The Data Management System (DMS) of the Global Terrestrial Network for Permafrost (GTN-P) brings a new range of standardization and interoperability for a larger use of the in-situ permafrost temperature and active layer thawing metadata and data (gtnp.org & gtnpdatabase.org). The DMS provides tools for data analysis, data processing, quality assurance and control (QA/QC) through a set of internal functions and libraries. The end of the supply chain delivers highly structured global data sets in NetCDF files, aiming to be compliant with Climate and Forecast convention (CF1.6).

The integration of the in-situ terrestrial permafrost data and metadata within Earth System Models Programs represents a major challenge. Indeed, the GTN-P as well as other terrestrial networks should link processes, structures and technologies with existing marine and atmospheric networks, aiming at close cooperation. Due to their great heterogeneity and spatial variability, the in-situ terrestrial data are difficult to grid and not enough consensus or standards have been implemented for their management. GTN-P metadata have been computed in order to orientate new monitoring campaigns, giving a better representativeness of the monitoring network data sets packages. Active discussions are undertaken with the Obs4MIPs (Observations for Model Intercomparisons) group and with the World Climate Organization (WMO) for registering the GTN-P data products to an Earth System Grid Federation (ESGF).

ON THE PRECISION, ACCURACY, AND UTILITY OF OBLIQUE AERIAL 'STRUCTURE FROM MOTION' PHOTOGRAMMETRY FOR ROCK SLOPE MONITORING AND ASSESSMENT

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Recent advances in digital photogrammetric modelling have made possible (and practical) many applications of the technique to geotechnical and geological problems. The 'structure from motion' (SfM) approach to photogrammetry utilizes the information contained in a large number of detailed – but otherwise normal - digital photos to automatically generate dense 3D surface models. In contrast, previous approaches relied heavily on calibrated cameras and lenses, and complex manual intervention in the scene and processing, often with inferior results in uncontrolled circumstances. Furthermore, previous photogrammetric modelling of rock slopes has typically been land-based.

In this paper we summarize our experience in the development and refinement of applications of the SfM method to the assessment and monitoring of steep rock slopes, using oblique aerial photos. We collected photos suitable for oblique aerial photogrammetry (OAP) at nine hazardous rock slope areas of different character along Canadian railway corridors in Quebec, Ontario, and B.C., using an autonomous fixed-wing UAV (OAP-U; three sites), and manually from a moving helicopter (OAP-H; eight sites). We collected OAP photos on multiple occasions at three of these sites. With these data, particularly for OAP-H using full-frame, expertly acquired digital SLR photos, we demonstrate that: precision of 10-20 cm is achievable; scale-accuracy in the range of 5% is typical and 1-2% is common, in some cases even in the absence of ground reference; and shape-accuracy at a similar level to, although noisier than, aerial or terrestrial LiDAR can be expected in general. We show that change-detection analysis works well down to the scale of discrete blocks of approximately 0.5 – 1 m³, or near the hazard-threshold for some scenarios (e.g. rail operations). We also discuss the 'scale problem' which is inherent in all photogrammetric modelling, and describe novel yet practical solutions for cases where ground control or other remote-sensing data are not attainable.

In addition, we explore the potential utility of the OAP approach by citing examples of recent commercial and research applications, discussing the general limitations of the method, and outlining the requirements for a successful campaign. The main benefits of OAP are its rapid deployment (particularly of OAP-H), interchangeability with other sorts of 3D data, high-fidelity and full-colour nature, and the ability to develop 3D models of slopes that are otherwise inaccessible. In general, OAP can be quick to deploy, very reliable, and precise and accurate enough for rock slope monitoring and assessment.

ROCKFALL PROTECTION ALONG HIGHWAY 403 IN HAMILTON, ON: A RECENT RE-ASSESSMENT AND APPLICATION OF EMERGING SITE INVESTIGATION METHODS.

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The Niagara escarpment is a unique area of high relief and exposed bedrock in Southern Ontario between Niagara in the south, and Tobermory in the north. Its expression varies from vegetated gentle slopes to vertical cliffs tens of metres high, and associated active talus slopes with rockfall and other geohazards recognized at various locations along its length. The City of Hamilton is the focus of much of the risk, given the proximity of a dense population to the steep, rocky escarpment in this area.

Ontario King's Highway 403 (a four-lane divided highway also known as The Chedoke Expressway within Hamilton) transects the escarpment with a long approach along the toe of an active talus slope, and directly adjacent to exposed bedrock near to the crest of the escarpment, within the limits of the City of Hamilton. Engineered rockfall hazard protection extends for approximately 1.5 km through this area, with a combination of a 1000 kJ capacity rigid catchment fence and a narrow ditch/clear zone. Following a number of 2-5 m³ rockfall events in 2012, some of which impacted the fence and reached the shoulder of the eastbound lanes, a detailed assessment of the efficacy of the existing protection was proposed by the Ontario Ministry of Transportation.

In this paper we report on the application of traditional and emerging site investigation methods employed in this assessment. We focus on the use of oblique aerial photogrammetry using high-resolution digital photographs collected from a moving helicopter to generate a very detailed 3D terrain model of the 1.5 km long slope, from crest to road, and report on the use of that information in a number of novel ways to evaluate the protection provided, and recommend further risk management measures.

With the 3D data, we were able to clearly identify geological and geomorphological controls on rockfall occurrence and reach, evaluate the results of recent remediation work (scaling), identify potential detached (hazardous) blocks, develop detailed cross-sections of the slope for 2D simulations, and establish a baseline of the condition of the slope suitable for future 3D monitoring efforts. When combined with traditional site inspections, analysis of historical records, and observations of rockfall behaviour and protection performance during remediation work, we were able to perform a more detailed assessment of the protection and suggest more precise risk treatments, than if we were using more commonly applied methods.

PEAK STRENGTH OF LIME-TREATED LONDON CLAY UNDER SATURATED AND UNSATURATED CONDITIONS

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ABSTRACT: This paper investigates the effect of suction and lime treatment on the peak strength characterization of the partially saturated high plasticity London clay. A series of triaxial tests on statically compacted London Clay and lime-treated London Clay specimens were prepared at the same target void ratio and tested under partially saturated conditions. The tests concerned isotropic compression and shearing under constant suction or constant water content, using the axis translation technique. Based on the results, the effects of suction and cementation (brought about by the lime treatment) on the peak strength are evaluated and quantified within an elastoplastic partially saturated soil framework.

TRUE TRIAXIAL TESTING AND ITS APPLICATION IN DEEP ROCK MECHANICS

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To emulate the stress path in the rock mass excavation related to deep mining, a true triaxial testing (TTT) apparatus is needed to investigate the deformation and brittle fracture on hard rock, even to reveal what induces the rock burst? A novel TTT has been developed to take into account the post-peak behaviour for a 50×50×100 mm cuboid sample at Northeastern University, China, in which Mogi's original design idea was adopted. Some technical improvements were implemented to deal with difficult problems on the TTT designing, such as: remarkably increasing in the stiffness of the load frame, improvement the measurement of the volume change, combining the pneumatic and hydraulic technique for the floating in the vertical load frame. Furthermore, the end friction effect was assessed by a series of shear tests, it was found that the over anti-friction effect arising when using the Teflon sheet. Calibrations for individual transducer and a dummy sample were carried out to verify the TTT performance, and it achieves the design aim in accordance with preliminary tests results on granite. Applying the developed apparatus, a series of hard rock specimens were carried out loading fracture tests with different intermediate principal stress, the fracture mode, strength change have been identified, which will be as a guide in deep rock engineering excavation.

COMPRESSIVE STRENGTH OF CEMENTED SOIL REINFORCED WITH TIRE SHRED WASTE UNDER CYCLIC LOADING

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This study investigates the effect of static and cyclic loading on the performance of cemented soil reinforced with tire shred wastes. Waste gypsum mixed with cement had been used as a stabilizing agent. Different percentages of gypsum-cement admixture were mixed with the tested soil. Different percentages and sizes of tire shreds wastes were mixed with the soil treated with a fixed content of gypsum-cement admixture. The results show that the synergetic effect of combining gypsum-cement admixture and tire shred wastes had improved the performance of tested soil. While cyclic loading significantly reduced the strength of soil stabilized by gypsum-cement admixture, this reduction decreased with the incorporation of tire shred. Regardless of the number of loading cycles, the decrease in the reinforced soil tensile strength is minimized by increasing the content of tire shreds. It was also found that the size of the tire shreds tire has an insignificant effect on reinforced soil behavior under cyclic loads. Moreover, fatigue life for reinforced soil increases with the increase of both shreds tire and gypsum-cement admixture contents.

INVENTAIRE DES GLISSEMENTS DE TERRAIN FORTEMENT RÉTROGRESSIFS DANS LES ARGILES SENSIBLES DU QUÉBEC À L'AIDE DE LEVÉS LIDAR

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(1) *Transports Québec (Québec, Canada)*

Le ministère des Transports du Québec utilise depuis 2003 des levés lidar aéroportés pour la cartographie des zones exposées aux glissements de terrain. L'analyse de ces levés a permis de procéder à un inventaire détaillé des cicatrices d'anciens glissements fortement rétrogressifs dans les argiles sensibles, en analysant le relief à l'aide de "hillshades". Cette technique a permis d'identifier de nombreuses cicatrices inconnues auparavant et la précision des résultats permet souvent de distinguer entre les coulées argileuses et les étalements latéraux, même quand ceux-ci sont très anciens et recouvert de boisés. Bien que seulement environ 60% du territoire où on trouve des argiles sensibles ait été relevé par lidar jusqu'à présent, on dénombre néanmoins déjà 3700 anciennes cicatrices de glissements fortement rétrogressifs dans les mers post-glaciaires de Champlain, de Laflamme et de Goldthwait. Une liste des 50 plus grandes cicatrices trouvées à ce jour a été dressée.

MULTIPHYSICS TESTING OF THE STRENGTH OF CEMENTED TAILINGS BACKFILLS

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The cemented paste backfill (CPB) is a mixture of tailings from the processing operations of the mine, water and binders (2% to 7% by weight usually). It is commonly used for underground mine support and tailings disposal. It receives great interest as one of the most commonly used ways in mine backfilling around the world. To ensure its underground mine support role, the CPB must show sufficient mechanical stability during the mining operations. One of the most important parameters used to evaluate the mechanical stability of CPB is its uniaxial compressive strength (UCS). In the field, the UCS of CPB will be affected by a number of coupled thermal (T, e.g., heat generated by the binder hydration), hydraulic (e.g., drainage, self-desiccation), chemical (C, e.g., binder hydration, sulphate effect, mixing water chemistry) and mechanical (M, e.g., consolidation, self-weight pressure) processes that occur in CPB. However, the effects of these THMC processes on the strength development of CPB is not well understood.

In this paper, a laboratory multiphysics testing system is developed to investigate the effects of the interactions of these THMC processes on the strength of CPB. The setup is capable to cure the CPB specimens under controlled curing stress and various coupled THMC conditions, while continuously monitoring the evolution of total stress, pore pressure, suction, temperature, water drainage, chemical composition of the pore water and vertical deformation. Once the required curing time is achieved the specimen can be extracted and then subjected to UCS tests. Valuable results have been obtained with regards to the evolution of the strength of CPB under the influence of the THMC processes. The results obtained and the testing system developed will contribute to better understand the strength of CPB in the field, and more cost-effective and safer design of CPB structures.

QUANTIFYING THE SIGNIFICANCE OF THE HYDROLOGICAL CONTRIBUTION OF A ROCK GLACIER – A REVIEW.

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The important role of uncovered glaciers in the hydrological cycle has been well studied and documented in the scientific literature. On the other hand, very little is known on the hydrological role of rock glaciers, although they are common cryoforms found in many mountainous periglacial environments. Despite the lack of data and understanding as to the role of rock glaciers within the hydrological cycle some legislations have recently been implemented to protect them from any human activities, by erroneously including rock glaciers as part of the glacial environment. This paper reviews available literature on rock glacier and periglacial hydrology in order to synthesize available knowledge on the hydrological significance of these cryoforms. Our review shows that the number of publications focusing on rock glacier hydrology and potential water storage is small in comparison with published research on other aspects of rock glaciers, such as their morphology or dynamics. In mountain watersheds with glaciated terrain, hydrology has been studied intensively; in mountain watersheds where glaciers are absent but the presence of rock glaciers is considerable, there is no consensus of the relationship between rock glaciers and their hydrological role. Although there are some authors that suggest that rock glaciers do play an important role in the hydrology of down-stream water resources, there are also a number of publications that warn from such conclusions as they were based on qualitative information only, lacking actual data. This paper examines available literature on rock glacier hydrology and the different positions authors have adopted. We conclude that rock glaciers should be assessed under a holistic approach; their significant differences in dynamics, morphology and energy exchange to glaciers must be acknowledged. In addition, detailed field research is required in order to properly determine the role of rock glaciers and the periglacial environment on the hydrological cycle in mountain watersheds. This paper provides ideas for such investigations, as an accurate understanding of a periglacial watershed will only be possible when such data become available.

SWELLING CHARACTERISTICS OF BENTONITE BASED BARRIERS FOR DEEP GEOLOGICAL REPOSITORY FOR NUCLEAR WASTES: IMPACT OF UNDERGROUND WATER CHEMISTRY AND TEMPERATURE

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Nowadays, nuclear technologies have many applications in medicine, industry, transportation and agriculture. They produce about 11 percent of the Globe's electricity without releasing greenhouse gas. However, they produce millions of used spent fuel bundles and radioactive wastes every year. The nuclear wastes could harm people and cause many environmental problems for hundreds even thousands of years.

Canada and more than 30 countries have proposed building 300m to 1000m Deep Geological Repositories (DGR) for the disposal of the nuclear wastes in order to protect human and their environment. DGR concepts under development in Canada are based on a multi-barrier system. A crucial component of the multi-barrier system is the engineered barrier system (EBS) including buffer, backfill and tunnel sealing materials to develop physical, chemical, hydraulic and biological isolation for the nuclear waste. Bentonite-based material has been chosen for this critical use because of its excellent swelling capacity, low hydraulic conductivity and good ability to retain radionuclides in the case of failed canister.

However, the presence of bentonite-sand in deep geological repositories surrounding by aggressive environments of highly saline underground water, high temperature and under confining stress may cause mineralogical changes for bentonite-based materials and impact their physical and physiochemical properties, and thereby affecting the bentonite performance as an engineering barrier system and the overall safety of the deep geological repositories.

The objective of this research is to investigate the impact of Ontario's underground water salinity and heat generated by the nuclear wastes on the swelling capacity of bentonite-sand engineered barrier materials. Free-swelling and swelling pressure tests have been performed on bentonite-sand mixtures subjected to various chemical (groundwater chemistry) and thermal (heat generated) loading conditions. Valuable results have been obtained with regards to the durability and performance of bentonite-sand barrier for DGR located in Ontario. The obtained results have shown that the groundwater chemistry can significantly deteriorate the swelling properties of the tested bentonite-sand barrier material, whereas the temperature has little effect on the bentonite-sand swelling potential.

**IMPLEMENTATION OF OIL SAND DRILL CUTTINGS WASTE IN CONTINUOUS FLIGHT AUGER PILES
CONCRETE MIXTURES**

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The major constituent in the continuous flight auger (CFA) pile is the concrete, and hence, understanding the concrete mixture behaviour and optimizing its design are essential. A laboratory study was undertaken to evaluate the fresh and hardened properties of CFA concrete mixtures. Concrete properties of interest were flowability, compressive and tensile strengths, and modulus of elasticity. Use of fly ash (FA) and oil sand drill cuttings waste (OSW) in the concrete mixtures and their effects on the measured properties were quantified and compared. Variation of hardened properties with curing time has been quantified. Results show that FA addition with a rate less than 20% can adversely affect the concrete mixture flowability. On the other hand, OSW addition had an insignificant effect on the concrete flowability. Strength gaining rates for concrete mixtures incorporating FA and OSW were higher than that of the control mixture. The results suggest that OSW can be used in CFA piles, replacing some of the FA without adversely affecting the concrete performance. This can result in cost savings for the production of CFA piles and disposal of OSW.

EFFECT OF OIL SANDS DRILL CUTTINGS WASTE ON MICROPILES GROUT PROPERTIES

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Micropiles are a small-diameter (typically less than 300 mm) drilled and grouted piles. A micropile is constructed by drilling a hole, placing a steel reinforcing element, typically a mono central bar, into the hole and grouting it using neat cement. However, cement is an energy-intensive material, and its production generates a significant amount of carbon dioxide. In an effort to develop sustainable and environmentally benign micropile construction, a feasibility study was performed on using oil sands drill cuttings waste (OSW) as a replacement of cement in grout mixtures for micropiles. Cement was partially replaced with 10%, 30% and 50% of OSW by volume. Grout properties of interest were flowability, setting time, compressive strength and shrinkage. The results have shown that regardless of the replacement rate, OSW did not affect the flowability for the tested grout mixtures. However, increasing OSW replacement level reduced the 28-day grout compressive strength slightly. However, the achieved grout compressive strength was still higher than the minimum strength required by different standards. Moreover, at later ages, the OSW grout compressive strength gain rates seemed to increase. The results suggest that OSW can be used in micropiles leading to environmental and economic benefits.

EGT SAMPLING METHOD; TOWARD UNDISTURBED SAND SAMPLE

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A new sampling approach has been developed to stabilize fine grained granular (sand) material with the application of a thermal fluidizing gelatin. The gelatin's viscosity is inversely proportional to the temperature and when applied to the fine grained material was found to stabilize the soil when the temperature is approximately ± 10 ° C. Stabilization of the material is achieved without a noted change of gelatin phase and also without a density variation. A sample of Ottawa Sand, which has been stabilized with the the gelatin, can be handled in a similar manner as a clay material and sub-sampled without noted difficulty. A comparative analysis of the mechanical behavior of the reference populations assessed shows that the proposed stabilization method, by applying the gelatin, preserves the mechanical (intact) behavior of sub-samples. A laboratory program was completed to simulate the injection of a warm gelatin solution into saturated sand in order to validate the applicability of this technique to field conditions. A numerical model was utilized to predict the location of the gel injected into the saturated sand in space and time, to identify when stabilization will be achieved and also to identify the total volume of the stabilized sand. The numerical model takes into account the following parameters: type of injection (spherical or radial), concentration and temperature of the gel, temperature of the porous medium and hydraulic injection load. Four (4) differential equations were utilized in the development of the numerical model and required application of thermal non-equilibrium as there is a significant temperature difference between the injection fluid (gelatin) and the soil matrix. The problem observed with this approach to confirm the validity and viability of this sampling technique was related to the degree of saturation of the soil sample.

SUVIS DE LA CONDUCTIVITÉ HYDRAULIQUE D'UNE GÉOMEMBRANE BENTONITIQUE (GMB) LORSQUE EXPOSÉE À DIFFÉRENTS LIXIVIATS ET À DES CYCLES DE MOUILLAGE-SÉCHAGE ET DE GEL-DÉGEL.

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Tel que rapporté dans certaines publications et études de cas, lorsque qu'une géomembrane bentonitique (GMB) est en contact avec certains fluides ou un sol fortement chargé en cations, un échange cationique peut alors avoir lieu. Dépendamment de la nature des cations, cet échange peut engendrer une modification de la capacité de gonflement de la membrane et, par le fait même, une augmentation de sa conductivité hydraulique. De plus, il a été démontré que les cycles de mouillage-séchage de même que ceux de gel-dégel peuvent avoir un impact sur la conductivité hydraulique d'une GMB. Dans le cadre de la restauration d'un site minier abandonné générateur de drainage minier neutre contaminé localisé au Québec, l'utilisation d'une GMB dans le concept de restauration a été proposée pour limiter l'infiltration d'eau dans les résidus miniers. Dans le processus d'approbation du concept proposé pour la restauration du site par l'état* des essais en laboratoire ont été réalisés afin d'évaluer l'impact des facteurs précédemment cités sur la performance à long terme du recouvrement utilisant un système GMB dans les conditions de terrain spécifiques du site. L'objectif du programme d'essais était d'évaluer quel pouvait être l'impact combiné du gel-dégel et des cycles de mouillage séchage sur la conductivité hydraulique des GMB à court et long terme sous différentes conditions. Afin de représenter les conditions de terrain, trois solutions ont été utilisées lors des cycles en laboratoire, i. de l'eau distillée, ii. de l'eau souterraine provenant du site et iii. de l'eau de pluie synthétique représentative des conditions du site à étude ayant percolée au travers un matériel granulaire provenant d'un banc d'emprunt local, représentatif du matériel qui pourrait être utilisé dans le recouvrement lors des travaux de restauration. Ces trois solutions ont été utilisées comme lixiviat de saturation et de percolation dans une GMB lors de l'évaluation de l'impact des cycles de mouillage-séchage et de gel-dégel sur sa conductivité hydraulique. Le nombre de 4 cycles est utilisé dans les essais standards normalisés du GMB et représente le comportement court terme dans les essais. En se basant sur d'autres essais et publications réalisés sur ce type de matériel, un nombre de 10 cycles a été retenu pour évaluer le comportement à long terme du GMB selon différentes conditions de terrain. Les résultats de ces essais ont permis d'orienter le type de recouvrement sélectionné pour la restauration du site minier.

REVUE DU GLISSEMENT DE TERRAIN DE 1993 À LEMIEUX, ONTARIO : DONNÉES PRÉLIMINAIRE DE L'INVESTIGATION GÉOTECHNIQUE DE 2014

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Le 20 juin 1993, un glissement de terrain d'une superficie de 16,9 ha s'est produit en bordure de la rivière South Nation, dans la région de Lemieux en Ontario. Une partie des sols emportés par le glissement a été fortement remaniée et s'est écoulée sur une distance de 3,3 km dans la rivière. Certaines portions du glissement se sont toutefois rompues sous la forme de horst et graben, engendrant de grands pinacles pratiquement intacts. Des investigations géotechniques ont été effectuées récemment afin de préciser les caractéristiques du glissement de façon à pouvoir mieux étudier son mécanisme. En plus de la pose de piézomètres à deux endroits, cinq sondages au piézocône, deux forages avec échantillonnage et 3 essais au scissomètre de chantier ont été réalisés sur le pourtour de la cicatrice pour caractériser les conditions intactes. Huit autres sondages au piézocône ont aussi été effectués à l'intérieur de la cicatrice afin de déterminer la position de la surface de rupture. La topographie pré-rupture a aussi été établie par photo-restitution afin de déterminer les conditions de stabilité initiale.

SATURATED AND UNSATURATED PREFERENTIAL FLOW IN MINE WASTE ROCK - LABORATORY EXPERIMENTS AND MODELLING APPROACHES

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Understanding flow processes and water distribution inside waste rock piles is crucial to predict effluent quality, assure long-term geotechnical stability and develop sustainable remediation strategies. One of the main issues is related to saturated and unsaturated preferential flow, which may exceed the average hydraulic conductivity of the waste rock by up to two orders of magnitude (and more). Numerous attempts have been made in the past decade to investigate the underlying physical processes and to derive conceptual models for reproducing observations, using laboratory- and field-scale experimental setups as well as numerical flow models. Nevertheless, there is still a significant lack of understanding for the controlling parameters and how to represent the underlying processes in numerical models accurately.

A series of an intermediate-scale laboratory infiltration tests on waste rock in a column (1 m of height, 0.3 m of diameter) was conducted. Variable volumes of water have been applied and infiltration rates, suctions and outflows at the column base continuously monitored. Observations clearly indicate the presence of dual porosity outflow, with matrix- (porous media) and macropore-driven (preferential) flow components. In order to validate findings and retrieve additional information on residence time and the exchange between 'old' and 'fresh' water in the small and large pores, a series of tracer experiments have been also conducted.

The observations have been modeled based on a recently published concept using randomly-distributed fractures to represent the presence of macropores in the waste rock. The application of this concept can reproduce much better the observed two-component outflow compared to the classical equivalent porous media approach typically used.

ÉTABLISSEMENT DE SCÉNARIOS D'ACCÉLÉRATION ET DE VITESSE DE GRANDS GLISSEMENTS ROCHEUX ACTIFS : LE CAS DE BLACK LAKE

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Dans les dernières années, au pourtour de la mine LAB d'Amiante du Canada (LAC) dans la région de Thetford Mines (Québec, Canada), de multiples glissements de terrain sont survenus. Cette mine à ciel ouvert, anciennement exploitée par la compagnie minière LAB Chrysotile, est constituée de deux fosses séparées par un seuil. Déjà en 2010, un glissement majeur affecta le mur Ouest de la fosse principale. Au mois de juillet 2012, des glissements importants se sont produits dans la partie Sud-Est de cette même fosse, emportant partiellement la route régionale 112 qui avait déjà été déplacée sur le remblai de l'ancienne voie ferrée. Le volume mobilisé en 2012 était d'environ 20 millions de m³.

Le glissement de 2012 est encore en mouvement, et selon divers scénarios, un volume maximal de 50 millions de m³ pourrait être mobilisé. De plus, la mine n'étant plus en opération actuellement, le niveau d'eau dans la fosse augment rapidement. Si une accélération soudaine du glissement survenait lorsque le niveau d'eau dans les fosses est élevé, une vague pourrait en résulter. Il est à noter que le niveau d'ennoisement, qui sera atteint d'ici une vingtaine d'années, est plus bas de moins de 10 mètres par rapport à la ville avoisinante, localisée à moins d'un kilomètre du glissement. Afin de modéliser une telle vague (voir Leblanc et al. dans cette conférence), et d'évaluer le danger potentiel, divers scénarios de vitesse et d'accélération de la masse ont dû être élaborés.

Cet article fera une brève revue des accélérations et vitesses de quelques glissements rocheux au volume comparable, avant de faire une synthèse de la cinématique du problème. Finalement, après une brève analyse de la géométrie du glissement de Black Lake, des scénarios de vitesse et d'accélération seront élaborés.

A NUMERICAL STUDY OF THE INFLUENCE OF GROUNDWATER FLOW ON HEAT LOSS FROM RESIDENTIAL FOUNDATIONS

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The insulation of above ground shell in residential building has been considerably improved in the past two decades. However, few efforts were made to reduce heat loss from the foundation through surrounding soils. A numerical and experimental study was initiated by Université Laval and IREQ (Hydro-Quebec research institute) to explore the effect of the different heat transfer mechanisms on energy efficiency of foundations, including buried walls and basement slab.

This paper aims at determining the relative effects of groundwater flow (heat convection) on the total heat loss towards surrounding soils using a finite elements method to solve coupled heat and mass transfer in porous media. Three different soils were studied: clay, silt and sand.

The results show that the flow of groundwater under the foundation has a significant influence on the total foundation heat loss if the surrounding soil is made of coarse grained soil such as pervious sands. As expected, the high water conductivity of sand has a strong influence on total heat loss due to varying pore-water velocities (hydraulic gradient). For example, under a typical hydraulic gradient of 0.0043, if the water table is located in the vicinity of the base of the foundation, the total heat loss increases by approximately 20% due to the effect of heat convection compared to hydrostatic conditions where pure conduction prevails. This influence decreases with increasing distance of water table from the basement slab. On the other hand, the results also show that low permeability soils such as silts and clays have insignificant influence on the total heat loss. Very low pore-water does not allow for noticeable heat extraction under any water table or hydraulic gradients conditions.

MODELING THE THERMAL CONDUCTIVITY OF SNOW OVER A WIDE RANGE OF POROSITY.

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Abstract : In cold regions, the ground surface may be covered by snow for a long period. Because snow has a relatively low thermal conductivity compared to frozen soil, the presence of a snow cover can significantly modify the heat transfer between the ground and the atmosphere. The thermal conductivity of snow varies mostly with density, but also with crystalline structure and grain to grain contact. Human activities such as winter maintenance may also lead to dramatic changes in the snow properties. Compacted snow accumulated on the side of any infrastructure may therefore be significantly denser and thus more conductive than fresh snow.

The objective of this paper is to modify and validate an existing thermal conductivity model that will be useful to estimate the thermal conductivity of any type of snow at any density. New thermal conductivity data as well existing data are analysed to expand the validity of the Côté and Konrad model originally developed for two phase porous materials such as soils and cemented materials.

The paper first briefly presents background information on the thermal conductivity of snow as well as the Côté and Konrad model based on the relative thermal conductivity framework used herein. This model introduces an empirical parameter that accounts for structure of two phase porous materials. This parameter is independent of porosity for mineral materials. However, the analysis of data from the literature shows that the structure of snow can also be linked to porosity. The empirical parameter from the thermal conductivity model of Côté and Konrad is thus re-assessed with respect to the Hashin and Shtrikman limits. A new relationship between the structure parameter and porosity is developed and integrated in the model.

In order to validate the proposed model, new laboratory test results are presented for different types of snow. As expected, the results showed that the thermal conductivity increased with decreasing porosity (increasing density). Values between 0.094 W/mK and 0.591 W/mK were obtained for porosity varying from 0.32 to 0.75, which is consistent with data reported from the literature.

The paper shows that the new model can predict fairly well the thermal conductivity of snow. The model is also validated with other independent data from the literature with very satisfying performances over the full range of porosity and with respect to physical limits.

IN-SITU LOADING TESTS OF SMALL-DIAMETER HELICAL PILES

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Abstract: The present research investigated the behaviour of three single-helix piles with shaft diameters ranging from 7.3 cm to 11.4 cm. The research conducted axial compression and tension loading tests of helical piles installed in cohesive and cohesionless soils located in Alberta. Subsurface conditions of testing sites were investigated using cone penetration tests (CPT). Correlations between the axial capacity and final installation torque were proposed based on the testing results. The correlations were found to be dependent of pile dimensions, loading directions, and soil types. It was observed that the torque factor, the ratio of pile capacity to installation torque, varied with the amplitude of axial capacities. In addition, CPT-based method and several indirect methods were used to predict the pile capacities and compared with the field test results. It is shown that the CPT-based method provides adequate agreement with the test results despite that modified end bearing coefficients for helical piles were adopted for capacity prediction. It is therefore recommended that CPT-based method could be used directly to predict the pile axial capacity.

Key words: helical piles, pile capacity, field loading test, CPT-based method

NUMERICAL MODELING OF SINGLE-HELIX PILES USING OPENSEES

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Abstract: Helical piles are widely used in Western Canada for many engineering applications. Soil-helical pile interactions are important for the helical pile industry and have been conventionally investigated using continuum finite element analyses, which require sophisticated modeling of soils and piles. The present research conducted simplified numerical modeling of soil and single-helix pile systems on the platform of the Open System for Earthquake Engineering Simulation (OpenSees). The numerical model adopts the beam-on-nonlinear-Winkler-foundation (BNWF) method for simulating soil-pile interactions. Soil reactions to piles are simulated by a series of q-z, t-z, and p-y springs. The ongoing numerical modeling is intended to calibrate the performance of in-situ helical piles under axial loads and to understand the load-transfer mechanism during in-situ loading tests. Cone penetrometer tests (CPT) results of each test site are used as the input to parameters of the numerical models. Preliminary results have shown that BNWF method could properly simulate the capacities and load-displacement curves of single-helix piles.

Key words: helical piles, pile capacity, numerical simulation, OpenSees

GEOHAZARD INVESTIGATIONS OF PERMAFROST AND PERMAFROST GAS HYDRATES IN THE OUTER SHELF AND UPPER SLOPE OF THE BEAUFORT SEA

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In his 1972 publication in the CJES, Ross Mackay made a milestone scientific contribution which substantially advanced the understanding of the factors controlling the distribution, origin and thermal regime of offshore permafrost beneath Arctic shelves. Mackay proposed that two types of permafrost were widespread beneath the Beaufort shelf; subsea permafrost that was in equilibrium with negative seabottom temperatures, and submerged terrestrial permafrost which was in disequilibrium. He also pointed out that in certain settings a thin offshore active layer was likely. The concepts proposed by Mackay were quickly accepted by industry, who at the time were actively undertaking hydrocarbon exploration in the area. Mackay's work fostered several decades of close collaboration between industry, government and academic scientists. This led to new geothermal measurements and well log interpretations that documented and mapped a thick body of offshore permafrost beneath the southern Beaufort Sea.

The recent sale of offshore leases in the outer shelf and upper slope has stimulated a new phase of research in the Canadian Beaufort. This paper will present results from ongoing permafrost and geohazard research being undertaken through a collaboration between the GSC, DFO, MBARI, KOPRI, U. Bremen and industry partners. In the past 5 years, we have had the opportunity to undertake 5 marine research expeditions to investigate permafrost and permafrost gas hydrates properties and processes in the transitional area from the outer shelf to upper slope. Following the example of Mackay, and fundamental to our science, we have developed testable hypotheses to guide our field work. To this end we have carried out geothermal modeling to provide a conceptual model of the geothermal setting and changes that may have occurred in the permafrost and gas hydrate regime as a consequence of Holocene marine transgression.

This paper will present a review of some of our recent findings including modeling results and efforts to use seismic techniques to document the extent of permafrost at the shelf edge. The paper will highlight some of the new research techniques we have employed to study active geologic processes, including; high resolution bottom mapping with Autonomous Underwater Vehicle (AUV), sediment coring and investigations of pore water and ground ice geochemistry, in situ strength measurements with a drop cone penetrometer device, studies of sea bed release of gas and ground water undertaking using a Remotely Operated Vehicle (ROV) and bottom founded oceanographic moorings.

3D DATA COLLECTION FOR EMERGENCY RESPONSE SITUATIONS

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Linear infrastructure corridors in rugged terrain are typically vulnerable to rockfall and rockslide type natural hazards from slopes high above the cut slopes at corridor level. Operationally, the consequence of such an event can range from minimal maintenance and repair of warning systems, to removal of debris from the corridor, through to complete closure and rebuilding of the infrastructure impacted by the hazard. The consequence of repairs, maintenance, and construction along single track railway lines is compounded by the fact that during any such activity the flow of traffic, people and goods, is impeded or stopped. Detailed evaluation of a natural slope prior to rockfall failure, or immediately after a hazardous event, can be completed using various 3-dimensional (3D) remote sensing techniques. This paper focuses on 3D data generated using helicopter based oblique aerial photogrammetry (OAP-H), an emerging method of remote data collection that does not require ground access to establish ground control. This paper discusses two case studies in which a railway line experienced a rockslide event which resulted in the requirement for an immediate engineered response. The first study is located along a CN railway line 150 km northeast of Vancouver BC where a rockslide activated a slide detector fence and impacted a rock shed protection structure. An immediate response was undertaken by CN as the rockslide originated at the same location as a previous event that resulted in a four day railway outage. The second case study, located 20 km north of Sept Iles Quebec, involved a rock slide event that resulted in a derailed a train and a prolonged closure of the track. An emergency response was conducted by QNS&L to develop ground based geometric information about the site. In both case studies the utilization of OAP-H enabled detailed 3D surface models of the terrain to assess the present situation.

USE OF NATIVE SOIL IN THE MSE WALL DESIGN IN THE GREATER TORONTO AREA

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Using granular soil as the reinforced fill is a standard requirement and common practice in the MSE Structure industry. MSE structure designers however, are often facing the challenge from the owner/contractors to use the on-site soil (native soil), or whatever soils available to them for cost saving purpose, or, due to the site inaccessibility of importing the granular soils. In the Greater Toronto Area (GTA), most native soils are typically non-granular in nature which have high percentage content (around 50%) of fines (particle size < 0.075mm) such as silt or clayey silt. The impact of applying such native soil on the MSE wall design, construction and subsequent performance can be significant.

This paper presents a detailed review through several case histories involving applying native soil in the MSE walls (with welded wire form facing) of varying heights and loading conditions. It is found that although a careful design is the important first step including selection of proper soil design parameters and provision of special sub-drain system to address the clayey and less permeable native soils, the success of an MSE wall using native soil primarily relies on the site quality control. Fill placement thickness, compaction method and installation rate are the key elements that govern the fill quality. Prolonged construction period will likely occur particularly in wet season due to the difficulties in moisture control in order to attain the required density. This will also lead to possible distortion or deformation along wall (face) profile during the construction as the result of excessive and uneven compaction efforts. Post construction monitoring data further indicated that MSE walls built with non-granular soil can have larger lateral movement (not related to the foundation settlement) up to 5% to 7% of wall height and the movements including (settlement) at the top of the wall may last for a long period (a few years) possibly contributed by clayey fill's secondary consolidation after compaction. The Owner/contractor should be advised of these potential consequences prior to accept their request of engaging native soils, even though it may provide an initial cost savings

MEASUREMENT AND MODELLING OF THE IMPACT OF CLIMATE-INDUCED CHANGES IN SNOW PHYSICAL PROPERTIES ON THE GROUND THERMAL REGIME.

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The presence of a snow cover greatly limits ground cooling in winter and thus affects ground thermal regime and permafrost stability. Arctic warming induces changes in snow cover and in the conditions that govern snow metamorphism, which impacts snow density and therefore snowpack height and snow thermal conductivity. Furthermore, increased vegetation due to warming also affects snow physical properties by limiting snow erosion and compaction by wind, and by favoring the formation of depth hoar layers, which have a much lower thermal conductivity than the wind slabs that prevail in the absence of vegetation. To investigate these effects, we have deployed snow, soil and meteorological monitoring stations in forest tundra, shrub tundra and herb tundra in Nunavik and Nunavut. In particular, we have monitored the thermal conductivity of snow and soil at several levels. Results demonstrate the effect of vegetation and of climatic conditions. For example, the occurrence of melt-freeze events in the snow lead to the formation of hard fairly dense layers of high thermal conductivity that favor ground cooling. The results were modelled using the Crocus snow physics model coupled to the ISBA land surface model. Multiple and contrasting effects were simulated. These include the impact of shrub growth, which leads to ground warming, and the effect of more frequent snow melting events which, by increasing snow thermal conductivity, act as a negative feedback to ground warming.

THE USE OF SUE SUBSURFACE UTILITY ENGINEERING DATA DURING THE DESIGN AND IMPLEMENTATION OF A GEOTECH PROGRAM.

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Subsurface Utility Engineering (SUE) is a valuable risk mitigation tool by allowing designers to gain knowledge of what lies below ground prior to the design phase of a project. SUE involves touches all aspects ranging from designation, to locating and ultimately conflict analysis. For years underground infrastructure has been installed resulting in our underground rights of way becoming very congested. Additionally, we are currently at the end of life for much of the existing plant, therefore upgrades will be required to maintain the quality of our services. The growth of land development, mass of housing and maximum use of land has contributed to our infrastructure not being able to keep up. With the trends being witnessed in the past few years and the concentration of major infrastructure projects/urban revitalization, Airport expansions the need for SUE in all aspects has become apparent. The introduction and use of SUE has become a key factor of overall risk mitigation and smart planning in infrastructure/development projects. The need for SUE is crucial to successful infrastructure projects and is a key point of risk mitigation in the Ontario Infrastructure/Development market. T2 will showcase a few recent Major Transportation projects where the use of SUE has provided the engineers with informative information up-front. The information has allowed designer to be proactive and not reactive to infrastructure conflicts and design changes needed to meet the demand of the projects.

With Utility infrastructure being the backbone of all our modern amenities and transportation hubs T2 will demonstrate the need for integration of SUE ASCE-3802 during the design encompassing all items in Utility engineering from conception to utility coordination and relocation. To the end and turnover of the information and the need to apply CSA 250 the Canadian standard for as built infrastructure. With proper management and application can lead to having the hidden unknown factors of infrastructure not be an issue and risk. References from past projects will be provided and demonstrate the use of SUE and information management in the real world environment.

MESURES DE RADAR EN PUIITS POUR LA LOCALISATION DU NOYAU IMPERMÉABLE DU BARRAGE DE LA ROMAINE-2

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La Romaine-2 est le premier grand barrage du type à noyau de béton bitumineux construit par Hydro-Québec. La Société souhaite valider les déformations anticipées du noyau imperméable en béton bitumineux du barrage obtenues par modélisation. La méthode de mesure par radar en puits en mode réflexion a été sélectionnée afin d'en évaluer le potentiel à déterminer la géométrie du noyau.

Des levés radar ont été effectués dans les deux inclinomètres verticaux situés en crête de part et d'autre du noyau, avant la mise en eau et après le remplissage à 95% du réservoir. Les levés de tomographie entre les inclinomètres amont et aval ont permis de déterminer le champ 2-D des vitesses de propagation radar dans le plan des inclinomètres sur la hauteur du barrage. Les tomographies radar entre forage ont pu mettre en évidence la distribution des vitesses de propagation associées directement à la teneur en eau. Les levés radar en mode réflexion ont mis en évidence la nature complexe des réflexions probablement associées à des variations latérales de granulométrie et aux hétérogénéités du remblai le long des inclinomètres.

Deux réflecteurs sont détectés à environ 30 ns et 60 ns en temps réduit, parallèlement aux inclinomètres. Avec la distribution des vitesses estimée par tomographie radar, les distances aux réflecteurs ont été déterminées, soit approximativement 2 m et 3,4 m. Le premier serait lié à une variation de composition granulométrique entre l'ilot de protection compacté légèrement entourant l'inclinomètre, et le remblai situé de part et d'autre le noyau, compacté mécaniquement. Le second serait attribuable à l'interface remblai/noyau. La faiblesse des réflexions et le bruit important n'ont pas permis de positionner cette interface de manière précise. En tenant compte des erreurs associées à la localisation des réflexions et à l'estimation des vitesses il existe une incertitude qui varie de 20 cm à 40 cm. Une forte atténuation du signal radar localisée à la base du barrage n'a pas permis de déterminer la position du noyau au niveau de son assise sur le socle en béton.

Dans les levés en réflexion après la mise en eau, deux réflecteurs parallèles à fort pendage (≈ 800) ont été mis en évidence entre 35 et 50 m de profondeur dans l'inclinomètre amont. Ils n'étaient pas présents lors des levés lorsque le réservoir était vide. Ces plans semblent s'arrêter soit au contact séparant les deux types de remblai situés entre l'inclinomètre et le noyau, soit à l'inclinomètre.

BACK ANALYSIS OF CONSECUTIVE SLIDES IN A VOLCANIC TUFF SLOPE. SHEAR STRENGTH PARAMETER ESTIMATION.

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Shear strength of volcanic materials is related to physicochemical factors which drive to cementation when the material is not fully saturated, giving place to an apparent cohesion which can reach high values. Cementation is lost when the material is saturated or due to small strains. The main consequence is that the shear strength of these materials can range between values characteristic of soils to values for soft rocks.

Even more, it is known that shear strength parameters for this kind of soils obtained by laboratory tests usually results in overestimation and mistaken stabilization solutions.

During the design of the stabilization solution of a slope in volcanic tuff close to San Salvador (El Salvador) we could compare the results of laboratory tests done with undisturbed samples with the strength parameters obtained from the analysis of the successive slides developed over the slope. The strength parameter estimation was improved as there have been at least three sliding in the same slope whose geometry was enough known.

The slides developed through two different types of tuffs: "tierra blanca" formation and "café" color tuffs. The geotechnical study points out how these materials have soil appearance once they have slid, although when they are in situ its consistency resembles rock strength.

According to the geological cartography and the geotechnical data, a set of strength parameters for this kind of soil which could explain the sliding sequence in the studied slope was determined.

INHERENT AND INDUCED ANISOTROPY IN GRANULAR MATERIALS

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Many naturally occurring geomaterials are anisotropic at the macroscale, which is strongly related to their microstructure. Sedimentary rocks (like shales), for example, display an inherent anisotropy, which results from the presence of bedding planes. In granular materials, the anisotropy may originate from the shape of the grains. It is well known, for example, that the strength properties of sand with elongated angular-shaped aggregates are strongly affected by the direction of loading in relation to the direction of deposition. But even if the skeleton itself may be considered as isotropic, e.g., sand with nearly spherical particles, there is usually a bias in the distribution of void space, due to initial compaction, which also triggers the anisotropy that may evolve during the deformation process. Whether inherent, induced or a combination of both, the anisotropy in microstructure may have a significant effect on both the strength and deformation characteristics of the material and should be accounted for in the context of analysis and design of geotechnical structures.

The primary objective of this study is to demonstrate that a significant degree of anisotropy may occur in particulate materials that have nearly spherical aggregates (i.e. are typically considered as isotropic) provided there is a bias in the distribution of pore space due to the initial densification process. The study includes both an experimental and theoretical component. An experimental program is conducted on dynamically compacted samples of Ottawa standard sand (C109), and incorporates a series of tests performed at different orientation of the specimens. A plasticity formulation based on the critical plane approach is employed. A systematic procedure for identification of material parameters is proposed and some numerical simulations of a series of triaxial tests are conducted. The mathematical framework is enhanced by an evolution law for the material fabric.

STUDY OF SOIL STRENGTH IMPROVEMENT USING POLYMERS

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The application of cured, polymer-stabilized soils could be a solution toward more economically-feasible, sustainable structures in numerous purposes of geotechnical and pavement engineering. This research investigates methods of increasing ductility and unconfined compressive strength of polymer-stabilized soils by means of curing methods. With this purpose in mind, a mixing-curing method was developed. The resultant specimens showed significant improvement in strength and ductility, dry, saturated and partially-saturated environments.

PRELIMINARY RESERVOIR IMPACT LINES FOR THE SITE C CLEAN ENERGY PROJECT

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The Site C Clean Energy Project is a proposed third dam and hydroelectric generating station on the Peace River in northeast British Columbia, Canada. The Site C dam would be an earthfill dam with a height of approximately 60 m and would create a reservoir that would be approximately 83 km long. A detailed assessment was undertaken to characterize the potential for groundwater changes, flooding, shoreline erosion, slope instability and landslide-generated waves resulting from the impoundment and operation of the proposed reservoir. The results of this assessment were used to generate preliminary reservoir impact lines that delineate areas of potential hazard. Four preliminary impact lines have been prepared in accordance with guidance provided by the International Commission on Large Dams: a Flood Impact Line, an Erosion Impact Line, a Stability Impact Line, and a Landslide-Generated Wave Impact Line. The reservoir impact lines are linked to recommendations for site-specific analysis, land use, and monitoring. They are intended to support an environmental assessment and, should the Project proceed, the management of risks to public safety and infrastructure. The objectives of this paper are threefold. First, this paper provides definitions for the Flood, Erosion, Stability, and Landslide-Generated Wave impact lines. Second, it describes how preliminary reservoir impact lines were developed for a proposed new hydroelectric project in a geological environment comprising marine clay shales and a complex sequence of fluvial and glaciolacustrine sediments. Third, it illustrates how, when combined with emerging hazard and risk tolerance criteria, impact lines can be used to help communicate and manage geohazard risks around existing and proposed new hydroelectric reservoirs, and potentially along river, lake and marine shorelines.

EMULSION POLYMER STABILIZATION FOR MINE TAILINGS

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The mining industry produces significant amounts of mine tailings (MT). Most of the MT are disposed of in on-site impoundments behind engineered earth and rock dams, which leads to a variety of environmental and safety concerns. This paper presents a feasibility study for the use of a commercial emulsion polymer to stabilize MT. Sieve analysis, specific gravity and Atterberg limits tests were conducted to characterize the MT test specimens. The simple fall cone method was adopted to evaluate the liquid limit and undrained shear strength of MT mixed with an emulsion polymer solution at concentrations 0.5, 1, and 2% of the dry weight of the MT. Moreover, the unconfined compressive strength was determined to quantify the amount of improvement in stabilized MT as the emulsion polymer concentration was varied. Scanning electron microscopy imaging was also conducted to study the microstructure of the polymer-MT system. The results indicate that the inclusion of emulsion polymer enhances the properties and strength of the MT, with higher emulsion polymer concentrations leading to greater enhancement. This enhancement is mainly attributable to the higher viscosity of the emulsion polymer fluid and the bonding between the polymer and the MT particles.

GTN-P DEVELOPING IN SOUTHERN PART OF EASTERN SIBERIA

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The report contains the synthetics of geocryological monitoring results in Chara Region, Northern Transbaikalia and Baikal Region in different permafrost conditions. The monitoring includes the automated ground temperature and manual active layer dynamics observations. The analysis ways and visualization forms were considered as well as collaboration with other types of natural processes monitoring including the geobotanic and hydrological observations. The team from Institute of Environmental Geosciences (Russian Academy of Science) continues the measurement of the ground temperature at 11 sites across Kodar-Udokan Ridge System following the recommendation of GTN-P project. Two new CALM sites were established in Chara Depression in 2013. Since 2012 the GTN-P geotemperature monitoring is supported by Irkutsk Institute of Earth Crust, Siberian Branch of Russian Academy of Science. This region is important because the active geocryological dynamics near southern border of permafrost zone. The multidisciplinary approach helps to distinguish the local the permafrost state variability from common regional trends in the permafrost system.

DEVELOPMENT OF SPECTRAL PSEUDO-STATIC METHOD FOR DYNAMIC SLOPE STABILITY ANALYSIS

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There is currently a number of methods for dynamic stability analysis of slope or embankment. Many of these methods are still in the field of research, without effective integration into common practice. This may be related to insufficient validation of these methods, but also to their complexity in the analysis or the determination of the dynamic parameters. From this point of view, the pseudo-static method remains attractive due to its simplicity, despite its incapacity, in its current form, to take into account some parameters involved in the dynamic analysis. This study aims to examine, in the first place, the limitations of the pseudo-static method in order to examine the possibility of developing a more effective analysis method that allows keeping the benefits of pseudo-static method.

The analysis of the stability of a slope or embankment by the pseudo-static approach consist to replace the action of the earthquake by a constant inertial force proportional to the maximum acceleration of the excitation and applied to the mass of potentially unstable ground. The pseudo-static method is widely criticized in the literature since it ignores the earthquake effect on shear strength and, in addition, masks the dynamic aspect of the problem (site effect, degradation of the module, synchronizing the movement, etc.). Despite this, it is still widely used in practice at different levels and almost all over the world. This paper will also present the results of a large number of numerical simulations that were used to develop a new method of pseudo-static analysis. In this method the pseudo-static coefficient varies with depth reflecting the dynamic properties of soil.

EXPERIMENTAL MODELING OF CONDITIONS FOR DISSOCIATION RELIC GAS HYDRATES IN PERMAFROST

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One possible reason for the active methane emissions on the Arctic shelf may be into-permafrost gas hydrate formations, existing in the strata of melting shelf permafrost. The formation of these into-permafrost hydrates could occur almost simultaneously with permafrost, when, after regression of the sea and consequent deep cooling and freezing of rocks observed the emergence of a zone of gas hydrates stability. It should be noted that the roof of hydrate stability zone may exist not only at depths of 200-250 meters but above by a local increase in pressure during the freezing gassed horizons. Formed at shallow depths into-permafrost gas hydrates in future could be preserved and go to the metastable state (relic condition) due to geological display the effect of self-preservation of gas hydrates. Under the favorable conditions, the depth of self-preservation relic gas hydrates in permafrost may be a few tens of meters. In the context of subaquatic permafrost degradation the relict hydrates that are above gas hydrate stability zone (less than 150-200 m) will be primarily subject to a process of decomposition caused by increased negative temperature of sediments, melting and salinity.

To assess the conditions of dissociation of relic gas hydrates in permafrost we conducted special experiments to assess the thermal decomposition of gas hydrate formation by heating artificial hydrate-bearing frozen sedimentary samples, as well as the influence of salt transport processes in the dissociation of into-permafrost gas hydrates accumulations. The objects of investigations were sand and loamy sand samples, than were taken from the permafrost horizons of the Laptevs' Sea shelf.

It was found that during heating of frozen sediments containing self-preserved gas hydrate the process of decomposition starts and ends earlier than the pore ice melted. This temperature shift increases with increasing content of soluble salts in sediments. The presence of critical temperature, at which the active dissociation of relic gas hydrates allow us to say that the gradual increasing of negative temperature of frozen hydrate-bearing sediments can course volumetric expansion of hydrate. This can provoke powerful streams of methane from melting hydrate-containing sequences.

We obtain experimental data on the dissociation of porous gas hydrate formations in the interaction of frozen hydrate-containing sediments with salt solutions. It is shown that the migration of salts can cause active dissociation of pore hydrates and methane emissions in frozen hydrate-bearing soils, which is important when considering methane emission from Arctic shelf with degradation of relict permafrost.

EXPERIMENTAL EVALUATION OF CHANGES IN PERMEABILITY OF FROZEN SEDIMENT AT THAWING.

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Changing the gas permeability of rocks at their freezing and thawing is important to assess the accumulation of natural gas in rocks, as well as calculation of gas emission in freezing and thawing rock. The methods and results of experimental studies of gas permeability of frozen sands (fine and silty) in the process of thawing have been presented in this paper. The experiments have been performed in a special device allowing the evaluation of the gas permeability of wet samples of the dispersed rocks under a wide range of temperatures (-15 - +30 oC) and pressures (up to 100 bar). During experiments have been found that during thawing of frozen samples increase of permeability depended on water content (ice content). So for samples of fine sand with water content over 10% permeability increased by more than an order, with a water content of 5-10% - increase in 2 - 3.5 times, with water content below 5% - less than 2 times. For silty sand, in general, the results were similar. At water content more than 10% of the samples permeability have been increased by more than an order, at a water content of 5-10% - 2 - 6.7 times, at a water content of less than 5% - less than 2 times. The increase in permeability during thawing is associated with the change in the structure of the pore space, the possible redistribution of water in the pores, volume changes during phase transitions of ice-water.

PUMPING TEST IN A CONFINED AQUIFER: HOW TO DETECT A POORLY SEALED MONITORING WELL AND CORRECT ITS DRAWDOWN DATA

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When a well is monitoring a confined aquifer, its riser-pipe must be perfectly sealed against the borehole wall. A poor seal produces a hydraulic short-circuit (HSC) and preferential seepage in it. Then, the static water level in the monitoring well (MW) is not the aquifer piezometric level, which is unknown. During a pumping test, a poorly sealed MW gives incorrect drawdown and recovery data. This paper shows how to detect the HSC, and obtain the correct data, using the example of a pumping test near Moncton, NB. The usual methods for interpreting the drawdown and recovery data did not take into account a HSC: they yielded close values for transmissivity T , but storativity S values differing by 500%. The proposed method detected a HSC: the static water level in the MW was 124 cm below the piezometric level in the aquifer. Then, drawdown and recovery data were corrected and reanalyzed, which yielded new and close values for T and S , thus supporting the diagnosis of a hydraulic short-circuit.

HIGHWAY 63:11 PINCH POINT EAST WALL NORTH OF ATHABASCA RIVER BRIDGE IN FORT MCMURRAY, ALBERTA

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Highway 63:11 to the north of the Athabasca River Bridge in the City of Fort McMurray, Alberta is situated on a narrow river terrace bench formed during the down-cutting action by the river. A sharp drop off is present along the east side of the highway where a branch of the Athabasca River has eroded into the east side of the terrace bench. The narrowest part of the terrace bench is about 60m wide, which created a pinch point/space constraint for the proposed highway grade widening at this location.

Due to geometric constraints and conflicts with underground utility lines, a 380 m long retaining structure was constructed along the top of bank of the Athabasca River to accommodate the grade widening of Highway 63 to 8 lanes. The retaining structure consisted of an up to 6 m high above-ground gravity wall supported on an underground pile wall. The underground pile wall consisted of one row of cast-in-place concrete piles, socketed into limestone bedrock with one level of grouted ground anchors bonded into the same bedrock formation.

The design and construction of the retaining structure was completed between 2005 and 2013. The underground pile wall included the installation of 134 piles and 113 grouted ground anchors. Due to potential cost-savings and safety concerns due to the proximity of work area to Highway 63 driving lanes, strand tendons were used to reinforce grouted ground anchors instead of traditional bar tendons commonly used in local pile wall projects. Slope inclinometers and vibrating wire load cells were installed in selected piles and anchors respectively to monitor the short and long term performance of the wall.

In order to reduce the lateral deflection of the retaining structure, a high performance soil erosion control mat was anchored along the eroded face of the bank slope to prevent future erosion and loss of passive resistance downslope of the wall at the sharp drop off location.

The paper provides a brief summary of the design and construction aspects of the wall, including the instrumentation monitoring results.

MECHNICS OF RAINFALL INFILTRATION THROUGH RESIDUAL SLOPE WITH DIFFERENT SOIL PROFILE

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Slope failures happened at the Skudai campus in Johor, Malaysia. Two instrumented slopes and two physical laboratory models were investigated for the effects of soil characteristics and capillary barrier on the mechanism of rainfall infiltration in slope and to examine one-dimensional rainfall infiltration behaviour of unsaturated soil. Analysis showed that for Site-1, the continuous rainfall has caused a significant increase in the soil's moisture, decrease in negative pore-water pressure (from 28 kPa to 0). On the other hand, the same rainfall induces a very small change in negative pore-water pressure. The experimental result shows that the two-layer system under the influence of a high precipitation rate is primarily governed by the water retention capacity of the fine soil and the response of suction distribution and redistribution to rainfall infiltration was influenced by the particle size of the soils. The results showed that the permeability of the soil mass plays an important role in slope instability. There are other factors that may influence the soil response to rainfall infiltration such as mineralogy of clay content and the dispersibility of the soil.

HIGH-RESOLUTION MONITORING OF THAW SUBSIDENCE AFFECTING THE ACCESS ROAD TO UMIUJQA AIRPORT IN NUNAVIK (QUEBEC)

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In the context of climate warming in excess of 2 °C as observed over the last twenty years in Nunavik (Quebec), the vulnerability to thaw subsidence of man-made infrastructures is widespread. For instance, located on the eastern shore of Hudson Bay in the discontinuous permafrost zone, the access road to Umiujaq Airport shows major structural problems due to permafrost degradation. The settlement of the road surface is due to thaw consolidation taking place in a 3.7 m thick layer of ice-rich silt underneath a superficial layer of deltaic sand. From its completion back in 1991 to the beginning of the 21st century, the road embankment was behaving as expected without any noticeable deformation. The first evidence of thaw subsidence to a naked eye affecting the road was reported in 2005. The road surface at this moment looked wavy with the subsidence troughs and crests affecting the full width of the road embankment. The first leveling survey relative to a benchmark on a rock outcrop nearby using an optical level and total station was performed in July 2006 along a 300 m segment of the road. Compared with the as-built drawings of the access road, the differential thaw subsidence was as much as 60 cm and the subsidence volume was evaluated to 527 cubic meters. A yearly monitoring program was then undertaken to assess the rate of thaw subsidence. In summer 2009, after another leveling survey, the road embankment was reloaded to level the surface. The access road and the streets of the northern village of Umiujaq were also paved to reduce the dust emission by the traffic. Another leveling survey was carried out in October 2009 after the embankment reloading to pursue the monitoring program. Since summer 2012, a ground-based Light Detection And Ranging (LiDAR) was also used to map the spatial distribution of thaw subsidence. After the road maintenance in 2009, the thaw subsidence was still progressing but under the form of a large localized depression perfectly fitted by the asphalt over. A major longitudinal crack in the pavement was also forming away from the depression. In summer 2013, due to traffic hazard, the pavement was removed and the embankment was again reloaded. The monitored thaw subsidence increased linearly with time at rates between 5 and 15 cm/year. No more thaw subsidence was observed since summer 2013. The thaw consolidation of the silt unit is now completed.

STABILITY OF EXPOSED CEMENTED BACKFILL IN UNDERGROUND MINE STOPES

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Backfilling of mine stopes contributes to ground control and ore recovery. Mining methods involving the use of cemented backfill pillars require the exposed face of backfill remains stable during removal of one of the support walls to create the adjacent stope. Determining the minimum required strength of the cemented backfill is thus a critical issue to avoid production and safety problems. Accordingly, a few studies have been conducted to assess the required strength of backfill in stopes with an open face. This paper presents numerical simulations results that investigate the response of exposed backfill during sequential excavation, considering the effect of stope geometry and material strength. These results are then compared with analytical solutions developed to obtain the required backfill strength. The simulations indicate that such analytical solutions are based on some assumptions that do not reflect well the actual behavior of the backfill and the related failure mechanism. The results are analysed and discussed in terms of their practical implications.

SWELLING POTENTIAL OF QUEENSTON SHALE IN LUBRICANT FLUIDS

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The swelling behaviour of Queenston Shale and other shaly rocks from Southern Ontario has been thoroughly studied for the past decades. Most of the performed studies in the past were based on deriving the swelling potential of the shaly rocks from the free swell tests in fresh water. However the effect of lubricant fluids that are used in the drilling process, such as polymers solution and bentonite slurry, on the swelling behaviour of Queenston Shale is lacking and need to be investigated. In order to evaluate the effect of drilling fluids on shale's swelling potential, a series of free swell tests was performed on samples of Queenston Shale from Southern Ontario adopting the polymers solution, bentonite slurry and fresh water as the ambient fluids that induce swelling to commence. The results of these tests have revealed significant difference in the derived values of the swelling potential of Queenston Shale in the lubricant fluids and in fresh water. Both of the polymers solution and the bentonite slurry have clearly suppressed the swelling and have reduced the swelling potential of Queenston Shale in contrast to that in fresh water. Moreover, the suppression effect of the polymers solution on the swelling of Queenston Shale was more evident and reached up to 69% and 85% in the vertical and horizontal directions respectively, in contrast to that in fresh water. This finding is particularly important for the evaluation of the swelling associated with the drilling process and in the design of underground structures in Queenston Shale of Southern Ontario. However, the behaviour of other swelling rocks in the lubricant fluids needs further investigation.

GEOTECHNICAL PROPERTIES OF A COMPACTED SAPROLITIC RESIDUAL SOIL BASED ON ADVANCED LABORATORY TESTING

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As part of the construction of an earth core rockfill tailings dam in the Dominican Republic, saprolitic residual soil was used as the low permeability fill (LPF) material in the core of the dam. Saprolitic residual soil was also present in the foundation of the dam. This paper discusses geotechnical properties of the LPF based on advanced laboratory testing. A companion paper presents the geotechnical properties of the undisturbed saprolitic residual soil in the dam foundation.

This paper initially presents the index properties of the LPF such as gradation and Atterberg limits to characterize this material, then follows with the results of advanced geotechnical tests: consolidation tests, unconsolidated undrained triaxial compression tests (UU), isotropically consolidated undrained triaxial compression tests (CIU), anisotropically consolidated undrained triaxial compression tests (CK0U and CAU) and monotonic and cyclic direct simple shear (DSS) tests.

Effective stress shear strength parameters obtained from CIU, CK0U and CAU triaxial tests are presented and discussed. The effects of initial consolidation stress states (i.e., isotropic or anisotropic consolidation) and different shear modes (i.e., shear in triaxial compression or in direct simple shear) on the static undrained shear strength of the LPF material are investigated and discussed based on the results of UU, CIU, CK0U, CAU and monotonic DSS tests. In addition, undrained shear strength reduction due to cyclic loading of the LPF is estimated by comparing the results of monotonic and cyclic DSS tests, performed at different cyclic shear stress ratios.

The results of these tests indicate how this material would behave under different initial stress states, loading conditions and shear modes. At present, there are limited data of this type on saprolitic residual soil that are readily available in the literature and hence the comprehensive data set presented in this paper will add to the geotechnical knowledgebase for such material in similar regions

ANALYSIS OF RIGID MONOPILES IN LAYERED ELASTIC SOIL

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A continuum based analysis to obtain head deflection and rotation for rigid monopiles supporting offshore wind turbines is presented. Free body diagrams with appropriate external and internal forces are considered for the monopile and soil separately, and the principle of virtual work is used to derive two sets of equilibrium equations – one for the pile and the other for the soil displacements. The equations are solved analytically and numerically to obtain the monopile head deflection and rotation. A parametric study is performed to obtain equations which directly give values of monopile deformations as functions of pile dimensions and soil moduli. The advantage of the analysis is that it produces results much faster than equivalent finite element analysis, and does not require cumbersome inputs of geometry and mesh like those required in finite element analysis.

GEOTECHNICAL PROPERTIES OF AN UNDISTURBED SAPROLITIC RESIDUAL SOIL BASED ON ADVANCED LABORATORY TESTING

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During the design and construction of an earth core rockfill tailings dam in the Dominican Republic, the geotechnical properties of the saprolitic residual soil in the dam foundation were characterized using advanced laboratory tests. Saprolitic residual soil was also used as the low permeability fill (LPF) material in the core of the dam. This paper discusses geotechnical properties of the saprolitic residual soil in the dam foundation based on advanced laboratory testing. A companion paper presents the geotechnical properties of the LPF.

This paper initially presents the index properties of the undisturbed saprolite such as gradation and Atterberg limits to characterize this material, then follows with the results of advanced geotechnical tests: consolidation tests, unconsolidated undrained triaxial compression tests (UU), isotropically consolidated undrained triaxial compression tests (CIU), anisotropically consolidated undrained triaxial compression tests (CK0U and CAU) and monotonic and cyclic direct simple shear (DSS) tests.

Effective stress shear strength parameters obtained from CIU, CK0U and CAU triaxial tests are presented and discussed. The effects of initial consolidation stress states (i.e., isotropic or anisotropic consolidation) and different shear modes (i.e., shear in triaxial compression or in direct simple shear) on the static undrained shear strength of undisturbed saprolitic residual soil are investigated and discussed based on the results of UU, CIU, CK0U, CAU and monotonic DSS tests. In addition, undrained shear strength reduction due to cyclic loading of the material is estimated by comparing the results of monotonic and cyclic DSS tests, performed at different cyclic shear stress ratios.

The results of these tests indicate how this material would behave under different initial stress states, loading conditions and shear modes. At present, there are limited data of this type on saprolitic residual soil that are readily available in the literature and hence the comprehensive data set presented in this paper will add to the geotechnical knowledgebase for such material in similar regions.

APPLICATION OF REINFORCED EARTH WALLS WITH LARGE RECTANGULAR PANELS IN ONTARIO

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A Reinforced Earth wall is designed as a coherent gravity structure and is constructed of a combination of soil and reinforcement materials, with a facing system that is most commonly precast concrete panels. Since early 1980's, cruciform shape panels 1.5m x 1.5m have been popular and widely utilized in Ontario. In the 1990's, large rectangular facing panels with a 3m width and a 1.5m height gained popularity among DOT's in the USA. Recently this type of facing was introduced to the clients in Ontario and 4 structures have successfully been built, mostly semi-integral abutments.

There are some technical considerations in the design of a large panel i.e.the stress distribution in different load conditions, such as striping, lifting, installation, earth pressure, etc. All these cases are analyzed individually and different methods are examined in the analysis. In this paper we present a model using flexible springs and study how the soil reinforcement length can affect the reaction forces at the connection to the precast panels. The results are verified by 3-dimensional analysis and compared with other approaches in modeling and design methods.

There are advantages to the use of this type of facing of which speed of manufacturing is one of them. In addition, the architectural finishes on the pre-cast panels can be better implemented on the rectangular panels. The many options of architectural finishes are very popular in urban areas. Moreover, utilizing the large panels in combination with discrete soil reinforcements e.g. galvanized steel strips, is suitable for MSE walls in semi-integral abutments. The limitations and advantages due to the size of the panels are all discussed in this paper.

HOW PERMAFROST THAW MAY IMPACT FOOD SECURITY OF JEAN MARIE RIVER FIRST NATION, NWT

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The Jean Marie River First Nation (JMRFN) and its project partners combined and shared traditional, local and scientific knowledge to produce climate change vulnerability maps of traditional use areas near Jean Marie River. The landscape of the JMRFN lands is changing. Changes have been observed by the community members and documented by the researchers during the geological field work. It is undeniable that these changes are significant. The impact assessment on food security tells that changes have and will have considerable impacts on country food. For example, an average of 33.4% of sites, indicating the presence of animals used for food, overlap with areas vulnerable to permafrost. The JMR people's diet is composed of 75% country food so this gives them great concerns in terms of food security. The geological survey and mapping results suggests that: 1- Approximately 50% of the study area encompasses grounds having a medium to high vulnerability to permafrost thaw. 2- The permafrost present on our land is warm and close to degradation. Several areas already are experiencing severe degradation processes. 3- The resulting landscape changes affect the wildlife habitat and wildlife behavior. 4- The permafrost degradation process is quite advanced in some areas, and with the ground temperature being close to the 0°C threshold, it is possible that the degradation process will be completed in only a few decades. This information gives an approximate yet short, time frame to develop our adaptation strategies. The vulnerability hazard map resulting from this project is tailored to the needs of the JMRFN community, is culturally oriented and, when overlain with spatial traditional land use information, brings a new, integrated perspective regarding climate change impacts on the JMRFN. In light of the results of this study, there are several issues that require attention: 1- The immediate issues are the access to country food and the quality of the food that is decreasing. 2- In the future the quantity of country food will be added to the list of issues. The quantity of animals and plants that we currently use for food are likely to be reduced as the degradation of permafrost continues to change their habitat. This project represents a prototype for future surveys and mapping aimed at identifying and quantifying the impacts of permafrost degradation from a broader and more holistic viewpoint that combines western science and traditional and local knowledge.

NON-DARCY AND RADIATIVE EFFECTS ON CONVECTIVE EMBANKMENT MODELING

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The growing necessity for natural resources has prompted a renewed interest in Arctic and sub-Arctic regions, and led to the development of new transportation corridors. The design of the transportation lines within these corridors is challenged by the presence of seasonally frozen soil and permafrost, which are sensitive to minor changes in heat transfer at the ground surface. Disregarding the effect of these manmade structures on the surface heat balance may result in significant thaw, and settlement. Over the years, a number of techniques have been proposed to mitigate the effect of embankment construction on the surface heat balance. These techniques include the use of air ducts, thermosyphons, and convective (or air convection) embankments to enhance wintertime heat extraction. This paper focuses on the design of convective embankments, which generally hinges on the use of numerical models that describe buoyancy-driven flow and heat transfer in porous media. A review of the literature reveals that most of these models assume that heat transfer occurs by conduction and convection, and that airflow can be described with Darcy's law. This is inconsistent with recent experimental evidence that suggests that radiative heat transfer is significant, and that Darcy's law does not adequately describe the relation between superficial flux and gradient in rockfill materials. In response to these shortcomings, a new model is herein derived to account for both radiative heat transfer and non-Darcy effects. After demonstrating its ability to solve fairly complex steady-state problems, the model is used to gain insight into the relative importance of radiative heat transfer and non-Darcy flow on the thermal response of a typical railway embankment. The radiative heat transfer is shown to be much greater during the summer months. This significantly increases the temperature at the base of the embankment, which in turn, increases the wintertime convective heat transfer. This additional heat extraction does not counteract the effect of the radiative heat transfer, and the active layer is shown to be wider than that computed without radiative and non-Darcy effects.

A GENERALIZED GLOBAL OPTIMIZATION APPLICATION AND ITS USE IN DETERMINING THE HYDRAULIC PROPERTIES OF UNSATURATED SANDS

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In its simplest form, global optimization consists in minimizing or maximizing a fitness function by iteratively choosing a set of input parameters from a selected range, and computing the value of the function. Although it dates back to the origins of geometry, it is now extensively applied in various fields of engineering. The literature abounds with different global optimization algorithms that can be divided in two main classifications: deterministic and stochastic algorithms. In the deterministic algorithms, the mathematical function is directly related to fixed and unique parameters whereas the parameters of stochastic algorithms are treated as random variables with joint posterior probability distributions. This paper focuses on the deterministic algorithms that have been implemented in a generalized global optimization application. Some of these algorithms are based on evolutionary strategies in which the underlying idea is that alternative, or candidate, solutions play the role of individuals in a population that evolves within the environment defined by the fitness function. These include the genetic algorithm, the canonical differential evolution algorithm and its self-adaptive variants. The other population-based algorithm is modeled on a type of artificial intelligence known as particle swarm. These algorithms are integrated into a comprehensive combined modeling application that uses the JUPITER API to communicate with any process model with batch processing capabilities. After a brief description of its structure and algorithms, the capabilities of the application are illustrated by finding the hydraulic property functions of unsaturated silica sand through inverse modeling of a multistep outflow experiment with both suction and cumulative outflow measurements. The self-adaptive strategies are shown to be particularly well suited to this optimization problem in which the fitness landscape changes as the alternative solutions move towards the global optimum. The optimized hydraulic property functions are also shown to be in excellent agreement with those independently determined using steady-state methods.

ANTHROPOGENIC TRANSFORMATION OF THE ACTIVE LAYER SOIL IN OLDEST CITIES IN NORTHEAST RUSSIA

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The paper reports the rapid changes in geological conditions, intensive soil salinization, water table rise and increased salinity of suprapermafrost water, and extensive development of cryopegs in the area of Yakutsk. Seasonal patterns of soil solution behavior, chemical fluxes, pH and Eh are discussed. Multiple changes in acidity/alkalinity and in contents of organic and other constituents make the groundwater more aggressive and increase the corrosiveness of soils.

In recent years, due to climate change and an increase in revenues of precipitation changed the concentration of salts in the upper horizons of soils of the city (in the depth interval 0.0-0.5 m.). Within the city area of saline soils with concentrations above 0.2% decreased by more than doubled from 71% in 1984 to 7% - in 2011.

The maximum salinity of soils (> 0.2%) are confined to the interval depths of 2-4 m, with an average power-layer 2.3 m.

The progressive development of cryogenic processes leads to changes in the bearing capacity of soils and to damages of buildings and structures. Most buildings in danger of failure are located within the older section of Yakutsk built-up by the early 20th century.

THAWING SOILS TESTING

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Currently, thawing soils testing perform mainly in laboratory, because field tests are expensive and time consuming. Thawing soils testing conducted to determine two deformation characteristics (thawing coefficient (A) and coefficient of compressibility(m)). Tests can last from 1 to 4 weeks. Therefore, reducing test time is an important issue for our research. We studied 500 undisturbed samples of soil. Samples were marine genesis and selected in the north of Russia. Thawing soils testing conducted in compression device. Samples had a diameter 7.1 cm, height 35 cm. Samples selected from 1 to 6 meters and represented by sands, silt, clayey silt. Soils are characterized by a large variety of cryogenic structure and texture. Tests identifying deformation characteristics of thawing soils are performed in three stages. Stage I was consolidation of frozen sample at freezing temperature with natural load. Stage II was thawing of sample at the same load. Stage III was consolidation of thawed sample step by step. Each load stage was maintained until settlement reached relative stabilization that was taken as equal to 0.01 mm per 12 hours. In total, there were five load stages. We calculated deformation characteristics, using a straight relationship between relative deformation at each stage and strain. We got straight relationship between deformation after thawing and thawing coefficient (determination coefficient 99%), using a large amount of experimental data. Settlement frozen ground in first stage did not exceed 5% of total settlement. Thus, it is possible to reduce test in 5 times, if we will perform only compression test during thawing. And then we can calculate thawing coefficient and coefficient of compressibility on the basis of established relationships. The relative error of the proposed method does not exceed 10% for calculating the thawing coefficient and more than 30% for coefficient of compressibility. Values of thawing coefficient are the largest contributor in calculation of settlement thawing soils (more 80%). Marine sediments have high ice content for that reason 85% of the total settlement occurs during thawing. We calculated settlement for different types of soils at thaw depth 1 meter. Then we compared the settlement, which was calculated using the deformation characteristics obtained by standard and proposed method. Difference between two methods does not exceed 2 cm for sand and 8cm for silt. Test time can also reduce to 8 hours, but then decrease the accuracy of calculations.

CLIMATE GETS WARMER-BUT WHY PALSAS DO NOT THAW?

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The Arctic and northern permafrost areas are very sensitive to climate change and recent reports suggest dramatic changes are occurring in the cryosphere. Palsas, peat mounds with a perennially frozen peat and mineral soil core, are a typical phenomena in the circumpolar zone of discontinuous permafrost. In Finnish Lapland palsas can be up to 10 metres in height and cover a square kilometer in area. They can be several thousands of years old, but some recently formed palsas have also been detected.

An experimental field study of palsa formation has been carried out over several thawing seasons.

It has been found that palsas follow a cyclic development. New palsa rises above the mire surface. In mature stage the surface cracks and peat blocks slide down along the edges. The frozen core then loses its insulation and thaws leaving a water pond on the mire surface. Peat growth slowly fills the pond allowing the cycle of palsa growth to restart. However, a curious aspect is that palsas are rather stable.

Laboratory measurements of the physical properties of peat provide an important insight into why palsas do not easily thaw in response to increasing air temperature. Based on these observations and field experiments the future effect of climate change on palsas will be described.

MIGRATION OF POTASSIUM CHLORIDE FROM SALT WELLS INSTALLED IN LOW-SALINE, HIGHLY SENSITIVE CLAY AT THE NTNU RESEARCH SITE DRAGVOLL, TRONDHEIM, NORWAY

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Six salt wells filled with potassium chloride (KCl) were installed in January 2013 at the NTNU research site Dragvoll. Potassium chloride improves the mechanical behavior of low-saline, highly sensitive quick clays. To monitor the migration of potassium from the salt wells into the quick clay deposit, one of the wells is monitored by Schlumberger Divers and BAT ground water monitoring system. The instruments are positioned 0.5 m and 1.0 m from the salt well. The divers are set up to measure the water column, conductivity and temperature once a day. As well as monitoring the increase in conductivity due to increased total dissolved solids (TDS), it monitors the seasonal variations in the subsurface. Ground water samples are extracted from the BAT standard filter tips.

Due to the low permeability the transport mechanism is dominated by chemical diffusion. The arrival time of the plume is detected by the diver. The analyzed TDS and ion composition in the ground water samples provides data to evaluate the migration velocity. The migration velocity is here defined as the effective diffusion coefficient including retardation due to dispersion and ion exchange. The diffusion coefficient will change with changing concentration gradients.

The salt plume was detected by the diver 0.5 from the well fifty days after installation of the salt well. 520 days after installation it reached 1.0 m from the well. The diver conductivities, however, do not correspond to expected values of TDS based on often used correlations. The conductivities are correlated to the TDS analyzed in the ground water samples. This paper will present a two year long time series from the salt well research site Dragvoll.

THERMOSTABILIZATION OF FROZEN GROUND FOUNDATION BY MEANS OF LOW-TEMPERATURE COOLANT

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In the permafrost propagation areas thermal interaction between constructions and foundation soil leads to the thawing of soil and, therefore, to the loss of soil bearing capacity. One way to solve this problem and to minimize such negative influence is to use facilities for foundation soil thermostabilization: the seasonal cooling devices working during period of air temperatures below zero; machine methods of cooling with compulsory ventilation of coolant.

Liquefaction of natural gas is important and even priority technology of gas import and usage. At the stages of designing and operation of gas-condensate fields infrastructure the problem of thermostabilization of foundation soils appears. Thus, one of the perspective decisions could be potential possibility of partial utilization of the liquefied natural gas cooling or some others liquid hydrocarbons such as ethane, propane etc.

In contrast with usually applied seasonal thermostabilizers (TS), use of cooling capacity of the LNG complex allows: to provide reliable operation of a construction all the year round and irrespective of climatic conditions; to utilize selected gas for cooling of the foundation soil; to provide much higher rate of the soil frost penetration; to minimize effect of the frost heaving (the high rate of frost penetration provides minimization of volume of water migrating to the freezing front); to freeze cryopegs with various degree of a mineralization.

Besides obvious advantages of LNG utilization as a refrigerant liquid for soil thermostabilization it can lead to appearance of negative processes, such as frost cracking caused by emergence of big gradients of temperature near the wall of thermostabilizer tube. For that matter, it is required to pay special attention to the determination of optimum value of LNG-inlet temperature and the constructive solution of TS, for the purpose of prevention (minimization) of process of frost cracking.

The task description and software products used for mathematical modeling are given in this article, and also results of calculations of frost penetration process of surrounding soil with various grain size compositions and salinity degree, and cryopegs with different mineralization are presented. The estimates of tension arising during the rapid frost penetration which allow us to find optimum values of LNG-inlet temperature and constructive solutions of TS, for the matter of minimization of process of frost cracking are given.

LABORATORY STUDY ON THE GEOTECHNICAL BEHAVIOR OF POTASSIUM CHLORIDE SATURATED CLAY FROM DRAGVOLL, NORWAY

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Introducing potassium chloride (KCl) to low-saline, highly sensitive quick clay improves the mechanical properties of the clay to such an extent that it no more appears as quick. Highly sensitive, low plasticity clays are transformed to clays with low sensitivity and increased plasticity. Mini-block samples with a diameter of 16 cm from the NTNU research site Dragvoll, Norway, were stored in KCl-slurry over some time to investigate how the normally consolidated, low plastic and highly sensitive quick clay responded to the change in its clay-water system. To evaluate the storage effects, samples from the same depths were tested after extraction and stored submerged in de-aired water for the same amount of time as the ones stored in KCl.

Index testing, Atterberg limits, pore water chemistry and cation exchange capacity are analyzed on all samples. The storage effects have an impact on the results, as well as osmoses due to an oversaturated solution of KCl in the storage container. Consequently the data on the mechanical behavior is not fully reliable. Even so, it is evident that KCl improves the mechanical behavior of the quick clay significantly. The remolded shear strength is increased from 0.1 kPa to around 5 kPa. The plasticity index (IP) is increased from around 6 to around 15, and the liquidity index (IL) is decreased from around 3 to 0.6-0.7. The potassium concentration is significantly increased. Sodium (Na⁺), magnesium (Mg²⁺) and calcium (Ca²⁺) are released into the pore water as K⁺ enters the adsorbed positions.

The geotechnical parameters from this laboratory study are not reliable. Even so it gives valuable information to future laboratory setup.

INVESTIGATION ON THE SOIL THERMAL CONDUCTIVITY OF DIFFERENT UNDERLYING SURFACES IN THE NORTHERN QINGHAI-TIBETAN PLATEAU, CHINA

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Several numerical methods are applied and compared in the calculation of soil thermal conductivity (STC) in the Kekexili (QT01), Beiluhe (QT02, QT03), Kaixinling (QT05), and Tongtianhe (QT06) regions in the northern Qinghai-Tibetan Plateau based on data from January 2004 to December 2013. The results show that the STC of the active layer in the study region exhibited marked seasonal variations: it was low during the cold season but high in the warm season. Averagely, the mean value was 1.080 Wm-1K-1, ranging from 0.752 to 1.371 Wm-1K-1. In the frozen state (FS), STC was 0.955 W.m-2.K-1 while in the unfrozen state (UFS), it was 1.204 W.m-2.K-1. STC increased with increasing soil bulk density but decreased with increasing vegetation cover of the underlying surface; STC of alpine frost meadow soil was greater than that of alpine frost steppe soil; fine-grained soil with low unfrozen water content and a low saturation degree resulted in low STC in the cold season; and monthly mean STC can be well expressed as a function of conventional meteorological data. Verification results further ensured that the proposed model accurately predicts monthly STC values.

FORMULATION D'UN NOUVEAU MATÉRIAU ROUTIER À BASE DE SÉDIMENTS MARINS DE DRAGAGE

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En France, plus de 50 millions de m³ de sédiments marins sont générés chaque année par les opérations de dragage. Ces sédiments ne peuvent pas être réemployés directement en techniques routières sans un traitement spécifique. Afin d'améliorer la compacité des sédiments, l'ajout d'un matériau granulaire est recommandée. L'utilisation du sable de dragage afin d'améliorer le mélange granulaire contenant les sédiments est une des solutions afin de mieux gérer la production de ces deux éléments (sable et sédiments). Dans cette étude, un nouveau matériau routier à base de sable et de sédiments de dragage a été formulé et traité par plusieurs types de liants. Les performances mécaniques des différents mélanges obtenues ont été suivies par la mesure au laboratoire des résistances de compression et diamétrale.

DETERMINATION OF FROZEN AND THAWING SOILS VISCOSITY USING SPHERICAL STAMP TEST

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Rheological properties of soils (creep, stress relaxation, strength reduction over time) connected with viscosity. Viscosity need to know to get the model of elastic-visco-plastic deformation of soils. Bingham-Shvedov equation, which is often used in soil mechanics, contain dynamic viscosity. Dynamic viscosity depends on temperature, stress-strain state, time, changes in structure of soil. Viscosity has a large scatter of the experimental data at various test. We have developed a method of constructing rheological curves frozen and thawed soil using spherical stamp test. This test is simple and does not take a lot of time, so it can be applied universally. We calculated dynamic viscosity of different soils using Stokes equation and compared values with standard methods. Data differ slightly. We got a relationship between the dynamic viscosity and temperature, grain size, salinity of soils and compared dynamic viscosity of frozen and thawing soils.

MODÉLISATION NUMÉRIQUE DU COMPORTEMENT DES SOLS RENFORCÉS PAR LA MÉTHODE D'HOMOGENÉISATION.

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La présente étude est une contribution à l'analyse de la stabilité des pentes, basée sur les relations contraintes – déformations du matériau constitutif. Deux modèles de comportement, élastique et elasto-plastique ont été utilisés dans la modélisation du sol avec la définition de deux critères de rupture de type Mohr Coulomb et Von Mises. A cette fin, un programme de résolution des problèmes bidimensionnels des sols, par la méthode des éléments finis, a été développé. Les résultats obtenus sont en bonne concordance avec les résultats acquis dans d'autres études tirées de la littérature. Le programme élaboré est structuré et conçu de manière à être enrichi par d'autres modèles de comportement plus complexe.

STATIC AND CYCLIC DESIGN ASPECTS FOR FOUNDATION PILES OF OFFSHORE WIND FARMS

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Part of the proposed transition of the German energy market to renewable energy will be based on the large-scale development of offshore wind farms. The installation of approximately 6500 MW capacity is scheduled until the year 2020. Different innovative foundation concepts are used depending on water depth, soil and environmental conditions as well as the electric capacity of the installed turbine. Monopile foundations currently dominate near-shore wind farms with water depths lower than approximately 20 m and/or medium size turbines whereas in areas with larger water depths and/or large scale turbine sizes (e.g. the 6 MW class) space frame structures like tripods, tripiles or jacket structures are the prevailing foundation type.

Due to large pile diameters (approximately 2.5 m for jacket piles and maximum 7 m to 8 m for monopiles), cyclic loading effects from wind and waves in combination with relatively low self-weight of the structure and the pile installation in an offshore environment, novel challenges emerge for the pile design. This contribution summarizes the specific static and cyclic design aspects as well as installation facets in the German offshore wind industry.

The predicted static pile capacity of open-ended large diameter tubular steel piles for space frame jacket foundation concepts in the North Sea with predominantly non-cohesive soil has not been verified by in-situ static pile load tests so far. Over the past years the semi-empirical design methods (e.g. ICP-05, UWA-05) which include installation and geometry effects have become increasingly popular since they have been calibrated with a large database of pile tests, however with rather small pile diameter. Based on a representative pile geometry for a jacket foundation and generic non-cohesive soil profiles this contribution illustrates the variety of predicted static pile capacity using the semi-empirical design methods and the widely used pure-empirical method from Germany as well as the design method of the API.

It has been documented previously that cyclic load has a negative effect on the static pile capacity. However, it has been a challenge since to quantify the amount of the pile capacity degradation. This contribution presents new innovative design methods from Germany allowing the computation of pile capacity degradation and pile displacement accumulation. A worked example utilizing the analytical Kirsch/Richter method and the numerical method of Thomas shall reveal major influence parameters and the outcome of the cyclic axial pile design of a jacket pile foundation in non-cohesive soil.

ETUDE DE CORRÉLATIONS ENTRE LES RÉSULTATS D'ESSAIS PRESSIOMETRIQUES ET DE PÉNÉTRATION DYNAMIQUE. CAS DE LA STATION HAI EL BADR - MÉTRO ALGER

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La communication présente une étude de corrélation entre la pression limite préssiométrique PI et la résistance de pointe dynamique issues des résultats des investigations géotechniques réalisées dans les sites de Hai El Badr et Ain Naadja entrant dans le cadre de la réalisation du Métro d'Alger extension C. Une synthèse des travaux antérieurs sur les corrélations est présentée; par la suite les essais géotechniques réalisés dans le cadre de notre étude sont décrits. Les données géotechniques pour les différents types de sol rencontrés dans la région seront analysées puis on exécutera notre corrélation. Cette dernière sera comparée aux conclusions de l'étude bibliographique.

TIME EVOLUTION OF THERMAL CONDUCTIVITY AND INTRINSIC PERMEABILITY OF A SNOW COVER

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Snow metamorphism is a process that modifies its properties over time. Among those characteristics, the intrinsic permeability and thermal conductivity govern the heat and mass transfer processes, nonetheless, only a few studies assess the change of these snow properties during the winter. This paper presents the experimental results of the evolution of the relationships between intrinsic permeability, thermal conductivity and porosity of a single snow layer over time. Snow batches were collected at Laval University in the winter of 2014 at weekly intervals and always at the same height from the ground. They were later reworked to produce samples of different porosities. Permeability and thermal conductivity measurements were carried out successively on each sample of known porosity using a commercial thermal needle probe and a custom designed double-walled cylinder air permeameter. The experimental results obtained for the different samples ranged from 3.59×10^{-9} to 8.71×10^{-11} m² for the permeability and from 0.089 to 0.372 W/mK for conductivity with porosity varying from 0.46 up to 0.80. A temporal evolution of the relation permeability-porosity has been observed while no significant changes in the relation conductivity-porosity were noticed. An effective radius corresponding to each snow batch and sample was obtained using an existing permeability (Calonne) model. That radius has allowed the quantification of the temporal evolution process. Result showed an asymptotic behavior of the calculated effective grain radius and corresponding specific surface area. The new data from thermal conductivity measurement were used to validate the Côté and Konrad two-phase porous geomaterial model.

THERMAL CONDUCTIVITY OF BOTTOM SEDIMENTS IN THE EAST SIBERIAN ARCTIC SEAS: CASE STUDY IN THE BUOR-KHAYA BAY

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Among Arctic carbon reservoirs, subsea permafrost, hydrates, and associated methane (CH₄) deposits are the most worrisome owing to high heat transfer from rapidly warming shallow Arctic seas. The East Siberian Arctic Shelf (ESAS) is a big portion of the Arctic shelf and hosts over 80% of current subsea permafrost and along with it, unique Arctic shallow CH₄ hydrates. Degradation of subsea permafrost results in increasing permeability for gaseous CH₄ long preserved in seabed deposits within and beneath permafrost. This process manifests as extensive significantly elevated CH₄ ebullition, driving significantly elevated CH₄ aqueous concentrations up to 3 orders above atmospheric equilibrium (Shakhova et al., 2010, 2014). Nevertheless, knowledge about the present thermal state of subsea permafrost is mainly based on modeling results, which are controversial. In that sense, actual values of thermal conductivity are crucially needed.

Thus, in spring of 2011 we organized and accomplished the complex physical and biogeochemical Russia-US study (called Siberian Shelf Studies) based on the dry sediment core drilling from the fast ice in the Buor Khaya Bay (Laptev Sea) down to sediment depth ~55m.

In this report, we represent the first results of in situ measurements of the major sediment core thermodynamical parameters in the ESAS including thermal conductivity, water content, density, porosity, lithology and the state of pore water in the gassy sediments.

A REVIEW OF GEOMETRICAL METHODS FOR DETERMINATION OF LANDSLIDE VOLUME AND FAILURE SURFACE GEOMETRY

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Even though computers possess an increasing power, only few methods are available for the volume calculation of landslides, as well as the construction of their failure surfaces or profiles across landslides based on sparse data. However, available data permit now to go to 3D representations.

In this paper we review existing methods that permit to extract the landslide failure surface in 2D profiles or as full 3D surface. Most methods are based on morphometric characterizations, displacement observations, and interpolation techniques, leading to the estimation of surfaces.

The simplest methods used to assess landslide volume either assume a mean thickness multiplied by the landslide surface area or use a semi-ellipsoid. Based on expert knowledge, profiles of landslides can be drawn based on a synthesis of the available data that are surface morphology, boreholes, geophysics interpretation, etc. These methods can be improved using more automatic methods such as splines.

The observation of the total displacements at surface or the velocity vectors, can lead to the construction of longitudinal profiles of failure surfaces that may be circular or not. The observation of the scarp alone and the total displacement can provide the thickness of the landslide in the case of a translational landslide.

In the case of debris-flows, the classical way is to perform surveys multiplying the surface of the section of the available sediments (based on observation) by the length of reaches. The transversal profile section can be replaced by polynomial functions to estimate maximum scouring potential.

The modelling of 3D failure surfaces and volumes can be performed using a DEM and morphometric features providing the limits of the unstable volume of rocks or soils. This uses various interpolation techniques such as 3D splines, surface fitting, etc. In the case of rockslides, the major discontinuities defining the instability limits observed at surface are used to extrapolate them in the rock mass in order to define the volume of the unstable rock mass.

The Sloping Local Base Level (SLBL) is a method which provides a 3D surface from DEM based on the assumption that a failure surface can be extrapolated from the limits of the unstable mass assuming some geometrical properties about its shape such as order, slope, curvature etc. The advantages of the SLBL method are that it can be easily parameterized and fairly automated.

These methods can provide important information on landslide geometry and volume when detailed field investigations are lacking.

EXTREME VALUES, SKEWED DISTRIBUTIONS, POWER LAWS, CHAOS AND FRACTALS IN GEOTECHNIQUE

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Many natural geological phenomena vary in space and/or time according to power laws or other skewed statistical distributions. Simple examples include grain size distribution of soils, discontinuity dimensions in rock, variation of hydraulic conductivity in geologic units, and size distribution of landslides. Power laws imply a fractal structure and the potential for chaotic behavior, as well as the absence of a characteristic scale, and consequently a scale-dependent behavior in space, time or both. This paper examines some of the statistical peculiarities associated with such phenomena, including expected and extreme values and expected variability, and subsequently discusses potential related issues and challenges in geotechnical practice, including: scaling test results from lab to field scale; error propagation and scenario selection in risk analysis; probabilistic slope stability assessment; and, the unexpected and potentially unpleasant consequences of obtaining more subsurface information in complex geologic settings.

CO-SEISMIC LARGE LANDSLIDES IN SENSITIVE CLAY IN EASTERN CANADA, LOOKING FOR A PGA THRESHOLD FOR SEISMIC TRIGGERING

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This paper examines the search for a peak horizontal ground acceleration (PGA) threshold for triggering large co-seismic landslides in sensitive clay in eastern Canada, with the aim of supporting regional risk analysis in a HAZUS framework. Literature sources document a number of small co-seismic landslides associated with small or moderate earthquakes which produced a PGA between about 0.04 g and 0.15 g at the landslide locations. Two papers describe a large number of large, co-seismic, sensitive-clay landslides with measured dates; many of these are associated with the 1663 Charlevoix earthquake, from which site-specific firm ground PGA can be estimated; these range from about 0.03 g to 0.81 g, with several landslides initiating with PGA less than 0.1 g. A clear PGA threshold for triggering of large co-seismic landslides in sensitive clay cannot be inferred from these available data. Earthquake magnitude and distance appear to provide a better basis for discriminating between the potential for small, nuisance landslides and large rapid earth slides in the study area.

LIQUEFACTION SUSCEPTIBILITY MAPPING DERIVED FROM TERRAIN MAPPING, EXPERIENCE ON LONG LINEAR PROJECTS

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Long linear projects, like buried pipelines, may traverse a range of physiographic, geologic and seismic settings. Areas with elevated seismic hazard that contain loose, saturated cohesionless soils may be affected by liquefaction and its attendant hazards (i.e. buoyancy, subsidence, lateral spreading) in the event of a design earthquake. This paper examines the development of liquefaction susceptibility maps from the methodology of Youd and Perkins (1978) relying on airphoto-based terrain mapping prepared at medium scale (1:20,000) according to accepted methodology in British Columbia (Howes and Kenk, 1997). Borehole drilling with in-situ testing, supported by surface geophysical surveys, allows the generation of statistics relating the Youd and Perkins susceptibility categories to expected thickness of loose, saturated, cohesionless soil, expressed as the probability of encountering non-zero thickness of $(N1)_{60-cs} < 5, 10$ or 15. Medium scale mapping is shown to be a reliable basis for screening at preliminary design, with potential for improvement through larger scale mapping.

RESEARCH ON FROST-HEAVING CHARACTERISTICS AND ITS UNLOADING EFFECT OF ARTIFICIAL FROZEN SOIL

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Abstract: A new geotechnical technique of artificial refrigeration and freezing up aquifer to be frost-curtains was available in reinforcement of unstable stratum and insulation of groundwater in foundation engineering. Although it has super performances such as excellent waterproof, higher rigidity and strength, the frost force and deformation have great influences on retaining and supporting structures and frost-heaving force is one of the main and huge loads in artificial frozen projects. However there are significant unloading effects and deformation control by the discharge holes (grooves) in our studies and applications. From the whole process of research including FEA analysis and experimental and in-situ test, the frost-heaving mechanics, characteristics of frost-heaving force and deformation in artificial frozen soil, behaviors of unloading effect around construction were system studied and shown in this paper. Achievements may provide theoretical basis on further research on techniques of artificial frozen aquifers and future applications of ground freezing envelope method.

Key words: artificial frozen soil; frost heaving; retaining and supporting structures; restrain function; unloading effect

N2O AND CO2 DYNAMICS IN A FROZEN SOIL

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Gas dynamics influences soil/atmosphere gas exchanges. It thus influences various economical or environmental activities such as contaminated sites, oil sands, mine residues, landfills, tar sands, and biological activities. Even though this important contribution of gas movement for Canadian activities and considering that most of the Canadian soils freeze during a large part of the year or are permanently frozen (permafrost), gas dynamics in frozen soils is illknown.

The literature indicates that even when soils are nearly saturated once frozen, gas formation occurs in depth. The processes are not clear. Thus, an in-situ setup was installed in a pasture field to study gas dynamics during the cold season. A field plot (15m×15m) was instrumented at 49 points at two depths (0.125 and 0.25m). CO₂ and N₂O soil concentrations and CO₂ emissions were measured several times during two winters. Physico-chemical soil properties such as temperature, moisture, density, nitrate and N content were measured at the same points.

During both winters, soil gas concentrations show similar tendency with very large spatio-temporal variability. During the frozen period, CO₂ and N₂O increased at all depths, faster for CO₂ than for N₂O. CO₂ concentrations tended toward a maximum in mid-Winter (February) and remained constant until thawing at depth. A very quick (2-3 days) release of soil gas was observed during warming periods in March at both depths, with a small time lag for deeper depths. Then gas concentrations increased again until thawing when another burst of emissions occurred. Soil gas concentrations during winter showed continuous productions of CO₂ and N₂O due to microbial activities that were maintained even during the coldest periods and high gas concentration.

During both winters, gas emissions were much lower than those of the summer. Rather than being continuous, they occurred during very narrow time periods not only during spring time and may represent an important part of yearly gas emissions budget. Their high spatial variability (CV>1000%) were correlated with soil gas concentrations, snow thickness and other soil parameters.

Spatial and temporal variability of soil gas concentration and emission will be discussed with other soil properties along with implications for the industry.

THE BEHAVIOUR OF METAL CONTAMINANTS IN SILT SAND AND GRAVEL

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An investigative study is reported to determine the behaviour of metal contaminants in silt sand and gravel. The discharge of heavy metals arise from a number of different sources including natural but also urban activities such as transport, waste processing spills and infrastructure. The existence and concentrations of heavy metals are reported at different soil depths up to 4.0 m in some cases. A soil box experiment was conducted with a silt sand of permeability, $k = 3.9242 \times 10^{-5}$ m/s (ISO standard). The sand was placed on a bedding of 6 mm pea-gravel, inside the test box. Copper Nitrate, Chromium Nitrate, Nickel Sulphate and Lead Nitrate were dissolved, mixed with RO (reverse osmosis) water for use in four separate experiments. The metal solutions were sprayed on the topsoil and a maturation period of one week was allowed for metal equilibrium in the sand to occur before water irrigation representing a three year rainfall was commenced. Column tests were conducted with the same silt sand and gravel and under similar experimental conditions. This was done in order to measure scale up effects on leaching between the two experimental setups. Copper flushing was very slow, it was strongly absorbed to the silt sand and gravel. The release was linked to organic matter and pH of the soil. Its adsorption by the gravel was found to follow Freundlich Isotherms with a regression coefficient, R^2 of 0.999987. Greater reproducibility and retention was shown by the pre-acid washed soil in the column experiment. Similar behaviour although less complex was observed from the chromium. Thus in general Chromium was entirely retained (34mg/Kg) within the experimental system, and its released concentrations were very low. Nickel was shown to have a good aqueous solubility thus it was freely mobile in the sand. There was some minor adsorption of Nickel though lower than that of Copper and Chromium. There was a total retention of Lead by the silt sand, indicating Lead's good affinity for soil particles coupled with its poor aqueous solubility. The scope of the study was three years equivalent rainfall which is low compared to other areas in the world (with up to 5,000mm/annum in the UK or more elsewhere). It was concluded that a longer period with higher rainfall might also produce more leaching of the added metals but in general all the metals are retained quite well within the box experimental setup.

PROBABILISTIC ANALYSIS OF TWO MECHANISMS OF FAILURE IN GEOSYNTHETIC REINFORCED SLOPES USING MONTE-CARLO SIMULATION

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Reinforced slopes with horizontal layers of geosynthetic reinforcement can have different mechanisms of failure. In this paper two major mechanisms of failure for reinforced slopes are investigated. In the first mechanism, the critical slip surface passes beyond the reinforced zone. The second mechanism is characterized by failure surfaces that intersect some layers (composite failure) or all of the reinforcement layers. For a target value of the factor of safety, and a specific value of the reinforcement length, there is a minimum value of the reinforcement tensile strength to generate the first mechanism. For values greater than the minimum value of the reinforcement tensile strength, there is no change in the mechanism of failure and the value of the factor of safety. On the other hand, maintaining the reinforcement tensile strength at this minimum value and increasing the reinforcement length generates the second mechanism. In this study, probabilistic slope stability analysis of these two mechanisms is carried out using Monte-Carlo simulation of slopes with different purely frictional soils and slope angles. It is shown that for first mechanism cases and minimum reinforcement length, increasing the tensile strength of the reinforcement does not change the value of probability of failure. For second mechanism cases and a minimum value of the tensile strength, increasing the length of the reinforcement increases the value of the factor of safety (the change in the factor of safety may be different for different cases); however, the corresponding value of probability of failure decreases dramatically. It is also shown that for first mechanism cases, typical variability in reinforcement tensile strength is too low to change the probability of failure and probability of failure depends only on the value of the factored friction angle (friction angle divided by the factor of safety). Therefore, for a target value of the factor of safety, it is possible to have a unique chart to calculate probability of failure for simple slopes with purely frictional soils. Several charts are provided to calculate the minimum length of reinforcement and corresponding probability of failure for different soil and reinforcement strength and a target value of the factor of safety. Additional probabilistic-based charts are provided to show the effect of random variability of reinforcement strength on probability of failure and also the difference between probabilities of failure for the first and second mechanisms of failure for a target value of the factor of safety.

COMPARAISON EXPÉRIMENTALE DES MÉTHODES MASW ET H/V BRUIT DE FOND DANS L'ESTIMATION DES EFFETS DE SITE LITHOLOGIQUE DANS LE BASSIN DE DAMIEN

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L'objectif de cet article est de comparer les résultats obtenus lors des campagnes d'essais sismiques par les méthodes MASW et H/V bruit de fond, réalisées dans la plaine de Damien (Port-au-Prince, Haïti). Ces deux méthodes utilisent la propagation des ondes dans les couches superficielles et permettent d'identifier les interfaces entre les couches présentant des contrastes d'impédance et/ou de vitesse plus ou moins importants. Ces contrastes sont souvent à l'origine des effets de site lithologiques. Un rapprochement entre le contenu fréquentiel des ondes indiqué par la méthode H/V et la vitesse de cisaillement indiquée par la méthode MASW, est fait en fonction de l'épaisseur des couches. La confrontation de ces deux types de résultats dans la plaine de Damien (fréquences fondamentales et vitesses de cisaillement), contribue ainsi à l'amélioration du choix des techniques d'estimation d'effets de site lithologique, dépendamment des caractéristiques géophysiques des sols.

ECOLOGICAL BOARD FOR GROUNDWATER'S OF THE IRRIGATED GROUNDS

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The agricultural production on the irrigated grounds can not carry on without mineral fertilizers, pesticides and herbicides. Especially it is shown in Uzbekistan, in cultivation of cotton. There is an increase in mineralization, rigidity, quantity of heavy metals, phenols and other pollutions in the cotton fields. Thus there is an exhaustion of stocks of fresh underground waters. In the year 2003 we were offered to create the ecological board to prevent pollution to get up to a level of subsoil waters in the top 30 centimeter layer of the ground. We carried out an accumulation and pollution processing. This layer possesses a high adsorbing ability for heavy metals, mineral oil, mineral fertilizers remnants, defoliant and pesticides. In order to remediate a biological pollution treatment processing should be taken into account. The idea is consisted in the following. The adsorption properties

of coal is all well-known that the Angren coal washing factories in Tashkent area have collected more than 10 million tons of the coal dust to mix with clays. We have picked up association of anaerobic microorganisms which, using for development, destroys nutrients of coal waste pollutions to a harmless content for people. Coal waste inoculation also are scattered by these microorganisms on the field before plowing. Deep (up to 30 cm) plowing brings them on depth from 5 up to 30 cm. Is created by a plough a layer with necessary protective properties. The norm of entering depends on the structure of ground and the intensity of pollutions. Laboratory experiments have shown that 50% of pollutions can be treated by the ecological board and are processed up to safe limit.

MODELLING OF ELUTION TESTS WITH THE ICP INTERFACE BETWEEN COMSOL AND PHREEQC

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The iCP interface allows the coupling of PHREEQC, a geochemical modelling code, and COMSOL a finite element software package, for the modelling of reactive transport in soils. With the iCP interface, the equations describing the transport of chemical species in pore water are first solved in COMSOL. The updated chemical analyses for each cell are then sent to a PHREEQC model for thermodynamic and kinetic calculations. In this paper, the iCP interface was tested by modelling the transport of a conservative tracer (Br) and the elution of metals (Cu, Cd, Pb, Zn) in a column containing a natural soil (calcareous sand with some silt and gravel). A double porosity model was programmed in COMSOL to take into account preferential flow in larger pores. PHREEQC was mainly used to model the dissolution of calcite present in the soil and the precipitation of metal carbonates. This paper is centered on a coupling between hydrodynamic and geochemical equations, but the iCP interface could also be applied to multiphysics models involving mechanical (e.g., cementation) and thermal (e.g., heat produced by chemical reactions) equations. Examples of potential applications in geotechnical and geoenvironmental engineering are given.

INFLUENCE DE LA COHÉSION APPARENTE SUR LA STABILITÉ DES PENTES À VIVY-MITCHELL (HAÏTI)

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L'objectif de cet article est d'analyser la stabilité des pentes sur le site de Vivy-Mitchell en tenant compte de la cohésion apparente. Dans notre travail, nous nous intéressons plus particulièrement à l'étude de modélisation numérique de ce site, basée sur les caractéristiques expérimentales des échantillons prélevés. Pour compléter cette étude de modélisation, une étude semi-paramétrique sera menée pour les caractéristiques incertaines de ces échantillons. En ce sens, des paramètres mécaniques seront modifiés tour à tour afin de modéliser leur influence sur cette stabilité. Cette modélisation a été accomplie avec le logiciel GEOSLOPE utilisant les méthodes d'équilibre limite couplées avec les méthodes des éléments finis afin d'analyser le rôle de la cohésion apparente sur cette stabilité. Les applications effectuées à partir des différentes approches examinées dans nos modèles ont permis de comprendre l'influence de la cohésion apparente sur la stabilité au niveau du glissement de Vivy-Mitchell.

SOME INNOVATIVE SOLUTIONS DEVELOPED FOR VARIOUS ASPECTS OF DESIGN AND CONSTRUCTION IN THE TERRITORIES OF PERMAFROST SOILS.

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Solving the problem of stabilization of permafrost during the development of cold regions is a complex task. This article describes a number of innovative solutions developed for various aspects of design and construction in such areas.

One of the most important problems is regulation of the thermal balance at the surface. For example sunscreens developed by Professor Kondratiev to protect the road embankment slopes from thawing were tested and shown to be effective in China. However, in snowy Russian winter, the issue of redistribution of snow caused by the installation screens takes place. The newly developed panels stabilize the temperature of the soil surface and reduce the radiation component due to the snow accumulation, employing the benefits of natural climatic processes.

Another important issue is the assessment of risks on the hottest underground pipelines. A feature of simulation of a hot underground pipeline is that simply knowing the area of thawing or a maximum draft of soil is not enough. It is also necessary to evaluate the movement of soil adjacent sections relative to each other at each time point which makes it possible to predict the stress in the pipeline. Thus the developed method allows assess the risks in the operation of the pipeline.

Accuracy of simulations crucially depend on the availability of reliable laboratory data on thermophysical properties of soils. For example, one of the most difficult parameter to determine is the thermal conductivity. Behavior of unfrozen water in frozen soils leads to a strong dependence of thermal properties of the soil temperature which eliminates the use of non-stationary measurement methods. The newly developed instrument allows measurement of the whole complex of thermal parameters of frozen soil in actual relevant range of temperatures including sub-zero values. Results of these measurements can be used in calculations using the enthalpy method without intermediate ratios in it. This technique enables making predictions of a higher quality.

SHORT AND LONG TERM COMPRESSIBILITY OF ROCK PARTICLE ASSEMBLAGES

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During construction and first impoundment of rockfill dams, significant deformations can occur due to the crushing of highly stressed rock particles. In order to improve our understanding of this phenomenon, short term and long term compressibility of assemblages of rock particles was studied with one-dimensional compression tests in a large oedometer cell. The main results from the test program, carried out in a special experimental apparatus which can reproduce different stages of the life cycle of the rockfill dams, are presented in this paper. These results revealed that short term compressibility tends to be more important for samples with a wide grain size distribution curve, a low density and when the samples were wetted prior to loading. Furthermore, the compressibility was successfully related to a breakage factor, highlighting the importance of breakage on deformations of rockfill. With respect to long term compressibility, it appears that the ratio between the time-dependent index and the compressibility index, $C_{\epsilon,t}/C_{\epsilon,\sigma}$, tends toward a constant of about 0.02 for dry rock particles and 0.03 for saturated samples.

UNDERSTANDING DYNAMIC SOIL PROPERTIES ROLE IN A LANDSLIDE

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Landslide damages have been very noteworthy both on infrastructure and on human lives. Many impressive landslides have recently occurred in Lebanon. This region is much known for its tectonic activity due to the fact that it is limited in the east by the major fault of Yammouneh, extension of the Dead Sea fault that crosses the Middle East, and by many minor faults in the west. The purpose of this research is to evaluate the importance of soil dynamics properties on a landslide and to understand how a slope will behave under seismic loading in terms of safety in relation with slip surface observed. In this study, we will consider landslides that occur on the pan Arab highway, precisely in Dahr el Baidar area. In fact, this region is located between 1000 and 2000 m altitude above sea level, is subjected to a rate of rainfall ranging between 1100 and 1700 mm and has a mountainous Mediterranean climate.

Based on the undertaken analysis, it is realized that water effect is an important triggering factor for the landslide. In fact, the presence of water might diminish the soil mechanical parameters and hence be an initiating element for instabilities. From an earthquake Engineering point of view, sensitivity studies have been carried out, in order to understand slope failures. First, the effect of earthquake acceleration on the soil behavior in the slope is pointed out. For instance, the peak period of the acceleration response spectrum seems to increase with higher earthquake accelerations and durations. Moreover, this peak period and the soil acceleration amplification depend on the dynamic parameters of the soil deposit. Indeed, the amplification varies as a function of soil shear moduli and soil damping. This study shows how the slip failure surface moves from one layer to another layer as a function of changing soil rigidity. It is important to underline that increasing the stiffness contrast between surface and deeper layers does not affect the slip surface, but reduces the factor of safety by 55% in some cases.

Finally, it is interesting to see how amplification of acceleration in time domain will depend on soil dynamic properties, whereas amplification of RRS (Ratio of Response Spectra) in frequency domain will only depend on the soil thickness above rock and the rock's acceleration response spectrum. The results obtained would certainly help in understanding the behavior of soils in a slope under earthquake conditions.

ESTIMATION OF SOIL STRENGTH PARAMETERS USING ARTIFICIAL NEURAL NETWORKS MODELLING

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Due to the limitations and complexities associated with undisturbed soil sampling and laboratory shear test analysis, the estimation of soil strength parameters (e.g., internal friction angle and cohesion) is a challenge in geotechnical engineering practice. These parameters have an important role in determining soil bearing capacity and slope stability analysis, and are commonly approximated by characterizing physical soil properties in empirical and numerical methods by using Atterberg limits and grain size distribution. They are among the necessary inputs for most geotechnical modeling software and yet, despite their ubiquity in modeling software, the use of physical soil parameters in modeling has been largely restricted to traditional regression analysis, which cannot be used to solve complex and highly non-linear real world problems. For such applications, artificial neural networks (ANNs) can overcome the problems inherent to traditional regression analysis by changing the function of transfer and in the case of highly non-linear phenomena, by changing the number of hidden layers and nodes.

In this study, we tested the reliability of ANNs in predicting soil strength parameters for different soil types based on their Atterberg limits and grain size distribution. The main objective was to find a satisfactory relationship between input and actual measured values using ANN models. The effect of ANN geometry on the performance of the models was also assessed. In all cases, the correlation factors were greater than 0.96, demonstrating that ANNs are powerful tools for predicting soil strength parameters and that Multi-Layer Perceptron provides the best results.

Keywords: Soil Strength Parameters, Internal Friction, Cohesion, Clay Soil, Artificial Neural Networks

NUMERICAL MODELLING OF THE EARTH PRESSURE DISTRIBUTION ON BURIED STRUCTURES WITH GEOFOAM INCLUSIONS

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Expanded polystyrene (EPS) geof foam has been successfully used as lightweight fill material in geotechnical engineering applications. This is attributed to its low density and high compressive strength. In this study a 2D nonlinear finite element analysis is conducted to investigate the effect of embedding a geof foam layer within the backfill material on the earth loads transferred to the walls of the buried structure. The earth pressure distribution is investigated for two different types of geof foam material commonly used in geotechnical engineering practice. The numerical model is first validated using experimental data and then used to study the effect of different parameters (e.g. geof foam thickness, location and density) on the earth pressure distribution on the buried structure. Conclusions are made regarding the effectiveness of using different geof foam inclusions in reducing the earth loads on subsurface structures leading to cost-saving design.

STABILITY APPROACH FOR THE NORTH SPUR, CHURCHILL RIVER VALLEY

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Nalcor Energy's Lower Churchill Project developed the Muskrat Falls site located on the Churchill River in the province of Newfoundland and Labrador, 35 km west from Happy Valley – Goose Bay. Part of the closure of the river is achieved by making use of an actual piece of land, a spur. This "North Spur" is a marine and estuarine deposit which naturally provides a partial closure of the Churchill River valley. A major slide on the downstream face of the North Spur, in November 1978, revealed the fragility of this natural dam. Maintaining the integrity of the North Spur after the reservoir impoundment is critical to the project, therefore the design of stabilization measures included different studies.

Some of the most well known landslides in the world occurred in sensitive clay. This includes Rissa, Norway in 1978 and, Saint Jean-Vianney, Quebec in 1971. This phenomenon is more common in northern countries following historic glaciations. In the previous decades, scientific and engineering research has significantly progressed in understanding this type of landslide. Significant progress in numerical modeling has led to a better understanding of slope processes and stability assessments. (L'Heureux et al, 2013) has added a new approach to deal with progressive failure mechanism.

Early in the Muskrat Falls Project planning and design, the stability of a natural dam (The North Spur) was identified as a project hazard. Mitigation measures have been designed and developed for the stability of the North Spur and these have been reviewed by independent experts. The Muskrat Falls Project will improve the stability of the North Spur which involves dealing with sensitive clay present at this location.

This paper presents the methodology used to study the progressive failure mechanism which could impact the stability of the North Spur. The study covered the mapping and classification of landslides scarp which have already occurred in the Churchill River Valley, the stability analysis before and after stabilization works, and the different prevention methods to eliminate the potential triggers.

PERFORMANCE EVALUATION OF BURIED PIPELINES SUBJECTED TO RELATIVE SOIL MOVEMENT

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Buried pipelines are important infrastructure for modern society. Damage to these structures can cause negative impacts on the quality of living in today's society. It is sometime necessary to install utility pipelines near an existing natural or man-made slope. These pipelines can experience significant increase in lateral earth pressure as a result of possible slope movement. In this study, a coupled finite-discrete element framework is used to investigate the performance of buried pipeline subjected to relative soil movement in both the axial and lateral directions. The framework allows for the explicit simulation of the soil movement at the particle level and at the same time capturing the structural response of the buried structure. The stresses and deformations developing in the investigated pipe as a result of the soil movement will be presented and recommendations related to the critical pipe-slope configuration will be identified.

NUMERICAL MODELLING OF DETERIORATED EARTH LEVEES

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The invasive wildlife activities in earthen structures have been reported in different parts of the world. The estimated worldwide annual cost of damage to earthen structures and the associated infrastructure due to these activities exceeds billions of dollars. This geotechnical problem has been traditionally dealt with as a maintenance issue rather than a challenging design problem and a long-term performance concern. Validated using centrifuge experiments, a series of three-dimensional finite element models were built to simulate the introduction of idealized animal burrows in existing levee structures. The role of burrow diameter and location on the hydraulic performance of the levee is investigated. In addition, the mechanics governing the progress of failure within the deteriorated levees are highlighted. Finally, recommendations are presented regarding the need for an early detection system to prevent internal soil erosion and minimize the risk of levee failure.

NORTH SPUR STABILIZATION WORKS: 50 YEARS OF HISTORY

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Nalcor Energy's Lower Churchill Project developed the Muskrat Falls site located on the Churchill River in the province of Newfoundland and Labrador, 35 km west from Happy Valley – Goose Bay.

Part of the closure of the river is achieved by making use of an actual piece of land, a spur. This "North Spur" is a marine and estuarine deposit which naturally provides a partial closure of the Churchill River valley. A major slide on the downstream face of the North Spur, in November 1978, revealed the fragility of this natural dam. Stabilization works must be completed before impoundment to ensure the long term integrity of the North Spur and viability of the project.

Churchill River banks shows landslide scarps and active erosion marks. North Spur itself exhibits a complex stratigraphy which includes sensitive clay layers. There has been improvements in characterization methodologies and evolution in geotechnical science in the last decades which are very important to the development of the approach to stabilization of the North Spur. Paper will present how changes and improvements in geotechnical science and techniques have help to modify our knowledge of stratigraphy and soil properties, which has led to a change in stabilization works and an improvement in the overall safety of that natural dam.

DYNAMIC LOADS ON COHESIVE AND NON-COHESIVE SOILS IN A NATURAL DAM: FROM SITE-SPECIFIC STUDY TO MODELING

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Nalcor Energy's Lower Churchill Project developed the Muskrat Falls site located on the Churchill River in the province of Newfoundland and Labrador, 35 km west from Happy Valley – Goose Bay.

Part of the closure of the river is achieved by making use of an actual piece of land, a spur. This "North Spur" is a marine and estuarine deposit which naturally provides a partial closure of the Churchill River valley. A major slide on the downstream face of the North Spur, in November 1978, revealed the fragility of this natural dam. Maintaining the integrity of the North Spur after the reservoir impoundment is critical to the project, therefore the design of stabilization measures included different studies. The design of stabilization measures included a study of the dynamic stability of the North Spur, taking into account a seismic event with a 10,000-year return period

Past continental glaciations followed by glacial, fluvio-glacial and marine deposition formed the overburden in the Muskrat Falls area of the lower Churchill River. Based on data from detailed geotechnical investigation campaigns (boreholes, scissometer, seismic CPTu), the stratigraphy of the North Spur, from ground surface to bedrock level, was interpreted. This is comprised of an upper sand, a stratified drift (two major deposits of silty sand and silty clay material), a lower marine clay and a lower aquifer (pervious sand and gravel layer). In order to select appropriate stabilization measures, the resistance against liquefaction for granular materials and cyclic softening for clay materials had to be examined. Given the site configuration with its upstream and downstream slopes, the usual 1D flat ground methods were more or less applicable, a 2D equivalent-linear and non-linear dynamic response analyses give a more complete understanding. This paper presents the steps in the methodology used for the study, going from conservative simplified and imprecise methods to more precise but also more complex (and sometimes less over-conservative) methods. Finally, the use of good quality geotechnical information led to conclusive results and to a choice of adequate stabilization measures that meet current safety criteria.

LAB EXPERIMENTAL AND CONSTITUTIVE STUDY OF COLORADO SHALE AT ELEVATED TEMPERATURES

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ABSTRACT

The thermo-hydro-mechanical behavior of shale has gained increasing attention in cap rock integrity assessment of fairly shallow thermal oil recovery projects in Western Canada. Exposure of shale cap rock to high-pressure steam in thermal recovery processes induces thermo-mechanical stresses that can cause material failure, and hence adverse environmental and economical consequences. As such, it is important to understand the effects of high temperature on the mechanical behaviour of shale.

The paper presents an integrated experimental/constitutive study of Colorado shale which serves as a cap rock to underlying oil-rich formations in the Cold Lake area, East-Central Alberta, Canada. Among others, results of drained thermal consolidation tests (under isotropic stress) and isothermal triaxial compression tests (at) show that: 1) volume changes due to drained heating are greatly influenced by consolidation history and initial bonding, 2) initial secant moduli of the tested samples decrease with elevation of temperature, and 3) the peak and post-peak failure envelopes are nonlinear and lead to reduced shear strengths at higher temperatures. In order to implement these important effects into an elasto-plastic model, three key constitutive features are considered: 1) plastic volumetric strains can be linearly decomposed into mechanical and thermal parts, 2) coupled thermal and mechanical elastic volumetric strains satisfying the path independence in the thermodynamic sense are used, and 3) the critical friction angle is pressure- and temperature-dependent. Thermo-mechanical responses computed from the proposed model show good agreement with experimental measurements.

Key words: Constitutive Modelling, Lab Experimental, Shale, Elevated Temperature Triaxial testing, Thermoplasticity.

RECENT SYNTHESIS RESEARCH ON THE PERMAFROST CARBON FEEDBACK

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Carbon release from permafrost thaw and the microbial decomposition of previously frozen organic matter is considered one of the most likely positive feedbacks from terrestrial ecosystems to the climate system in a warmer world. Here we will report on new findings generated by a research network (www.permafrostcarbon.org) whose objective is to link biological C cycle research with well-developed networks in the physical sciences focused on the thermal state of permafrost. The overall goal is to produce new knowledge by synthesizing existing data that can be assimilated by biospheric and climate models and that will contribute to future global environmental assessments.

An expert elicitation revealed that C release from permafrost zone soils is expected to reach 162-288 Pg C by 2100 and 381-616 Pg C by 2300 under the strongest warming scenario considered (Schuur et al. 2013). Network activities helped to update the Northern Circumpolar Soil Carbon Database with spatially distributed datasets of soil coverage and soil C storage (Hugelius et al. 2013) and new estimates of deeper permafrost C in deltaic and yedoma soils (Hugelius et al. 2014). Assessment of permafrost C quality and its vulnerability to mineralization over time was assessed through synthesis of aerobic (Schädel et al. 2014) and anaerobic (Treat et al. 2015) incubations. Finally, ongoing activities are focusing on predicting change in permafrost C dynamics resulting from abrupt permafrost thaw and thermokarst, which exposes previously-frozen C to microbial processes but also alters hydrology and thus the balance of carbon dioxide and methane emissions. We are using mapping, data synthesis, and simple land cover change modeling to better understand the relevance of abrupt thaw to the overall permafrost C feedback. Wetland thermokarst and thaw lake landscapes are estimated to cover 14% of the permafrost domain, split evenly between the two types of landscapes. However, these landscapes store ~30% of 0-3 m soil C stocks, and likely store a disproportionate amount of organic C deeper than 3 m.

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IMPROVEMENT OF PIEZO-ELECTRIC RING ACTUATOR TECHNIQUE (P-RAT) USING NUMERICAL SIMULATIONS

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The importance of shear wave velocity (V_s) has been widely recognized as a key design parameter for soils subjected to dynamic loading. The past several decades have seen a significant increase in the use of shear wave velocity in geotechnical applications, especially those involving earthquake ground response analysis, liquefaction potential, and soils characterization in terms of geotechnical and mechanical properties. Shear wave velocity can also be used to monitor setting and hardening of cement-based materials and also to characterize solid materials (rock, concrete, etc.).

Unlike conventional geotechnical parameters, the V_s can be measured either in situ or in the laboratory on disturbed or undisturbed soil samples. Laboratory studies that address parameters which affect V_s have been more comprehensive and conclusive than having field studies. However, only a limited number of laboratory tests are available in order to evaluate V_s of soils. These include the resonant column test, the ultrasonic pulse test, and the piezoelectric bender element test.

A new technique, piezoelectric ring-actuator technique (P-RAT) has been developed in the geotechnical laboratory at the University of Sherbrooke between 2007 and 2009 (e.g., El Gamal Dean, 2007; Ethier, 2009). This technique can be incorporated into conventional apparatus and can be used to measure shear wave velocity of solid material since the technique obviate penetrating the sensors into the sample that may be needed in Bender Element technique. This paper presents a description of the P-RAT technique developed at the Université de Sherbrooke and the results of numerical simulations conducted with ANSYS in order to study the interaction between the P-RAT components and between the P-RAT and sample (soil or solid). The numerical Simulations demonstrate that modification can be done in order to improve the performance of P_RAT and in also to expand his applicability in civil engineering.

EXPERIMENTAL CHARACTERIZATION OF EFFECTIVE STRESS IN UNSATURATED GRANULAR MATERIALS

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It has been established that the behaviour of geo-materials is highly dependent on their state of water saturation. For the purpose of constitutive and numerical modelling, the determination and validation of an effective stress in unsaturated soils is an essential step. Several procedures have been developed for predicting the effective stress of unsaturated soils in the recent years using the water retention curve and various effective stress parameters and variables such as total pressure and pore air and water pressures. Several fundamental approaches have been proposed such as thermodynamics and micro-mechanics. Researchers have also suggested mathematical relationships such as elliptical and hyperbolic functions, curve fitting techniques and artificial intelligence methods to predict the effective stress of unsaturated soils. The article reviews and compares the principal formulations of effective stresses available. Furthermore, a new unsaturated oedometer apparatus, developed at the University of Sherbrooke, has been used to carry out an experimental determination of the true effective stress reigning in an unsaturated idealised granular medium made of glass beads. The oedometric device uses two water and air pressure/volume controllers to control the suction with the axis translation technique. The mechanical loading system is an electromechanical frame allowing for automated testing. The article presents the results from consolidation tests under controlled conditions of saturation and wetting-drying tests in overconsolidated conditions, interpreted in the light of an effective stress for unsaturated soils.

ESTIMATION METHODS FOR DETERMINING ONSET TEMPERATURES OF FREEZING, AMOUNT OF UNFROZEN WATER AND THERMAL CHARACTERISTICS OF CRYOPEGS AND SALINE ROCKS FOR YAMAL PENINSULA

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Saline rocks and cryopegs are widespread in the territory of the Yamal Peninsula. These are characterized by marine type of salinity. Salinity of rocks is ranges from 0.05 to 1.2%. Mineralization of cryopegs varies from 6 to 150 g / l, the composition is sodium chloride with a minor amount of sulphate.

Kryummelya formula for seawater was used with a corresponding correction factor values obtained by statistical processing to estimate onset temperatures of freezing for cryopegs

The curve of the phase composition of moisture for cryopeg is qualitative close to that of sea water, but quantitative it changes. Calculation formulas that were approximated by power law and logarithmic dependences, are proposed for two characteristic bands of the temperature curve of the phase composition changing.

Calculation ratio for determining of heat absorptive capacity for cryopegs are proposed taking into account dependence of the temperature, total mineralization and water ionic composition

For saline rocks the temperatures of freezing is evaluated as an additive measure that summarizes the effect of surface forces of soil, the concentration and type of ionic composition of pore solution

Estimation the amount of unfrozen water in saline rocks includes as the influence of adsorption and meniscus forces as salinity

Regression analysis, which allows to obtain a relation in the form of analytical dependence was used for calculation of the thermal conductivity as a function of the total moisture content, dry unit weight and salinity

Estimation methods are implemented with the help of a software product which has been developed and then tested on extensive experimental material. The software uses the following input data: total mineralization initial value; cryopeg concentration and composition based on samples chemical analysis and the analysis of approximate ratios for estimation of the above-mentioned properties in which only the total mineralization initial value is used

THE MUSKRAT FALLS HYDROELECTRIC DEVELOPMENT: DESIGN AND CONSTRUCTION PROGRESS

Greg Snyder (1)

(1) FEC, Professional Engineer (St. John's, Canada)

Nalcor Energy's Lower Churchill Project is located on the Churchill River in the province of Newfoundland and Labrador, Canada. It consists of two potential hydroelectric sites and associated transmission systems: Gull Island hydroelectric development, located 225 km downstream of the existing Churchill Falls Generating Station; and Muskrat Falls hydroelectric development, located 60 km further downstream. The present generating site now being developed by Nalcor Energy is the Muskrat Falls hydroelectric facility located on the lower reaches of the Churchill River, approximately 35 km west of the town of Happy Valley – Goose Bay, Labrador.

This paper presents an update on the current progress of this generation facility. Several major contracts have now been awarded and construction of the Muskrat Falls Project is well under way. Construction will take approximately five years with completion in 2018. This project is being built in a northern environment, which will present many interesting challenges which must be met by the design and construction teams working on the Project. This paper provides an overview of the design and construction of the project, and provides an update on the current progress on construction.

MUSKRAT FALLS – NORTH SPUR DAM BREAK ANALYSIS

Greg Snyder (1)

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The Muskrat Falls Hydroelectric Development is located approximately 34 km west of the town of Happy Valley-Goose Bay in Newfoundland and Labrador. The four-unit, 824 MW generating station includes a five bay gated spillway, a roller compacted concrete (RCC) overflow dam, and rockfill dam. A critical feature of the development is the North Spur, a natural earth embankment that constricts the river at the project location. The North Spur is 1,000 m long, 500 m wide and 45 to 60 m high, and consists of unconsolidated mixed sand and marine silt and clay. Stabilization of this land mass is a key part of construction of Muskrat Falls. Measures will include installation of a bentonite cut-off wall, installation of a pumped drainage system, and slope stabilization.

As part of feasibility studies for Muskrat Falls, Nalcor Energy engaged Hatch Ltd. to perform dam break assessments for the North RCC Dam. In 2014 a dam break analysis of the North Spur was initiated to confirm the assumption that a dam break of the North RCC Dam provided a good indication of the consequences of failure of the North Spur. It was also to verify the assumptions that inundation and timing of flooding from the hypothetical failure of the North RCC Dam would be more severe than that from the North Spur.

A HEC-RAS (Hydrologic Engineering Centers - River Analysis System) model of the Lower Churchill River was used and hypothetical breaches under Inflow Design Flood (Probable Maximum Flood – PMF) as well as during 'fair weather' conditions were simulated. The analysis included an assessment of the sensitivity of the results to several model parameters such as breach formation time, breach width and breach bottom elevation. This was done taking into account information on the type of materials making up the North Spur, as well as the planned stabilization works; the sensitivities therefore account for the uncertainty of how the North Spur materials would fail in a dam breach. It was confirmed that a breach of the North Spur would result in peak water levels that were comparable to, or less than, those for a breach of the North RCC overflow dam, and times to peak water level were longer

GEOTECHNICAL OBSERVATIONAL METHOD USED IN A COMPLEX DAM STABILIZATION WORK

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Nalcor Energy's Lower Churchill Project developed the Muskrat Falls site located on the Churchill River in the province of Newfoundland and Labrador, 35 km west from Happy Valley – Goose Bay.

Part of the closure of the river is achieved by making use of an actual piece of land, a spur. This "North Spur" is a marine and estuarine deposit which naturally provides a partial closure of the Churchill River valley. A major slide on the downstream face of the North Spur, in November 1978, revealed the fragility of this natural dam. Maintaining the integrity of the North Spur after the reservoir impoundment is critical to the project, therefore the design of stabilization measures included different studies.

For complex soil stratigraphy with a high level consequence, the Observational Method (O.M.) is a good engineering tool. Design is completed based on the most probable conditions, and then work is done to develop a complete set of pre-engineering solutions for possible changed conditions and other issues that may actually be encountered in the field during construction. The O.M. is being used on the Muskrat Falls Project for the North Spur Stabilization Works.

Prior to the start of construction, the project team held workshop session with a group of experts. The workshop began with a revisiting of the current designs, which included challenging the available soil parameters, properties and other available information and analysis. A brain storming exercise was then held to identify and highlight the potential impact of the most unfavorable conditions for a range of parameters. For each of them, a solution was proposed and a pre-design was done.

This paper presents major issues encountered during development and application of the O.M. process and presents recommendations to avoid difficulties and traps in order to obtain the best results from the application of this process.

POWERHOUSE AND SPILLWAY ROCK EXCAVATION AT MUSKRAT FALLS

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Nalcor Energy's Lower Churchill Project developed the Muskrat Falls site located on the Churchill River in the province of Newfoundland and Labrador, 35 km west from Happy Valley – Goose Bay.

Major construction on the Muskrat Falls project started in 2012 with the Bulk Excavation contract, which involved excavation for the construction of Muskrat Falls powerhouse and spillway structures. This work required the excavation of 2.5 million of rock mainly composed of granitic orthogneiss and migmatites with an evident foliation.

Most of large civil structures are built on or into rock mass. The excavation and preparation of the foundation of these structures requires a thorough and accurate knowledge of rock mass properties and existing geological structures. The characterization of the rock mass to determine and evaluate geo-mechanical parameters is a crucial task which has to be undertaken to enable the design of the structure. Geotechnical investigations and analyses include coring, core logging, geological mapping, seismic refraction survey and laboratory testing. These are the main sources of geological and geotechnical data that have been used in design for many years. Recently, the use of geo-camera in boreholes has become available and greatly improved the quality of the data collected and this has helped in the preparation of a safe and economical design.

In addition, a tool that has become available to modern construction is the use of controlled perimeter line drilling with large diameter holes in the concrete structure areas. This reduces the overbreak concrete quantities and improves the straightness of the rock walls. Thus the quality of the final rock surface is enhanced reducing the project costs and improving the construction schedule.

This paper presents investigation, design and construction steps that were undertaken for the Powerhouse and Spillway excavation at the Muskrat Falls site using these two specific tools; the geo-camera and controlled perimeter line drilling with large diameter holes. With this approach, the project was able to achieve a high quality final product on schedule and within budget.

A RHEOLOGICAL APPROACH TO THE MECHANICAL BEHAVIOR OF SOME MARLS SAMPLES IN HAITI

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Rheology is known as the science of the study of the flow of viscoelastic materials, which have intermediate behavior between elastic solids and Newtonian fluids, submitted to external stresses. This science has lot of applications in the plastic or rubber industry for example...

In geotechnics, mechanical properties of soils are determined by triaxial, direct shear and oedometer tests but, they are static and, for a country like Haiti where the seismic hazard is important, it is very useful to know the values of mechanical parameters under dynamic loading which will help to understand the mechanism of soil stability. The objective of this paper is to present the principals of this technique (rheology) and the way it was used to determine mechanical properties of some Haitian marl samples.

Two different marl samples (taken from the "Morne Delmas" geological formation) were used in order to determine the effects of mineralogy, vibration frequency, clay/carbonates percentage and water content on the rheological properties. A small amount, 5 or 10 g depending on the water content (20% for solid consistency or 40% for plastic consistency) of soil samples, is needed for the tests. The under 53 μ m diameter particles are used in this study because the rheological behavior depends on this portion of the soil.

A cone-cone rheometer RPA2000 (Rubber Process Analyzer 2000) has been used to perform the oscillatory tests. A storage modulus (G') and a loss modulus (G'') were measured for strain going from 0 to 100% and at three different frequencies (0,5 Hz, 1Hz and 10Hz). The ratio G''/G' gives the linear viscoelastic deformation and its limit value : $G''/G'=1$ (break point) reflects a disintegration of the material and leading to a liquid behavior. The maximum length of the test is 20 minutes. Thus, the strain value at the break point is lower for the soils with swelling mineral at three working frequencies. The more the soil is rich in CaCO_3 , the more the strain at the break point is high. The strain at the break point goes higher with increasing frequencies. Increasing the water content of the soil reduces the strain value at the break point.

VIRGIN AND REMOLDED MONOTONIC RESPONSE OF SHORT ASPECT RATIO MONOPILES FOR OFFSHORE WIND TURBINE FOUNDATIONS

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Offshore wind power has gained momentum as a means to diversify the world's energy infrastructure; however, little is still known of the global stiffness behavior of the large diameter low aspect ratio monopiles which have become the foundation of choice for offshore wind towers. Traditionally, offshore foundations have been associated with gravity structures for the oil and gas industry, which in general need to resist large vertical loads with limited lateral and moment loading. However, wind towers are purposely designed to be subjected to large lateral and moment loads from the wind in order to maximize power generation. A principal aspect of pile response to lateral load that requires assessment is the ultimate lateral pile capacity, to ensure the foundation has sufficient strength in an extreme loading event. Geotechnical centrifuge tests were conducted and numerical models are being developed to examine the monotonic behavior of low aspect ratio piles in soft clays. Monopiles with aspect ratio of two were tested in the 150g-ton centrifuge at Rensselaer Polytechnic Institute. The soil properties of the test bed were characterized by T-bar penetrometer tests. Initial pile test results include moment-theta and force-displacement for various loading conditions typically encountered in offshore wind tower installation in water depths up to 30 m. This paper focuses on ultimate capacity of short aspect ratio monopiles after cyclic loading. Remolded monotonic capacity is compared to virgin monotonic capacity for both pure horizontal loading and pure rotational loading over a range of eccentricities.

CARACTÉRISATION STATISTIQUE DE LA RÉSISTANCE EN COMPRESSION UNIAXIALE DU ROC INTACT POUR UN PROJET MINIER.

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La conception des ouvrages miniers souterrains repose sur une caractérisation géotechnique du massif rocheux. La variabilité, l'hétérogénéité et l'anisotropie du massif rocheux rendent difficile la sélection de valeurs représentatives des paramètres géomécaniques. Une campagne d'essais géomécaniques doit répondre aux contraintes pratiques et financières, tout en s'assurant de la représentativité des données. Lors d'essais en laboratoire, la société internationale de mécanique des roches suggère de tester un nombre minimal de spécimens par type de roche. Cependant, certains auteurs affirment qu'il n'est pas possible de déterminer à priori le nombre d'essais nécessaires à la détermination des paramètres géomécaniques, que ce nombre varie selon le type de test et le type de roche.

Certains auteurs ont récemment proposé un niveau de confiance statistique à atteindre pour les différentes propriétés géomécaniques et ce aux différentes étapes d'un projet minier. À l'aide d'une étude de cas, réalisée sur deux sites miniers québécois, cet article étudie le potentiel de la théorie du faible échantillonnage et de la théorie bayésienne modifiée afin de quantifier l'incertitude et le niveau de confiance des données géotechniques. De plus, il suggère une méthodologie permettant de lier directement l'incertitude des données et le niveau de confiance des données géotechniques pour toutes les étapes d'un projet minier. Ces analyses statistiques permettront de caractériser systématiquement la résistance en compression uniaxiale du roc intact d'un projet minier.

DESIGN AND CONSTRUCTION OF A THREE-STOREY CONCRETE BUILDING ON LIQUEFIABLE SOILS IN VICTORIA, BC.

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As our cities continue to grow, traditionally less desirable areas such as reclaimed land and contaminated sites are becoming the location for new development sites. These sites provide unique and interesting challenges to engineers. The foreshore in Victoria has undergone a number of changes over the years with large sections of fill having been placed to increase the land surface within much of the foreshore area. One such site was selected for the construction of a new three-storey concrete building.

A staged geotechnical investigation was undertaken to assess the conditions of this known contaminated, fill site. The field investigation consisted of both Becker Penetration tests (BPT) and Standard Penetration tests (SPT) followed by bedrock probing with an air track percussion rotary drill. The soil conditions at this site generally consist of a variable thickness of fill material overlying a thick deposit of marine clay. The fill materials are generally loose to compact and are comprised primarily of gravelly sand to sand and gravel and contains pockets of large rock fill. The underlying marine clay is firm to soft.

The design level earthquake for this structure is the 1:2,475 year event which results in a peak horizontal firm ground acceleration (PGA) of 0.6g for this site. As a result, seismic considerations governed the foundation design. Estimated liquefaction induced lateral displacements within the fill were up to 6 m and vertical settlements varied from about 0.1 m to 0.3 m. The potential for a flow slide following the design level earthquake was also assessed.

Due to a number of constraints, site improvements (such as soil densification, soil replacement, etc.) were not a viable option for the development. The final design of the building foundations consisted of rock-socketed caissons designed to resist the seismic deformations. Underground utilities and roadways adjacent to the structure were not designed to resist seismic deformations.

Additional challenges included planning and executing a geotechnical investigation within a congested active work site and meeting the environmental requirements for working adjacent to the ocean within contaminated fill.

RECENT VARIATION OF DAILY PRECIPITATION AND TEMPERATURE OF THE LOWER LIARD RIVER BASIN

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Since the mid-90s, discharge from streams and rivers draining the discontinuous permafrost zone of the southern Northwest Territories has increased and these rates have accelerated in recent years. Work done by Connon and others suggested two hypotheses; one is related to meteorology and other to landscape changes and feedbacks caused by the permafrost thaw. To address the meteorological hypothesis wavelet transforms of observations were used to explore the dominant oscillations of precipitation and temperature in the Lower Liard River Basin between 2004 and 2014. Wavelets provide information about the nature and time– frequency localization of oscillations. Preliminary results show considerable similarity among individual series from ten climate stations for temperature and for precipitation. As expected, there are differences in the interannual between temperature and precipitation variability; for temperature, there were significant oscillations of about 4, 8, 16 and 256 to 365 days in all stations, for precipitation the significant oscillations were at 16 to 32 days. These results suggest that the temperature signal has a large spatial domain, while the precipitation signal has a smaller spatial domain.

IMPACTS OF HIGH ARCTIC PERMAFROST DISTURBANCES ON ECOSYSTEM STRUCTURE AND FUNCTION

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Across the Fosheim Peninsula, Ellesmere Island, permafrost disturbances are widespread, occurring in the form of active layer detachment slides and retrogressive thaw slumps. This research project analyzes the overall impacts of these disturbances over short- and long- time scales on ecosystem structure and function. The short-term impacts of disturbance were quantified by measuring ecosystem fluxes, specifically carbon-dioxide and water vapour fluxes using the eddy covariance technique. Fluxes were measured from multiple active retrogressive thaw slumps and surrounding control tundra over a multiyear period to determine the impact of these disturbances on ecosystem function. Footprint analysis was done using multiple footprint modeling techniques, including wind direction partitioning and a two dimensional gradient diffusion and crosswind dispersion model. This latter method allowed us to calculate overall disturbed and control fluxes using a dual eddy covariance sampling design setup. Control tundra, measured using fluxes from undisturbed terrain, acted as small carbon sink throughout the short growing season. This differed from the disturbed tundra, as the overall net ecosystem exchange indicated these zones act as a carbon source. This eddy covariance technique was consistent with flux measurements measured using a static chamber system, which allowed the overall fluxes to be partitioned into their component parts. To address the impact of permafrost disturbance on ecosystem structure, vegetation from several recovered active layer detachment slides was measured and characterized. Results indicate distinct stages of revegetation during landscape recovery. This was consistent with measured landscape variables, including active layer depth, soil temperature, soil moisture, and nutrient concentrations, which also displayed differences across a disturbance gradient. Overall, the short-term impacts of permafrost disturbance on ecosystem function indicate shifts in net ecosystem exchange due to disturbance activity. Over the long-term, ecosystem structure shows lasting impacts of disturbance even after several decades of recovery, as seen through distinct vegetation communities found within recovered landslides.

COMPORTEMENT DES GÉOCOMPOSITES DE DRAINAGE À MINI-DRAINS EN CONDITIONS HIVERNALES

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Le drainage est une composante indispensable de l'efficacité des ouvrages de génie civil, de génie environnemental et minier. L'utilisation de matériaux naturels tel que graviers ou sable est largement rependue mais tend à être remplacé par des solutions plus adaptées en terme de réduction de l'emprunte environnemental, développement durable et constructibilité. Ces solutions géosynthétiques ne sont néanmoins pas toutes adaptées au conditions extrêmes rencontrées dans le grand nord canadien. En effet, les structures types nappes drainantes homogènes présentent une rigidité telle que leur installation peut présenter des contraintes importantes. En revanche, l'utilisation de géocomposite de drainage à mini-drains flexibles est possible et dans la plupart des cas largement considérée.

Cet article présente les caractéristiques de ce type de géocomposite, les résultats d'essais en laboratoires vis-à-vis de la rigidité au froid et présente deux études de cas de réalisation d'un bassin et d'une réhabilitation de site minier dans le nord canadien.

PERMAFROST STABILIZATION THROUGH CONVECTION PIPE COOLING

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Road embankment stability, thermal stability, and hydraulic drainage design within permafrost terrain are all inter-related design, construction, operation, and maintenance issues which require coordinated, dynamic, innovative engineering solutions. The degradation of permafrost resulting from ground disturbance and/or climate change can result in both embankment and subgrade instabilities. Most northern construction projects are subject to continuous or extensive discontinuous permafrost conditions. This poses a significant challenge since cost effective highway systems are required for sustainable economic growth.

The Department of Transportation in the Northwest Territories has teamed up with the University of Ottawa, GeoStabilization International, and Terratech Consulting to develop a new method of permafrost stabilization.

The method involves installing long, narrow, steel pipes into the ground. The pipes facilitate passive convection as the cooling mechanism. The top end of the pipes is covered with clean blast rock. The rock forms an air convection embankment (ACE). The ACE is an effective method used to lower embankment temperatures. The convection pipe cooling (CPC) method takes advantage of airflow within the ACE and drives the cooling effect below the road structure, deep into the subgrade. Convection through the pipes shortens the travel distance for heat to escape from the ground, in a similar manner to how wick drains expedite embankment dewatering. Frozen conditions deep below the structure will eliminate the risk of consolidation and differential settlement.

An outdoor experimental test site has been completed in Yellowknife. The experiment is providing quantitative insight into the following aspects of the CPC method: 1] the ability of open-ended, narrow pipes to facilitate convection cooling below the ground surface; 2] the effect of a secondary air passage channel by the insertion of a smaller diameter tube within the convection pipe; 3] the effect of installing the convection pipes at various angles to the vertical; and 4] the thermal gradient effect of the convection pipes.

The new method of permafrost stabilization developed, the field experiment test conducted, and the results obtained will be presented and discussed in the paper.

ENGINEERING CHARACTERISTIC OF GLACIAL TILLS IN GTA

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The geological history of the Greater Toronto Area (GTA) has included several advances and retreats of glaciers of Illinoian and Wisconsin ages. The stratigraphy across the GTA varies with cohesive and cohesionless glacial tills, and interglacial deposits of fine grain glaciolacustrine and coarse grain interstadial outwash. The glacial tills are usually heterogeneous with the presence of soft layers and cobbles and boulders.

A series of laboratory and in-situ testing on the glacial tills have been carried in relation with the subway and LRT projects in the GTA. The laboratory tests include unit weight, moisture content and Atterberg limit measurements, grain size analyses, triaxial compression tests, and consolidation tests. The in-situ testing includes standard penetration tests (SPT), field vane tests, prebored pressuremeter tests and seismic tests. The size and frequency of boulders and cobbles were measured in the field observation of a shaft excavation.

This paper will present the laboratory and in-situ test results as well as field observation. The distributions of soil parameters for glacial tills including water content, unit weight, grain size, size and frequency of boulders and cobbles, Atterberg limits, overconsolidation ratio, compression and recommission indices, undrained shear strength, friction angle, cohesion, modulus and shear wave velocity will be provided. The modulus obtained from triaxial tests, pressuremeter tests and seismic tests will be compared and discussed. The possible correlations between various soil parameters and SPT N-value will be developed.

COMPARISON OF PILE CAPACITY ESTIMATED BY SIGNAL MATCHING (CAPWAP®), ICAP®, AND CASE METHOD OF DRIVEN STEEL PILES PERFORMED AT AN INDUSTRIAL SITE NEAR EDMONTON, ALBERTA

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High-strain dynamic testing commonly known by the pile industry as PDA testing has become an efficient and cost-effective method of quality control of driven piles. The standard approach used to estimate the pile capacity from PDA testing is by signal matching software programs such as CAPWAP®, DLTWAVE® and AllWave-DLT®. This approach is relatively time consuming and requires an experienced person to properly interpret the results. A faster approach is the use of the CASE method, which is a closed form solution, but requires a selection of a damping constant not always adequately known for the subject site. The iCAP® method is an automated signal match program that provides a faster signal match solution to estimate the pile capacity for uniform driven piles under simple pile-soil interaction conditions

As part of the quality control for driven steel pile installation at an industrial plant site near Edmonton, Alberta, approximately 190 driven steel pipe piles were PDA tested. This represented about five percent of the installed piles. The PDA tests were conducted on pile sizes ranging from 254 mm to 762 mm and depths ranging from 10 m to 24 m and were performed at the End of Initial Drive (EOID) and at the Beginning of Restrike (BOR).

The site geology consisted basically of thin discontinuous deposits of glaciolacustrine clay and discontinuous deposits of aeolian sand overlying a thick glacial clay till stratum containing sand layers.

This paper provides a comparison of the estimated pile capacities from the 190 piles using the signal matching software CAPWAP®, the automated signal matching iCAP® program and also with the CASE method. Due to the significant number of pile tested a statistic approach in comparison of results will also be provided.

IN-SITU CHARACTERIZATION THROUGH COMBINED INTERPRETATIONS OF PRESSUREMETER, FIELD VANE, AND SEISMIC PIEZOCONE TESTING AT THE GLOUCESTER, ON

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In December 2014 we performed a suite of in-situ tests at the Gloucester, ON Canadian Geotechnical Research Site in order to interpret the stress-strain behaviour of the highly sensitive Champlain/Leda clay deposit. The in-situ testing program included a seismic-piezocone penetration test, four piezocone dissipation tests, four field vane tests, and four strain-controlled pre-bored pressuremeter tests. The focus of this paper is not the interpretation of the individual in-situ tests, but how the interpretation of different in-situ tests can be combined to better characterize the in-situ soil. We investigated the well characterized Canadian Geotechnical Research Site for two reasons. First, we could compare our combined interpretations with published results. Second, to contribute our field investigation program and interpretations to the characterization of the Champlain/Leda clay at the Canadian Geotechnical Research Site

WARMING OF PERMAFROST IN THE CHIC-CHOCS RANGE, TOWARDS DISAPPEARANCE OF SPORADIC MOUNTAIN PERMAFROST IN SOUTH-EASTERN QUEBEC?

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In southern Quebec, mountain permafrost is restricted to the highest bare ground flat summits of the Chic-Chocs Mountains. The existence of a marginal permafrost body was reported on Mont Jacques-Cartier – the highest point in southern Quebec (1273 m a.s.l.) – in 1977 by way of a thermistors cable installed in a 29 m deep borehole. Initial results revealed that this permafrost body is contemporary but near the thawing point and thus highly sensitive to minor regional climatic fluctuations. With a 36-year long record of ground temperature, this summit is one of the longest permafrost-monitoring sites in North America and is therefore of great interest to study the impact of climate change on sporadic mountain permafrost.

We measured air, ground surface and permafrost temperatures on summit of Mont Jacques-Cartier. Long-term air temperature time-series were reconstructed for the 1940 to 2014 period using proxy weather station and local adiabatic lapse rate. Modeled variations of air temperatures were highly correlated to recorded permafrost temperature over the measurement period. We used regional climate projections provided by the consortium Ouranos to simulate the response of the permafrost thermal regime to future air temperature changes.

From 1978 to present, the modeled MAAT has warmed by $+0.04^{\circ}\text{C}/\text{yr}$, with a more pronounced increase during the cold season. The modeled MAGST evolution is of the same order of magnitude than the MAAT. In the recent period, the measured MAGST was close to 0°C (e.g. 0.1°C in 2010, -0.1°C in 2012) which is critical to permafrost preservation. The long-term record [1978 to present] of ground temperature provided by the borehole shows that the permafrost temperature followed the long-term rise of MAAT and MAGST with the same decadal fluctuations. A clear warm side deviation of the temperature profile from 1978 to present ($+0.21^{\circ}\text{C}/\text{yr}$ at 14 m depth from the 1980's to 2010's) is observable and the thickness of the active layer increased by ≈ 0.7 m/yr from 2008 to 2012. If this recent warming trend continues, the complete thawing of the alpine permafrost of Mont Jacques Cartier is imminent. Spatial modeling showed that the probable actual extend of the permafrost body is ≈ 2 km² and that it would decrease by 77% with an air temperature warming of $+2^{\circ}\text{C}$ compared to the climate normal 1980-2010. According to the simulation of the ground thermal regime based on regional climate projections the permafrost could probably become relict and completely disappear after 2040.

MICROZONAGE SISMIQUE DE LA VILLE DES CAYES (HAÏTI)

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Durant un tremblement de terre, les dégâts observés dépendent non seulement de l'énergie libérée et de la typologie des constructions, mais aussi de la nature des sols. Face à ce constat, de nombreuses études de microzonage sismique sont réalisées en divers lieux afin de mitiger les conséquences des séismes. De cette façon et après le séisme du 12 janvier 2010, l'État haïtien a élaboré un programme de microzonage pour les principales villes d'Haïti (Port-au-Prince, Cap-Haïtien, Port-de-Paix, Fort-Liberté, etc.).

Ces études de microzonage sont généralement basées sur la collection de données sismologiques, géologiques, géophysiques et géotechniques. Dans la plupart des cas, les données recueillies sont complétées par de nouvelles mesures in situ qui permettent de définir une catégorie spécifique de sol à chaque type de terrain. L'objectif d'un tel programme consiste à cartographier les zones ayant des réponses sismiques semblables en raison de leur nature lithologique, leur topographie, leur distance épacentrale, leur degré de saturation, etc.

Cet article porte sur le microzonage sismique de la ville des Cayes à Haïti. En effet, des mesures de vitesse des ondes de cisaillement à partir des essais d'analyse spectrale des ondes de surface (SASW) ont été exécutées dans quarante sites de la ville des Cayes. Ces mesures ont permis de caractériser les formations superficielles jusqu'aux profondeurs de 30 à 50 m. À côté des essais SASW, des études géotechniques constituées d'essais SPT, de pénétromètre dynamique (PD) et d'essais MASW ont été compilées pour la caractérisation des sols de la ville. Ces dernières mesures ont été effectuées dans la région plaine à des profondeurs d'investigation atteignant 10 à 30 m. Des corrélations de la littérature, entre PD, SPT et Vs ont aussi permis d'établir des profils de vitesse des ondes de cisaillement.

Les profils obtenus par corrélations et ceux évalués directement par SASW sont en accord dans les sites proches considérés. Ce constat prouve que les profils de vitesse obtenus par SASW correspondent à la rigidité réelle du sol.

La catégorisation des sols, sur la base du paramètre Vs30 comme il est indiqué dans le code national du bâtiment du Canada (CNBC), fait ressortir deux classes de sol dominantes dans la ville des Cayes. Il s'agit des sols de classe C, en région montagneuse, et des sols de classe D en plaine. Cependant, des sols de catégorie D en certains terrains montagneux très altérés et la catégorie E aux voisinages des côtes ont été également trouvés.

FINITE ELEMENT MODELLING OF STONE COLUMN INSTALLATION: REVIEW OF MODELLING PRACTICES AND CASE STUDY WITH PLAXIS 2D

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Stone column is used for many different applications, such as improvement of bearing capacity, lateral drainage for the consolidation of cohesive soils and liquefaction remediation. In the dry installation method, a vibrating probe is inserted in the soil to the required depth and pressurized stone is pushed at the tip of the probe. The back and forth lifts of the probe with subsequent pushing of stone enlarges the cavity and creates a rigid column. The stone columns are closely spaced into a triangular or rectangular mesh to create a group effect. This technique was first developed for the consolidation of clays but it is now often used for loose sands, making it a very versatile technique. Although the theoretical behavior of stone columns in weak soil is well known, the installation effect of stone on the encasing soil is still a subject of debate which needs investigation. Many design procedures capture the group effect of the installation by increasing the lateral to vertical stress ratio (K). However, the increase of soil density is often neglected, especially in cohesive soils. Most design methods are either semi-empirical or analytical and to fully understand the installation effect, a numerical model can be of great help. This article discusses the different numerical modelling practices for the stone column installation and establishes a comparative review of the numerical techniques and constitutive laws used in the literature. Furthermore, taking advantage of the best practices in numerical modelling of stone column expansion, a numerical model was created with PLAXIS 2D in axisymmetric geometry to reproduce the lateral expansion of stone in sand. The host material is modelled with a hardening soil constitutive relation to represent the repetitive loading and unloading of the sand during expansion. The results are then calibrated with two experimental stone column tests carried out at an intermediate scale in our laboratory.

SECANT PILED SHAFT CONSTRUCTION AND MICROTUNNELLING IN SAND

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Three secant piled shafts (~18m deep, ~59ft) and two 1200mm ID (47.2 inch ID) microtunnels were required at the intersection of Mayfield Road and Kennedy Road in Brampton, ON to facilitate the installation of a 750mm diameter Concrete Pressure Pipe (CPP) Feedermain. Two of the shafts were backfilled after construction and the third was used as a permanent works valve chamber. Previous attempts to cross this intersection had failed due to the ground conditions.

Owing to the time of construction (Winter) and ground conditions, it was decided to construct the shafts using the secant piled method. The water table was on average 5m deep from ground level, however, it was known to rise to ground level on occasion. 1180mm diameter (46.5 inch diameter) secant piles were installed using a Bauer BG36 piling rig. All piles were installed with a steel liner advanced ahead of the auger and the concrete was placed using a modified 32m concrete pump truck with a tremi pipe attached to its boom. The shafts were excavated underwater with a positive head of water maintained inside the excavation to prevent basal heave. Construction divers were used to inspect the underwater excavation ahead of sealing the base of the shaft with a tremi plug. This plug was placed with a concrete pump truck and a custom high-flow self-consolidating tremi concrete mix. All tunnelling for the project was done with the Herrenknecht AVN1200 Tunnel Boring Machine (TBM).

The site area lies on a glacial till plain overlain by cohesionless glacial outwash deposits with wide-ranging texture. Depressions in the surface of the till are infilled with peat. Previous trunk utility installations through this area involved complete replacement of the peat by engineered fill, necessitating use of sheet piling along the edges of the right of way. The existence of this sheeting and tiebacks further complicated the project described herein.

The notoriously difficult ground conditions at the project location proved extremely challenging at all stages of construction. Problems encountered ranged from ground loss due to poor interlocking of the secant piles as well as ground loss during the tunnelling stage when the TBM emerged into the reception shafts. The Owner's proactive decision to specify the project using sealed shafts and microtunneling mitigated many of the in-ground risks associated with the project.

ASSESSMENT OF SOIL LIQUEFACTION POTENTIAL OF AN EMBANKMENT DAM IN THE CHARLEVOIX SEISMIC ZONE – CASE STUDY ON THE COMPARISON OF THREE TOTAL STRESS METHODS

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Paying attention to soil liquefaction is of great importance for civil engineering projects and in particular in embankment dams. The complexity of a fully effective stress hydro-mechanical coupled 2D numerical model is often out of reach for most practitioners. Simpler methods exist to conservatively assess soil liquefaction potential in certain specific cases. This article compares three total stress methods to evaluate the liquefaction potential of an embankment dam located in the Charlevoix Seismic Zone (CSZ), a highly seismic region of Quebec in eastern Canada. The soil liquefaction assessment is realized based on 3 available methods: a preliminary semi-empirical method based on Idriss & Boulanger (2008), a 1D nonlinear FDM ground response with FLAC 6.0 and a 2D equivalent linear FEM analysis with Quake/W. All three methods simplify the dynamic response of the embankment in their own way and they all have their specific strengths and weaknesses. The simplified method is the easiest to apply, but it does not account for the 2D geometry of the problem as the geometry can greatly amplify the earthquake acceleration at the top of the embankment dam. Neither does the 1D FDM. Also, although the 2D FEM with Quake/W accounts for the geometry, the equivalent-linear approach can over or under estimate damping and stiffness during strong motion or quiet periods. In this aspect, the non-linear 1D analysis with FLAC is more suited to properly account for the dynamic response of the soil. This case study compares all three methods as a means to adequately and conservatively assess soil liquefaction potential in an embankment dam.

ÉVOLUTION DES TOURBIÈRE À PERGÉLISOL DU LAC À L'EAU-CLAIRE (NORD DU QUÉBEC) EN RÉPONSE AUX CHANGEMENTS CLIMATIQUES

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Les tourbières, notamment les tourbières à pergélisol sont des écosystèmes très sensibles aux changements climatiques. Ces écosystèmes sont caractérisés par des buttes de tourbe gelée nommées « paises ». Jusqu'à aujourd'hui, les différentes études réalisées sur les tourbières à paises du nord du Québec ont été effectuées sur celles situées près ou sur la côte de la baie d'Hudson. Il s'avère que ces tourbières ont eu un développement similaire et synchrone : le milieu fut d'abord un étang qui s'est transformé en tourbière minérotrophe puis en tourbière ombrotrophe avant la formation des paises, suite à l'installation du pergélisol. La dégradation des paises a débuté à la fin du Petit Age glaciaire (1850) tant au nord du Canada qu'en Europe, en réponse au réchauffement climatique. La présentation portera donc sur l'étude d'une tourbières à paises, située sur la rive nord du lac à l'Eau-Claire (LEC), à 150 km de la baie d'Hudson, au-delà de la limite marine de la mer de Tyrrell. L'objectif principal de la recherche sur cette tourbière est de retracer l'impact du climat sur l'évolution de ces milieux. Les objectifs spécifiques sont les suivants : 1) reconstituer l'évolution végétale d'une tourbière à paises, depuis sa formation, 2) déterminer l'évolution des conditions trophiques de la tourbière, 3) comparer les résultats obtenus au lac à l'Eau-Claire avec ceux d'autres études réalisées en Hudsonie et en Jamésie, dans le but de cerner l'impact du climat sur ces écosystèmes. Pour atteindre ces objectifs, nous privilégions l'analyse macrofossile de la tourbe qui fut accumulée depuis la déglaciation. .

DISCONTINUITY ORIENTATION IN JIGSAW CLASTS FROM VOLCANIC DEBRIS AVALANCHE DEPOSITS AND IMPLICATIONS FOR EMPLACEMENT MECHANISM

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Jigsaw fractures in clasts have been noted in the deposit of large (>1 Mm³) volcanic debris avalanches and non-volcanic rock avalanches at numerous locations around the world but they have rarely been systematically studied. This project applied terrestrial photogrammetry to characterize the discontinuity orientation of jigsaw clasts in the debris avalanche deposits around Taranaki, New Zealand.

Taranaki is an approximately 2,500 m high stratovolcano on the North Island of New Zealand. The evolution of Taranaki during the Quaternary is characterized by the cyclical growth and collapse of the volcanic edifice. Up to 13 distinct large (>1 Mm³) debris avalanche deposits have been identified to be originating from Taranaki. Terrestrial photogrammetry was used to obtain the orientation of 355 discontinuities in jigsaw clasts at 7 stations on the west side of Taranaki.

The discontinuity pattern at all 7 stations has a dominant concentration of discontinuities (DS1) with a dip direction between 045-080° (NE-ENE), a secondary concentration (DS2) with a dip direction between 315-350° (NW-NNW), and a third grouping (DS3) with a dip direction between 215-240° (SW-WSW). The constant discontinuity orientation in jigsaw clasts from stations separated by approximately 10 km has implications on the landslide debris transport and emplacement mechanisms. The orientation of discontinuities in the jigsaw clasts are also compared with discontinuity orientation in the in-situ rock mass on Taranaki.

Two emplacement mechanisms could result in consistent orientation pattern in the jigsaw clasts at all 7 stations. The first one would consist of dominantly laminar or plug flow in the upper part of the landslide debris as it is emplaced while the second model suggests that clast fracturing would occur late in the emplacement process. The supporting evidence and outstanding issues with each mechanism are discussed.

INCORPORATING SEISMIC DESIGN INTO A LARGE DIAMETER STEEL WATER MAIN IN PROXIMITY TO THE FRASER RIVER

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In order to meet growing water consumption demands of the communities south of the Fraser River, Metro Vancouver is in the process of installing a new 1.5 metre diameter water main called Port Mann Main No.2 in Coquitlam, BC. Due to the low-lying peaty soil along the proposed alignment and its proximity to the Fraser River, Metro Vancouver and its consultants Golder Associates and DGH undertook a significant seismic analysis to estimate the vertical and lateral displacements that the water main would be exposed to under the 1:2475 year seismic event. The seismic analysis was carried out using 1-D and 2-D ground response analyses and finite difference (FLAC2D) modeling of lateral displacements. Results indicate liquefaction in the upper 10-15 metres with significant vertical and lateral displacements. These soil movements were used in conjunction with finite element modelling of the pipeline to account for soil-structure interactions. The pipeline design was optimized to account for these forces. Results also indicated a differential movement of up to 4 metres between the water main and its connecting point to the seismically designed Port Mann Water Supply Tunnel. Innovative techniques using large diameter rotating ball joints and flexible expansions joints were incorporated into the design to account for this significant differential movement.

ENGINEERING GEOLOGY, ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY AND DISPLACEMENT MONITORING OF THE DAWSON CITY LANDSLIDE, YUKON

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The Dawson City landslide is a pre-historic slope failure located at the northern city limit of Dawson City. The landslide occurred at the faulted contact between an older ultramafic rock unit that is trusted on top of a younger metasedimentary rock unit. The fault damage zone results in the very blocky nature (up to seven discontinuity sets) of the failed rock mass and led to a pseudo-circular failure mechanism. The landslide deposit is composed dominantly of ultramafic rocks.

A series of split trees, disturbed soil exposing stretched roots and trenches suggest ongoing movement in both the headscarp and deposit. Various monitoring techniques were initiated in 2006 to confirm and quantify the displacement rate in these areas. Based on seven years of displacement monitoring, the unstable section in the headscarp is moving downslope at a rate between 2-12 cm/yr (average 7 cm/yr) while the trenches along the edge of the landslide deposit suggest displacement rates between 9-27 cm/yr (average 18 cm/yr). Within the limited length of the displacement time-series no temporal trend is observed in the displacement rate while some spatial trends appear to be developing. It is unlikely that the displacement rates observed over the last 7 years could be sustained for several decades without resulting in mass failure from the headscarp. As such, the observed displacement are considered to represent a renewed phase of activity for the landslide. The reactivation of displacement in both the headscarp and the debris could be due to changes in mean annual temperature and precipitation amount. Other workers have reported an increase of 2.9°C over the 1955-2004 period in Dawson City and a decrease of 14.5% over the same period.

A 200 m long electrical resistivity tomography (ERT) profile was conducted across the Dawson City landslide deposit. A zone of high resistivity at depth was interpreted to represent ice in the debris. This suggests that while it is located at low elevation and south facing the landslide debris is moving as a rock glacier.

MONITORING OF PERMAFROST IN RUSSIA: RUSSIAN PERMAFROST DATABASE AND THE INTERNATIONAL GTN-P PROJECT

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Monitoring of the permafrost zone is an integrated system of observations of permafrost, assessment, monitoring and forecast of its change in time and space under the influence of natural climatic and anthropogenic factors. The unique database of long-term geocryological monitoring which have been performed at a number of special sites all over the World allows learning cyclical and trending components of change in the active-layer features and the frozen ground temperatures, as well as the rate and rhythm of cryogenic processes. These data characterize permafrost response to global warming and technogenesis.

International and Russian studies with the CALM and TSP programs and numerous similar projects revealed the urgent need to combine studies of the near-surface permafrost in its interaction with adjacent geospheres under the "umbrella" of common ideas and organizational efforts. The fact that many key-sites already are complex and examined by experts involved in various ongoing programs indicates the presence of good prospects in this direction.

A new level of international cooperation and technological support in permafrost studies was achieved after the International Permafrost Association (IPA) launched the project GTN-P (Global Terrestrial Network for Permafrost). In May 2013, the GTN-P Strategy and Implementation Plan was discussed and accepted at the WMO Headquarters in Geneva. National Correspondents from the countries participated in this meeting formulated the problems concerning worldwide database on the near-surface permafrost properties and there spatial-temporal variability.

During the implementation of the project, the Russian participants of GTN-P realized that at the initial stage of the project the national branch of the GTN-P database could serve to bring together various institutions, individual researchers and enthusiasts to overcome methodological challenges. It concerns first of all data which exist in formats not covered by GTN-P templates for subsequent convergence with GTN-P and testing the effectiveness of these advanced formats in terms of the future development of the GTN-P project.

It should be noted that a close interaction with the National Weather Service is a huge advantage to empower GTN-P databases for the purposes of assessment of the permafrost spatio-temporal variability in respect to the spatial-temporal variability of conditions at the atmosphere-surface interface. So, it seems appropriate to turn to the WMO and the National Meteorological Services with a proposal to include air and ground temperature measurements (to 15-20 m depth) at landscapes surrounding the weather stations.

DEEP EXCAVATION WITHIN VARVED SILT DEPOSITS FOR CONSTRUCTION OF ULTRA VIOLET WATER DISINFECTION FACILITY IN COQUITLAM, BC

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Metro Vancouver completed construction of its Coquitlam Ultra Violet Disinfection Facility as part of upgrades to its water supply and purification system. The Coquitlam UV Disinfection Facility is located within the watershed of the Coquitlam River Valley, south of the Coquitlam Water Reservoir. The facility serves approximately one third of the Lower Mainland's water supply. The facility comprises eight UV reactors, housed within the main building, two valve chambers, and electrical and mechanical rooms. The site is underlain by coarse grained water-bearing alluvial deposits, substantial varved silt deposits and underlain by extensive sand deposits. Excavation extended some 10 to 18 m below ground surface and into adjacent slopes. Excavation through the alluvium required a network of interception channels. Excavation into the silt required extensive dewatering/depressurization of the lower sand aquifer well in advance of excavation to maintain stability and prevent base heave. Vertical excavation up to 18 m deep in challenging soil conditions required careful and coordinated design between dewatering systems and shoring systems. Use of tied back secant piles and dewatering wells were instrumental in successful excavation and shoring. Challenges were encountered with the non-plastic varved silt which was extremely erodible and prone to washout and face instability. Careful base preparation of the exposed silt was necessary to avoid compromised subgrade conditions.

Comprehensive and detailed technical specifications were instrumental in the success of the excavation, dewatering and base preparation.

PENICILLIUM FUNGI FROM PERMAFROST: BIOSYNTHESIS OF SECONDARY METABOLITES, PECULIARITIES OF GROWTH AND DEVELOPMENT

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It is known that *Penicillium* genera fungi are the very creative object for the searching of the new biologically active compounds. For *Penicillium* fungi strains isolated from long-frosted deposits are most probability to wait the synthesis the potent biologically active compounds which can help to producers survive and adapted to this conditions.

Various probes of permafrost were found to contain predominantly mycelial fungi, *Penicillium* spp. including, with small-size single-cell conidia (Ozerskaya et al., 2009). The low temperature can stimulate protective mechanisms, characteristic for the fungal cells. These mechanisms includes the enhance of the concentration inside the cells of thregalosa, poliols and polyunsaturated fatty acids and synthesis of the enzymes active at the low temperature (Robinson 2001).

Biosynthesis of the secondary metabolites by 83 strains of *Penicillium* fungi have been studied. The strains were isolated from various regions of permafrost: in Antarctica, from the North America (Canada), in North-East Asia (Kolyma), and in Kamchatka also. 25 known secondary metabolites were identified and 2 new compounds - quinocitrinines were elucidated of the structures in the studied strains. Cultures are the producers of the secondary metabolites of the different structural groups. Clavine alkaloids were presented α -cyclopiazonic acid, fumigaclavines, festuclavine, rugulovasines, agroclavine-I, epoxyagroclavine-I. Diketopiperazine alkaloids of the roquefortine group were presented tryptophanyl dehydrohystidildiketopiperazine, roquefortines, glandicolines, meleargrin. Benzodiazepine alkaloids cyclopeptin and cyclophenin were identified also. Quinoline alkaloids were presented as viridicatine and quinocitrinine, and quinazoline alkaloids – fumiquinozoline F and G. Substances with poliketide nature were identified also such as ochratoxines A and B, mycophenolic acid, griseofulvin and PC-2.

These substances on their biological activity were assigned to mycotoxines. Considering global warming forecasts, our data on the toxigenic potential of the fungi will be of interest for specialists dealing with human and animal health.

Recently, a new system has been developed for the identification of the *Penicillium* subgenus fungi, which, along with micro- and macro morphological characters of strains studied, makes use of their secondary metabolite profiles (Samson, Frisvad, 2004). Use of secondary metabolites in taxonomy is based on empirical observations of general physiological and biochemical characteristics in phylogenetically related organisms. Identification of the species are problematic often from the existence of the general interspecies morphologic signs, it was a special sense to know the ability of the sprains to produce secondary metabolites having diagnostic significance. It was noted that accordingly of the signs for the rested 42 strains.

ADDRESSING EROSION WITHOUT RIPARIAN DISRUPTION VANCOUVER ISLAND BC

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Innovative construction techniques involving reinforced earth, soil anchors and a design build approach, not only provided economical road reconstruction, it also satisfied the long term needs of stakeholders while saving the forested riparian area along the shores of a hydro reservoir.

Waterways are common transportation corridors and desirable for homes and recreation, however the waters edge is a dynamic place. Not only is this area high in ecological value, rich with food and riparian shade, it is often actively eroding causing instability in the slopes above. The challenge of maintaining infrastructure without damaging the ecological value always proves challenging.

The road highlighted in this paper is situated within the limits of a small Village on Vancouver Island. The outer lane of this road had to be closed due to fill slope failures down to the reservoir and recreation area below. Steep slopes, high rainfall, tight budgets and multi stakeholders defined the job; Geosynthetic Confined Soil (GCS) and soil anchors fixed it.

This paper highlights how a collaborative approach between the Municipality, Power Authority, environment and designer developed the long term, low impact solution that kept the riparian zone intact.

APPLICABILITY OF MIXED HYBRID FEM TO NUMERICAL EVALUATION OF PHASE CHANGE WITH LATENT HEAT IN FREEZING FOUNDATION

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Stress distribution on underground structure due to frost heave should be properly evaluated for securing the structural safety. In numerical simulation for interactive behavior between soil and structure, the phase change from water to ice within saturated soil must be detected appropriately with enough accuracy in the freezing sequence as well as its stress condition because the frost heave ratio is decided by the freezing rate and the stress condition of freezing soil.

One of the most popular methods for such numerical analysis is finite element method (FEM). In a frost heave simulation by FEM with heat conduction, structures and foundation are modeled into finite elements, and mechanical stress analysis coupled with heat conduction is carried out to observe the change in stress distribution due to frost heave. The method has an advantage that both of heat conduction and stress analyses can share the same model of FEM. In usual FEM for heat conduction analysis, however, temperature at each node is the objective variable, and the heat flux is estimated as a differential of temperature based on a shape function assigned to each element. As a result, heat fluxes at a boundary are not continuous in neighbourhood. Thus, the heat balance accumulated in an element possibly includes some numerical error, and it may become serious disadvantage for accurate estimation of phase change with latent heat.

The authors introduced mixed hybrid FEM technique which can evaluate the heat balance due to flow-in and flow-out through the boundaries of an element, and examined the effect of numerical accuracy in phase change detection on the stress evaluation by comparing the results by the mixed hybrid FEM with those by a usual FEM. Here in the mixed hybrid FEM, the governing equation expressed as a nondegenerate form is decomposed into simultaneous equations for Fourier law and the heat balance, and the objective variables of temperature and heat flux are separately defined at each boundary unlike FEM, not at each node. Consequently, phase change with latent heat can be estimated more strictly than FEM and appropriate frost heave ratio is given to the corresponding element at the right timing in the freezing sequence. For the calculation of mechanical stress analysis due to frost heave, usual FEM technique is adopted. It is concluded that the applicability of mixed hybrid FEM to numerical evaluation of phase change is confirmed.

THE ROLE OF SOILS AND VEGETATION COVERS PROPERTIES IN FORMING ACTIVE LAYER THICKNESS ON TWO CALM SITES

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Two new CALM sites (100x100m) were organized near Chara settlement in 2013. Grid nodes are spaced at 10-m intervals, yielding a regular array 121 (11 x 11) of data collection points.

The territory is characterized by continuous permafrost, average annual air temperature -7.2°C and average ground temperature -2 to -5°C . High density grid measurements, investigations of vegetation cover and properties of soils were undertaken for understanding of active layer features on the first site.

First site is situated on the first Chara river terrace with elevation ranging from 729 to 730 m above sea level. Upper part of geological section is presented by sandy silts and peats overlaid by alluvial sands. According to 121 measurements the average thaw depth was 0.59 m. The measurements of the active layer thickness show the smallest values (0.31m) of seasonal thaw depths under dwarf shrub-moss cover. The highest values (up to 1.28m) of active layer thickness were observed under old dirt roads.

Second site is situated on the fluvial plain with elevation ranging from 705 to 706 m above sea level. Surface of studied area is subjected by poorly drained. The geological section is presented by sandy silts and peats overlaid by alluvial sands. Vegetation cover on this site is presented by hummocky tundra and hummocky mire. Obtained data (121 measurements) shown 0.55 m of average thaw depth. The smallest values (0.38m) of seasonal thaw depths were observed under sedge-moss cover near trees. The highest values (up to 0.8m) of active layer thickness were observed under sedge cover (old dirt road).

On these sites were conducted field tests of soils and vegetation covers properties. During fieldwork samples were collected for laboratory tests. The main factors which determinate active layer thickness are moisture, density and thermal properties of soils and vegetation covers and landscape (disturbing degree of environment). Moisture of samples varies from 15 to 480%, density varies from 0,4 to 2 g/cm³. Values of thermal conductivity varies from 0,17 to 1,6 W/m*K. As a result of tests were found out principles governing active layer thickness.

**COMPOSITION, STRUCTURE AND PROPERTIES OF FROZEN AND THAWED SOILS, BAYDARA BAY
COAST KARA SEA: VARIABILITY AND TRENDS**

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The Arctic coastal zone is very sensitive to any environmental changes. Understanding of the interaction between permafrost and sea is important due to active development of these territories (constructing coastal facilities, offshore pipelines, etc). Knowledge of soils properties are required for cryological forecasts. Multicenter studies were conducted on the west coast of Baydara bay Kara Sea as a part of major international project SAMCoT. The studied area is characterized by continues permafrost distribution. Mean annual air temperature for study territory are near -6.6...-5.7°C. This investigations carried out on the 2 observation sites of Baydaratskaya Bay coast located on low and high marine terraces, which are composed by interbedding sediments, such as silty clays, silt and silty sands. Soils samples were collected and studied in the laboratory. Physical properties, including thermal and strength properties, and phase composition of water in frozen samples were studies by laboratory tests. The moisture content of samples varied from 10 to 205% and density varied from 1,15 to 2.05 g/cm³. Thermal conductivity of frozen soils varied for sands from 1.53 to 2.05 W/m•K, for silts from 1.0 to 1.7 W/m•K, for silty clays from 0.97 to 1.56 W/m•K. Unfrozen water content in the soils for different grain-size soils varied over a wide range with highest values for saline soils. Variability trends in thermal properties and phase composition of water in frozen samples were obtained, depending of temperature, moisture content, density, soil salinity and peaty soil. Borehole's logs with the variability of composition and soil properties with the depth were received as a result of field and laboratory studies. Based on the available data temperature and active layer thickness were estimated. The result of estimation showed a good convergence with the field observation.

ESTIMATION OF ELASTIC MODULUS FOR LIMESTONE ROCK USING IN SITU AND LABORATORY TESTS

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The elastic modulus index is an important index for the design in most of the geotechnical engineering works. According to that, good estimation value of the Elastic Modulus is an important value different foundations design. In this paper, practical value of the Elastic Modulus in limestone rock was estimated using in-situ and laboratory tests. In situ tests using seismic down hole or pressure meter tests gives a highly estimation value for the practical elastic modulus of limestone rock compared to the laboratory unconfined test method. However, in situ tests are more costly than laboratory tests. According to that, a Good value of limestone elastic modulus using laboratory tests can be estimated by using correlation between the in situ tests and the laboratory test data. Estimated Practical design values for Elastic modulus of limestone rock from laboratory should be used for primary design. Geotechnical engineers should perform in situ tests for verification of elastic modulus of limestone in case of important projects.

BEHAVIOR OF BORED PILE CAPACITY USING STATIC AND DYNAMIC LOAD TESTS

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In recent decade, dynamic load test is increasingly being used for bored pile load testing. Based on experience and extrapolation, it is found that the best way to predict pile behavior is to perform a pile loading test. In this study, a comparison between the behavior of pile capacity due to static and dynamic load tests was performed. High Strain Dynamic Pile Testing (HSDPT) using CAPWAP (Case Pile Wave Analysis Program) is used to estimate the pile capacity and static pile tests was also performed on those piles for comparison.

Field bored piles of 600 mm diameter and penetrated up to the bearing strata were chosen for the study. Test results showed a consistent relationship between the dynamic and static tests to a good extent. The dynamic pile load test is a simple test from the view point of quality control and also it is offering a considerable saving in time and cost compared to static tests. In the same time dynamic tests require less space and can be used for predicting the pile capacity. Good correlation between dynamic and static bearing load is predicted. Recommendations of the study, is to perform at least one static test at any studied area for calibration.

PERFORMANCE BASED DESIGN OF ABRADED SOLDIER PILE IN DEEP EXCAVATION

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Due to the recent demand of deep excavations for high-rise structures and shopping malls, the retaining structures are extensively constructed in the city of Tehran. This study surveys the performance of the temporary soldier pile system that it restrained by concrete piles and anchors, in Niayesh Complex project, located in Tehran. The maximum height of walls equals 43m with 37m groundwater depth.

Some numerical models were developed using Finite Element and Limit Equilibrium software, based on results of field and laboratory tests. The design criteria was based on the minimum horizontal deflection criterion because of important urban utilities adjacent to the project.

Soldier pile construction process was carried out, considering the sequence of construction stages. Considering depth of excavation and number of piles around the project, there were some limitations on equipment of pile drilling and the contractor was not able to reach to suitable depth for fixed length piles under the excavation bed. Instead of using rakers as suggested in the literature, the design team decided to use additional anchors and temporary soil buttresses during the construction to avoid delays and difficulties associated with utilizing rakers.

To prevent crack propagation in piles during drilling and installation of the anchors, and also to use the full mobilized shear force in piles, whole anchors were installed in mid span of piles with horizontal Waller. The Waller helps to evenly distribute the anchors forces in 2 adjacent piles and also reduces horizontal drilling length.

During construction, the modeling results were back-analyzed and compared with the in-situ monitored data. As it was an EPC project, the results of monitoring and back analysis are applied to optimize system design during construction.

ANALYSE NUMÉRIQUE DE L'ESSAI DE PÉNÉTRATION STATIQUE CPT EN VUE DE DIMENSIONNER LES FONDATIONS SUPERFICIELLES

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L'article présente une modélisation numérique par éléments finis de l'essai de pénétration statique CPT en vue de l'analyse du comportement des fondations superficielles continues ou circulaires en étudiant le problème de pénétration en grandes déformations d'une pointe conique dans un massif argileux/sableux en suivant une approche Lagrangienne par le biais du logiciel CRISP 2D. La modélisation en axisymétrie en incluant des éléments d'interfaces a permis de déterminer la résistance en pointe pénétrométrique q_c à partir de la courbe d'enfoncement pénétrométrique.

En outre, une étude paramétrique a permis de déterminer le facteur du cône N_k de chaque catégorie de sol et d'étudier sa variation en en fonction de l'indice de rigidité I_r .

Finalement, en se basant sur les résultats de la simulation les facteurs de portance pénétrométrique K_{c0} et K_{c1} ont été calculées et comparées avec celles issues du règlement français DTU-13.12 qui sont basées sur des essais du chargement des fondations en vraies grandeurs, un bon accord a été constaté entre l'approche numérique et expérimentale.

ARCTIC PERMAFROST THERMAL VARIABILITY ACROSS AN ENVIRONMENTAL GRADIENT FROM CONTINUOUS TO SPORADIC PERMAFROST IN THE NORTHERN HEMISPHERE – A PAGE21 COMPILATION

Hanne Christiansen (1), Julia Boike (2), Ko van Huissteden (3), Birger Hansen (4), Margareta Johansson (5), Go Iwahana (6), Graham Gilbert (7), Boris Biskaborn (2)

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For GTN-P session

Permafrost temperatures have been recorded in dominant ice-rich periglacial landforms in six different landscapes of continuous, discontinuous and sporadic permafrost for improved understanding of physical permafrost processes, and for the comparison of these processes between sites. Additionally, CALM data from each of the six sites have been compared. The field sites were selected to cover an Arctic environmental gradient across all permafrost areas in the Northern Hemisphere, and at the same time include only field sites, which provides long-term permafrost monitoring parameters such as permafrost ground temperatures and active layer thickness. Data is jointly stored in the Page21 data management system which collaborates close with the GTN-P system, allowing for easy intersite comparison of key parameters. The field sites are located in Abisko, Sweden (68°N, 19°E), Zackenberg, NE Greenland (74°N, 20°E), Svalbard, Norway (Adventdalen & Ny Ålesund) (78°N, 16°E), Kytalyk, Russia (71°N, 147°E) and the Lena Delta, Russia (72°N, 127°E). The landscapes vary from high-relief mountainous terrain to deltaic and floodplain lowlands, and are thus characteristic of large parts of the permafrost landscapes of the Northern Hemisphere, representing the landscape variability. The combination of these sites accounts for the temporal variability of Arctic ecosystems with respect to permafrost age and dominant periglacial landforms. Mean annual air temperatures (MAAT) across the gradient vary from -0.7°C in Abisko to -14.3°C in Kytalyk. Mean annual ground temperatures (MAGT) at the depth of zero annual amplitude (ZAA) in the permafrost vary for the period 2012-2014 from close to 0°C in the warm sporadic permafrost of Abisko to -8°C in the continental, continuous permafrost of Kytalyk, with intermediate values of -6.7°C in Zackenberg and -4.4°C in Svalbard, both located in continuous permafrost areas. These numbers all come from lowland sedimentary landforms. This distribution clearly reflects the overall climatic control, but studying the duration of the annual freeze-in, frozen and thawing periods, in combination with the active layer thickness, reveal large differences between sites, controlled by different conditions for each of the field sites.

THE DEEP-SEATED LOWLAND RELICT PERMAFROST FROM THE SUWALKI REGION (NE POLAND) - ANALYSIS OF CONDITIONS OF ITS DEVELOPMENT AND PRESERVATION

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Relict permafrost found at a depth of 357 to more than 450 m, discovered in the Suwalki region (NE Poland) in 2010, confirms that up to now such a phenomenon has probably still remained undetected not only across Central Europe. The Udryn PIG-1 research borehole drilled in northeastern Poland (54°14'49"N, 23°03'29"E, 223 m a.s.l.) revealed a permafrost layer, at least 93m thick, within the sedimentary succession below a depth of 357 m. The base of the permafrost has not been reached at 450 m depth, where the drilling stopped, so its total thickness remains unknown. The relict permafrost, unexpected in this part of Central Europe, is in the ice–water transition phase at a temperature close to 0°C. Hydrogeological investigations indicate that the groundwater type is HCO₃-Na of cryogenic origin, with a very low mineralization level (TDS = 0.495 gdm⁻¹)

Analysis of geophysical and hydrogeological data indicates the possibility of preserving the permafrost in the central part of the Suwałki anorthosite massif over an area of probably 20-25 km² (or more). Preliminary results of geothermal modelling indicate that the present-day maximum depth of the permafrost floor is about 470-500 m, with its maximum paleothickness at the end of the LGM period of up to about 650 - 700 m. The difference in mean ground surface temperature (GST) between glacial and interglacial conditions for the Polish Lowlands, derived from deep borehole temperature logs, amounts to 18.1 °C +/- 2.36 °C. The difference in the temperature between the Weichselian Glaciation and Holocene in NE Poland is greater than that in the West Siberian Platform with deep relict permafrost (Urengoy region).

The development of such a thick permafrost results both from a very low average annual temperature in the Weichselian Glaciation and very low terrestrial heat flow density (HFD). It is very possible that similar zones of deep relict permafrost occurrences, undetected so far, may exist in other areas of the Precambrian Platform not only in Poland, but also in the neighbouring countries. A much greater area of similar relict permafrost probably exists in the area of the Ketrzyn anorthosite intrusion located nearly 110 km west of the Suwalki massif.

These findings are of significant importance for the reconstruction of past climate conditions and analysis of the deep subsurface thermal regime in the Earth's crust.

MASS MOVEMENT OF A STONE-BANKED SOLIFLUCTION LOBE AND SYNGENETIC DYNAMIC OF PERMAFROST IN THE HIGH ARCTIC, WARD HUNT ISLAND, CANADIAN HIGH ARCTIC.

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The high Arctic, which is essentially bare of vegetation, will respond strongly to climate changes and will be characterized by an acceleration of periglacial processes associated with permafrost thawing. On Ward Hunt Island (Nunavut), repeated freezing and thawing cycles on slope trigger various types of mass movements. Our project focuses on the influence of stone-banked solifluction lobes on permafrost dynamics. This type of mass movement entrains material downslope at a very slow rate (mm to cm y⁻¹), but repeatedly, which permits a high positive total mass budget on the long term (100s to 1000s y). The displacement of solifluction lobes depends mainly on movement related to heave-settlement and downslope gravity creep of active layer soils. Subsurface hydrology (including ground ice melting) plays a crucial role in the dynamics of pore water pressure and thus solifluction lobes deformations. The morphology of these lobes is characterized by a frontal and peripheral ridges made of coarse gravel and stones. This material has a high hydraulic conductivity and quickly distributes subsurface water according to the lobe's morphology, preferentially through concentrations of coarser, sorted, washed-out gravel conduits forming subsurface flow paths. The cryostratigraphy of the ridges is characterized by ice-poor cryofacies with crustal and interstitial cryostructures. Behind the frontal ridge and constrained by lateral ridges, longitudinal depressions accumulate saturated silty gravelly sand sediments, partially covered by mosses and plants. The active layer in the depression is shallower and the cryostratigraphy is characterized by ice-rich cryofacies with lenticular cryostructures, indicating syngenetic permafrost aggradation. Because of the continuous sliding of solifluction lobes downslope, the resulting cryostratigraphy shows a succession of these two types of cryofacies.

These findings show that substantial accumulation of material downslope greatly modifies permafrost dynamics and creates layers of ice-rich and ice-poor zones. In a context of climate change and active layer deepening, this accumulation of ice may contribute to slow down locally permafrost degradation, due to the significant heat input required to overcome the latent heat effect represented by this new volume of ground ice. However, thawing of stony gravel layers will likely be rapid due to the low ice content of the material. Thawing of this high hydraulic conductivity material will strongly modify downslope hydrology with heat advection through subsurface water flow creating a positive feedback for active layer deepening.

CHARACTERIZATION OF MODEL UNCERTAINTY FOR PULLOUT RESISTANCE OF SOIL NAILS

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This paper presents an evaluation of the accuracy of the prediction of the ultimate pullout resistance of soil nails using the effective stress method (ESM). The bond strength between the nail and soil is calculated using the ESM in the US and Hong Kong. Due to the complexity of nail-soil interactions, inherent variability in soil properties and installation, pullout model accuracy can be significant. Hence, statistical characterization of model bias, where bias is the ratio of measured to predicted pullout capacity, is important for reliability-based (probabilistic) design for the ultimate pullout failure limit state for soil nails and eventually for calibration of the pullout limit state expressed within a load and resistance factor design (LRFD) framework. A total of 119 ultimate nail capacity data points from field pullout tests were collected from the literature and used to estimate the accuracy of the current ESM and to propose empirical-based corrections. Based on the available data, the current ESM pullout model gives a mean bias value of 3.83 with a coefficient of variation (COV) of bias values of 0.73. This means that the current approach is excessively conservative (on average) by a factor of almost four and the spread in prediction accuracy is very large. In addition, the accuracy of the current model for prediction of soil pullout capacity is shown to be dependent on the magnitude of predicted pullout capacity (or ultimate bond strength) using the ESM which is undesirable. The paper introduces empirical corrections that can be applied to estimated bond strengths to improve the accuracy of the ultimate pullout capacity equation and to remove the undesirable dependency noted above.

DÉVELOPPEMENT D'UNE PROCÉDURE DE CONCEPTION DES INFRASTRUCTURES DE TRANSPORT CONSTRUITES SUR LE PERGÉLISOL TENANT COMPTE DE L'ACCUMULATION DE NEIGE LE LONG DU REMBLAI

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L'effet isolant du couvert neigeux est bien connu et son impact sur le pergélisol a été largement étudié en terrain naturel. De son côté, l'activité humaine peut affecter la répartition de la neige qui perturbe alors la température à la surface du sol. Par exemple, en faisant obstacle au vent, les infrastructures de transport linéaires (routes, pistes d'atterrissages ou chemins de fer) favorisent l'accumulation de neige le long de la pente du remblai à l'abri des vents dominants. Cet épaissement du couvert neigeux accroît significativement la rétention de chaleur dans le sol en hiver. Conséquemment, une dégradation importante du pergélisol se produit sous les pentes et le pied du remblai affectant la capacité portante du sol d'infrastructure et pouvant causer des tassements importants endommageant significativement les infrastructures.

La présente étude vise à développer une procédure de conception permettant de prendre en compte l'accumulation de neige préférentielle le long des remblais d'infrastructures de transport.

L'approche générale du projet repose sur l'utilisation d'un modèle bidimensionnel réalisé à l'aide d'un logiciel de modélisation géothermique (Temp/W ou SvHeat) représentatif du régime thermique dans la neige et le sol sous-jacent au pied du remblai. Ce modèle sera calibré à l'aide de données de températures collectées durant l'hiver 2014-2015 à deux sites d'études : le long de la piste d'atterrissage de Tasiujaq au Nunavik et le long de l'autoroute de l'Alaska à Beaver Creek au Yukon. Une fois le modèle jugé adéquat, des analyses de sensibilité seront accomplies afin de quantifier l'impact des paramètres de conception associés à la géométrie du remblai tels que la hauteur et l'angle des pentes.

L'article exposera la méthodologie, les résultats ainsi que les conclusions de l'étude. Pour les deux sites d'essais, la géométrie des remblais ainsi que les conditions climatiques associées seront présentées en lien avec l'instrumentation installée. De plus, les données enregistrées permettront d'illustrer le régime thermique dans le couvert neigeux et dans le sol sous-jacent par des profils de températures caractéristiques pour les deux sites d'essais. Le modèle ainsi que les paramètres d'entrée seront présentés. Enfin, les résultats des simulations permettront de quantifier l'impact de la géométrie du remblai sur le régime thermique du pergélisol.

Veillez noter que l'article sera rédigé en anglais.

RELIABILITY ANALYSIS OF SOIL LIQUEFACTION BASED ON STANDARD PENETRATION: A CASE STUDY IN BABOL CITY

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There are more probabilistic and deterministic liquefaction evaluation procedures in order to judge whether liquefaction will occur or not. A review of this approach reveals that there is a need for a comprehensive procedure that accounts for different sources of uncertainty in liquefaction evaluation. In fact, for the same set of input parameters, different methods provide different factors of safety and/or probabilities of liquefaction. To account for the different uncertainties, including both the model and measurement uncertainties, reliability analysis is necessary. This paper has obtained information from Standard Penetration Test (SPT) and some empirical approaches such as: Seed et al, Highway bridge of Japan approach to soil liquefaction, The Overseas Coastal Area Development Institute of Japan (OCDI) and reliability method to studying potential of liquefaction in soil of Babol city in the north of Iran are compared. Evaluation potential of liquefaction in soil of Babol city is an important issue since the soil of some area contains sand, seismic area, increasing level of underground waters and consequently saturation of soil; therefore, one of the most important goals of this paper is to gain suitable recognition of liquefaction potential and find the most appropriate procedure of evaluation liquefaction potential to decrease related damages.

RELIABILITY-BASED METHOD FOR ASSESSING LIQUEFACTION POTENTIAL OF SOILS

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This paper explores probabilistic method for assessing the liquefaction potential of sandy soils. The current simplified methods for assessing soil liquefaction potential use a deterministic safety factor in order to determine whether liquefaction will occur or not. However, these methods are unable to determine the liquefaction probability related to a safety factor. A solution to this problem can be found by reliability analysis. This paper presents a reliability analysis method based on the popular certain liquefaction analysis method. The proposed probabilistic method is formulated based on the results of reliability analyses of 190 field records and observations of soil performance against liquefaction. The results of the present study show that confidence coefficient greater and smaller than 1 doesn't mean safety and/ or liquefaction in cadence for liquefaction, and for assuring liquefaction probability, reliability based method analysis should be used. This reliability method uses the empirical acceleration attenuation law in the Chalos area to derive the probability density distribution function and the statistics for the earthquake-induced cyclic shear stress ratio (CSR). The CSR and CRR statistics are used in continuity with the first order and second moment method to calculate the relation between the liquefaction probability, the safety factor and the reliability index. Based on the proposed method, the liquefaction probability related to a safety factor can be easily calculated. The influence of some of the soil parameters on the liquefaction probability can be quantitatively evaluated.

STABILITY ANALYSES OF THE CEMENTED BACKFILL IN A PRIMARY STOPE SANDWICHED BY AN UNCEMENTED BACKFILLED SECONDARY STOPE AND ANOTHER EXCAVATED

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In many underground metal mines, mining backfill has become a necessary element utilized to improve ground stability, achieve a maximum recovery of ore, and reduce mining waste disposal on ground surface. To ensure a successful application of the backfill, a safe and economic design of the backfill should be carried out with an adequate solution that can be used to assess the required strength of the backfill. In the early 1980s, Mitchell et al. proposed an analytical solution to estimate the minimum required strength of the backfill exposed by the exploitation of an adjacent secondary stope. This model has been commonly accepted in academy and mining industry, leading to significant reduction in binder consumption. Recently, Li and Aubertin have revisited this model and proposed several modifications (Li and Aubertin 2012; Li 2014). It is noticed that these existing solutions have been developed by considering the stability of the cemented backfill body (in a primary stope) exposed on one side by excavation of a secondary stope. In practice, however, the primary stope is usually sandwiched by two secondary stopes. A critical issue is to estimate the stability of the cemented backfill in the primary stope when one secondary stope is mined and filled with a low or binder-less backfill, while the other one is excavated. The uncemented backfill in the first secondary stope can exercise a pressure on the primary stope cemented backfill. This pressure has never been taken into account in previously mentioned analytical solutions for evaluating the stability of cemented backfill. Here, we propose a new analytical solution that can be used to assess the stability of a backfill design or to determine the required strength of the backfill for the case that the cemented backfill of the primary stope is surrounded by one excavated secondary stope and another one filled with an uncemented backfill.

A NUMERICAL STUDY ON THE STRESS DISTRIBUTION IN BACKFILLED STOPES CONSIDERING NON-PLANAR INTERFACES BETWEEN BACKFILL AND ROCK WALLS

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Mining backfill is widely used in underground mines around the world to maintain ground stability and maximize ore recovery rate. To successfully apply backfill, it is a critical issue to evaluate the stress state in backfilled stopes. The previously published works have shown that numerical modeling is a very effective mean to accomplish this task. It is noted however that most of the numerical modellings were performed by not considering interface elements between the backfill and the rock walls. In some cases, planar interfaces were introduced between the backfill and rock walls, showing that the stress states can be different from those without considering interface elements. In practice, rock walls of mine stopes are rarely planar due to production blasting and artificial supports (rock-bolts, grids etc.). The consideration of planar interfaces between backfill and rock walls is not representative of mine field conditions. In this article, the stress distributions in backfilled stopes will be analyzed using FLAC3D by considering non-planar interfaces between backfill and rock walls. It will be seen that the stress state within the backfilled stopes is largely dependent on the roughness of the interfaces. A discussion will be given.

THE EFFECT OF SALINITY DIFFERENCE BETWEEN PORE FLUID AND AMBIENT FLUID ON ROCK SWELLING

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Consideration of swelling characteristics of shaley rock is essential for design of underground structures such as tunnels. It has been shown that the rock swelling time dependent deformation (TDD) is mainly due to osmosis and diffusion between the rock pore fluid and the ambient fluid. It is reported that a salinity difference between the rock pore fluid and the ambient fluid is a key factor that control swelling (Lee and Lo, 1993).

An extensive experimental program has been carried out to investigate the effect on rock swelling due to the salinity difference between rock pore fluid and the ambient fluid having different salt concentrations. Queenston shale and Georgian Bay shale in Southern Ontario, and Shaftsbury shale in British Columbia, were used in this study. The test program includes the free swell tests, semi-confined swell tests and null swell tests with measurements of salinity of rock pore fluid and calcite content.

It is observed that, for a given salinity difference from pore fluid of rock to the ambient fluid, significant effect on swelling potentials, both in vertical and horizontal directions during the free swell tests on Queenston, Georgian Bay and Shaftsbury shale samples were observed. The effect of salinity difference on swelling potentials and suppression pressure during semi-confined swell test and null swell test, respectively was also observed. Based on the swelling tests results on three rock formations, higher salinity difference resulted in higher swelling potential. In this study, it is confirmed that the major controlling mechanisms of the swelling for not only Queenston shale, but also Georgian Bay and Shaftsbury shales, are the osmosis and diffusion processes between rock pore fluid and ambient fluid as described Lo and Lee, 1993. The practical implications of results are discussed.

CURRENT RESEARCH ACTIVITIES IN KAIST GEO-CENTRIFUGE CENTER FOCUSING ON SOIL-FOUNDATION-STRUCTURE INTERACTION UNDER SEISMIC LOADING

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This paper presents a general overview of KAIST Geotechnical Centrifuge Testing Center and current research activities focusing on Soil-Foundation-Structure Interaction (SFSI) under seismic loading. The KAIST Geo-Centrifuge facility, which was developed in 2009, includes a 5 m platform radius geotechnical centrifuge, an in-flight shaking table, a four degree-of-freedom in-flight robot and general modeling equipment. This facility is providing a good opportunity to perform various experimental research for geotechnical engineers in Korea, and research and development will be further activated in this area. Among current research activities, the dynamic centrifuge model tests for a single degree of freedom system with a shallow foundation and offshore wind turbine structures with various foundation types are introduced. The dynamic behavior of the models in both fixed and SFSI condition is obtained by applying small amplitude dynamic loading. The model structures are exposed to various seismic loadings to evaluate seismic behavior of prototype structures. The numerical study to calibrate and compare with the testing results is also performed. Through the physical and numerical modeling for the model structures, the importance of SFSI in performance based seismic design.

CRYOFACIES OF GLACIER-DERIVED PERMAFROST GROUND-ICE, BYLOT ISLAND, NUNAVUT

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Massive ice bodies are important subsurface permafrost features found in northern landscapes. Ice-cored terrains contains large masses of nearly pure ice typically having gravimetric water content greater than 250% and minimal thickness of 1 meter. It has been demonstrated that in situ freezing of water pumped into the soil porosity by cryosuction could develop massive tabular ice bodies (Mackay, 1971). Other hypotheses include the burial of ice (glacier, snow, fresh water, sea), with buried remnants of glacier ice being the most common type of buried ice. Identifying the origin of massive ice remains a great challenge for permafrost scientists since both buried ice and intrasedimental ice presents similar characteristics. A number of approaches can be used to investigate massive ice origin, but there is actually no comprehensive method to accurately assess the origin of massive ice. Identification criteria were defined based on physical characteristics of the ice such as the texture, fabric, sediment and gas inclusions, and deformation structures in the ice. This paper aims to present a detailed description of the cryofacies and cryostructures of the two main types of buried glacier ice. Here, the cryostratigraphic approach is applied in order to describe and characterize the shape and distribution of the ice within the frozen sediment (French and Shur, 2010). The inner structure and texture of the ice is also investigated using thin section of ice seen through cross-polarized light. Englacial ice from snow metamorphism shows clear to whitish ice, with large crystals (cm) and small gas inclusions (mm) at crystal intersections. Basal glacier ice displays ice-rich suspended, layered, porous visible, crustal and lenticular cryostructures, with small ice crystals and low concentration of gas inclusions (mm). These cryostructures showed great similarities to cryostructures of englacial and basal ice exposures found on actual glaciers on Bylot Island (C79 glacier) and in Alaska (Matanuska glacier). As massive ice of glacial origin usually implies large volume of underground ice, the melting of this ice could lead to extensive slope failures and settlement of the ground surface, with significant impact on permafrost geosystem landscape dynamics and attendant damages to infrastructures (Stephani et al., 2014).

Mackay, J.R. (1971), *Canadian Journal of Earth Sciences*, 8(4):397-422

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French and Shur (2010), *Earth-Science Review*, 101:190-206

IMPROVING GROUND SUPPORT DESIGN WITH DISTRIBUTED STRAIN MONITORING

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An observational approach to tunnel design and construction is commonly employed in order to assess excavation driven displacements which, in turn, affect temporary tunnel support design decisions. In weak ground conditions, a correct and accurate evaluation of such measurements is critical to both the safety and to the economics of the construction process. The current monitoring practice is often limited to capturing the inner profile of the excavation and conditions at surface (e.g. geodetic monitoring). Yet, the behaviour of the ground around and ahead of the excavation face may be more pertinent to the optimization of the tunnelling construction process. This necessitates a capable solution for monitoring the ground and temporary support system installed in order to mitigate and control excess deformations during tunnel development. The Umbrella Arch is a portion of such a support system, forming a structural umbrella from the insertion of an assortment of longitudinal support members (e.g. grouted elements, spiles, and forepoles), installed in the direction of the tunnel from within the excavation, above and around the crown of the tunnel face. Within this context, an application of an optical frequency domain reflectometry (OFDR) technology combined with longitudinal members of the Umbrella Arch is presented.

This state-of-the-art optical technique monitors strain with a sub-centimeter spatial resolution (i.e. at intervals of 1.25 mm); allowing a continuous strain profile (never before effectively achievable at this resolution) along the length of the specimen to be determined. Highlighted within this paper is the technique that was utilized to instrument the various support members, which was a non-trivial undertaking. Additionally, the testing procedure and results from various bending, axial, and shear configurations are presented and discussed. Such tests were designed in order to simulate the complexities of in-situ ground behaviour, as well as to prove the capability of the optical technique to overcome the constraints of conventional, discrete instrumentation (e.g. foil-resistive-strain gauge, extensometers, inclinometers). As such, an optical device is presented with the capability to “see” and “sense” into the ground ahead of the working face. This can be realized as a novel tool which allows the engineer to react and make adjustments to the support and excavation process in response to future ground conditions. In this manner, the optical tool also provides unparalleled information concerning the behaviour and the interaction between the ground medium and the support elements which can be back-analyzed for predictive numerical model methods.

ANALYSIS OF FLOW THROUGH JOINTED ROCK USING A MULTI-SCALE HYBRID FINITE ELEMENT APPROACH

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Seepage through fractures and fracture networks is a complex phenomenon, the understanding of which has important applications in geoenvironmental engineering. Understanding how groundwater flows through jointed rock masses may provide insights leading to more effective groundwater use and improved understanding of contaminant transport through jointed rock. This paper presents a numerical model for seepage through jointed rock using a multi-scale hybrid finite element approach, which extends a hybrid polygonal finite element seepage model. Recent work in the same research group has extended a hybrid polygonal finite element model for solid continua to a hybrid discrete element-finite element (FEM-DEM) approach capable of capturing multi-scale mechanical behaviour in granular materials. A similar extension is made in the present paper to model seepage using a combination of hybrid polygonal seepage elements for body regions and joint or fracture elements for flow in fracture networks. The polygonal body elements allow geometric representation of grains, intact blocks or representative volumes of a rock mass, whereas the joint elements allow localized pathways of hydraulic conductivity, which may be significantly different from the average rock mass conductivity. This combination of elements allows the model to be applied at various length scales, and to naturally incorporate the effects of anisotropy and heterogeneity. In particular, the present paper presents preliminary results of simulations at two different scales: (i) using the joint elements to model flow in a single irregular fracture and (ii) using a combination of polygonal body elements and joint elements to simulate groundwater hydraulics at the scale of a rock mass. The modelling framework is somewhat simplified, ignoring, for example, mesoscale influences owing to flow interaction at fracture intersections. We discuss the implications of the simplifying assumptions and how the model may be extended in future work.

PROBABILISTIC SLOPE STABILITY ANALYSIS OF REINFORCED SLOPES BY FINITE ELEMENT METHOD

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A probabilistic slope stability analysis tool for geosynthetic reinforced slopes that combines the shear strength reduction method (SSR) with probability theory was developed using a finite element method (FEM) code for unreinforced slopes. The numerical model in combination with the shear strength reduction method was first used to compute probability of failure and factor of safety for simple unreinforced slopes with purely cohesive and cohesive-frictional soil. The results are compared to those from combined limit equilibrium method (LEM) and Monte Carlo simulation recently published in the literature. The results are shown to be in good agreement. The numerical model was also verified by duplicating other FEM results for simple unreinforced soil slopes published in the literature, which also showed excellent agreement. The validated FEM code was then modified to investigate reinforced slope cases. To verify the new code, a general reinforced slope case was examined using the new program and the FEM software package SIGMA/W. Displacements and reinforcement strains calculated using both programs agreed well. The utility of the new code in combination with Monte Carlo simulation and the shear strength reduction method is demonstrated by a number of examples. The results of analysis are presented in the form of plots of probability of failure versus factor of safety for simple slopes with random soil variability. The general approach applied to reinforced soil slopes is novel and offers a powerful tool to relate conventional notions of factor of safety for reinforced soil slopes to margins of safety described by more meaningful probability of failure.

INFLUENCE OF CHOICE OF SMALL- AND LARGE-STRAIN MODE IN FLAC ON SOIL-GEOSYNTHETIC INTERACTION PROBLEMS

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Soil-geosynthetic interaction plays a major role in the performance of mechanically stabilized earth structures such as reinforced soil walls, steep slopes and embankments. Program FLAC is now used routinely by engineers for the design and analysis of these structures. Accurate numerical modelling requires the use of appropriate constitutive models which has been the subject of much research. However, numerical outcomes may also be sensitive to geometric nonlinearity which is detectable when numerical simulations are carried out in both small- and large-strain modes in program FLAC. The paper examines three examples of soil-geosynthetic interaction problems using FLAC. The cases are: 1) horizontal pullout of a geosynthetic layer in a pullout box; 2) a single layer of reinforcement below a footing, and; 3) a reinforcement layer over a void. FLAC simulations are carried out in small-strain mode (i.e., without mesh update) and in large-strain mode (i.e., with mesh update). Numerical results are used to quantitatively demonstrate good agreement between simulation results using the two modes for some example cases and large differences in other cases. Examples of poor numerical results are demonstrated by comparing numerical outcomes using both approaches with physical test results available in the literature. This paper will assist engineers to identify those conditions where numerical simulations of geosynthetic reinforced soil structures should be carried out in large-strain mode in order to avoid unreasonable numerical outcomes.

CARACTÉRISATION DES ZONES EXPOSÉES AUX GLISSEMENTS DE TERRAIN FORTEMENT RÉTROGRESSIFS À L'AIDE DE LA MESURE DE LA RÉSISTIVITÉ ÉLECTRIQUE, RÉGION DE BROWNSBURG, QUÉBEC

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La vallée de la rivière aux Vases, dans la région de Brownsburg au Québec, est constituée d'argile sensible et ses berges sont parsemées de nombreuses cicatrices de glissements de terrain, dont plusieurs atteignent des dimensions de quelques centaines de mètres. De concert avec l'université Laval, le ministère des Transports du Québec a entrepris récemment des investigations détaillées dans cette région, afin d'étudier la possibilité d'utiliser la mesure de la résistivité électrique des sols pour caractériser les zones exposées aux glissements de terrain fortement rétrogressifs. Dans une section transversale de la vallée, une tomographie par résistivité a été effectuée sur une longueur de 1,6 km. Une série de 6 sondages au piézocône, incluant la mesure de la résistivité électrique, ainsi que 4 forages avec prélèvement d'échantillons ont été réalisés le long de cette section. Cette présentation porte sur la description du contexte géologique et géotechnique et l'analyse préliminaire des résultats d'investigation obtenus.

INCIDENCE OF LATE PLEISTOCENE SYNGENETIC PERMAFROST DEVELOPMENT ON LANDSCAPE EVOLUTION, BEAVER CREEK AREA, SOUTH-WESTERN YUKON, CANADA.

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The Beaver Creek area is located at the foot of the Wrangell/St-Elias Mountains, at the margin of the Mirror Creek Glacial extent (antecedent to the last glacial maximum). Preliminary AMS radiocarbon of wood fragments and peat extracted from permafrost cores suggest that the site was not glaciated during the last glacial maximum. Cryostratigraphic analysis of permafrost cores from 22 boreholes ranging from 3 to 15m by Stephani et al. (2014) revealed three distinct permafrost layers that accumulated syngenetically over a diamicton since 46 ky BP or before. The latter has been interpreted as remnant of the recession moraine of the Mirror Creek glaciation. The first (older) permafrost layer is in lacustrine/peat deposits, the second comes from an eolian/organic accumulation phase and the last is the contemporary ice-rich permafrost table formed during the Holocene. The morainic hills, well drained, are characterized by forest vegetation (essentially spruce) whereas the topographic lows are occupied by muskeg vegetation. The muskeg areas are characterized by a thin active layer, a thick organic cover, a thick quasi-syngenetic upper permafrost layer and an ice-wedge network close to the surface whereas the forested areas follow the opposite trend. The rolling topography of the recession moraine influenced the accumulation and redistribution of sediment in the landscape, with large accumulation in topographic lows and minimal to no accumulation on morainic hills. Observations on additional boreholes indicate that the eolian sedimentation phase was followed by an organic and ice accumulation phase, which is still active today. This differentiated permafrost pattern strongly influences heat and mass transfers at the landscape scale and suggests that this type of geosystem will respond non-linearly nor uniformly to changes in the surface heat or mass balance.

Stephani, E., et al. (2014). A geosystems approach to permafrost investigations for engineering applications, an example from a road stabilization experiment, Beaver Creek, Yukon, Canada. *Cold Regions Science and Technology* 100: 20-35.

ROCKGLACIERS ON THE RUN – AN ADVANCED APPROACH TO ASSESS ROCKGLACIER EVOLUTION

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Rockglaciers as a visually detectable landforms of mountain permafrost have received considerable attention concerning their kinematics and thermal characteristics. Monitoring results have shown acceleration and/or deceleration of some rockglaciers as well as seasonal velocity changes related to ground temperature variations. Despite the extensive kinematic and thermal monitoring of these creeping permafrost features, few attempts have been undertaken to understand and model their dynamics so far.

In order to improve the understanding of rockglacier dynamics, there is a need to analyze the landform in a holistic setting, which includes its spatial and temporal long-term development. This study presents a modeling approach which assesses rockglaciers with different characteristics concerning their position in a typical coarse debris process chain: rock wall --> rock fall --> talus slope --> permafrost creep --> rockglacier. Headwall recession, creep processes and sediment transport are assessed using a multi-method-approach combining remote sensing and terrestrial surveying methods. A numerical flow model based on the conservation of mass within the debris process chain is used to calculate the evolution of rockglacier surfaces. The flow model is used to generate observed rockglacier geometries and rheologies which are then subjected to variations in driving forces such as temperature and the supply of sediment and ice. In addition degrading developments in the landforms are induced.

The modeled degrading features are compared to changes in surface morphology deduced from multitemporal digital terrain models at different sites in Switzerland. The DTMs were developed during the last two decades and allow the identification of possible signs of degradation at a high spatial resolution. The modeling helps to understand the driving forces of these morphological changes and shows which influence sediment supply and temperature variations have on the morphological and rheological evolution of rockglaciers. Further, it elaborates to which degree these variations can be held responsible for signs of degradation.

The main objectives of this study are: a) to present a holistic approach to investigate rockglacier dynamics which assesses the rockglacier as an integral part of a high mountain periglacial sediment transport system b) to recommend a methodological setup which provides suited data for the assessment of rockglacier evolution c) to apply a numerical flow model to investigate rockglacier evolution and the role of temperature and sediment input variations and by that d) to address possible implications for rockglacier destabilization.

**A NUMERICAL STUDY OF HEAT LOSS FROM RESIDENTIAL FOUNDATIONS TROUGH SOILS:
INFLUENCE OF VAPOUR DIFFUSION AND SURFACE EVAPORATION**

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The insulation of residential building has always been a concern for energy efficiency and economic purposes. Aboveground insulation of houses has been significantly improved in the past thirty years. However, too few efforts aimed at reducing heat loss from the foundation through surrounding soil. A numerical and experimental study was initiated by Université Laval and IREQ (Hydro-Quebec research institute) to explore the effect of the different heat transfer mechanisms on energy efficiency of foundations, including buried walls and basement slab.

This paper aims at determining the relative effects of surface evaporation and soil vapour diffusion on the total heat loss towards surrounding soils. A finite elements method is used to solve coupled heat and mass transfer in porous media. Three different types of soils are studied: clay, silt and sand.

The results show that surface evaporation/infiltration significantly influences soil moisture distribution and thus its thermal conductivity and heat capacity distributions, resulting in variations of heat flux due to conduction compared to hydrostatic conditions. The results also show that surface evaporation does influence the amount of vapor movement within pore air but the inferred heat transfer due to vapour diffusion still remain insignificant compared to pure conduction. This heat transfer mechanism can thus be neglected for the assessment of the foundation heat loss through surrounding soils in the moderately cold climatic conditions of the Province of Québec

NOUVELLE INVESTIGATION GÉOTECHNIQUE DU GLISSEMENT DE TERRAIN DE 1971 LE LONG DE LA RIVIÈRE DE LA NATION SUD, ONTARIO.

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Un très grand glissement de terrain d'une superficie d'environ 28 hectares, s'est produit dans la nuit du 16 au 17 mai 1971, le long de la rivière de la Nation Sud, à environ 6 km au nord du village de Casselman en Ontario. Le volume de débris mobilisé se situe entre 6 et 7 millions de mètres cube et la distance de rétrogression du glissement atteint 400 m à partir du sommet du talus initial. L'analyse des débris à l'intérieur de la cicatrice du glissement révèle la présence de horsts et de grabens, typique des étalements dans les argiles sensibles. Le Ministère des Transports du Québec et l'Université Laval ont collaboré à la réalisation d'une investigation géotechnique afin de caractériser les propriétés géotechniques des sols en place. La campagne comprend deux forages, trois scissomètres et cinq piézocônes situés au pourtour du glissement afin de déterminer les paramètres de résistances mécaniques des sols intacts et remaniés. De plus, plusieurs sondages au piézocône ont été réalisés à l'intérieur de la cicatrice du glissement afin de détecter la position de la surface de rupture et de caractériser les débris du glissement. Les principaux résultats de cette campagne d'investigation, ainsi qu'une revue des études réalisées dans les années 70, seront présentés.

NUMERICAL MODELS FOR ANALYZING THE CONSOLIDATION BEHAVIOUR OF MINE TAILINGS

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Prediction of compressibility behavior of soft soil deposits, such as mine tailings and hydraulic fills, is important in mining and dredging industries. Theory of large-strain consolidation has gained universal acceptance due to its superior predictions of the consolidation behavior. Earlier work on large-strain consolidation behavior of soils was mainly focused on the development of piecewise linear models for the estimation of settlement response of the field soils or accelerated consolidation in the centrifuge model tests. The centrifuge method is particularly attractive because it requires only a few hours of monitoring to obtain the consolidation characteristics of soft soil in the laboratory.

Two constitutive relationships, such as void ratio-effective stress and void ratio-hydraulic conductivity, are commonly used in the analysis. These relationships are generally deduced by fitting an empirical equation to the computed data of effective stress vs. void ratio and hydraulic conductivity vs. void ratio obtained from small strain consolidation tests. Deducing compressibility and hydraulic conductivity of consolidating soil from the field or laboratory settlement response with time is an inverse problem. The values of compressibility and hydraulic conductivity deduced from settlement vs. time response are influenced by the selected form of void ratio-effective stress and void-ratio-hydraulic conductivity equations. The inverse analysis of the centrifuge tests is, therefore, important for validating the applicability of the constitutive relationships. The inverse analysis for analyzing the laboratory centrifuge tests is, however, computationally expensive due to limitation on the numerical time-step.

In this paper, we propose finite-difference numerical technique for analyzing the settlement response of field soils and accelerated consolidation in the centrifuge model tests. An implicit finite difference method is used to use large numerical time-steps as the method is unconditionally stable. A detailed convergence analysis of the proposed technique is presented. A comparative analysis with respect to the piecewise linear technique using the Eulerian coordinate system is provided. The proposed numerical model is validated on several experimental data from the literature. It is demonstrated that the proposed model is computationally inexpensive and appropriate to use in the inverse analysis.

THE INFLUENCE OF HYDRATE VEINS ON THE GEOMECHANICAL BEHAVIOUR OF FINE-GRAINED SOIL

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Gas hydrates form in deep-water marine sediments and have been suggested to pose a significant geohazard by acting as potential triggers for submarine slope failures. This occurs when bottom water temperature and/or pressure changes result in hydrate dissociation, which generates excess pore pressure by the release of free gas into the host sediment pore space, leading to a weakening of the sediment. Recent drilling expeditions, with improved sampling techniques, have revealed that within fine-grained marine soils the hydrate forms complex, sub-vertical, interconnected, stiff hydrate veins within the soil. These vein networks are hypothesized to prevent full consolidation of the soil by forming a stiff, load-bearing framework within the soil skeleton, which results in the observed underconsolidation of the hydrate-bearing sediment seen in numerous drilling expeditions. Consequently, the dissociation of these vein networks will lead to the transfer of overburden pressure onto the underconsolidated soil, potentially exceeding the undrained shear strength of the material, leading to failure. However our current understanding of the strength and deformation behaviour of hydrate-bearing sediments is limited to laboratory studies in which hydrate is formed within the pore space of coarse-grained sediments. This paper highlights research that was carried out to examine the effect of hydrate veins within fine-grained soil on the strength and deformation behaviour. Advanced laboratory techniques were developed to form fine-grained soil specimens with simplified vertical, cylindrical, synthetic hydrate veins. K₀-consolidation of the hydrate-bearing soil was carried out to determine a relationship between the degree of underconsolidation of the fine-grained soil and different hydrate-to-soil area ratios. The hydrate veins were then dissociated, and the deformation behaviour of the underconsolidated fine-grained soil, due to the imposed effective vertical stress, was observed. The results from the laboratory tests were then modelled using a finite element analysis program to confirm the properties of the hydrate and soil. As human activity on the sea floor increases and sea bottom temperatures rise due to global climate change, understanding the geomechanical response of fine-grained sediments hosting hydrates will allow for an improvement in the understanding and prediction of this geohazard.

RECYCLING WASTE GYPSUM IN SOIL STABILIZATION APPLICATIONS

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Solid waste management is a serious problem worldwide as amounts of produced wastes are increasing annually. For example, the disposal of gypsum waste plasterboard, widely used as dry wall across North America, represents a serious environmental issue. Consequently, more attention is focused on the use and recycle of such waste as an alternative material in construction applications. Hence, reducing the amount of wastes sent to landfills leading to environmental and economic benefits. Therefore, this study examines the potential of reusing gypsum wastes as a stabilizer material for earthwork projects. Recycled gypsum, mixed with cement or lime at different ratios, was used as a stabilizer for very soft clay soil. The compressive and cone strengths, secant moduli, unit weight, water content and Atterberg limits tests were conducted to evaluate the improvement in stabilized soil properties. The results indicate that the inclusion of gypsum-cement or gypsum-lime admixtures improved the mechanical properties of the stabilized soil, with higher admixture concentrations leading to greater improvement. Moreover, the soil specimens stabilized using gypsum-lime admixture exhibited higher strength gain rate and reduction in plasticity index and water content than those stabilized by gypsum-cement admixture. It is concluded that the proposed stabilizing technique can be advantageous for both waste management and construction industries.

A METHOD FOR DETERMINATION OF WATER CONTENT IN REAL AND MODEL POROUS MEDIA IN EQUILIBRIUM WITH BULK ICE OR GAS HYDRATE

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On the base of experimental determination of water potential in soils the thermodynamic schemes are considered for i) equilibrium with ice water content in hydrophilic porous media depending on temperature (for negative temperatures on Celsius), ii) equilibrium water content with gas hydrate in hydrophilic porous media depending on temperature and pressure of gas hydrate-former (methane, natural gas, etc.).

Measurements of water potential (and/or thermodynamic activities of water) were carried out on the Decagon company (USA) WP 4 device. This device allows to determine in the automatic mode water potential by a condensation method in the samples at some range of temperatures near room temperature.

Two types of porous media were used: the artificial samples with known sizes of pores (controlled pore glasses from Asahi, Japan) and natural clays (kaolin and polymineral clay). Experimental data on water potential depending on water content of samples are presented at the range of temperatures 20-30 oC.

The model is developed for thermodynamic properties of pore (confined) water in porous media. This model is applied for estimations of unfrozen and non-clathrate water contents in the samples.

In the method for calculation of unfrozen water content depending on temperature the generalized dependence "freezing temperature of confined water via measured thermodynamic activity of confined water" is used. In the method for calculation of non-clathrate water content depending on temperature (at fixed gas-hydrate former pressure) the generalized dependence "hydrate formation temperature of confined water via measured thermodynamic activity of confined water" (for methane and natural gases) is used.

Discussion of the results is presented.

PERMAFROST DEPTH AND PAST CLIMATE CHANGE INDICATED IN TEMPERATURE DATA OF A 140 M DEEP BOREHOLE IN THE EL'GYGYTGYN IMPACT CRATER, NE RUSSIA

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This study focuses on a permafrost temperature record observed in a 140 m deep borehole drilled as part of an interdisciplinary scientific campaign targeting El'gygytgyn Crater in NE Russia.

This crater was formed by an Asteroid impact 3.6 Myr ago. Temperature data recorded over more than two years are available from borehole 5011-3, which is placed in alluvial fan deposits partly covering the western part of the crater basin. The thermal properties of the subsurface needed for modelling studies are based on laboratory measurements of representative core segments from the recovered quaternary deposits and data from published literature.

Initially, we performed steady-state numerical simulations for studying the general permafrost distribution today, using a code for subsurface heat transport including latent heat effects. Sensitivity studies reveal the influence of variations in thermal properties on the permafrost depth.

Comparing the results from these steady-state simulations with the temperature data imply a significant influence from transient ground surface temperature changes on the subsurface temperature field. Accordingly, we performed transient modelling studies with a time dependent boundary condition at the ground surface.

The comparison and calibration to observations of these simulations allow determining not only the recent mean annual ground surface temperature, but also the ground surface temperature history, though with large uncertainties. Besides some signals to be attributed to the warming from Pleistocene to Holocene, the data show strong evidence for a comparatively large amplitude of the Little Ice Age (up to 4 K), with low temperatures prevailing far into the 20th century.

The transient modeling also allows the estimation of the time dependent variation in permafrost depth: at the location of borehole 5011-3 today and 20 000 years ago we estimate a permafrost thickness around 340 m and 480 m, respectively.

Measured temperature data will become available through the open data base GTN-P, Global Terrestrial Network for Permafrost (<http://gtnp.arcticportal.org/>).

NUMERICAL INVESTIGATION TO EVALUATE THE PERFORMANCE OF BORED PILES WITH MULTIPLE DEFECTS

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Bored piles are commonly used to support heavy structural loads in weak soils. Cast-in-place bored piles may experience construction related defects which negatively impact the load carrying capacity and settlement of the pile. In this study, a series of numerical simulations is performed using ABAQUS software to evaluate the response of a concrete pile with different types of defects. This includes improper end-bearing, discontinuity in the pile shaft, necking, and poor concrete quality. The results of the analysis are summarized for each investigated case and the load-settlement relationships are compared with the case of intact pile. The outcome of this study will help engineers to identify and characterize the defect type based on the results of conventional pile load tests.

A NEW CONSTITUTIVE MODEL FOR SIMULATING TIME-DEPENDENT BEHAVIOR IN DEEP UNDERGROUND ENVIRONMENT

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It is a common phenomenon that the rock mass around deep tunnel excavation can exhibit time-dependent deformations that may lead to instabilities during the construction process in the short-term or even severe collapses and delayed failures in the long-term. The latter can be considered as a critical design aspect during the construction and operation of underground repositories projects where the projects' life exceed the 100 year life period of civil engineering underground structures. Consequently, it is very important to both take into consideration and predict-estimate the gradual development of the irreversible deformations that can affect and maybe increase the Excavation Damage Zone (EDZ). This phenomenon can be observed mainly in weak rock masses or rock masses subjected to high in situ stress environments and it is usually attributed to creep, squeezing and other time-dependent processes. Therefore, numerical modeling methods and advanced constitutive models are required to reproduce and assess time-dependent behavior.

In this paper a new constitutive model to simulate time-dependency is presented and more specifically, a visco-plastic model coupled to a strength degradation and stress relaxation function enabling to simulate different time-dependent processes that may occur simultaneously or act individually. Thereafter, this model is compared to other time-dependent models by performing numerical analysis in both 2D and 3D dimensions available as well to closed form and analytical solutions and the error function is estimated. Moreover, a sensitivity analysis is performed to investigate the effect of the proposed model's parameters. Numerical analysis is performed in both 2D and 3D dimensions and the results are compared with the case history's data. Drawing on the results, this paper highlights the mechanisms of the viscous models and the implications that may arise in underground projects design.

THE ROLE OF OIL POLLUTION IN THE FORMATION OF SALINE FROZEN SOIL PROPERTIES

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Gas and oil reserves are located mainly in the northern regions, and the majority of them - in the field of dissemination of permafrost. Much of the permafrost zone is occupied by saline frozen rocks.

Oil pollution of soils can occur in various ways: in mining, storing it in the fields, also there is a risk of leakage during the transportation of crude oil and petroleum products. During the oil extraction oil contamination often is accompanied by salinization of the soil. The sources of salts are stratified fluid, waste water, the contents of barns and other geochemically active substances used for extraction and desalting. In addition, the joint salinity and contamination can occur at the outpouring of oil on the territories where saline soils are distributed.

The forecast of temperature regime, seasonal thawing and freezing, development of negative processes and structural engineering is impossible without knowledge about soil properties. The obtaining of high-quality data about soil thermal properties and water phase composition is significant for calculation of thermal fields and evaluation of buildings thermal effects on soils-foundation.

The authors developed experimental techniques and assessed their applicability for saline and polluted soils during freezing-thawing process. The investigation of granulometric composition, water phase composition and thermal properties of saline and polluted soils was conducted *in vitro*. In our research we studied the characteristics such as freezing point, unfrozen water content, thermal conductivity, heat, thermal diffusivity. The regularities of changes in these characteristics on temperature, salinity and oil pollution are obtained. Authors identified the role of oil pollution in the formation of thermal properties and water phase composition of the saline soil.

In the analysis of the results led to the following conclusions:

- oil contamination has no influence on the temperature of freezing in a non-saline and saline soil, but has a different effect on the kinetics of the process of thawing of soil;
- the study of the joint influence of salinity and oil contamination on the water phase composition revealed dominant influence of salinity on all the investigated properties, oil pollution has almost no effect on the amount of unfrozen water in soil.
- the thermal conductivity decreases with increasing of oil content in non-saline soils; there is no influence of oil pollution on thermal conductivity in saline soils

SUCCESSION IN TUNDRA LANDSCAPES AND ITS IMPLICATIONS FOR POLAR RESTORATION EFFORTS: CASE STUDY OF HERSCHEL ISLAND, YT, CANADA

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With future warming and resource extraction activities, the presence and areal extent of thaw subsidence in the circumpolar Arctic are predicted to increase. In the context of restoration, this presents unique challenges for mitigating ecosystem change and developing effective restoration strategies for environmentally sensitive areas and derelict lands. This research investigates natural revegetation patterns following permafrost disturbance by retrogressive thaw slumps on Herschel Island, Yukon, Canada. Seven sites were chosen for the study, representing undisturbed areas in addition to 250 year old, 20 year old, and 10 year old stabilized thaw slumps. Proportional abundance of plant ground cover, species diversity, and percent cover of different plant functional groups are presented. Results indicate that distinct vegetation assemblages are associated with each age class, and that substantial differences between undisturbed and stabilized tundra persist for centuries. This has important implications for the stability of these landscapes, as the long time scale of natural recovery limits our ability to mitigate the effects of these disturbances on the surrounding environment. Using the natural successional plant communities presented here as a guideline, ecological restoration methods using propagule addition which targets effective natural initial colonizers are suggested. If our goal is to control erosion, create habitat, and enhance freezeback in these landscapes at an accelerated pace, this type of restoration intervention may be necessary and is thus a promising direction for future research.

ON THE USE OF MICRO-PILES TO IMPROVE THE CAPACITY OF EXISTING FOUNDATION

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Modern technique of ground improvement has been proven to be effective in improving the bearing capacity of shallow foundations. It is however, challenging to apply these conventional methods to existing foundation. Micro-piles have been effectively used in different ground conditions to enhance the soil confinement and consequently improve the bearing capacity and reduce foundation settlement. In this study, the results of model tests that have been conducted to investigate the behavior of a strip footing strengthened using micro-piles are presented. The effect of different parameters, including, micro-pile spacing and diameter is examined. Bearing capacity of the investigated footing with and without the introduction of micro-piles is evaluated. The results showed that the installation of micro-piles around an existing footing can significantly enhance the load displacement response and increase load carrying capacity of the supporting soil.

EFFECT OF CLIMATE CHANGE ON SOIL COVERS IN NORTHERN CLIMATES

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Soil covers must be designed for long-term or perpetual containment of waste. Climate change poses a number of challenges to design, operation and long-term performance of covers. Loss of performance might occur due to an increased ingress of water and oxygen into the underlying waste or erosion of the cover to support vegetation. Similarly, drought conditions compounded with increased temperatures could result in a lower degree of saturation in the cover resulting in increased oxygen ingress to reactive waste or deterioration of hydro mechanical cover material properties impacting performance. For cover design in colder regions, energy balance is critical as it is intimately linked to the prediction of long periods of freezing, and timing of thawing of layers with depth. One of the containment strategies used in cold regions is that either the waste or part of the cover can be frozen into the permafrost; however, with increasing changes in climate and deteriorating permafrost in the northern environments this containment method may no longer prove to be a suitable design option. A significant number of studies have addressed permafrost degradation due to changing climates, however the effect of climate change on waste management facilities that employ soil covers and rely on either partial or complete containment by permafrost remains uncertain. This paper focuses on understanding the critical energy balance of a soil cover for frozen waste in permafrost degrading due to climate change. The effect of different climate change scenarios is assessed for the establishment and deterioration of permafrost, with the intent that climate change becomes an integral part of the cover design process. Existing coupled soil atmospheric models were also employed to understand the moisture and temperature dynamics in various soil cover types.

CORING OF UNCONSOLIDATED PERMAFROST DEPOSITS IN SVALBARD AND NE GREENLAND: METHODOLOGICAL SUCCESSES AND CHALLENGES

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Recent field investigation in the Adventdalen Valley (central Spitsbergen, Svalbard) have focused on reconstructing Holocene permafrost and landscape development from frozen sediment cores obtained using three scales of drilling infrastructure. The applied coring techniques range from small, portable hand-drills to large, immobile drill rigs, designed for obtaining bedrock cores from depths of greater than one kilometer. In addition, a unique drill rig, designed by Dipl.-Ing. Lutz Kurth Bohr- und Brunnenanlagen GmbH in collaboration with Kolibri Geo Services, was acquired in 2011. This drill rig, called the UNIS permafrost drill rig, is intermediate in scale and permits core retrieval down to a depth of ca. 40 m. The rig can be transported around the landscape by snowmobiles during winter – reducing the environmental impact when retrieving shallow cores from remote Arctic regions. The combination of these three methods has allowed us to assemble knowledge regarding the physical state of permafrost with regards to spatial variations in ground-ice conditions and sediments from different geomorphic settings and sediment types both on Svalbard and in northeast Greenland.

Core retrieval with the hand-drilling technique is limited to a depth of ca. 4 m. The hand-drill consists of a small powerhead, drilling extensions, and an unflighted core barrel with diamond cutting teeth. Approximately 25 cores, 2 m to 4 m in length, have been retrieved from Greenland and Svalbard using this method. The UNIS permafrost drill rig was acquired in response to the need to evaluate the potential effects of on-going climatic changes on periglacial landform activity in various permafrost areas throughout Svalbard. The rig consists of a hydraulic engine, air compressor, boom, and drill head. Compressed air is used as a drilling fluid to cool the drill bit and transport cuttings to the surface. This method has been used to retrieve cores totalling between 10 m and 25 m in length at ca. 8 locations in Svalbard and Greenland. In September 2012 an industrial drill rig was used to drill a 60 m well in the ice bonded Quaternary deposits in the Adventdalen valley bottom. This operation, funded by the UNIS CO2 Laboratory, utilized a triple core barrel system and water, as a drilling fluid. With this system, it was possible to retrieve a near-continuous 60 m frozen core.

The objective of this submission will be to present the three main drilling methods with a focus on the strengths and limitations of each technique.

UNDERSTANDING THE TRIGGERING MECHANISMS OF THE 2014 OSO LANDSLIDE

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In March 2014, near the town of Oso in Washington State, a devastating landslide was triggered that took the lives of 43 people and covered an area of over 2.5 km². The catastrophic consequences associated with flow slides such as this example emphasize the critical need for accurate and timely landslide predictions. Often these predictions are dependent on historical landslide behaviour in order to evaluate present day risk. However, previously triggered landslides in the surrounding Oso area were not highly mobile flow slides, which makes the complex nature of predicting these types of events highly challenging. In order to improve predictions of these types of events it is critical that the pre-failure conditions and triggering mechanisms of such an event are understood. In this paper, it is hypothesized that it was a unique combination of initial conditions that enabled the Oso landslide to transition into a highly mobile flow slide. To study this hypothesis, a numerical model was calibrated based on recent publications of flow slides triggered in physical model experiments. The finite element program was then used to perform a parametric study on the influence and sensitivity of the triggering conditions present at the time of the Oso landslide. The soil properties, slope dimensions, groundwater conditions, and precipitation intensity and duration at the site of the Oso landslide have been well defined and served as inputs into the model. In simulations using drier soil conditions, the mobility of the landslides triggered on varying slope angles was not significant. However, during extreme precipitation simulations, a landslide triggered on a more gently inclined slope was shown to have a higher mobility than one triggered on a steeper slope. The results of the parametric study show that the gently inclined slope angle and the antecedent precipitation during the month leading up to the Oso landslide were key components in triggering the devastating flow slide. The results of this study highlight that slope angle and antecedent precipitation should be both evaluated and hold significant weight when calculating landslide risk.

NUMERICAL ANALYSIS OF LIQUEFACTION MECHANISM IN HYDRAULIC FILL DAMS

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As one of the most complex and controversial topics in geotechnical engineering, liquefaction is a major seismic hazard to various earth structures. Loose and saturated deposits in seismic areas are most susceptible to this phenomenon. Reports of failure in Hydraulic fill dams indicate that one of the most prevalent and destructive failure modes in such geotechnical structures is liquefaction. In this paper, using Finite Difference Method, the behavior of the Lower San Fernando dam, being by far the best documented case, during 1971 San Fernando earthquake was studied and the corresponding liquefaction induced slide was investigated. So, using nonlinear soil constitutive models, the excessive pore water pressures and displacements in different points of the model were computed using an explicit finite difference method. Furthermore, the results were compared with those obtained from field investigations and numerical analyses conducted by other researchers. Based on the current comparisons, the predicted displacements, pore pressures and deformation patterns are in a reasonable agreement with the findings of previous studies.

U.S. GEOLOGICAL SURVEY: CLIMATE AND PERMAFROST MONITORING NETWORKS - ARCTIC ALASKA

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In the late 1970's the USGS began periodic monitoring of permafrost temperatures in an array of deep boreholes on the Arctic Coastal Plain in the National Petroleum Reserve - Alaska (NPR-A). By 1990 these data were indicating significant permafrost temperature changes. In order to understand and attribute causes of the observed changes in deep permafrost, and to improve future climate impact assessments, the USGS established an array of climate-monitoring stations to form the U.S. Department of the Interior/Global Terrestrial Network for Permafrost (DOI/GTN-P) Observing System. This two-component array currently consists of 16 automated surface stations and 23 deep boreholes spanning the National Petroleum Reserve–Alaska and the Arctic National Wildlife Refuge. The first surface stations were installed during August 1998, so now more than a decade of high-quality observational data are available from some locations. Aspects of the physical environment monitored each hour by these stations include shallow permafrost temperature at 10 depths (from 5 to 120 centimeters), active-layer thaw depth and duration, soil moisture, air temperature and pressure, wind speed and direction, upwelling and downwelling shortwave radiation, surface albedo, snow depth and duration, and rainfall. Deep permafrost temperatures from the entire borehole array are acquired every 5 years. The full borehole permafrost record spans 40 years. An overview of the DOI/GTN-P observing system is presented along with representative data. Initial trend analysis from the surface station array indicates that air temperatures and near-surface ground temperatures are increasing at a rate of about 1 K/decade. Active layer duration, an important physical and ecological parameter, is increasing, driven by a distinct delay in the date of autumn freeze back by approximately 3-4 weeks in the last 15 years.

SITE PREPARATION FOR VANCOUVER AIRPORT DESIGNER OUTLET CENTRE, SEA ISLAND, RICHMOND, BC

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This paper presents a case history of the site preparation that was undertaken for a large commercial retail development on Sea Island, Richmond, British Columbia, near the Vancouver International Airport. The site low grade required filling to achieve flood protection. The site subsurface conditions included loose sand and silt that can liquefy under the design earthquake for the area and soft compressible deep deltaic deposits that can generate large long-term settlement under fill loads. The site investigation and analysis concentrated on estimating the expected post-construction long-term settlement and assessing the soil liquefaction hazard under the national building code design seismic event. A preload treatment was designed to achieve an acceptable post-construction settlement performance of the large number of small buildings and adjacent public amenities. In-depth soil densification using the vibro-replacement method was selected to mitigate the risk of soil liquefaction and foundation shear punching failure. The site preparation was complicated by the proximity of the Fraser River, a recently built active airport light transit train and a vital jet fuel pipeline that required relocation. The paper describes a comparative interpretation of both Static Cone Penetration Tests (CPT) and Standard Penetration Tests (SPT) for soil liquefaction assessment and mitigation. The paper also describes the calibration of settlement analysis and calculations using long-term field monitoring data available from nearby sites.

INVESTIGATION OF PILE BEHAVIOR IN LIQUEFIABLE SOILS DURING EARTHQUAKES

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The presence of a liquefied soil layer in seismic areas has significantly influenced on the behavior of piles during earthquakes. This is partly due to the reduction of strength and stiffness of the liquefied soil as the pore water pressure is increased. Considering the observed pile damages during earthquakes, identifying the factors involved in the seismic response of such structures in liquefiable soils is of special importance. In the current study, with making use of Finite Difference Method (FDM), the influence of the liquefied soil layer slope and the water table level on the pile behavior has been assessed. The results indicate that the magnitude of maximum shear force and bending moments produced in the piles are increased as the slope of the liquefied soil layer increases; this is due to the increase of loads exerted by the liquefied soil layer on the corresponding pile surface. Based on the present study results, it is also observed that lowering the water table level in the steeper slopes leads to a reduction of internal forces, whereas these forces are increased in more level ground surfaces.

PERMAFROST CONDITIONS IN THE NORTHERN REGIONS THAT HAS TO BE CONSIDERED IN THE ARCHITECTURAL DESIGN.

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This paper first offers the definitions of permafrost and then deals with the history of continuous and discontinuous permafrost in northern regions of Canadian Arctic particularly in Yellowknife the Capital of the Northwest Territories.

The extensive permafrost region of Northwest Territories poses special engineering problems for the design, construction, and maintenance of all types of structures. Lack of knowledge about permafrost has resulted in tremendous maintenance costs and even in relocation or abandonment of certain structures.

the research will explores the global warming that effects the permafrost conditions in the architectural and engineering design of buildings in the north. The study will explains that permafrost in northern regions contains carbon, about twice as much as the atmosphere, and then attempts to explore, the impacts of thawing carbon-rich permafrost in production of greenhouse gases which is important for architects and engineer to know in their professional practice.

In conclusion, this paper offers some suggestions that because of the unique environmental conditions that exist in permafrost area, how the special architectural and engineering procedure should be used to provide the most economical and practical methods for design and development in the permafrost regions of the northern regions. ,

GEOLOGICAL MAPPING AND GEOTECHNICAL CHARACTERIZATION OF A SUBGLACIAL TRACTION TILL FROM EXCAVATIONS NEAR FORT MCMURRAY, ALBERTA

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The construction of the north starter dyke of the Sand Cell 2 Tailings Dyke at Jackpine Mine, near Fort McMurray, has permitted the geological mapping and geotechnical characterization of glacial units typically encountered south of the Fort Hills Thrust Moraine. The lithologies, internal structures and contacts between the glacial units were mapped in three excavations as part of this study. The collected data was supplemented with remote sensing, site investigation and laboratory testing data from the surrounding area to form a geological model for the study area. This study has provided further insight into the Quaternary geological setting of Fort McMurray and its implications on the design and operations of tailings dams and seepage management systems in the oil sands industry. The study concluded that a glacially overridden and streamlined moraine is present above a buried, tunnel channel, known regionally as the Kearn Channel. The moraine is overlain by a sequence of glacial-fluvial outwash sands transgressing upwards into proglacial lacustrine deposits.

The moraine comprises matrix-supported, subglacial traction till and glaciotectionized rafted bedrock, both of which were derived from the reworking of the geotechnically problematic Clearwater Formation. The moraine is analogous to the Firebag Till. Large-scale deformation structures and erosional channels were mapped within the moraine. Geotechnical testing indicated that the subglacial traction till is typically of intermediate plasticity with a spatially variable silt and sand content. Advanced testing and empirical correlations were used to derive two sets of characteristic values for the subglacial traction till, applicable for the geotechnical design of the tailings dyke. The overlying unit of plane-bed and cross-bedded, glacial-fluvial outwash sands are likely to influence the pore pressure response of the underlying till and overlying lacustrine units.

COMPARAISON RÉGIONALE DE LA DYNAMIQUE DES AVALANCHES DE NEIGE; DES CHIC-CHOCS (QUÉBEC, CANADA) AU MONT WASHINGTON (NEW HAMPSHIRE, ÉTATS-UNIS)

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Historiquement, les avalanches de neige constituent un géorisque important dans le Nord-Est nord-américain. Au Québec, il s'agit du deuxième risque naturel le plus important en termes de fatalités depuis 1850. Au Mont Washington (New Hampshire, États-Unis), lors des quinze dernières années, 44 personnes ont été accidentées après avoir été prises dans une avalanche; 3 en sont décédées. Dans un contexte d'augmentation de la fréquentation du terrain avalancheux des milieux alpins et subalpins par les skieurs et les alpinistes, une compréhension accrue des scénarios météorologiques expliquant l'occurrence d'avalanches de neige est primordiale. Bien que des études aient été menées à l'échelle locale, il n'existe aucune donnée sur la dynamique avalancheuse à l'échelle régionale. Les objectifs de cette étude sont : 1) de comparer le synchronisme des années de forte activité avalancheuse dans les Chic-Chocs (Gaspésie, Québec) et au Mont Washington; 2) d'identifier les différents scénarios météorologiques favorables à l'occurrence d'avalanches de forte intensité dans les deux massifs, et 3) d'identifier les systèmes synoptiques préférentiels associés à ces scénarios météorologiques. Les années de forte activité avalancheuse ont été identifiées par dendrochronologie. Les résultats préliminaires montrent que l'activité avalancheuse régionale dans les Chic-Chocs et au Mont Washington est généralement asynchrone. Or, les scénarios météorologiques expliquant le déclenchement d'avalanches de neige sont similaires dans les deux régions d'étude et favorisent l'occurrence d'événements causés par les impacts directs des aléas météorologiques. Cependant, l'asynchronisme des chronologies semble indiquer que ces scénarios météorologiques sont associées avec le passage de différents systèmes synoptiques.

A NEW SOFTWARE TOOL FOR SITE-SPECIFIC SEISMIC ANALYSIS AT DIFFERENT HAZARD LEVELS

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The 2010 National building code of Canada (NBCC) refines the fourth generation seismic design guidelines proposed in the 2005 NBCC and provides comprehensive data on the expected seismic loading intensity at different cities across Canada at a specific hazard level. The amplification factors F_a , F_v proposed in the code correspond to ground motions that have a 2% chance of exceedance in 50 years. While this sets the ultimate design target, there are many instances when a knowledge of the amplification factors at other hazard levels is required.

A utility software developed at Carleton University incorporates all aspects of such analysis into one common tool; Selection of site specific hazard levels, generation of artificial ground motions to match the local site and hazard levels, and the one dimensional SHAKE type analysis. While the drawbacks of using artificial ground motions are recognized, this approach allows the evaluation of the response under a large number of time history records, and thus the averages are expected to be more meaningful. This tool uses data available through Google maps api, and geological survey of Canada (as part of the NBCC 2010 database) to generate site specific input motions for any address in Canada.

A numerical study has been undertaken to evaluate and compare site specific amplification factors under different seismic hazard levels that represent return periods of 100, 500 and 1000 years, in addition to the 2500 year event at three sites in Ottawa. Both, artificial ground motion records generated to match the expected hazard levels and recorded time histories in the local region were used to run a number of one dimensional site amplification analysis which enabled the generation of site and hazard specific amplification factors. The effect of using artificial spectra-matched ground histories is compared to the outcome of analysis using recorded time histories.

SMALL STRAIN MODULUS AND DAMPING MEASUREMENTS USING SIMPLE SHEAR

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This paper presents the details of the modifications made to the Carleton University simple shear device to enable the measurement of very small strains in an attempt to develop modulus reduction and damping curves for dynamic analysis. Modulus reduction and damping curves are key input parameters in site response analysis to evaluate the potential for local site amplification during earthquakes.

Two ultra-high resolution LVDTs were added to the device, and both the signal conditioning system and the data acquisition program were improved to enhance the measurement resolution of the device. These changes enabled the measurement of very small movements to allow reliable measurements at strain levels as low as 0.001%.

A series of tests were conducted on two different sands at different density states over a range of confining stress levels, and a local sensitive clays at in-situ stress level to evaluate the performance of the device after the modifications. These test results indicate that this device has sufficient repeatability to measure the shear modulus and modulus reduction characteristics from strains ranging from about 0.001% to 5%. The device was used to measure damping curves over the same strain range as well but it was noted that there was relatively large scatter in the damping data compared to the modulus reduction data.

THE RESULTS OF 5- YEAR EXPERIMENT OF METHANE PRODUCTION FROM FROZEN SOILS

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It is essentially important to identify sources of methane and to estimate the total flux of methane on the Earth. The question of origin of the methane as well as presence and activity of methanogenes at low temperatures remains unclear. Methane production was observed at low temperatures in the laboratory during a long-term experiment.

Samples of frozen soils were taken from Yakutsk (Russia), Fairbanks (USA) and Tomakomai (Japan) and incubated at -5°C in order to study possible methane production. The Yakutsk soil sample was a sandy loam and had a natural salinization of about 0.08%. The Alaskan sample was taken from eluvial deposits in the active layer. The Tomakomai sample was taken from the experimental forest of Hokkaido University, in a flood-land of a creek. All samples were over saturated by de-ionized water to keep anaerobic conditions of incubation. The weight of each soil sample was about 300 g of wet soil. The soil was incubated in glass flasks covered by a rubber plug. The flasks were placed in a refrigerator in a vertical position and frozen at the temperature of -5°C for three days. After freezing the air in the flasks has been exchanged to nitrogen to have anaerobic conditions; some samples were sterilized at 121°C for 1 hour. Then the flasks were kept in the refrigerator at -5°C. The measurement of methane content in the air of the flasks was conducted through the rubber plug by a syringe at various intervals-from week to a month. The samples were incubated for about 5 years. During the experiment some samples were thawed and frozen again.

We almost did not observed methane emission from the Yakutsk samples. The emission from the Alaskan and Tomakomai samples was slow; however, methane concentration in the air of flasks was significantly increased at thawing. We observed an increase of the carbon dioxide emission also.

DETERMINATION OF SOIL-WATER CHARACTERISTIC CURVE OF SLURRIED AVONLEA CLAY

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Determination of the soil-water characteristic curve (SWCC) of clay slurries is difficult because of settling during the application of suction (Ψ). Three different methods were used in determining the SWCC of a slurried sample of highly expansive Avonlea clay ($w_L = 180\%$, $w_P = 60\%$, $PI = 120\%$) at the liquid limit. These methods include the pressure plate (0 to 500 kPa), pressure membrane (500 kPa to 1500 kPa) and potentiometer (1000 kPa to 300,000 kPa). Data were plotted with gravimetric water content (w), volumetric water content (θ) and degree of saturation (S). The air entry value (AEV) for w , θ and S were 28 kPa, 100 kPa and 1000 kPa corresponding to gravimetric water contents of 200%, 145% and 60%, respectively. A shrinkage curve was determined to understand the above data. The shrinkage was found to be a J-shaped with normal shrinkage from $S = 100\%$ to 80 % ($w = 200\%$ to 43%) which then gradually entered a low residual shrinkage from $S = 80\%$ to 40% ($w = 43\%$ to 14%) with a shrinkage limit of 23%. The AEV obtained from the S versus Ψ plot corresponded to a water content of 60% (w_P) which correlated well with the shrinkage curve.

CONSOLIDATION PROPERTIES OF A CLAY-RICH URANIUM SLURRY

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The main objective of this paper was to investigate the consolidation properties of a clay-rich uranium slurry using a custom fabricated test equipment. The volume compressibility, measured at low effective stress of 0.3 kPa to 30 kPa, showed a reduction in void ratio from 2.7 to 2.1. The entire relationship was found to consist of an initial flat slope due to flocculation followed by a steeper slope due to microstructural collapse under loading. The hydraulic conductivity was determined after the completion of primary consolidation under incremental loads and the reduction was found to be one order of magnitude (10⁻⁹ m/s to 10⁻¹⁰ m/s) for the measured effective stress range.

DEVELOPMENT OF A METHOD TO DETECT SUBSIDENCE BY D-INSAR IN PERMAFROST REGIONS

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One quarter of the northern hemisphere is covered by permafrost and characterized by seasonal surface thaw (active layer). Warming provokes a deeper thawing layer during the summer months and this potentially has consequences for the ecosystem and the local infrastructure. The main goal of the proposed future study is to develop a new method that improves high-resolutions detection of vertical movements (freeze- thaw) using TerraSAR-X satellite data. The detection of fine-scale vertical surface movements by thawing and freezing will be explored using differential interferometry (D-InSAR). Furthermore, the TanDEM-X DEM will be evaluated by means of LiDAR and d-GPS records for an arctic region (Mackenzie delta area) with tundra vegetation.

MULTI-PROXY RECONSTITUTION OF THE RAPID DRAINAGE EVENTS OF A THERMOKARST LAKE AT MARRE-SALE, YAMAL PENINSULA, SIBERIA (RU).

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Marre-Sale (N69°42'03"–E66°48'52"), located on the western coast of the Yamal Peninsula is well within the continuous permafrost zone of Occidental Siberia (RU). MGST at location was –6.37°C for 09/2009–09/2010 interval (1). Scores of stable and active thermokarst lakes were observed in the thick and ice-rich Pleistocene deposits (2) constituting the flat terrace, along with sparse meandering streams and dendritic gully networks. Ice-wedge polygons network, either intact or eroded (baydzherakhii), were common through these lowlands. Lake drainage through gullies were frequent in this area due to coastal thermal erosion (3). However, detailed onsite monitoring of lake drainage with event reconstitution have rarely been reported in the literature. One such lake ($\approx 0.4\text{km}^2$), located $\approx 2\text{km}$ south of Marre-Sale research station, was closely studied through the events leading to its ultimate drainage in 2010 and the subsequent geomorphological evolution of its lake basin.

The objective of this paper is to present the reconstruction of the successive drainage events of a lake at Marre-Sale, using a multi-proxy approach. Proxies included historical aerial photography and satellite imagery validated in the field with a GPS. Successive lake levels and vegetation distribution were surveyed along a cross-section of the drained lake basin. The drained lake area was then divided into eco-geomorphic zones based on the succession of stages.

The first drainage event occurred during the 1980s through a 150m long gully connecting the lake with the Kara Sea littoral to the west. This gully initiated as a result of coastal erosion dynamics, the littoral erosion first reaching and exposing ice-wedges, then cutting through ice-rich lacustrine sediments from a small ancient drained lake located behind, and then through ice-wedges toward the recently drained lake. A second drainage event began in 2007 and was completed in 2010, via the evolution of the original gully breaching the lake shore and reaching the level of the lake. Several retrogressive thaw slumps were observed following the recent disturbance. Implications of this type of rapid lake drainage processes for ice-rich permafrost terrains dynamic at the landscape scale are discussed.

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LARGE-SCALE AND LONG-TERM SETTLEMENT MONITORING: THE BENEFITS OF USING REMOTE SENSING FOR MAJOR GEOTECHNICAL PROJECTS.

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Remote sensing is defined as any technique for measuring, observing or monitoring a process or object without physically touching the object under observation (non-intrusive). This technology can thus lend itself to monitoring large areas that are either difficult to reach or to instrument (i.e., unstable slopes near transport corridors, buildings, railroads, tunneling/excavation).

One of this technique is called satellite-based Synthetic Aperture Radar Interferometry (widely known as InSAR) where the energy source is provided by emitting a signal and recording the reflected signal. Similar to LiDAR (Light Detection And Ranging), InSAR technique can work in daylight or darkness but do not provide the same information. Indeed, LiDAR is often used to map opaque surfaces at very high resolution in order to create a Digital Topographic Model (DTM) whereas InSAR technique is much more adapted to measuring change in surface in the order millimetres for every single image pixel of the image.

Nowadays recent satellite constellations enhance frequent monitoring (every 4 to 12 days) and high density of measurement (1m to 3m spatial resolution). This remote sensing technique provides a wider and more uniform spatial coverage compared to sparse point measurement available through standard geodesy techniques (e.g. GPS, levelling points).

The 12.5km Ottawa Light Rail Train (OLRT) project started in 2013 and includes a 2.5km tunnel in the downtown of Ottawa, Ontario and should be completed by 2018. For this mega project it is crucial to identify issues and to mitigate potential long-term impacts of project construction. To provide increased information on possible impacts, levelling survey type monitoring was an option but this tedious process could not be done for the entire OLRT corridor without large costs and invasive installation of surveying monuments. Thus a technique based on remote sensing was chosen as an alternative and a large scale InSAR monitoring program started in the spring of 2014.

The spaceborne dataset collected through the project contains a wealth of information about the city's critical infrastructure: bridges, railroad, train station, airport with runways etc. InSAR derived results, with a standard deviation of +/- 4mm, present a robust large scale monitoring method complementary to traditional techniques. To extend life of aging critical infrastructure and assessed climate change impacts, monitoring program should include a long-term remote sensing component.

**TASSEMENT ET INSTABILITÉ DES ARGILES SENSIBLES; DES DÉCENNIES DE DONNÉES NOUS
AIDERONS-ELLES À APPORTER DES SOLUTIONS?**

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L'est du Canada, principalement le Québec et l'Est de l'Ontario, sont au prise avec un grave problème résultant de leurs dépôts argileux sensibles. Les tassements et problématiques générés par l'assèchement et la dessiccation de ces argiles sont en augmentation et les coûts en croissance en regard des réchauffements climatique qui s'accroissent. La stabilité des pentes et des rives en raison des effets climatiques extrêmes et changeants et les phénomènes hors norme mesurés à nos cours d'eau accentuent cette problématique également. Quelles sont les données connues des résultats de cette problématique sur nos milieux urbains et la société quant aux coûts, au nombre de structures et infrastructures touchées et des méthodes de remédiation? Comment les géotechniciens peuvent-ils analyser ces phénomènes et comprendre toute l'ampleur de leur répercussion sur le patrimoine bâti de ces régions? Quelles mesures peuvent être prises afin de pallier à ces problèmes? Comment pouvons-nous orienter l'implication des codes nationaux dans les solutions à apporter à cette problématique? De par ses 18 années passées à analyser et solutionner les problèmes générés par l'assèchement de l'argile et l'instabilité des pentes et à étudier ce phénomène, le conférencier abordera ces questions et apportera des éléments de réponses. Avec plus de 6 000 à 7 000 cas du genre analysés, solutionnés et étudiés, combiné à une analyse de problématique similaire ailleurs dans le monde, l'échantillonnage permet maintenant de porter un regard tout autre sur l'implication de ces sols sur notre environnement et y apporter un nouveau regard. Les méthodes et approches appliquées aux argiles de Londres entre autres, argiles similaires aux nôtres, méthodes qui se sont améliorées en raison de la grande sécheresse de 2003 en Europe, nous donneront aussi un nouveau regard sur ce phénomène qu'est l'assèchement des argiles sensibles.

DYNAMIC GROUP PILE EFFECT UNDER FULLY COUPLED NON-LINEAR SOIL-PILE-STRUCTURE INTERACTION IN SOFT CLAY

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There is an increasing awareness in geotechnical and structural engineers about the incorporation of seismic soil-structure interaction in the seismic performance-based design of pile foundation and supported structure. Accurate prediction of their response requires analysis with fully coupled consideration of soil-structure interaction mechanism, particularly in soft clay deposits with strong nonlinear behaviour. In a group pile foundation, seismic soil-pile interaction can lead to a group effect different from the p -multiplier assumption that is basis for the conventional guidelines for lateral design of group pile foundations, available in the design codes (API, CFEM). This study aims to look into the dynamic group effect under influence of the vibrating structure with varying structure-to-soil relative stiffness on the dynamic group effect in the course of a coupled soil-pile-structure interaction. For this purpose, a 3D dynamic finite element model is developed in the framework of OpenSees code, with a nonlinear constitutive model. The model consists of a soft clay deposit resting on rigid bedrock and a pile group supporting a SDOF system. In order to simulate the dominant geology configuration in city of Ottawa, the dynamic and monotonic properties of Ottawa's soft clay (Leda clay) obtained from simple shear tests and resonant column are input to the elasto-plastic constitutive model of soil. The contribution of group size including pile spacing and number of piles on dynamic group effect are the other variables to be investigated in this study.

SPATIAL VARIABILITY OF PERMAFROST HAZARDS TO COMMUNITY INFRASTRUCTURE, ARVIAT, NUNAVUT

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Communities in western Hudson Bay currently face a number of changes to their environment including warming ground temperatures, permafrost thaw, and an emerging coastline. This isolated region is also experiencing rapid population growth, community expansion, and infrastructure deficits with requisite building space constrained, in large part, by permafrost hazards. This research addresses a knowledge gap in the characterization and spatial distribution of warm, saline, ice-rich permafrost conditions at spatial scales suitable for community adaptation planning.

Most Canadian Arctic communities are located along coasts covered by the sea within the last 10 000 years. These communities have inherited a problematic legacy of saline permafrost due to rapid freezing of the former seabed upon emergence and exposure. Relict saline pore-water in permafrost sediments weakens inter-granular bonds, decreasing structural bearing capacity, and depresses ground thaw temperatures. For communities such as Arviat, underlain by warm permafrost already approaching 0C, the risk of permafrost degradation is compounded.

Recent literature supports the concept of a transition layer in Arctic soils, located between the active layer and permafrost. This transition layer is typically frozen, but experiences intermittent thaw on sub-decadal to multi-centennial time scales. It is also commonly ice-enriched, depending, in part, on soil moisture and silt content. The extent of transition layer development in Arctic soils has fundamental implications for soil response to climatic warming.

To represent both conditions at the community scale, we employ a model of near-surface ground-ice conditions in the transition layer and salinity in the underlying permafrost. This model is based on the combined analysis of 1:10 000-scale aerial photographs, QuickBird satellite imagery, sediment samples, and a 2014 digital elevation model (2 m horizontal scale). Results from this analysis generated two components informing the permafrost model: a community-scale drainage/ground wetness model and surficial geology map.

Ground wetness is used as the primary control variable for the model. High moisture content in the seasonal active layer promotes near-surface ground-ice accumulation in the transition layer. Silt content of surficial geology units is used as the secondary control. Unfrozen pore-water in permafrost migrates to the transition zone in silt-rich soils, concentrating saline conditions in the underlying permafrost.

This is the first systematic attempt to model both near-surface ground-ice and salinity conditions in near-surface permafrost at the community scale. It is conducted in partnership with the Government of Nunavut, Hamlet of Arviat, and 3VGeomatics and will inform community adaptation efforts in the face of a changing environment.

MODEL BEARING CAPACITY TESTS IN A LARGE LABORATORY SIMULATION OF POLYMER AMENDED MFT

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This paper investigates desiccation-consolidation of in-line flocculated oil sand mature fine tailings (MFT) and the consequent increase in undrained shear strength and bearing capacity in a laboratory simulation of multilayer deposition. Three layers of oil sand tailings of initial thicknesses of 0.3 to 0.35 m were deposited into a 0.7 by 1 m box in plan. The tailings, deposited at initial solids concentrations of approximately 36%, were dosed at 650 g of anionic high molecular weight polymer per tonne of dry MFT, were prepared using laboratory methods designed to be representative of field mixing conditions. The box was equipped with a drainage system, water content and pore-water pressure sensors distributed at varying heights, and scales. Height displacement sensors, photo cameras and hand measurements of crack width, length and height were used to estimate three-dimensional volume change.

The key finding with respect to dewatering was the role of cracks in evaporation. It was found that the appearance of cracks corresponded to an increase in evaporation rate. Moreover, the actual evaporation rate exceeded potential evaporation for times that coincided with ongoing crack growth. Subsequent to the cessation of crack growth, evaporation rates declined to or below the value of potential evaporation.

Vane shear tests were conducted before the deposition of each new layer. From these tests, the tailings, demonstrated relatively high shear strength in a comparably short period of dewatering time, reaching an undrained shear strength of > 5kPa, once they were dried out to 55-60% solids concentration in the top layer. Dewatering time was even shorter for the latter layers, where the underlying layers were aided by self-weight consolidation.

Plate load tests were performed directly on the tailings, after the third layer was dried to approximately 60% and 70% solids concentrations, with a circular plate with a diameter of 10.5cm. The model bearing capacity tests results were compared to values obtained using the modified effective stress approach considering the influence of matric suction.

APPROCHE VIRTUELLE POUR LA GÉNÉRATION DE MILIEUX GRANULAIRE ET L'ÉVALUATION DE LA CONDUCTIVITÉ HYDRAULIQUE.

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Les caractéristiques hydrodynamiques d'un sol dépendent essentiellement de la géométrie de la structure du réseau poral. La quantification de cette structure complexe n'est pas aisée. Elle est caractérisée par des propriétés géométriques liées à la forme (morphologie) et à la connexion (topologie) entre les pores. Plusieurs approches sont proposées. L'approche la plus simple consiste à représenter le milieu poreux par un ensemble de tubes cylindriques parallèles. D'autres représentations plus complexes sont proposées dans la littérature telle que la représentation de l'espace poral comme un assemblage de pores en réseaux. Ces réseaux sont des maillages réguliers de l'espace bi ou tridimensionnel de topologie variée. Devant l'échec relatif de la stricte description géométrique du réseau poral, un outil de simulation virtuel pouvant générer un milieu poreux avec différentes compacités et se caractérisant par une bonne capacité de prédiction de la conductivité hydraulique saturée a été développé. Dans la pratique, la conductivité hydraulique est essentiellement déterminée en laboratoire ou à l'aide de relations empiriques. Les relations empiriques proposées nécessitent la connaissance de paramètres qui demeurent entachés d'incertitudes et parfois difficiles à évaluer. On peut citer notamment la surface spécifique mais aussi la tortuosité. Cette dernière traduit l'arrangement particulière au sein du milieu poreux. La littérature propose plusieurs relations de la tortuosité. Pour la plus part, ces relations ont été établies sur des modèles en deux dimensions. L'approche virtuelle permet au préalable de générer un milieu poreux constitué de particules sphériques dans un volume élémentaire représentatif qui sera soumis à un écoulement. Une représentation visuelle de la tortuosité dans un milieu tridimensionnel généré virtuellement est présentée. L'analyse de problèmes associés à la caractérisation de milieux poreux à partir de la distribution des lignes d'écoulement (tortuosité) sera aussi présentée. Les images des champs de pression dans les pores dus à l'écoulement seront aussi montrées. Par ailleurs, cette approche permet de définir précisément la surface spécifique et la porosité. Ce papier présentera aussi le principe de génération des milieux poreux constitués de particules de forme naturelle. Les résultats expérimentaux seront comparés à ceux obtenus à partir des relations empiriques.

ROLE OF CRYOGENESE IN FORMATION OF COMPOSITION OF LATE PLEISTOCENE-HOLOCENE DEPOSITS IN KOLYMA LOWLAND, NORTH EAST YAKUTIA

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The complex geocryology studying of Duvanny Yar, main Yedoma exposures at North East Yakutia, focused on cryolithology and sedimentary origins of Late Pleistocene and Hlocene deposits.

In Cold Regions transformation of sediment (diagenesis process) into deposit are accompanied by processes of cryodiagenesis, what lead to formation of specific deposits. One of mainly factors is cryogenic weathering – selective destruction of minerals and forming of these specific distributions on grain-size fractions (Konischev, Rogov, 1993). This process is intensive in active layer, the most temperature unstable layer of permafrost. For assessment of cryogenese was used Cryogenic Weathering Index (CWI) – ratio between quarts and feldspars in thin sand and dust fractions.

Samples from different facies of Ice Complex and Cover Layer were collected in summer of 2013 in Dyvanny Yar. Laboratory studying include grain-size, mineralogy, CWI calcultaiion and scannig electronic microscopy.

The detailed investigations of Ice Complex of Dyvanny Yar deposits have ascertained the cyclic structure of cryolithogenic strata by the changes in the environmental conditions during the process of sedimentation. It has found that the most favorable conditions for cryogenic weathering had occurred at the Late Pleistocene-Holocene, as evidenced by high values CWI (up to 2,5) and morphology of quarts grains from Cover Layer.

In Yedoma thickness we can select 2 main types of deposits: lower layer with thick (3-5 m) and infrequent (10-15 m) ice wedges and upper layer with thin (0,5-2 m) and freuqent (3-6 m) ice wedges. According our studying first facies was sedimented in shallow lake, slow stream and downslope processes. Upper facies of yedoma was sedimented in slow and thick rivers, floodplained. CWI values indicate a cyclic change of permafrost conditions during the forming of Ice Complex. The most cryogenese affected samples were collected from upper layer of Yedoma (CWI - 1.7).

Distribution of heavy minerals in grain size fractions shows, that in ice wedges mineral material is more sorting, than in mineral blocks. We think it's result of the existence of streams over the head of ice wedges during the period of accumulation of yedoma thickness.

AGRICULTURAL ADAPTATIONS TO CHANGING PERMAFROST CONDITIONS IN SOUTHERN YUKON

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Yukon agriculture is adapting to the challenges caused by existing and changing permafrost conditions. This study identifies indicators of permafrost and changing permafrost conditions, documents adaptations farmers are making and uses that information to improve the application of baseline soil mapping, climate scenario models, and the Agriculture and Agrifood Canada (AAFC) Land Suitability Rating System (LSRS) to modelling of future land suitability for agriculture. The study area consists of valleys surrounding Whitehorse, where agricultural development has occurred over the past century. Detailed 1:20,000 soil mapping is available for much of this area and is being currently being used with LSRS for modelling. The presence of discontinuous permafrost causes problems for agriculture so understanding where permafrost occurs and its condition is important for agriculture development. Warmer temperatures will likely increase the pressure for clearing and cultivating land underlain by near-surface permafrost with resultant warming and lowering of the permafrost table in these soils. Excess moisture as ground thaws can limit access, increase development costs and cause delays. Existing research (Burn 1998) and experience in the area has indicated that permafrost is present at depth in many areas not reflected in the surface vegetation. Existing research and observations also show that fire and cultivation can result in long-term changes to the thermal regime of soils particularly significant where ground ice is present at depth. In extreme cases, usually associated with moderately fine-textured soils (silts and clays), surface subsidence over decadal time periods can render fields unusable, underlying the importance of assessing deeper permafrost and ground ice conditions as well as surface soils in agriculture decision making. This ongoing study uses farmer's adaptations to permafrost and changing permafrost conditions to improve the application of LSRS in climate change modelling in discontinuous permafrost areas.

ANALYSE DE LA SIGNATURE LAISSÉE PAR LE TSUNAMI GÉNÉRÉ PAR UN GLISSEMENT DE TERRAIN AU LAC DES SEIZE ÎLES, QUÉBEC, CANADA, LE 15 AVRIL 2014

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Le 15 avril 2014, un glissement de terrain s'est produit sur la berge d'un lac dans la municipalité du Lac-des-Seize-Îles, à environ 100 km au nord de Montréal. Le glissement de terrain, dont la longueur et la largeur sont respectivement de 94 et 55 m, a mobilisé un volume estimé à 30500 m³ de matériau composé d'un till sableux à graveleux. L'élément déclencheur semble associé à de forts épisodes de pluie ainsi qu'à la fonte rapide du couvert neigeux, causant une infiltration rapide et importante d'eau dans le sol. La masse mobilisée, en s'étalant au fond du lac, a générée une vague qui a brisé et soulevé le couvert de glace intact à la surface du lac. L'eau et la glace ont détruit et endommagé de nombreuses résidences saisonnières, de même que de nombreux quais et abris à bateaux situés sur le pourtour du lac. La zone affectée s'étend sur près de 400 m au nord et de 600 m au sud du glissement. Des observations sur des photographies aériennes prises peu de temps après l'événement ont révélé l'existence d'une structure de fissures radiales sur la glace montrant l'évolution et la propagation de la vague générée. Des données bathymétriques relevées par des sondages de l'Université de Montréal en 2013 ont permis de déterminer la profondeur du lac dans la zone affectée. Cette profondeur varie entre 5 et 10 m à proximité du glissement de terrain. Des investigations de terrain réalisées sur les rives est et ouest du lac ont permis l'observation de marques sur des troncs d'arbre expliquées par le choc des fragments de glace lors de la phase d'inondation. La hauteur d'inondation peut atteindre 1,8 m sur la rive ouest, dans l'axe d'étalement du glissement de terrain. Le présent article présente toutes les évidences morphologiques sur et autour du lac concernant la génération, la propagation et l'inondation de la vague provoquée par le glissement de terrain.

LAKE BOTTOM IMAGERY: A SIMPLE, FAST AND INEXPENSIVE METHOD FOR SURVEYING SHALLOW FRESHWATER ECOSYSTEMS OF PERMAFROST REGIONS

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Freshwater ecosystems are very abundant in permafrost landscapes and show a great diversity of shapes, sizes, and limnological properties. They also play a key role in maintaining the traditional lifestyle of northern communities (e.g., fishing and hunting) and are hotspots for biogeochemical exchanges between terrestrial, aquatic and atmospheric environments.

Paleolimnology, the history of freshwater ecosystems (especially ponds and lakes) and their drainage basins based on lacustrine sediment archive analysis, has gone through several methodological and conceptual developments during the last decades. This multidisciplinary field greatly benefited from technological advances in many disciplines such as electronic microscopy, image analysis or radiometric dating. Yet, the first fundamental task of paleolimnologists has remained the same over the years: collecting good quality lake sediment cores at sites representative of lake internal and external conditions, generally – but not always – the deepest portion of the lake basin. This location is rarely the center of the lake and is hardly revealed by direct visual observations, which complicates the choice of the optimal sampling site. Seismic or acoustic technologies can be of great help in characterizing lake basin's morphology, but they are generally expensive and/or time-consuming, difficult to conduct in remote regions and poorly adapted to shallow thermokarst ponds and lakes.

Here we present a novel strategy of sampling lacustrine sediments using portable lake-bottom imagery, including user-friendly, GPS-assisted sonar technology, underwater HD photo-video camera, cellular phone and pore water pressure/temperature sensor. The sonar records depth signals and interpolates data between survey lines to create georeferenced bathymetric maps of lake/pond basins that can be visualized on-site. Lake bottom sediment conditions are visualized using a waterproof camera installed on a light-weight pole, controlled from a boat or the lake shore, which provides multi-directional photo/video. The camera is equipped with LED lights to be able to shoot pictures/videos of the water column and lake bottom even under restricted light conditions. A pore water pressure transducer/temperature sensor equipped with a datalogger is fixed on the pole and is used to continuously compute depth and water/lake bottom temperature. An antenna links the camera to a cellular phone/tablet which permits real time observation of lake water and lake bottom conditions. This optimized data-collecting set-up provides new insights into limnological aspects of remote aquatic systems such as thermokarst ponds and lakes, is efficient for localizing the best coring sites, and allows a better interpretation of the results.

MINIMIZING RISK IN KARST ENVIRONMENTS USING GEOPHYSICS

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Minimizing risk for any geotechnical project involves obtaining as much information as possible about potential hazards in both the planning and development stage of a project. Mapping karst is particularly challenging as it can be unpredictable both in location and size. Geophysics is a very useful tool for both targeting drill holes, and for linking data between drill holes. In this way, the risk of a karst feature going undetected is minimized. We present case studies and discussions on optimal methods for integrating geophysics into a workflow for minimizing risk in karst environments.

Seismic surveys are sensitive to contrasts in density in the subsurface and as such are ideal for mapping karst. They can be used to target drilling more effectively by identifying anomalous areas. In addition, seismic surveys can be used to increase knowledge between drill holes and so decrease the risk and liability. We present a case study of a seismic survey conducted in the early stages of a dam siting project in Cougar Creek, Alberta, which identified a potentially critical karst feature in the planned alignment.

In some situations direct detection of karst can be challenging for a variety of reasons. In these situations secondary effects of karst and may be more readily detectable using geophysics. We present two studies in which geophysics was used to map secondary karst structures in 3D and so triangulate the expected location of the karst.

IDENTIFYING RISK USING HYDROGEOPHYSICS

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In the surface mineable oil sands of northern Alberta, saline water from within the Devonian which occurs below the oil sands represents one of the major risks to mining operations. In the last few years, among the major oil sands operators, there has been a greater emphasis on understanding saline water from within the Devonian as part of their risk management programs.

In 2012, as part of their risk analysis, Suncor and DMT Geosciences studied one of the local known surface saline springs, Saline Lake, to map potential pathways for saline water from deep within the Devonian to the surface using a combination of airborne magnetics, airborne electromagnetic surveys, and water-borne seismic reflection. The study indicated a connection between the surface and structure observed in the Precambrian basement, which is a potential pathway for deeper saline water to migrate to the surface. The integration of multiple geophysical techniques over this structure identified geophysical indicators that may be used to map areas where the potential for a connection between the surface and the deep Devonian aquifers may exist.

A similar approach, but with the addition of ground electromagnetics was applied to Suncor's North Steepbank Extension (NSE) mine to produce a map showing areas of elevated risk of inflow of saline water into the mine. With the risk map, a mitigation strategy has been developed to reduce the risk of saline water to their mining operations.

RESPONSIBLE CULVERT DESIGN: EVALUATING CULVERT DESIGN LIFE FROM A SUSTAINABLE PERSPECTIVE

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In this paper there will be an examination of the relationship between culvert design life and sustainability. The design standards that apply to culvert design are AASHTO (American Association of State Highway and Transportation Officials), CHBDC (Canadian Highway Bridge Design Code), and AS/NZS (Australian and New Zealand Standards). These regulatory frameworks will be analyzed through the lens of sustainability. Sustainability will be addressed from the standpoint of a business model, environmental impacts through climate change and the effect of storm events, and wildlife habitat protection through the use of highway crossings. The literature that will be reviewed is; "The Sustainability Imperative", Harvard Business Review, David A. Lubin, and Daniel C. Esty, a study conducted by the City of Toronto about "Climate Change Vulnerability Assessment for Culverts", and also literature that is examining highway improvements to minimize environmental impacts in Canadian Rocky Mountain National Parks, and biodiversity impacts of a four lane highway and American Black Bears in North Carolina. Further relevant literature will be reviewed in this paper. Factors influencing design life are often neglected, and as a result can have hidden costs of repeated installation and ecological damage. In this paper based on our research, we have discussed that it is probable that culverts that have a longer design life will have a better sustainable position pertaining to environmental impacts.

SOIL PLUG FORMATION IN OPEN ENDED TUBULAR PILES

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The jacking force necessary to install open ended tubular piles is dependent on the resistances that are generated between the pile surface and soil during the installation process. Previous research has focused on providing greater understanding of these resistances in an effort to improve the efficiency and speed of the pile installation. External shaft skin friction along the length of the pile is typically accompanied by forces inside the tubular pile from either internal shaft friction or base resistance. The generation of base resistance, similar to a conventional pile, occurs if a soil plug forms inside the pile. The mechanics that govern the transition between internal shaft resistance, the onset of base resistance and full plug formation are not well understood.

The development of non-intrusive physical modelling capabilities using transparent synthetic soil in conjunction with Digital Image Correlation (DIC) have opened up new possibilities to develop our understanding of complex internal soil-structure interactions. Analysis of internal spatial deformation within the soil body is possible by tracking the trajectory of particles that are illuminated by a laser field and captured with successive digital images throughout the installation event. DIC enables the determination of vertical and horizontal displacements that yield the magnitude of strain experienced and thus offers the potential for enhanced understanding of soil plug formation. This paper describes a series of 1g and centrifuge physical model tests undertaken in transparent clay soil to observe the installation mechanics of open ended tubular piles in transparent soil. Model piles were manufactured from glass which enabled both external and internal soil pile interactions to be observed throughout the installation. The observations indicate that at shallow installation depths internal shaft resistances are prevalent; however, as the pile advances soil flows into the open end resulting in increasing internal resistance. This leads to the onset of soil plug formation and thus switching between the internal shaft friction and base resistance. Details of this mechanism offer new understanding of installation resistances and could lead to improved design understanding.

Furthermore, the work also presents a major milestone in advancing experimental methodology associated with transparent soil modelling whereby for the laser aided imaging transparent soil modelling technique has been successfully implemented within the centrifuge environment.

VÉGÉTALISATION DE SITES MINIERS À L'AIDE DE BIOCHARS

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L'exploitation minière transforme l'environnement en produisant différents résidus : résidus miniers provenant du concentrateur, boues résiduelles suite à un traitement d'eau et haldes à stériles miniers. La loi québécoise oblige maintenant les entreprises minières à fournir un plan de restauration de leurs sites, incluant ces résidus, qui sera mis en place à fin de leur vie utile. La mise en végétation de ceux-ci en fait partie. Cette étape représente toutefois un défi de taille puisqu'il s'agit de résidus instables, à pH extrêmes, secs, pauvres en matière organique et en éléments nutritifs et donc peu propices à la végétation. Des matériaux doivent donc être importés sur ces sites afin de favoriser la végétation. Le biochar, produit par la pyrolyse de matières organiques, possède des propriétés intéressantes pour la croissance végétale comme une forte rétention en eau, une faible densité, un pH basique et un nombre important de sites d'échanges cationiques. Le but de ce projet consiste à développer un substrat pour la croissance végétale sur ces résidus miniers dont les propriétés physico-chimiques sont améliorées par l'ajout de biochar. Deux types de biochars ont été combinés à différentes matières résiduelles fertilisantes en différents ratios formant huit substrats. Ces substrats ont été insérés dans des pots de 10 x 10 x 18 cm dont le fond était recouvert soit de 2 cm de roches provenant de haldes stériles acidogènes, de boues de chaulage ou de résidus fins, simulant les sites miniers visés par la végétalisation. Les propriétés physico-chimiques de ces substrats ont été analysées. Deux espèces de groupes fonctionnelles différents, *Alnus rugosa* (sous forme de boutures) et *Calamagrostis canadensis* (semé) ont poussé dans les 8 substrats en conditions contrôlées. La croissance et la santé des végétaux ont été suivies pendant quatre mois par différentes mesures comme le taux de germination, la biomasse, la photosynthèse, l'élongation et plusieurs autres observations. Les propriétés des biochars ont été mis en relation avec les propriétés des substrats comme la capacité de rétention en eau, la conductivité hydraulique, la disponibilité d'éléments nutritifs, la présence de métaux lourds et métalloïdes, le pH et la capacité d'échange cationique ainsi que la croissance végétale. L'issue permettra de documenter l'utilisation du biochar dans la fabrication de substrats pour la végétalisation de sites miniers.

REINFORCED SOIL COMPARTMENT FOR RAILROAD APPLICATION

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Although that the mechanically stabilized earth walls are widely use in the road and civil industry, there are often reluctances with this system in railways application, especially for high-speed railroad construction.

One of the uncertainties is coming from the lack of information about the strain on the structures under dynamic and cyclic load at high frequency, mainly for the high speed train. We need then to understand better the interaction in between the soil and the soil reinforcements in this condition.

This article will present the achievements in latest research program on Reinforced Earth walls in railway application under dynamic loading and discuss the effect of cyclic loads on the steel strip soil reinforcements. In addition, a project will be briefly presented for high speed train application.

There is also another reluctance related to the service life of the mechanically stabilized earth walls with steel reinforcements as the safety and durability of the structures over time is a big concern for railway organizations. Other issues such as the stray current effect on the metal soil reinforcements are also discussed in this paper.

FOUNDATION SOLUTIONS FOR LIGHT AND HEAVY CONSTRUCTION ON EXPANSIVE SOILS: CASE STUDIES

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In this paper two building projects of EllisDon Corporation are studied to compare the design and construction challenges involved in expansive soils. The first building is a hospital in Winnipeg, Manitoba which is a six-storey building with large span of 9-m. The second building is an agricultural building in Vancouver, BC. This building is a light weight building. Both of the buildings are founded on expansive soil.

Different foundation solutions are studied for both cases. The solutions are designed based on available geotechnical report. The geotechnical differences of the two expansive soils are also highlighted. The feasibility of the solutions are then investigated based on parameters like constructability, cost, and schedule.

Final recommendations are provided for the foundation type for each project.

PERMANENT SEISMIC DEFORMATION OF DRY SAND SLOPES

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The serviceability of slopes after earthquakes becomes a design concern when footings are founded near the slope crest. The literature focuses on the sliding block model and limit analysis to account for the permanent post-earthquake deformation. In this paper, the post-earthquake deformation of dry sand slopes is estimated by numerical analysis utilizing the finite element method. An artificial earthquake time history is used as a source of the seismic excitation. Different slope heights, slope angles, surface surcharges and peak accelerations are investigated. The seismic waves' propagation through the soil mass is also investigated. The results are presented in the form of charts intended to be useful for design engineers. In addition to quantifying the permanent post-earthquake deformation, the study recommends the safe setback distance for buildings near slopes.

OPERATIONAL PERMAFROST MONITORING IN NORWAY

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GTN-P

In southern Norway systematic permafrost ground temperature recording started in Jotunheimen in 1982, in shallow boreholes. Continuous long-term ground temperature monitoring was initiated in a 129 m and 20 m deep borehole at Juvvasshøe in 1999. Another monitoring program was started in 2001 in Dovrefjell in southern Norway, measuring ground temperatures in an altitudinal transect from deep seasonal frost at Hjerkinna to discontinuous permafrost at Snøheim in 11 boreholes, each 9 m deep. In northern Norway permafrost monitoring was initiated in 2001, and two 30 m deep boreholes were drilled in 2004 and equipped for continuous temperature monitoring. In 2007-2008 thirteen boreholes were drilled in the IPY TSP Norway project, the deepest Iskoras was 58.5m deep.

A significant upgrade and extension of the permafrost monitoring program was performed in 2014 at Juvvasshøe, Snøheim and Iskoras, which are now operational and a part of the official national network of real-time meteorological observations. New official automatic weather stations (AWS) were also established at these sites measuring air temperature, humidity, pressure, wind, snow depth and radiation. The combined official operational weather and permafrost stations are among the first of its kind hosted by a national meteorological institute. They serve as key-stations for the long-term permafrost and climate monitoring programs in Norway.

Historical and real-time observations are available for free downloading through self-service websites at the Norwegian Meteorological Institute (eklima.met.no, wsklima.met.no and arcticdata.met.no). Data will also be made available in the Norwegian permafrost database, NORPERM at the Geological Survey of Norway, and in the international Global Terrestrial Network on Permafrost (GTN-P) data system. Through arcticdata.met.no, a WMO Information System Data Collection and Production Centre, standardised index metadata will be made available for interaction with regional and global catalogues like WMO Global Cryosphere Watch. It will also facilitate data extraction interfaces to underlying databases and extraction of data in formatting adapted to international standards. Through the Global Cryosphere Watch (GCW), real time exchange of data can be set up using both Internet and in the future also WMO Global Telecommunication System if requested by the GCW user community.

New operational permafrost products will be presented, and previously acquired data from the sites included to present the latest changes in permafrost temperatures and active-layer thicknesses from various parts of Norway. Finally, we highlight the importance of high data quality, especially for warm permafrost sites.

MONITORING PERMAFROST CONDITIONS ALONG THE DEMPSTER HIGHWAY

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The Dempster Highway is a critical component of Canada's transportation infrastructure, because it is the only all-weather road that connects the western Arctic to the national highway network. For about 90% of its 736 km length, the highway has been built on continuous permafrost. The effects of climate change on ground temperatures have been well documented in northern Canada. Continued climate warming may pose a threat to the integrity of infrastructure and magnify the cost of highway construction, maintenance, and rehabilitation. This paper describes four long-term monitoring sites that were established in 2013-14 to characterize baseline permafrost conditions and follow changes in ground temperatures. The program was sponsored by Transport Canada, Government of Yukon, Government of Northwest Territories, Yukon College, and Carleton University.

Two sites in Yukon and two in NWT were selected for long-term monitoring of locations chosen to represent distinct environmental conditions. Evidence of massive ice was available at each site.. The sites in Yukon are in the Blackstone Uplands and in the taiga approaching Richardson Mountains. At both of these sites ice-wedge polygons dominate the terrain surface. The sites in NWT are in Richardson Mountains near the territorial border and in Peel Plateau. The border site is in colluvium, while the Peel Plateau site is in till. Three holes were drilled at all sites: one at the highway centreline, one at the toe of the embankment, and another 10 m off the road's toe. The target depth during drilling was 10 m, but this was not achieved in every case due to boulders or bedrock. Thermistor cables were installed in each hole and connected to a data acquisition system. Meteorological data are also collected at this location. Ground temperatures are collected every four hours and atmospheric data every hour. The installations on the Yukon side report the measurements in real-time by satellite transmission. With one year's data, we are able to present annual baseline statistics for the sites. A key finding has been that permafrost at the Blackstone site has not yet frozen back at depth, even though the annual mean ground temperature at 1-m depth is approximately -4 °C. We attribute this to ground water flow, which is also responsible for extensive icing of the Blackstone River.

IMPACT OF LAND COVER DISTURBANCES ON PERMAFROST LANDSCAPES: CASE STUDIES FROM YUKON COMMUNITIES

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The impacts of rising temperatures in permafrost regions are already being observed in many Yukon communities. Environmental changes can be exacerbated by human intervention and in many cases these operations can impact on the environment at a faster pace than those induced by climatic changes. When combined, climatic and anthropogenic changes can result in important hazards for community planning. Four case studies were selected to illustrate the impacts of land cover changes on permafrost landscapes.

Distinctive ground thermal characteristics can be notable in areas presenting contrasting vegetation cover. In a discontinuous permafrost region in Burwash Landing, under a FireSmart zone where trees are still present, the stability of the permafrost has been maintained with an active layer depth of 0.65m. Illustrating the impact of the surface disturbances, an adjacent fire cut area where trees have been cleared, has developed a near-surface talik (unfrozen zone in the permafrost) that reaches depths down to 8m.

Placer mining operations have disrupted the natural state of permafrost by stripping the top layers of soil and vegetation to access the gold bearing material beneath. A land plot shows early signs of permafrost degradation in a stripped area. By removing the insulating organic cover, the active layer has thickened to a depth greater than 1.6m in just under 10 years. In comparison, the adjacent forested zone is showing a frozen table starting at 52cm underlain by ice-rich permafrost. Thawing of ice-rich permafrost is slow and characterized by poor drainage conditions.

Removing vegetation and stripping the ground can also lead to the accelerated degradation of ice wedges. A residential area where a forest was cleared in the 90's for agricultural purposes now demonstrate a clearly visible polygonal network of ice-wedges (5-10m in diameter). The degradation of the polygons formed deep linear depressions (down to 50cm deep) in the landscape and water has been accumulating in the thaw-settlement troughs.

Another case-study presents how improper design of infrastructure built on permafrost can rapidly impact the ground thermal regime and cause thaw-settlements leading to foundation damages. A Yukon government building in Ross River shows severe signs of permafrost degradation as several cracks appeared throughout the structure since its completion 14 years ago. Even though the structure stands on a thick active layer (7m) the ice rich silt and clay deposits below are still subject to thermal degradation due to the heated crawl space beneath the school.

PERMAFROST CHARACTERIZATION FOR THE DEMPSTER HIGHWAY, YUKON AND NWT

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The Dempster Highway, a 736-km long public road, connects the Yukon transportation network, 40 km east of Dawson City, to Inuvik, NWT. The most southerly 80 km of the route is in discontinuous permafrost, but the remainder runs over continuous permafrost. Recently, there has been interest in the state of permafrost along the route, in order to assess the risks posed to infrastructure by climate warming. A number of agencies and initiatives have collected ground temperatures along the highway corridor, particularly NorthwesTel and the Cumulative Impacts Monitoring Program of AANDC/GNWT. In addition, Transport Canada, Yukon Government, and GNWT have recently installed four long-term permafrost monitoring sites, as discussed in a companion paper.

Air and ground temperatures have been collected primarily near NorthwesTel's telecommunication towers. Annual mean air temperatures along the route decline northwards from approximately -4 °C at Dawson to -9 °C at Inuvik. An exception to this pattern is the value of -9 °C for the Ogilvie Maintenance Camp, located in a steep-sided gorge at km 220. Mean summer (JJA) temperatures are relatively consistent along the route, but winter (DJF) mean temperatures decline northwards from about -19 °C at Dawson to -29°C at Inuvik, with a value of -30 °C at Ogilvie. (These data are for 2003-04, a year with complete records.) In contrast, measured annual mean ground temperatures do not vary systematically with latitude, but vary between -4.5 °C and -1.5 °C.

Ground ice conditions along the route vary with surficial geology. The most abundant ground ice has been found in glaciated landscapes. Ice-wedge polygons are common in the high valley of the Blackstone River and in the Richardson Mountains. Most of the highway lies below terrain of considerable relief, except in the Eagle Plain. As a result, icings build up over winter at many points along the route and complicate management of the freshet. A series of landscape units with distinct terrain management characteristics have been identified along the corridor: North Klondike Valley; Blackstone Uplands; Engineer Creek-Ogilvie River; Eagle Plain; Richardson Mountains; Peel Plateau; and Peel and Anderson Plains. This paper will present unpublished ground temperature data summarized from records collected at NorthwesTel facilities and in other projects, and summarize ground ice conditions determined from unpublished field investigations and recent literature. The terrain management units will be described and justified.

NUMERICAL MODELING OF SKIRTED FOUNDATION UNDER SEISMIC LOADS

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This study presents a technique that deals with earthquakes and its effects on both the substructure and the superstructure. A ten stories reinforced concrete building resting on raft foundation with two panels is represented using two-dimensional model with and without skirts. A series of models were run under different skirt's depths below the foundation level. The results showed that the skirts have a great effect in controlling the horizontal deformation for the subgrade as well as the superstructure. It has significantly decreased both the acceleration and the associated pore water pressure. Finally the skirts were found to increase the densification under the raft due to the lateral confinement of the subgrade.

STABILIZATION TO RAILWAY SUBGRADE USING SCREW PILES

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An innovative screw pile methodology has been used to stabilize a railway subgrade at Mile 3.9 on the Levis Subdivision in Quebec as well as Mile 204.7 and Mile 173.5 on the Lac La Biche Subdivision in Northern Alberta on the CN rail system. The principle behind the screw piles is to support the weight of the track structure consisting of the rail, ties, ballast and sub-ballast with a top helix and to transfer the load to a more competent strata with the lower helix.

At Mile 3.9 Levis Subdivision screw piles were used on an embankment on peat over bedrock. Following the success of this smaller scale trial application of screw piles in a shallow muskeg site, it was decided to use this concept but with much larger screw piles on the Lac La Biche Subdivision.

At Mile 204.7 and 173.5 on the Lac La Biche Subdivision, deep peat and soft compressible soils beneath the embankment resulted in a punching type failure which was affecting the track geometry at these locations. Conventional techniques, such as low flanking berms applied on either sides of the rail embankment were use in an attempt to stabilize the site but were not successful.

Due to the lack of a hard soil layer below the peat at Mile 204.7 the piles were designed with 2 large diameter helix at the bottom founded in a soft silty clay. The screw piles at Mile 173.5 were founded in a firm sand layer with a single helix at the bottom. A 24" in diameter helix was present at the top of the piles within the sub-ballast to support the load of the track structure in both cases.

Due to variations on site conditions, different configurations of screw piles were used at the two study sites on the Lac La Biche Subdivision. In addition, FLAC analyses were performed to optimize the performance of the piles at Mile 173.5. No further movement of the track has been observed since the installation of the screw piles at Mile 204.7 in March 2013 and since the installation at Mile 173.5 in February 2014.

This paper presents the success story of the screw pile application and analyzes and compares the 3 different designs used on the Lac La Biche Subdivison and the Levis Subdivision.

USING RESISTIVITY METHOD TO CHARACTERIZE WATER FLOW PATTERNS IN PERMAFROST ENVIRONMENT ILULISSAT, GREENLAND

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The construction of transport infrastructure in the north inevitably affects the hydrology of the watershed it overlaps by impeding water drainage on the land. Observations of events causing the rapid degradation of northern infrastructure suggest that liquid water transport and its thermal effects have been significantly underestimated in recent years in permafrost science and engineering. The consequences of convective heat transfers at the interface between flowing water and the ground, caused by concentration and channeling of runoff and groundwater around infrastructures, are poorly known.

Electrical resistivity is one of the most effective geophysical method to map and characterize permafrost, as it is sensitive to the state (frozen/unfrozen) of the ground, its ice content and subzero temperatures. To study the extent of permafrost degradation caused by the reorganization of water flow, electrical resistivity surveys were conducted perpendicular to a stream draining a small watershed, south of the airport of Ilulissat in Greenland. Ilulissat is located on the west coast of Greenland, north of the 69° parallel in the continuous permafrost zone. The soil of the study site consists of marine clay and silt. Permafrost temperature is between -1°C and -3.5°C. The first 4 meters of permafrost is ice-rich and show high resistivity values while the soil 4 meters below the ground surface is estimated to be unfrozen due to a high residual salt content in the porewater (Foged and Ingeman-Nielsen, 2009). The water flow patterns in the ice-rich zone are easily observable through lower resistivity values recorded due to permafrost warming at these locations. This paper present electrical resistivity profiles correlated with several permafrost properties such as: soil temperatures at different depths, active layer thickness, and water content of active layer and permafrost soils. Water discharge and water temperature in the stream were measured daily during the study period and implications for heat transfers are discussed.

L’AFFAISSEMENT DES CHAUSSÉES CONSTRUITES SUR SOL ARGILEUX À MONTRÉAL, QC.

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L’affaissement des chaussées construites sur sol argileux à Montréal, QC.

L’aménagement d’un territoire entraîne inévitablement un changement drastique dans le bilan hydrique qui prévalait avant la construction des rues, habitations et infrastructures urbaines. L’augmentation du ruissellement sur les surfaces minéralisées et les toitures diminue la quantité d’eau qui s’infiltré dans le sol. Lorsque le sol d’infrastructure est argileux, ces changements combinés à des périodes de sécheresses prolongées peuvent provoquer un assèchement de l’horizon supérieur du dépôt argileux. Cela cause une diminution de la teneur en eau du sol par altération de l’argile, entraînant des tassements du sol qui déforme les chaussées.

Les facteurs qui contribuent à l’affaissement des chaussées sur sol argileux sont examinés. Trois cas d’affaissement de chaussée sur sols argileux sont présentés. Dans chacun des cas les propriétés du sol, l’ampleur des déformations observées, les variations de teneur en eau et les facteurs qui peuvent accentuer la progression de l’assèchement sont discutés.

Des solutions différentes à ce problème ont été proposées et réalisées sur deux des sites étudiés. La première a consisté à modifier le système de captage et de drainage des eaux de ruissellement pour permettre leur infiltration dans le sol. La deuxième est une reconstruction sur une fondation granulaire plus épaisse. L’observation du comportement, plusieurs années après les travaux, permet de formuler des commentaires et mises en garde à prendre en compte dans la conception des infrastructures urbaines sur sol argileux.

Mots-clés : argile, assèchement, affaissement, chaussée, drainage, infrastructures

TESTING A LANDSLIDE-GENERATED TSUNAMI MODEL. THE CASE OF THE NICOLET LANDSLIDE (QUÉBEC, CANADA)

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The landslide-generated tsunami is a phenomenon that threatens infrastructures and lives. In order to assess comprehensively this phenomenon and the induced risks, we have developed a numerical model which aims to simulate the propagation of the landslide, the generation and the propagation of the wave and eventually the spread on the shores. The wave behavior is simulated using a model based on the shallow water equations stabilized by the Lax-Friedrichs scheme. The transition between wet and dry bed is performed by the combination of the aforementioned equations with viscous flow equations. This model underwent several numerical tests and successfully passed them. However, it needs further tests to confirm its capacity to be used as a predictive tool for risk assessment.

Thus, this study aims to run the model on a well-documented case study in order to calibrate and validate it.

The Nicolet landslide (Québec, Canada) occurred on the 8 May 2006 on the extrados of a meander of the Nicolet River located in the center of the St-Laurence Lowland. The materials are mainly composed by the Champlain Sea sensitive clays. This partially submerged landslide has a volume of about 13'000 m³, is 80 m wide and the crest retrogressed up to 15 m. Moreover, the geometry of the mass before and after the event is particularly precise thanks to ALS HRDEM acquired in 2003 and TLS point clouds acquired on 11 May 2006. During the sliding process the water was pushed by the front of the sliding mass leading to the generation of a wave. The resulting run-up distance up 60 meters on the opposite shore is clearly identifiable on an aerial photograph taken the 9 May 2006.

The high quality and quantity of data concerning the landslide mass as well as the induced wave make this site a case study of choice.

The simulation in one dimension of this event with our model gives a run-up up to 70 m. Compared to the real extent of 60 m, the 1D model behaved correctly. This confirms the capacity of our model to simulate properly this combination of phenomena. In reference to this latter statement, we are setting-up simulations in 2.5D and preliminary results show comparable run-up distances.

IMPACT OF VOID FORMATION ON BURIED PIPES

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Buried pipe infrastructure is of critical importance for maintaining the provision of fresh water supply and disposal of waste water services. Pipe infrastructure is sensitive to ground conditions and is reliant on the surrounding soil for support. It has been observed that during the service life of a pipe the surrounding soils may erode locally. Voids can be caused due to suffusion processes from natural ground water flow, high pressure water leaking from the pipe, ground movements induced by neighbouring construction activities or ground settlement from externally applied surface loads or poorly placed fill during installation. Ground movements and loss of support can accelerate deterioration of the pipe condition and ultimately lead to premature failure of the asset.

This study considers the effect of voids in close vicinity of a flexible pipe and evaluates the impact of void formation size on the stiffness and bending behaviour of the pipe when subjected to vertical surface loading. A series of plane strain centrifuge model tests are reported for a 0.3m diameter prototype flexible pipe for fully supported and unsupported conditions buried in dense sand. Spherical void geometries are considered and range from 0.5 to 2.5 the pipe diameter. Digital image correlation (DIC) is used to observe the interaction behaviour between the pipe and soil during applied surface loading. The displacement in the pipes was analysed using DIC and the calculated deflections were used to determine bending moments in the pipe using the central difference method. The sagging and hogging moments in the model pipes both increase with increasing void size. Bending moment diagrams were compared to a theoretical soil-structure interaction model generated from a combination of a Winkler spring model and elastic beam theory. The overall shape of the two model outputs are in general agreement with the experimental data which offers new potential to predict the behaviour, and possible failure, of buried pipe infrastructure.

HAZARD IDENTIFICATION AND EVALUATION USING UAV PHOTOGRAMMETRY FOR PIPELINE ROUTING

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The geotechnical engineering aspects of pipeline route selection is a multifaceted process involving detailed studies of ground conditions, natural hazards, and geological history. Assessing ground conditions typically involves preliminary desktop based terrain evaluation tools, boots on the ground field investigations, geophysical imaging, drilling/sampling/testing, and remote sensing data collection and interpretation. Various pipeline projects currently under consideration in Canada will traverse rugged terrain in western Alberta and British Columbia. Field work consisting of outcrop mapping and rockmass evaluation is typically constrained by visual examination at ground level or broad scale analysis conducted from a helicopter. Recent advancements in the field of Structure from Motion (SfM) 3-dimensional (3D) photogrammetry eliminate the onerous requirements of ground control and enable the generation of high resolution digital terrain models as variable resolutions. The SfM approach to photogrammetry requires a large number of significantly overlapping photos to reconstruct a 3D surface. Photographs can be taken from a variety of aerial platforms or terrestrial locations. Aerial based approaches, commonly referred to as Oblique Aerial Photogrammetry (OAP), are typically collected using a helicopter, UAV, or small fixed wing aircraft. In this project we demonstrate the use of OAP from a UAV (OAP-U) for the generation of a detailed terrain model for the evaluation of a pipeline route crossing a deep valley near Hope, British Columbia. The OAP-U data were collected on site by engineers conducting the field evaluation; the resultant data was used to map slope angles, geological structure, rockmass conditions, and establish a baseline 3D model of the site that could be used for future comparisons to assess ground changes. The use of OAP-U provided a rich 3D data source which facilitated an understanding of the site not possible with traditional approaches. The incorporation of OAP-U techniques into field mapping projects has greatly increased the information obtained in the field and resulted in a greater understanding of the terrain.

EXPERIMENTAL INVESTIGATION ON THE EFFECT OF A WASTE ROCK INCLUSION ON TAILINGS CONSOLIDATION

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The use of waste rock inclusions as vertical drains to increase the drainage rate of mine tailings is a promising technique to accelerate their consolidation. However, this approach raises a number of questions that remain to be addressed. Among these, the contrast between the properties of the two types of materials (the coarse-grained waste rock and the fine-grained tailings) can make the analysis of such co-disposal challenging.

An experimental investigation of the co-disposal of tailings and waste rock has been performed to help understand and assess the consolidation process, the drainage mechanisms and the ensuing pore water pressures dissipation, considering the materials interactions. An instrumented laboratory model made of a rigid box having a square section of 1.05 m x 1.05 m and a height of 0.75 m has been used for this purpose. Several scenarios of co-disposal were considered during testing.

The impact of the coupled horizontal and vertical drainage generated by the presence of the draining inclusion on the rate and magnitude of pore water pressures has been evaluated. The effect of drying of tailings from the surface, the influence of residual horizontal drainage and the variation of tailings hydraulic properties during the consolidation process have also been studied. The tests results show the complexity of the mechanisms of pore water pressures dissipation when tailings are co-disposed with waste rock, including differential settlements resulting from interactions at the interface.

GEOLOGICAL MAPPING OF A SUBGLACIAL TRACTION TILL FROM A SHEAR KEY EXCAVATION NEAR FORT MCMURRAY, ALBERTA

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This paper forms the second part of a study into the Firebag Till, which is encountered south of the Fort Hills Thrust Moraine in the Fort McMurray region. The lithology, thickness, internal structure and geotechnical behaviour of the Firebag Till can influence the operation of oil sands mines through the foundation stability of tailings dykes and waste dumps; the migration of seepage; trafficability and its suitability for use as a construction fill.

The paper is related to an excavation undertaken for a shear key at the Horizon Mine, near Fort McMurray. The excavation permitted the detailed geological mapping of a glacial till and its basal contact with the underlying Clearwater Formation. The till comprised a matrix-supported diamicton of intermediate plasticity derived from the reworking of the Clearwater and McMurray Formations. It displayed evidence of simple shear deformation such as reidal shears, clast imbrication, folded clasts and rafted bedrock, which indicated that locally, the Firebag Till is a subglacial traction till, in which deformation was likely the controlling formation process. The frequency of glaciotectonic deformation structures increased when the underlying Clearwater Formation bedrock comprised a low density, high plasticity silty clay facies. Fewer deformation structures were observed when the Clearwater Formation bedrock comprised a laminated, bioturbated, intermediate plasticity, clayey silt facies

AIR IN LABORATORY SEEPAGE TESTS: IMPLICATION, MEASUREMENT, REMEDIATION

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The work presented herein is part of a larger research project addressing the problem of internal erosion in till core embankments. Downward seepage tests are being carried out on soil models made of glass beads and natural sands. Experimental observations are compared with numerical results obtained by discrete element simulations using codes being developed at IREQ (Hydro-Québec). The numerical tools take into account complete saturation of the porous media. Therefore, soils samples must be fully saturated during tests. This article is concerned with the role of air in seepage tests results, the measurements to determine presence of air in pore water and the techniques to be taken in order to minimize the presence of air in granular samples. Several methods exist to minimize trapped air in pores. It is a common laboratory practice to use de-aired water. The issues in obtaining de-aired water either by cavitation, a physical method, or by addition of anhydrous sodium sulfite, a chemical method, are discussed. Dissolved oxygen (DO) can be readily measured in porewater and its relation with air saturation is examined. An oximeter or chemical titration by the Winkler method with azide modification are used to measure DO concentration. The effectiveness of a filter tank filled with sand installed upstream to prevent air entry during seepage tests is evaluated. Likewise, due to the greater solubility of carbon dioxide in water, air in voids of granular samples may be replaced by this gas before saturation and this approach is discussed. Finally, saturation measurements during placement are presented using the method proposed by Chapuis et al. (1998) along with DO concentration obtained during flow tests.

NUMERICAL SIMULATION OF COUPLED GROUNDWATER FLOW AND HEAT TRANSPORT IN A CONTINUOUS PERMAFROST ENVIRONMENT AT THE IQUALUIT AIRPORT, NUNAVUT, CANADA

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This study presents a series of numerical simulations to investigate the factors that control freezing and thawing cycles of the shallow soil zone near the surface of permafrost at the Iqaluit airport in Nunavut, Canada, in which permafrost degradation is seriously affecting the stability of existing runways, taxiways, aprons and access roads. The Iqaluit airport is located in the south-eastern part of Baffin Island at the head of Frobisher Bay, at latitude 63°75' N, in a region of continuous permafrost. Data collected from ongoing field investigations consist of soil temperature and movement, surficial geology, snowpack thickness, subsurface hydraulic and thermal properties, as well as water table elevations. The present study is mainly intended to identify the hydrogeological factors and environmental drivers that have the highest impacts on permafrost degradation at the Iqaluit airport, under various future climate scenarios. To generate future climate data for the airport, 24 different global circulation models (GCMs) are used from AR4 (IPCC Fourth Assessment Report) for the time series from 2011 to 2100. Based on the developed conceptual hydrogeological model, numerical simulations of coupled groundwater flow and heat transport have been completed to assess the influence of plausible combinations of hydrogeological parameters and surface conditions on the temporal and spatial evolution of permafrost degradation. Following the current condition simulation, a series of simulations have been developed which are presumed to be reflective of typical cold-region paved terrains. The scenarios considered here include: the presence of an unsaturated zone, the influence of snow cover, heterogeneity of subsurface glacial deposits including ice lenses, anisotropy in hydraulic and thermal properties, the influence of the unfrozen water content function, and the role of recharge and groundwater flow on the ground temperature distribution including the relative effect of advection versus conductive heat transport. The results obtained from the various simulations provide insight into the interactions between the physical/thermal processes and the response between permafrost and possible hydrogeological configurations, which are issues of concern to hydrogeological studies in cold regions.

A COUPLED SOIL SPRING FORMULATION FOR NUMERICAL MODELING OF BURIED PIPELINES

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Buried pipelines integrity and operability are significantly affected by surrounding geotechnical conditions including geohazards. Considering the effects of surrounding soil on the buried pipelines in form of ground movements or restraining the pipeline displacements is a crucial part of any pipeline stress-strain assessment.

Numerical beam-spring models are extensively used in pipeline engineering for pipe stress-strain analysis. The current state of practice (e.g. ALA 2001, PRCI 2004, and PRCI 2009) defines soil springs as three independent perpendicular springs in axial, lateral and vertical directions. Various studies have investigated the dependence between these spring components. Significant coupling effects are reported in different planes, which are not accounted for in the current state of practice. Examples of these coupling effects are explained in Daiyan et al. (2011a) for axial-lateral Pipe-Soil Interaction (PSI), Daiyan et al. (2011b) for axial-vertical PSI, and Cocchetti et al. (2009) for lateral-vertical PSI.

This paper proposes a new interaction model to couple the three spring components in granular material that allows a more representative simulation of PSI behavior. The significance of considering the three-dimensional coupling effects, using the proposed model, has been studied by means of examples of pipelines under operational and geohazard loading conditions. This has been achieved by implementing the proposed interaction model in the soil spring element formulation using finite element software, ABAQUS.

QUANTIFY HEAT ADVECTION IN THE ACTIVE LAYER: LABORATORY SIMULATIONS

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Rising temperatures due to climate change affect permafrost through radiative heat transfer and convective heat transfer at the air-soil interface, which then translate into conductive heat transfer into the ground according to the local atmosphere-surface thermal gradient. Surface run-off and groundwater flow also impact the ground thermal regime by convective heat transfer processes and must be taken into account to obtain an accurate global thermal balance. Surface run-off as well as water flow in the active layer both contribute to the deepening of the active layer, especially when the active layer is ice-rich. Although the influence of heat advection has already been demonstrated, the efficiency of thawing by convection compared to thawing by conduction has been poorly quantified so far. This knowledge gap has been in part created by the impossibility to control all parameters in natural settings and by the impossibility to separate physically, thus isolate mathematically, convective heat transfer from conductive heat transfer. The Peclet number is an indicator that can be used to determine which of the two phenomena is predominant. However latent heat is not included in the equation which limits the analysis, especially with very low flow.

To overcome field variability, experiments were carried out in a controlled environment to better understand field conditions through laboratory tests. To replicate physical permafrost models and compare the efficiency of thawing by convection versus thawing by conduction, eight equi-dimensional rectangular cells were designed and constructed. The sides of the cells were insulated to prevent lateral heat loss, leaving only the upper part exposed. The cells were filled with different saturated soils and frozen under the same conditions. In a temperature-controlled room, the cells were submitted to two different air temperature thawing conditions: 15 and 5°C. Four cells were thawed by conductive heat transfer. Four other cells equipped with discharge-controlled device were submitted to sub-surface flow. Water temperature prior to flow was controlled using high-inertia thermal baths. Slope and water temperatures, 15 and 5°C, varied between experimentations. Replicates ensured that intra-test variability was lower than inter-test variability. Preliminary results are novel and indicate that the efficiency rate of thawing by convection in comparison to thawing by conduction is proportionally correlated with temperatures (air and water), water flow and slope. Convection was 2 orders of magnitude more efficient when temperatures were different (warmer water temperature) than when they were equal.

SOME EXPERIMENTAL FINDINGS ON THE INFLUENCE OF MODE OF SHEAR ON THE CYCLIC RESPONSE OF NATURAL SILTS

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Saturated silt deposits are prevalent in most earthquake-prone soft-soil areas, and there is evidence that sites underlain by such soils have experienced ground deformations and failures. So far, much of the research focus has been on the earthquake response of sands and “relatively clean” sandy soils, whereas the behaviour of silty sands and silts has been investigated only on a limited scale.

The direct simple shear (DSS) test device allows continuous rotation of principal stresses about the vertical axis during shear, and is therefore, considered more suitable for mimicking shear wave propagation prevalent during earthquake loading. It is, however, difficult to estimate the stress state in a DSS specimen since the magnitude of the horizontal normal stress is unknown. In contrast, the triaxial test device allows full control of major and minor principal stresses during cyclic loading; however, the triaxial testing stress paths are less able to represent seismic wave propagation since it only allows “jump” rotation of principal stresses. Both the triaxial and DSS devices are used in industry practice, and there is a need to assess the difference between the cyclic resistance derived from the two devices. While significant work has been undertaken in the past with respect to sand behaviour, the current understanding on this aspect in relation to the behaviour of silts is limited.

With this background, a comprehensive experimental research program has been undertaken to compare the cyclic shear response of natural silts generated from DSS and triaxial testing. First, the results from tests conducted on undisturbed natural silts using thin-walled, sharpened-edge, stainless steel sampling tubes with no inside clearance are examined to explore this topic. Data from reconstituted and undisturbed specimens are then compared to provide critical insights into the suitability of using reconstituted specimens to predict field behaviour.

A TTOP-MODEL OF PERMAFROST DISTRIBUTION FOR THREE AREAS IN YUKON AND NORTHERN BRITISH COLUMBIA

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Air, ground surface and top of permafrost temperatures (TTOP) were measured at 58 sites in three areas of Yukon and northern British Columbia in order to: (1) explore relationships between climate-permafrost transfer functions and environmental variables, (2) assess and validate the TTOP-model, and (3) attempt the first implementation of the TTOP-model (Smith and Riseborough, 1996, 2002) for these regions with complex terrain. The strongest factors controlling climate-permafrost transfer functions are elevation and land cover, though slope, aspect, topographic position and surficial geology were also investigated. In 1000 iterations of the model using random equally possible scenarios, 64% of the TTOP-model predictions were within $\pm 1^\circ\text{C}$ of measured values, a result that is 6% better than applying a simple 3°C "total offset" to the mean annual air temperature. A sensitivity analysis confirmed that the TTOP-model is most sensitive to changes in snow, thermal conductivity of the ground and summer air temperatures. A land cover driven TTOP-model was then developed and implemented. The model correctly predicts high likelihoods of permafrost (> 0.6) for sites with permafrost present and low likelihoods (< 0.4) for non-permafrost sites.

INTERPRETING PUMPING TEST IN STRATIFIED CONFINED AQUIFERS USING THE EQUIVALENT MODEL

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Interpreting pumping test in stratified confined aquifer using the equivalent model

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ABSTRACT

Aquifer tests are commonly used to determine the hydrodynamic characteristics and aquifer boundaries of stratified confined aquifers. However, the interpretation of drawdown data provided by these tests is made by methods that use very simplistic assumptions of reality. The very common approach used in the case of heterogeneous and anisotropic layered aquifers is to consider the homogeneous and anisotropic equivalent model whose neither spatial nor temporal validity have been assessed. This paper proposes a new approach allowing the reliable use of this approach.

Key words: Layered confined aquifer, equivalent model, hydrodynamic characteristics, drawdown data

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CENTRIFUGE MODEL TESTS OF STRIP FOOTINGS SUPPORTED ON TWO-LAYERED CLAYS

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In practice the design of shallow footings is often simplified to conform to a classical theoretical bearing capacity solution whereby footings are assumed to rest on a single layer of homogeneous soil. In reality however, footings often are founded on bearing strata that consist of distinct layers having significantly different properties and soil strengths. This presents a challenge for the design engineer as to which soil properties are selected for the geotechnical design.

The effect of increasing strength with depth on bearing capacity has been addressed by several researchers, notably Davis & Booker (1973), and numerical solutions to the problem of footings resting on layered clays are reported in works such as Merifield et al. (1999). The latter work utilizes limit analysis to evaluate strip footing response for a range of soil strengths and soil layer thicknesses, reporting significant variations in the bearing capacity factor and observed foundation failure mechanism.

Owing to the natural variability of soil conditions it is difficult to validate the results of numerical studies at full scale by field testing. This is further compounded as there is a lack of physical model test data available to confirm the numerical analysis. This paper reports of a series of centrifuge model tests on surface strip footing test on a two layered soil bed having firm clay overlying soft clay, each of variable thickness. Plane strain test conditions enabled the use of Digital Image Correlation (DIC) to determine the relative displacement of the soil and reveal the foundation failure mechanics. General shear and punch failure were observed and determined to be significantly influenced by the layer thickness ratio. Large variations in bearing capacity factor were also determined. The centrifuge test data compares favorably with limit analysis conducted as part of the investigation, and with previous postulated numerical and analytical solutions. This work provides experimental validation of previous proposed theory for bearing capacity of layered soils and offers greater insight of factors that give rise to punching shear failure mechanics.

UNCONFINED COMPRESSION STRENGTH AND CORRESPONDING STRAIN OF DIESEL-CONTAMINATED FROZEN SILTY-SOILS

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The contamination of permafrost by hydrocarbons is an important concern in cold regions. In addition to negative environmental impacts, hydrocarbon contamination leads to loss of strength of the frozen soils. Models predicting the strength of diesel-contaminated and uncontaminated silty-soil specimens and their corresponding strain at peak stress, are developed using stepwise statistical analysis. The data used were collected from two series of laboratory-prepared specimens subjected to unconfined compression testing. The first series of specimens were prepared and tested at a temperature of -3°C and the second at -5°C . Water and diesel-fuel were added to a given mass of dry soil. The specimens were then tested in a cold room under constant temperature and strain rate. Stress and strain were recorded at 30-second intervals. Other independent variables such as the fluid content, density and temperature were also recorded. Detailed descriptions of the tests and their results have been reported by Chenaf et al. (2013). The significant variables for the determination of peak stress and corresponding strain were selected by the forward selection method or by their physical importance. The model coefficients were then calculated by multiple linear regression.

The selected models are simple and accurate. For the peak stress, three independent variables (total density, diesel content in the fluid and fluid content before the test) or (the total density, diesel content in the soil and fluid content after the test) were shown to give accurate predictions. For the corresponding strain, two independent variables (fluid content after the test and total density) were used. The variables represent physical quantities that can easily be measured in the lab or in the field. Multiple linear regression showed good correlation between observed and predicted peak stress ($R^2 > 0.86$) and good to acceptable correlation between observed and predicted strain at peak stress ($R^2 > 0.78$). The models were more accurate for peak stress than for strain at peak stress and more linear with data collected at -3°C than at -5°C .

Key words: frozen soil, diesel contamination, strength, stepwise analysis

INTERPRETATION D'UN ESSAI D'AQUIFERE DANS UN DYKE FRACTURÉ D'ANORTHOSITE SITUÉ DANS LA RÉGION DES LAURENTIDES, LAURENTIDES, QUÉBEC, CANADA

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Dans la recherche d'eau souterraine, les essais de pompage et de remontée sont utilisés pour déterminer le potentiel hydrique souterrain d'une formation rocheuse aquifère. Ce potentiel hydrique repose sur l'orientation, la densité et l'extension des fractures qui recoupent ces massifs rocheux sur lesquelles très peu d'information sont généralement disponibles. Dans cet article, les données d'essais de pompage et de remontée réalisés dans un socle rocheux d'anorthosite et de leuco gabbro situé dans les Laurentides sont présentées. Ces données sont utilisées pour extraire les paramètres hydrodynamiques du dyke en utilisant les méthodes disponibles d'interprétation. Dans l'utilisation de ces méthodes disponibles, certaines difficultés sont relevées. Elles sont discutées dans la présente étude.

Mots clés: aquifère, dyke, Laurentides, essai pompage, essai remontée, paramètres hydrodynamiques

LABORATORY TEST RESULTS OF THE THERMAL CONDUCTIVITY OF SEALING MATERIAL IN THE DGR AT DIFFERENT SATURATION DEGREES

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To protect the natural environment from the radioactive and chemically toxic materials, the concept of designing sealing systems in the DGR (Deep Geologic Repository) for the used power reactor fuels has been taking into account by Nuclear Waste Management Organization (NWMO). For clay based materials, five sealing components are currently being considered; 1. Highly Compact Bentonite (HCB), 2. Bentonite-Sand Buffer (BSB), 3. Dense Backfill (DBF), 4. Light Backfill (LBF) and 5. Gap Fill (GF). The heat produced by disposal waste package as a result of its radioactive decay, needs to be dissipated with buffer and backfill materials before going to host rock so that these materials should have a good thermal conductivity at a wide range of moisture contents. Thus, the size of the repository is highly associated with thermal conductivity of sealing materials. The focus of the previous studies reported in the literature was largely on saturated as-placed materials. At least during the initial peak temperature timeframe, it is necessary to have confidence in the bentonite properties of the relatively dry environment. In addition, due to the variability of properties of supplied Wyoming bentonites, NWMO also needs to strengthen the database of core properties, especially thermal conductivity at low saturation degrees. This paper summarized the study performed on the buffer and backfill sealing Material-Variability Study-Index tests mainly focused on the thermal conductivity in different saturation degrees. Results presented in this paper are the results of laboratory tests mainly conducted on HCB, GF and DBF materials. The Device used in thermal properties testing is a Hot Disk Thermal Constants Analyzer, which operates via supplying a pulse of constant power to a sample. Two-sided and one-sided tests were applied with this machine. Demand of high pressure for compacting bentonites at desired dry density, especially for low saturation degree samples resulted in modifying the molds and compaction machine. Preliminary test results on the HCB in two different Wyoming bentonites (MX-80 and National Standard) showed increasing thermal conductivity with the degree of saturation. Also a good agreement was observed between anticipated results and high repeatability.

EXCEEDING MOVEMENT DESIGN LIMITATIONS IN A TEMPORARY SHEET PILE WALL

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Tetra Tech EBA Inc. (Tetra Tech EBA) provided geotechnical engineering and construction monitoring services for site remediation of two work areas (defined as WA1 and WA3) located in Victoria, BC. These areas, along with the adjacent properties, have had a history of industrial use that resulted in contamination of soil and groundwater beneath the site, as well as sediments within an adjacent bay.

Geotechnical design parameters and surcharge loading for the design of the temporary shoring works were assessed by Tetra Tech EBA following review of the environmental drilling logs provided for the subject site. No site specific geotechnical borehole drilling and laboratory testing for geotechnical design parameters had been completed for the site through the Owner. As the Engineer of Record, Tetra Tech EBA took responsibility for the design of the temporary shoring works based on our assessment of the available information provided by the Owner (incorporating all soil, groundwater and surcharge loading regimes required).

Due to the lack of geotechnical information, the shoring specifications included the requirement for a survey monitoring program of the top of the shoring wall, i.e. using an observational approach to verify the performance of the shoring works based on assumed design parameters.

In WA1, movements of the sheet pile wall exceeded design by over 10. This movement exceeded anything experienced by the design engineer. Discussions with the owner and client regarding definitions of failure and what amounts of movement would be tolerable took place. The Client and Owner accepted the consequences of this excessive movement, including repair to adjacent infrastructure, as long as safety wasn't compromised. With the interlocking steel sheet pile system, the majority of movement occurred within a few sheets and, as long as they remained interlocked, the safety of personnel within the excavation was never compromised. The steel sheet pile wall was continuously monitored by Tetra Tech EBA personnel while workers were in the excavation and workers were not allowed to enter the excavation unless they were on a piece of equipment.

Although movement of the steel sheet pile wall was not the intended result, it provided us with an opportunity to push the limits of the design and redefine what is meant by failure.

NUMERICAL SIMULATION OF TRIAXIAL TESTING OF ROCKFILL

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Rockfill has been used as a construction material for thousands of years as it is relatively easy to produce, transport and place. Additionally, under most engineering applications of low to moderate stress, rockfill is relatively strong and relatively rigid.

Typically in engineering practice, rockfill structures such as dams and embankments are designed and evaluated assuming that the rockfill has a linear elastic stress-strain response, constant friction angles and is not affected by wetting. In the 1970s researchers including Leps (1970), Nobari & Duncan (1972) and Duncan & Chang (1970) conducted extensive studies on rockfill and found that it is characterized by a hyperbolic stress-strain response, stress-dependant friction angles, and an appreciable loss of strength and rigidity upon wetting. The differences between assumptions made in typical engineering practice and the actual behavior of rockfill have resulted in a number of surprises when large rockfill embankments and dams have undergone excessive differential deformations during wetting and mine waste rock piles have failed under static conditions.

Increasingly, larger rockfill structures are designed and evaluated with the assistance of numerical simulations that include constitutive material models and numerical methods that consider a hyperbolic response, the influence of effective stress on the friction angles and the effects of wetting, which are particularly important for large rockfill dams where only the upstream side of the dam is wetted.

Triaxial testing of the finer fraction of rockfill, often with some adjustment for the effect of scale, has been found to be a reasonable method for the evaluation of the strength and rigidity parameters of rockfill.

This paper presents a study of the use of four different software programs that were used to simulate triaxial compression testing of rockfill specimens that were tested under a range of confining stresses and in some cases subjected to wetting before or during compression. These programs are FLAC 2D (Itasca Consulting Group), PLAXIS 2D (Plaxis), SIGMA/W (Geo-Slope International) and RS3 (Rocscience). A hyperbolic constitutive model (built-in or customized based on Duncan & Chang) was used to simulate the response of the rockfill. The ability of each of the programs to simulate the test results, including the volumetric response, was compared to actual triaxial compression test results.

PRELIMINARY STUDY OF THE INFLUENCE OF CEMENTED PASTE BACKFILL FREEZING ON THE THERMAL CAPACITY AND CONDUCTIVITY

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Underground mine stope backfilling with cemented paste backfill (CPB) can provide safer working environment for miners and secondary ground support. Consequently, the amount of tailings to be stored at the surface is reduced which in turn will limit the potential environmental impacts. To date, very few studies have been performed on mine backfilling for mine operation in permafrost region where the stope walls temperature is around -10°C . Furthermore, the mixing water used for CPB preparation has natural salinity which can affect the backfill performance. Also, it is well known that the binder hydration process and the resulting unconfined compressive strength (UCS) of CPB are temperature-dependant. In the case of CPB in contact with frozen boundaries (i.e. stope walls) in the permafrost, knowing the variation in temperature gradient within the CPB mass and the ensuing freezing front displacement is essential for the mix recipe formulation (optimizing CPB compressive strength). The CPB thermal curing conditions in frozen stopes may be estimated using numerical modeling. Thermal conductivity and capacity functions of CPB as a function of curing time and decreasing temperature up to freezing point are then required.

The objective of this study is to perform laboratory investigation in order to develop such thermal functions. For this purpose, unsteady state measurements using the needle method with the KD2 Pro apparatus from DECAGON DEVICES were performed. This probe provides also the temperature change measurement. Different CPB mixtures were prepared at different solid mass concentration (standard Abrams cone slump heights values between 150 and 200 mm) with 0% (control) and 5% binder contents. Mixing waters with and without salt was used. The CPB ingredients (tailings, water and binder) were conditioned at targeted mixing temperature between 10° and 20°C . Samples in cylindrical molds were cured at different temperatures ranging between the mixing temperature and -10°C . Changes in thermal properties and temperature of CPB were measured. Results are presented and discussed. Preliminary models are proposed for describing the dependence of CPB thermal properties on the temperature and curing time.

FROST ACTION ON LIGHTLY LOADED PILES: THE ONTARIO SOLAR FARM EXPERIENCE

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The Ontario Feed-in Tariff (FIT) program was launched in 2009 to encourage the development of renewable energy technology in Ontario. The program quickly initiated the development of many solar farms across Ontario over a short period of time. These developments were generally carried out by the private sector as investment vehicles, with most developers having no prior experience in Ontario and/or Canada. Many developers applied foundation designs that were suited for southern United States or Europe conditions to Ontario conditions. In many instances the local ground and cold climate conditions were inadequately considered. This repeatedly resulted in constructability issues as well as poor foundation performance related to frost action of the solar panel supports, which generally consisted of a large number of lightly loaded piles. Improper consideration of the local ground conditions, depth of frost penetration and magnitude of potential adfreeze bond value(s), combined with insufficient construction oversight, also often resulted in failure to implement a design suitable for the actual subsurface conditions. The paper will provide a review of poor foundation performance at a large-scale solar farm development in southern Ontario. The paper will also provide minimum adfreeze values back-calculated from observed pile heave cases due to frost action at selected solar farm developments, for comparison with values published in literature and local design guidelines. A discussion on retrofit measures utilized to remediate heaved piles will be also be provided.

VISUALIZATION OF HEAT TRANSFER TO CHARACTERIZE SOIL-STRUCTURE INTERACTION OF ENERGY FOUNDATIONS

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Managing energy resources is fast becoming a crucial issue of the 21st century with geothermal heat exchange energy structures targeted as a viable means of reducing carbon emissions associated with regulating building temperatures. Limited information exists about the thermo-dynamic interactions of geothermal structures and soil owing to practical constraints of placing measurement sensors in proximity to foundations; hence, questions remain about their interaction behavior and long term performance. An alternative experimental method using transparent soil and digital image analysis is proposed to visualize heat flow in soil. Advocating the loss of optical clarity as a beneficial attribute of transparent soil, this paper explores the hypothesis that temperature change will alter the refractive index of the soil and therefore progressively reduce its transparency becoming more opaque. The development of the experimental methodology is presented and the novel visualization method adopted is correlated with soil temperature and verified.

The test methodology is used to observe the heat transfer process of an energy foundation and the interaction behavior discussed. The heating zone of influence of both a single and group of energy piles is considered and correlated with previous numerical investigations. The successful implementation of this technique provides a new approach to verify and develop understanding of thermo-dynamic processes in soil that will contribute to greater understanding of the effects of thermal performance of energy foundations.

FIELD STUDY OF DEGRADING PERMAFROST TERRAIN CONTAINING IMPORTANT MASSIVE ICE FEATURES, DRY CREEK, SOUTHWEST YUKON, CANADA.

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The Dry Creek study site (62°09'49"N and 140°40'55"W) is located along the Alaska Highway approximately 31 km south of the village of Beaver Creek, in a zone of discontinuous permafrost. Under an organic cover a few decimeters thick, the surficial deposit at the study is a glaciofluvial gravel of varying thickness. A portion of this gravel layer has been removed by earthwork to provide fill material during reconstruction of the Alaska Highway in the mid-1990's. The bottom of the excavation was then levelled and a rest area was constructed at the site. Major settlement problems occurred after the rehabilitation of the highway in 1994-95; however, previous settlement problems have already been reported for the area prior to rehabilitation work. This highway section requires intensive maintenance due to the presence of linear subsidence and cracks in the road embankment shoulders. Surface disturbances due to organics and gravel removal, ground levelling and compaction resulted in the development of thermokarst lakes, large depressions, linear settlement crossing the road in several places and sinkholes. A > 8.5 m deep and 30 m large depression was observed along the road embankment during the summer 2008 on the east side of the road. This led us to support the assumption that very ice-rich soils and most likely massive ground ice occurred at depth. All three electrical resistivity surveys conducted in 2013 and 2014 showed very high resistivity values at about 10 m depth. Micro-gravimetric surveys conducted in 2014 to evaluate the extent of massive ice the permafrost revealed strongly negative Bouger anomaly, especially for surveys conducted near a thermokarst lake and where depressions and sinkholes were reported (Loranger et al., submitted). Drilling and coring operations conducted during the summer 2014 revealed a very complex cryostratigraphy with layers of both ice-poor and ice-rich silt, pure ice layers and the striking occurrence of massive beds of sediment-poor ice several meters thick. The latter was encountered in 4 out of 10 boreholes. One 13 m deep borehole showed cryofacies of massive sediment-poor ice over a thickness of 9 m (2-11m). The cryostructure of the ice is characterized by micro-aggregates of fine-grained sediments suspended in pure ice. Geocryological analysis of the massive ice is required to determine its origin. Loranger, B., Doré, G., Fortier, D., Lemieux, C. (submitted). Massive Ice and Ice-Rich Soil detection by gravimetric surveying at Dry Creek, south-western Yukon Territory, Canada.

NUMERICAL STUDY ON THE EFFECT OF PARTICLE GRADING ON THE TRIAXIAL SHEAR RESPONSE OF AN IDEALIZED GRANULAR ASSEMBLAGE FROM MICRO TO MACRO

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Granular material, such as sand, powders and other media composed of discrete particles are quite common in nature and their behavior has been investigated by many researchers. Over the past decades significant progress has been made to indicate a strong correlation between the macro-scale angle of shearing resistance in granular material and inter-particle friction, particle shape or texture characteristics. But until now, there has been no consensus as to the effect of particle size on the shearing response of granular material, neither experimentally nor numerically.

The paper presents a DEM (discrete element method)-based micromechanical investigation of particle size distribution effects on the behavior of granular materials using commercial code PFC3D (Particle Flow Code in three dimensions). The numerical samples all have similar initial isotropic fabric and density, and the same confining pressure, but with different particle size distribution. A series of numerical 'experiments' (simulations) are carried out under drained triaxial compression conditions.

In addition, the micromechanical analysis is linked with and interpreted into the macro-scale responses that due to variations in the particle size distribution. For this purpose, the dilatancy and the shear failure modes of samples with varying particle size distribution is identified and quantified.

The macro-scale results of the simulations have been validated through the extensive laboratory test program performing triaxial compression tests on the glass beads in the range of 63 μm to 2000 μm .

Numerical results show that particle size distribution has a substantial effect on the stress-strain curve, peak strength and dilatancy characteristics of the granular assembly, which are in agreement with the experimental triaxial test results. Moreover, the particle size distribution significantly influences the corresponding microstructure evolutions and variations in contact properties in the particulate level. The origin of the different macro-scale response due to variations in the particle size distribution will be interpreted completely in the full paper.

DESIGN OF PILE GROUPS USING PILE LOAD TEST REACTION PILE DATA

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Recent major bridge projects in the Greater Vancouver Area showcase the experience of local geotechnical engineers. Large static pile loading tests have been conducted for the Pitt River Bridge (Tara 2012), Golden Ears Bridge (Fellenius et al. 2008) and Port Mann Bridge (Mitchell et al. 2013) projects. This paper briefly discusses different analytical approaches and reviews the approach as applied to recent case histories. The paper then considers the influence of reaction piles on the initial stiffness of the test pile and explores the application of different methods of interpretation to published test data for two of the local projects. In addition to the analytical approaches described above, a 3D finite element numerical analysis examines the relationship between the response of reaction piles during load tests and the behaviour of pile groups in compression. The paper summarizes the results of the analyses and provides suggestions for new design approaches.

REPRESENTATIVENESS IN THE FIELD SAMPLING OF CONTAMINATED SOILS

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Sampling contaminated soil in the field is a challenge for geo-environmental professionals. The volume of soil to characterize is usually very large and the mass reduction techniques to obtain representative analytical samples are not clearly explained in sampling guidelines and standards.

The Gy's Theory of Sampling, categorizes sampling errors and provides quantitative and qualitative means to control or eliminate them. Field grab sampling (FGS), is largely prone to sampling errors which affect its representativeness. This study assesses the representativeness of field grab sampling and an alternative field sampling (FAS) method based on TOS principles.

To quantify the representativeness of a sampling procedure, one needs to determine its bias and its reproducibility. This is difficult with real soil samples as the true analyte (e.g. contaminant) concentration is unknown and bias cannot strictly be determined. Therefore, we used four physical models of contaminated soil made of a mixture of crushed stone (with nominal diameter $d_N = 5$ cm and average diameter, $d_{50} = 3,5$ cm) and stainless steel microspheres ($d=0,14$ cm) (i.e. the analyte). The model mixtures had a microsphere content of 10 000 mg/kg or 100 000 mg/kg and a moisture content of 0% or 5% (w/w).

For the alternative sampling procedure, a longitudinal pile was constructed with 45,58 kg of each mixture. Fifteen increments (approx. 1,5 kg each) were extracted perpendicularly to the pile's longitudinal axis and across the total height of the pile, with an increment width thrice the nominal diameter of the crushed stone.

For grab sampling, a roughly conical pile was constructed from the remaining material (approx. 26 kg) of the longitudinal pile. Fifteen increments (approx. 0,5 kg each) were grabbed from the pile. The analyte concentration of each increment was determined by separating the microspheres from the dry matrix using a magnet. The representativeness of each sampling procedure was determined from the bias and the relative variance of the measured grain size distributions and analyte content.

The results showed that sub-samples obtained using the alternative method preserve the physicochemical properties of the pile. For example, for analyte content measurements, the maximum sampling bias was 40% for FAS and up to 2200% for FGS. The RSD was less than 20% for the FAS and up to 127% for the FGS on dry mixtures. The FAS lead to quantitatively more representative sample than the FGS. Analyte content and humidity had an effect on the representativeness of both sampling procedures.

POURQUOI PAS UN BACCALAURÉAT EN GÉOTECHNIQUE?

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La profession d'ingénieur civil couvre un champ étendu de pratique englobant la protection de l'environnement, la planification et la conception d'infrastructures durables, économiques et solides. Ce champ devient de plus en plus compliqué avec les outils de conception qui se multiplient tant au niveau des logiciels de calcul disponibles que des techniques de mesures en laboratoire et sur le terrain. Du côté amont cependant, le financement de la formation universitaire s'avère de plus en plus restreint et les pressions pour fournir un produit fini dans les plus brefs délais sont de plus en plus grandes. En plus du génie civil, les génies géologiques et des mines utilisent beaucoup de notions reliées à la mécanique des sols et des roches. La géotechnique est une matière complexe à insérer dans un curriculum de génie civil où chaque sous-groupe (structures, environnement, hydraulique, transport et géotechnique) veut occuper le plus d'espace possible au cours des quatre années du baccalauréat. Tous les intervenants s'accordent à dire que pour une pratique adéquate de la géotechnique, il faut consacrer un minimum plus d'une année à des études supérieures. N'est-il pas temps de changer la situation?

Bien qu'on puisse se questionner sur une trop grande spécialisation de nos diplômés, il serait possible d'exposer au départ de ce nouveau programme des notions de base indispensables en calcul, en résistance des matériaux, en chimie et en informatique tout en insistant davantage sur l'impact de la géologie des dépôts meubles et de la roche dans la conception des ouvrages et la conduite des travaux. Beaucoup de cours enseignés aux études supérieures pourraient être adaptés pour la dernière année du programme de premier cycle puisque les notions préalables auraient été approfondies et assimilées, contrairement à la situation actuelle où elles sont noyées à travers un ensemble de matières abordées superficiellement. Par exemple, un finissant actuel peut difficilement calculer avec assurance un mur de soutènement ou une fondation sur pieux avec des hypothèses réalistes. Compte tenu du peu d'heures de contact au baccalauréat, les étudiants sont mal à l'aise de devoir formuler des hypothèses sur la stratigraphie et les propriétés des sols et du roc alors que c'est là le propre d'un bon ingénieur géotechnicien qui souvent ne bénéficie pas de toute l'information nécessaire pour produire un calcul précis.

USING A LIMIT STATES APPROACH FOR ICE ROAD DESIGN

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Natural resource development in northern Canada has often relied on winter roads and ice roads to provide economical site access and resupply routes. These winter roads provide significant socio-economic benefits to the industrial sites and communities they connect. The state of practice for determining allowable loads has largely been based on empirical ice capacity equations developed in the 1970s. This approach is found in most of the ice bearing capacity guides being used in Canada. Ice road design undertaken with these guides is usually performed without any significant engineering analysis. Engineering analysis entails modelling floating ice as a bending plate and selecting an ice thickness that limits the maximum flexural stress to an allowable value. Modeling can account for ice properties, load configuration and other operational variables that are not considered explicitly in empirical equations. Industrial ice road operations that have sufficient construction quality assurance and operational controls in place can take advantage of higher allowable flexural stresses without compromising ice road safety.

NOR-EX has developed a Risk Management Framework to account for the quality assurance and operational controls used with ice road design. Initial development of the Risk Management Framework took place over the past 7 years on the Tibbitt to Contwoyto Winter Road. NOR-EX believes the Risk Management Framework can combine developments in GPR ice profiling and vehicle dispatch tracking to quantify the risks associated with ice roads.

NOR-EX is exploring the use of the limit states design (LSD) approach in the ice road design of the Tibbitt to Contwoyto Winter Road. This winter road typically handles 7000 haul vehicle loads per season bringing in 230,000 tonnes of fuel, supplies and equipment. Over 300 km of road, 80% over ice, is built each winter season and GPR ice profiling collects thousands of ice thickness measurements. By exploiting the ice data generated by GPR profiling and the dispatch system for tracking vehicle loads, we can generate probability distribution curves for ice resistance and vehicle load effects. This enables us to analyze the ice bearing capacity in the context of reliability based design. We are examining approximate probabilistic methods in generating reliability indices or producing semi-probabilistic load and resistance factors. Our expectation is that we will develop a quantitative basis for assessing risk when considering ice properties and operational controls in the design of ice roads.

METADATA PROTOCOL FOR GROUND TEMPERATURE MEASUREMENTS

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In northern Canada, ground temperatures are measured for a number of reasons including permafrost research and infrastructure development. A protocol for reporting metadata on ground temperature datasets will allow data to be easily shared between various stakeholders, and is a necessary step towards a public permafrost database. We outline a metadata protocol for ground temperature measurements developed through collaboration with both users and collectors of ground temperature measurements. Our collaborators are typically involved with: permafrost research and modelling, geotechnical engineering, and infrastructure performance monitoring. Our metadata protocol is divided into two categories covering –instrument installation and site conditions. Instrument installation metadata will include: site location, thermistor and data logger specifications, date and method of borehole drilling, details of borehole backfill and casing, and depth of temperature measurements. Metadata on site conditions will include details on: topography, drainage, vegetation, organic layer and soil properties, and subsurface stratigraphy.

GEOTECHNICAL INVESTIGATIONS FOR ROCK SOCKET DESIGNS FOR THE GATEWAY DUPLICATION BRIDGE, BRISBANE

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The second gateway bridge duplication in Brisbane, Australia involved the construction of a six-lane bridge immediately downstream from the existing bridge. The bridge structure spans 1.6 km between abutments with a central river span of 260 m. Each pier of the central river span (with compressive ultimate limit state socket loads up to 36 MN), consists of 24 bored piles of 1.8 m diameter.

This site is located close to the mouth of the Brisbane river and has Holocene (young material) generally overlying the Pleistocene (older) Alluvium. The following major sequences were intercepted at the central pier locations. Weak estuarine soils overlying, alluvial sands and gravels comprise the overburden. An upper, low to very low strength cap rock and low grade coal overlies inter-bedded sandstone, siltstone and mudstones of the Triassic within the investigated depths.

Pressuremeter tests were conducted in selected boreholes for the central piers. More than 110 intact rock cores were tested for UCS including deformation modulus from depths as deep as 50 m below ground level. Rock cores were subjected to Constant Normal Stiffness direct shear testing (CNS, which better simulates the stress conditions in rock socket/concrete interface) and Constant Normal Load direct shear testing (CNL, conventional rock direct shear tests) were undertaken on sandstone specimens with two different roughness profiles to investigate the pile peak side resistance. Osterberg cell testing was carried out on two sacrificial sockets to verify the findings from the CNS testing.

This paper presents the principal findings of the above investigations.

SURFACE WATER INFILTRATION EFFECTS ON THE PERFORMANCE OF THERMAL CAPPING SYSTEMS FOR WASTE ROCK IN CONTINUOUS PERMAFROST

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In Canadian Arctic and sub-arctic regions, reclamation of both open pit mines with potentially acid generating pit walls and potentially acid generating waste rock (PAGWR) piles in continuous permafrost presents many geotechnical challenges. Thermal capping, based mainly on site climate conditions, is often used to reclaim PAGWR piles. The goal of thermal capping systems is to maintain the PAGWR in a frozen state (i.e. below the maximum active layer depth) to prevent acid mine drainage and metal leaching. Thermal caps are attractive, because they are generally easier to construct than infiltration-control alternatives like bituminous liners and capillary break covers.

Design of thermal caps calls for an evaluation of the active layer thickness usually with thermal modelling simulating heat conduction through cover materials. However, the potential impact from surface water infiltration on thermal caps is not well understood and is often neglected in long-term simulations of the active layer used as a basis for cover design. This paper explores the long-term performance (100 years with climate warming) of two cover concepts: Thermal Capping #1 (65-200 millimeter [mm] sized clean rockfill) and a Thermal Capping #2 (0-600 mm sized coarse rockfill overlying a densely compacted till layer). The model represents each thermal cover over an open pit backfilled with waste rocks. The pit, located on sloping terrain, acts as a drain towards which surface water is converging. Two-dimensional (2D) heat conduction and convective heat transfer models (for flowing water from snowmelt and summer rainfall) were conducted by coupling TEMP/W and SEEP/W software by GEO-SLOPE International Ltd. The goals of this exercise were to assess the thermal impact of downslope flowing water through both covers and the backfilled waste rock. Modelling results show that the difference between Thermal Capping #1 and Thermal Capping #2 without an infiltration flux is relatively small. When infiltration representing mean site conditions is added to the model, the results indicate that the maximum active layer depth increases and that this increase is more pronounced for Thermal Capping #1. Differences in performance can be attributed to water flow through the backfill for Thermal Capping #1 and through the cover for Thermal Capping #2. Depending on site conditions, it appears that surface infiltration should be taken into account when designing thermal caps.

WINTER SOIL TEMPERATURES NORTH AND SOUTH OF TREELINE, CENTRAL NORTHWEST TERRITORIES, CANADA

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Air, ground surface, and permafrost temperatures were measured for two years (2004-06) at 26 sites near Yellowknife and the Colomac and Ekati mine sites, Northwest Territories. The Yellowknife and Colomac study areas are south of treeline in discontinuous permafrost, but Ekati is in continuous permafrost north of treeline. Vegetation, snow, and soil surveys were conducted to help assess the role of site-specific factors on climate-soil thermal relations. Air temperatures across the Slave Province were near climate Normal in 2004-05, but 4 °C higher in 2005-06, principally due to warmer winter conditions. South of treeline, annual mean surface temperatures ranged from -1.7 to 4.0 °C and were resistant to the increased air temperature of 2005-06, but north of treeline surface temperatures were considerably lower (-6.6 to -1.8 °C) and rose by 2.3 to 3.0°C in the second warmer year. Spatial and interannual variations in climate-soil thermal relations were associated with differences in the duration of active-layer freezeback. South of treeline freezeback was prolonged by a thick snow cover, while north of treeline, where snow covers were thinner, freezeback was shorter and allowed the ground to cool for most of the winter. The variability of ground temperatures south of treeline was controlled by the total water content of the active layer rather than snow cover. In the past, snow cover has been invoked as the principal factor responsible for spatial variation in permafrost temperatures. These data also demonstrate the important influence of active-layer moisture on ground temperatures in permafrost terrain

A COMPARATIVE STUDY ON THE ROLE OF CONSTITUTIVE MODELING IN NONLINEAR DYNAMIC ANALYSIS OF TAILINGS DAMS

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Tailings are residual material produced during the process of extraction of minerals from mined ores and are usually contaminated materials produced in slurry form. Depending on the ore type and milling process used to crush the ore, the grain size distribution of tailings range from medium sand to silt or clay. Slurry tailings are transported and discharged in large impoundments by pumping in a pipeline. Saturated tailings are usually retained in the impoundments by means of raised embankments (tailings dams). These are constructed in stages over the life of the impoundment with compacted natural soil, tailings materials and/or waste rock. Due to the usually huge dimensions of the impoundments, the great heights of the embankments and the site conditions like saturated loose granular foundation materials and high PGA, tailings dams represent a high-risk construction for the environment in case of a dam failure. In general, detailed numerical studies are conducted for seismic analyses of high-risk tailings dams during the design phase. However most of the analyses are performed using very simplistic stress-strain models such as Mohr-Coulomb, which in turn limit the reliability of the predictions. In the present study a tailings dam was analyzed for a seismic motion using the finite difference code FLAC and Mohr-Coulomb model. In addition, the SANISAND constitutive model was implemented and added to FLAC as a dynamic-link library. Results of the SANISAND performance at element test level and the seismic numerical analyses of the tailings dam are discussed, analyzed and compared with results obtained by using Mohr-Coulomb model.

INTEGRATING LABORATORY TESTING, PHYSICAL MODELLING AND SIMULATION TOOLS IN SUPPORT OF PIPELINE DESIGN FOR GEOHAZARDS

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Energy pipelines are a safe, cost-effective mode for the transport of hydrocarbon resources across terrain units with varied geohazards (e.g., subsidence, slope movement). The relative ground movement imposes loads on the buried pipeline that may cause local damage (e.g., ovalization, local buckle formation) and impair the mechanical performance with respect to serviceability or strength limit states. Exceeding these limit states may result in service interruption or failure and loss of product containment.

The current state-of-practice for the analysis, design and integrity assessment of buried pipelines subject to geohazards is based on structural pipe/soil interaction models idealized using beam and spring elements. This approach can be deficient when analyzing complex pipeline/soil interaction events that need to account for the effects of trench backfill and native soil properties, oblique load coupling and soil shear behaviour, large deformation events and deep burial conditions. Continuum finite element methods can address these deficiencies but require an integrated framework including experienced numerical modellers, laboratory tests to define input parameters for soil constitutive models and physical data to verify simulation procedures.

In this paper, the need to refine existing constitutive models within simulation packages, such as Abaqus, for the tailoring of soil behaviour to improve confidence in predictable outcomes for pipe/soil interaction events is presented. The soil elastic and strength properties vary with depth and the mobilization (i.e., strain hardening, softening) of strength parameters (i.e., friction angle, dilation angle) with plastic deformation is used. A series of reduced scale centrifuge tests for the oblique pipe/soil interaction loading events, in loose and dense sand were conducted. These tests confirmed the yield envelope can be characterized by two bounding surfaces that are related to the local soil failure mechanisms. These reduced scale tests and available full-scale tests are used to verify the continuum finite element modelling procedures simulating pipeline/soil interaction events. Comparison between the physical models and numerical simulations with respect to the force-displacement response and soil failure mechanisms is presented.

The framework for integration of these technical approaches in support of pipeline engineering design is discussed. The potential for improving current pipeline engineering practice is also explored.

FULL-SCALE PILE LOAD TESTS ON INSTRUMENTED CONCRETE PILES IN CLAY TILL, IN EDMONTON, ALBERTA

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Cast-in-place concrete belled piles founded in clay till are commonly used for support of heavily loaded foundations in the Edmonton area. Full-scale pile load testing on instrumented piles not only verifies load-carrying behavior and performance of the piles but also allows for the break-down of shaft and end-bearing resistance for the design. Based on the results of the pile load tests, an increase of geotechnical resistance factor from 0.4 to 0.6 can be applied in the geotechnical design. For projects with a large number of piles required, the overall benefit consisting of the increase in design reliability and the reduction in total piling costs can be substantial.

The paper presents the results of three full-scale pile load tests on instrumented cast-in-place concrete belled piles constructed in three separate project sites in the downtown area of Edmonton, Alberta. The shaft diameters of the test piles ranged from 0.9 m to 1.2 m, bell diameters from 1.8 m to 2.7 m, and test loads were up to 9,000 kN. Embedded strain gauges and tell-tales were installed in the test piles, which provided a reliable assessment on the shaft and end-bearing resistance. The paper describes the soil conditions, test results and discussion of results. Considerable variability in the test results was obtained at the test sites and this is discussed in the paper.

NUMERICAL STUDY FOR SOIL–SPRING STIFFNESS OF PILE GROUP

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The elastic foundation beam method (Winkler method) proposed in 1867, is still used in engineering design and remains attractive due to its simplicity. Many approaches have been developed to determine the soil-spring stiffness and typical values has been proposed for different type of soils and for different densities. However, these typical values generally ignore the effect of depth and the degradation of elastic parameter (G or E) as a function of strain. In this paper, a series of three-dimensional finite differences analyses are conducted to compute equivalent soil-spring stiffness's according to distortion level of the pile subjected to lateral loading. In these simulations the degradation of the shear modulus is incorporated in order to account for soil nonlinearity.

The idea is to develop equivalent springs that can be adapted to the pile lateral deformation. The stiffnesses of these springs vary depending on the distortion and may be adapted in an iterative process according to the pile deformation at each depth. This approach can be compared to the linear equivalent method used in dynamic analysis where an equivalent shear modulus is adapted according to the shear distortion. This type of linear equivalent spring is very useful for structural engineers who want to incorporate the effect of the lateral capacity of soil in their model.

This procedure was adopted to predict the soil-spring stiffness's of a pile group located under the central pier of bridge structure above the river Sault-au-Mouton (Longue-Rive, Quebec) and subjected to multi-loading conditions (vertical load, lateral loads and moments). The results of the interactive process used in the Longue-Rive Bridge will be presented to demonstrate the effectiveness of the proposed procedure.

BLENDED TRAINING AND COLLABORATIVE LEARNING FOR SOFTWARE USERS IN THE GEOSCIENCES

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Geoscientists and geoenvironmental engineers use scientific software in applications that can directly affect public safety. Geological hazard risk assessments, water quality geochemical assessments, and rock stability evaluations all involve the use of scientific software (i.e. numerical modelling programs). Research on identifying effective training practices for scientific software users in the geosciences has not yet been performed; as a result, scientific software training for geoscientists and geoenvironmental engineers is applied with questionable results. Correct use of scientific software is a pre-condition for correct, accurate interpretation of software output. This ensures reliable answers to scientific inquiries. Thus, there is currently a growing need for increased understanding of scientific software training processes in geotechnical education and at the same time a deficiency in the literature regarding this topic. Geoscientists have clearly indicated the usefulness of employing blended learning methods in mobilizing knowledge among users with respect to applying scientific software accurately. Blended instruction, described as the combination of online and traditional classroom instruction, has been used by an increasing number of post-secondary institutions and industry to enhance science and engineering research training. This qualitative investigation explores the needs of software users in the geosciences and geoenvironmental engineering regarding training in blended learning settings. Selected initial results reveal issues concerning ownership of ideas and exchange of feedback in traditional and online collaborations regarding correct application of scientific software. The study takes into consideration diverse educational backgrounds of software users in academia and industry. The results of this investigation will contribute towards effective scientific software training, successful application of the software and, as a result, dependable and realistic solutions to geotechnical problems.

LONG TERM CYCLIC LOADING EFFECTS ON THE SYSTEM STIFFNESS AND CAPACITY

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Abstract

Wind Energy field is growing each year especially for offshore farms. Monopile is widely used as an easy method of construction in offshore wind farms. A new hybrid system which is a combination of monopile and concrete plate are presented and tested in this work. Cyclic loading on different foundations system was presented in this work to study the effect of long term cyclic loading on the different systems. Wind loads from Boundary layer wind tunnel at Western University of Canada was used as a reference loads for 5 MW NREL (National Renewable Energy Laboratory) based wind turbine for up to 12000 cycles. Four main systems were selected from ABAQUS parametric study to be tested in the lab. A complete scaled down non dimensional framework of stiff systems were used under 1 g for series of static and dynamic loads based on (C. Leblanc 2010) in Ottawa sand. The accumulation rotation for different systems after number of cycles were calculated. The pile stiffness of the different systems were presented which found to be increased. An equation of scaling the systems by adding the plate effect were presented.

Keywords: Cyclic Loading, Wind Turbine, Pile, Stiffness.

DESICCATION-CONSOLIDATION MODELLING OF OIL SANDS FINE TAILINGS DEPOSITS

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The oil sand industry continues to explore alternate tailings disposal technologies that use some form of chemical amendment, such as a polymer, but also rely on post-deposition dewatering to generate tailings deposits that are reclaimable in a reasonable time. Dewatering occurs through several mechanisms, including particle aggregation through application of polymer or other amendment, but also consolidation and desiccation through evaporation, drainage, or freeze-thaw. Understanding the relative contribution of each mechanism will assist in selecting optimal thickness, amendment dose, and rate of rise, to minimize and control impoundment footprints.

This paper evaluates the performance of three software codes that couple desiccation to large strain consolidation, in modeling dewatering in field trials and well as large laboratory simulations of multi-lift deposition of polymer amended oil sand fine tailings. While the performance of the codes varies somewhat due to their different treatments of unsaturated flow, they all show skill in reproducing laboratory and field results. The paper discusses the relative merits of each code as a tool for aiding design of tailings deposition schemes. Analyses of hypothetical deposition scenarios are presented for each code.

TWO DIMENSIONAL, DEPTH INTEGRATED TWO DIMENSIONAL, AND THREE DIMENSIONAL MODELLING FOR GEOMETRY CONTROL OF TAILINGS DEPOSITS

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Many tailings technologies that dewater tailings through various mechanisms (thickening, in-line flocculation, centrifuge), in both hard rock and oil sands mining, are limited by the operational challenges of controlling the thickness, over all shape, and final slope of tailings deposits. The current paper summarizes a number of efforts to try to model tailings that exhibit a yield stress, with the objective of developing a design tool to assist operators in deposition planning. This includes modelling tailings flows in both 2D and 3D using the commercial finite volume based software CFX, and modelling tailings flows in 2D, a 2D depth integrated solution, and in 3D using smooth particles hydrodynamics codes modified from a freeware by our research group. We compare the results of these models with bench scale experimental data, and some limited field data. In the paper, we will review the advantages and disadvantages of each method and discuss their utility with respect to tailings deposition design.

THE USE OF ANALYTICAL METHODS IN THE EVALUATION OF THE SEISMIC STABILITY OF THE FRANKLIN FALLS DAM SUBJECT TO THE 1982 NEW HAMPSHIRE EARTHQUAKE

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The most common method to evaluate the anticipated seismic performance of earthfill and rockfill dams is the pseudo-static method elaborated by Seed & Martin (1966) with later recommendations for usage by Hynes-Griffin and Franklin (1984) and Bray & Travasarou (2009) and the permanent displacement (sliding block method) as developed by Newmark (1965) and advanced by Makdisi & Seed (1977) and Bray & Travasarou (2007). These methods were developed based on observations of the seismic behavior of dams on the west coast of North America and verified and calibrated based on numerical modeling that used west coast ground motions. The emphasis on west coast ground motions is due to the fact that the west coast is significantly more seismically active than the east coast, which provides an impetus for concentration on west coast ground motions and a relatively large database of ground motions and recorded dam seismic behavior.

The center and east coast of North America are seismically active, albeit not to the same degree as the west coast. Important differences between ground motions on the west and east coasts include the frequency content and the attenuation. Due to relatively harder and more intact bedrock, ground motions on the east coast are characterized by high frequencies and reduced attenuation of the energy (PGA and energy content) with distance from the source of the earthquake. The New Madrid (1811-1812; $M_w=7, 7.5, 7.7$ and 7.7), Charleston (1886; $M_w=7.3$), Miramichi, (1982; $M_w=5.1$ and 5.7) and Saguenay (1988; $M_w=5.9$) earthquakes are evidence of the potential for devastating earthquakes on the east coast.

The Franklin Falls Dam, with a maximum height of 42 m, is a flood control dam and is composed of earth and rock fill. During the New Hampshire earthquake, three records were obtained on the crest, abutment, and downstream of the Franklin Falls Dam.

This paper will present a summary of dynamic numerical analysis of the Franklin Falls dam subject to the 1982 New Hampshire earthquake and the corresponding pseudo-static and permanent displacement analyses. Findings and recommendations regarding the use of these methods for east coast ground motions are then presented

TACTILE SENSORS TECHNOLOGY APPLICATION ON BURIED STRUCTURES

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Soil structure interaction for buried structures is an important topic when it comes to investigating various techniques of ground improvement where obtaining a detailed assessment of their effect is needed whenever an experimental approach is selected. Tactile sensors provide a powerful tool that serves such purpose as they enable plotting 3D imaging of pressure distributions on the buried structures with extraordinary accuracy due to their minimal thickness and high flexibility. A series of experimental investigations on circular and square shaped culverts, were conducted in a small scale testing setup in which tactile sensors technology was implemented to better understand the influence of synthetic materials installations as Geofam or Geogrid. The purpose of this paper is to present the preparation, calibration and challenges encountered to successfully take advantage of such technology which although requiring huge efforts was satisfactory and promising in the authors opinion.

PREDICTIVE MODELS OF THE COMPRESSIVE STRENGTH OF CEMENTED PASTE BACKFILLS TAKING INTO ACCOUNT THE SELF-WEIGHT CONSOLIDATION

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Cemented paste backfill (CPB) is commonly used in most underground mines worldwide for stope filling. CPB provides local ground support and a safer working platform for miners and machinery, and allows a complete extraction of ore bodies. It also allows large amount (> 50%) of tailings storage underground, which in turn decreases surface tailings storage facility (TSF) management, thereby reducing environmental impacts. The suitability of underground CPB is invariably evaluated in terms of its unconfined compressive strength (UCS). Compressive strength, which varies between 100 kPa and 5 MPa, is usually used as a quality control parameter in the evaluation of the CPB strength properties. The required design strength of CPB is usually determined from laboratory-prepared CPB specimens poured into conventional plastic capped moulds and cured under drained or undrained condition in a humidity chamber at constant relative humidity (< 90%) and temperature (25°). However, numerous laboratory and in situ tests have shown for a given mix recipe and curing time, the UCS of in situ CPB specimens can be 2 to 6 times higher than the UCS of laboratory specimens using the same CPB mixture poured into conventional plastic moulds. This unexpected difference between laboratory and in situ UCS results cannot be ignored when optimizing CPB mix recipes. The possible reasons supporting this huge discrepancy between the UCS of mould and stope specimens could be well explained by the combined effects of placement, curing under stress, drainage, self-weight and/or time-dependent consolidation and binder hydration. To address this issue, an innovative experimental apparatus named CUAPS (curing under applied pressure system) was developed for preparing laboratory CPB specimens that realistically represent in situ consolidation conditions.

This paper present numerous UCS results obtained from plastic moulds, CUAPS apparatus and in situ core specimens. It was confirmed that the UCS from CUAPS backfill specimens were consistently higher than the one from plastic mould backfill specimens for a given CPB mixture recipe. Two semi-empirical general equations were proposed in order to predict the UCS of CUAPS-consolidated backfills from known UCS of plastic mould backfill specimens and the CUAPS-predicted UCS at a corresponding backfill depth. These two equations were both defined as a function of curing time and binder content. In addition, these equations can take into account the arching effect on the strength development within a backfilled stope. It has been demonstrated that these predictive equations can be used with 60% and 75% confidence limit.

REDESIGNING FIELD SCHOOL: SUCCESSFUL IMPLEMENTATION OF E-PARTICIPATION IN GEOTECHNICAL FIELD EXERCISES

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There is much academic debate in terms of what to include in undergraduate and graduate programs for GeoSciences and GeoEngineering students at Canadian Universities (and abroad). Another factor that requires attention is how to educate, with sound andragogy principles, university students in order to fully prepare them for the challenges associated with the workforce. In today's global classroom, there are many methods and tools that can be utilized in order to enhance the educational experience of an academic program in order for a student to gain fundamental knowledge, and be exposed to the relevant components associated with their field of study. In determining the proper balance of methods and tools to be utilized within a Geological / Geotechnical Engineering graduate program, a number of factors need to be considered. The most prevalent of these factors are: The current state of industry and their requirements, technological improvements, sustainable development and social demands as well as the advancement of educational tools and techniques. To this aim, the authors have investigated and employed innovative initiatives aimed at providing geo-graduate students with technology-enhanced learning opportunities that can augment their traditional on-campus lecturing techniques. This paper highlights the use of synchronous and asynchronous e-learning tools for the purposes of enhancing geological and geotechnical field exercises. This proof of concept case study demonstrates that field exercises, related assignments and real world learning does not have to be available only to those that can afford to participate in such excursions. As well, the introduction of such technology allows for the creation of innovative methods for designing field exercises with a view to using this material synchronously and/or asynchronously in the traditional classroom environment. The paper will underscore the relevance of the inclusion of such activities, technologies and associated teaching methods balanced against the very real time, fiscal and technology constraints and a need to optimize these factors.

DETERMINING STABLE SPANS OF UNDERCUT CEMENTED PASTE BACKFILL

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Using tailings as backfill offers many operational and economic advantages for underground mines. There are several challenges for the mining engineer in optimizing the geomechanical design of the underground backfill system, but one of the most difficult is determining whether or not undercutting a previously poured cemented fill will result in fill failure. Previously, Mitchell et al proposed several solutions to assess the stability of such a fill mass. For unreinforced fills in sub-vertical stopes (dipping more than 70°) three different analyses were proposed based on assumed failure mechanisms including: tensile detachment leading to caving; block sliding along the sidewall contacts; and tensile failure in a beam bending mode of flexure. In the proposed work an alternative limit equilibrium model will be proposed that has the advantage of assessing all three failure modes in a unifying mechanism of the undercut fill's behavior. The background to this approach will be described and the resulting equations for assessing stability and required fill strength will be given. For some typical mining cases, stability assessments using the proposed solution will be compared with the previously published Mitchell et al solutions. Finally, the solutions will be compared with some case histories available in the literature.

STUDY OF CORNER AND ABRUPT WALL ALIGNMENT CHANGES IN MECHANICALLY STABILIZED ENBANKMENT (MSE) WALLS SUPPORTING BRIDGE ABUTMENT LOADS

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Wall corners and abrupt facing alignment changes in MSE walls can often be seen at bridge abutments and around existing structures. The American Association of State Highway and Transportation has established guidelines for the design of MSE wall corners with enclosed angle of 120 degrees or less. They recommend two types of connections for the soil reinforcement in this area:

1. Soil reinforcement connection type 1. When there is insufficient room to accommodate the full length of the soil reinforcements, they shall be tied across to the opposite panels and designed for higher earth pressure as the corner is considered as a bin structure.

2. Soil reinforcement connection type 2. Provide additional reinforcement to be extended beyond the corner to stabilize it. These guidelines are not sufficiently detailed and comprehensive as the width of these corners varies and the bin theory (for the design of silos) might not apply to all geometry. Straight interpretation of these guidelines has resulted into large quantities of soil reinforcements and has created congestion within a very confined area, especially when the piles supporting the abutments are present. On-site installation of the connections and quality of workmanship have been challenging due to the overcrowding.

To alleviate these issues, one needs to fully understand the behavior of the fill and the contribution and interaction of all soil reinforcements within the corner confined area. With the aid of a 3D finite difference software, the Reinforced Earth Company USA and Canada performed several numerical analyses on 3D models with different enclosed angles and wall heights.

The findings from the study allow for a potential reduction of the amount of soil reinforcement, resulting in savings in materials and providing for ease in construction execution on site.

INVERSE MODELLING OF DESORPTION TESTS TO ESTABLISH THE HYDRAULIC CONDUCTIVITY OF UNSATURATED QUEBEC GRANITIC SAND

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The Multistep outflow method (MSO) has been widely used to determine the hydraulic conductivity functions of unsaturated soils. Accurate determination of these parameters is important for to predict the subsurface flow and water transport in soils. Inverse modeling methods can be used to estimate the hydraulic conductivity of unsaturated soils. These methods can be used to fit the existing expressions of flow of water in unsaturated soils to the experimental data. In this study, inverse modeling combined with the multistep outflow data was used to estimate the unsaturated hydraulic conductivity of three samples of Quebec Valcartier granitic sand. These tests were performed in laboratory under controlled initial and boundary conditions. During each test, soil matric suctions were measured at the bottom and within the soil sample using the transducers and microtensiometers. The commonly used models of van Genuchten (1980) and Mualem (1976) were used in this study.

Our results show that the solutions of the parameter estimation method are sensitive to measurement errors. Differences between measured and optimized soil water retention data were small. Optimized saturated hydraulic conductivity of the tested materials showed a very good agreement with Fillion 2008 measured values for the same materials.

OVERVIEW OF ANTICIPATED SUBSURFACE CONDITIONS AND GEOHAZARDS FOR A PROPOSED ALL-SEASON ROAD, PRAIRIE CREEK MINE, NORTHWEST TERRITORIES

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The Prairie Creek Mine is located in the southwest corner of the Northwest Territories, surrounded by the Nahanni National Park Reserve of Canada, which is a UNESCO World Heritage site, known for karst terrain of global significance and the South Nahanni River, a Canadian Heritage River. The mine and access routes have been a part of the landscape and history of the Northwest Territories since 1966, and the mine area is part of the traditional territory claimed by the Nahanni Butte Dene Band. The original winter road was 288 km long, accessing the site along the Ram and North Nahanni Rivers from the Mackenzie River to the northeast. In 1980, the construction of Liard Highway No. 7 allowed access from the southeast near Nahanni Butte, and a new winter route, shortened by over 100 km, was used for mine construction.

Thirty-five years later, in 2015, climate change, as well as environmental and operational factors have made a strong case for the project owner, Canadian Zinc Corporation, to consider an all-season road to access the mine, essentially following the winter road alignment. The all-season road will cross sensitive terrain including permafrost and karst, with the potential occurrence of thermokarst, sinkholes, debris flows and thaw slumps, as well as rock fall, rock slides, and snow avalanches in mountain terrain. Some 85 km of the road passes through Nahanni National Park Reserve, entailing some additional challenges in preserving critical terrain and valued features. Local communities have a strong interest in preserving the natural terrain, wildlife habitat and fisheries values, and cultural values.

Steps in evaluating the terrain along the proposed route included analysis of historical stereo aerial photos, review of geology and surficial geology mapping, review of recent high-resolution orthophotography and contour data derived from LiDAR, previous geotechnical and terrain analysis reports for the route and its predecessors, and other terrain and geotechnical reports from the region. Key aspects of the project included the evaluation of likely contributing factors of existing natural and/or anthropogenic slope instabilities in rock and soils as related to the surrounding terrain and/or permafrost; and ground-truthing in the form of geotechnical field investigation and laboratory testing. Goals of the project included providing baseline information on terrain, geology, soils, and permafrost to land managers, stakeholders, First Nations communities, and environmental reviewers, as well as providing a basis for the successful design and construction of an all-season road.

APPLICATION OF A 3D GROUNDWATER MODEL TO ASSESS PERFORMANCE OF THE MUSKRAT FALLS DAM NORTH ABUTMENT

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The Muskrat Falls Generating Facility (824 MW) comprises a central 4-unit powerhouse and spillway flanked by a RCC dam. The north abutment for the North RCC Dam, referred to as the North Spur, is a peninsula of land comprising stratified silty sands and sensitive glacio marine clays underlain by a granular aquifer and then bedrock. In 1978, a land slide occurred on the downstream side of the North Spur engaging approximately 1.0 million m³ of soil. The spur was subsequently stabilized using a system of pumped wells, which regulate piezometric levels in the land form.

When the Muskrat Falls facility is finished, the river level upstream of the North Spur will be raised by 22m. Remedial measures have been design for the Spur to control the piezometric rise during impoundment and operation as well as to ensure the spur stability. These measures include bentonite-slurry cut-off walls, impervious upstream blanket and installation of downstream drainage measures. This paper describes the development, calibration and use of a 3D groundwater model to assess these stabilization measures for the North Spur. The model was calibrated against initial piezometric levels in the spur prior to impoundment; as well as against the response of the spur during short- and long-term pump tests. Typical model results are presented to illustrate its' use to evaluate the spur response during reservoir filling; with and without cut-off walls, impervious upstream blankets and drainage

GEOMORPHOLOGY AND DYNAMICS OF THERMO-EROSION GULLIES: INCIDENCE OF SEDIMENTARY ENVIRONMENT ON GULLY SHAPE AND PERMAFROST EROSION RATES

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Convective heat transfers between running water and ice-rich permafrost (ice wedges) can create linear permafrost disturbance called thermo-erosion gullies. Retreat rates of such gullies can be as rapid as several hundred linear meters per year as observed by Fortier et al. (2007) on Bylot Island, Nunavut. Such gullies can vary in size from a few meters in length up to well-developed kilometer long network. Topography and hydrological components of periglacial geosystems are strongly modified by the inception and development of thermo-erosion gullies (Godin et al. 2014, Morgenstern et al. 2013). In the Qarlikturvik valley, on the southwestern plain of Bylot Island, we selected a Holocene ice-wedge polygons terrace covering a range of sedimentary environments in which thermo-erosion gullies formed. Shape and erosion rate of 4 thermo-erosion gullies varied between: 1) organic-rich loess deposit (R08, R06); 2) colluviums (N04); 3) eolian cover sands (R16). Linear retreat measurements for all 113 axis of the studied gullies (2011-2013), grain-size analysis and active layer thickness, humidity and temperature (2013) were used for spatio-temporal characterization. The organic-rich environment was incised by R08 with 94 erosion axis (24800m²) and R06 with 47 erosion axis (14908m²). This type of sedimentary environment had the highest rates of retrogressive erosion (82my⁻¹ for R08 and 48my⁻¹ from 2010-2013), reflecting the dense pattern of ice wedges and the ice-rich nature of enclosing permafrost soils. N04 formed in colluvium has a much more linear shape with 6 axis on 7366m². Two branches located at the head had a retreat of 116 meters over two years. R16 formed in eolian sand was linear in shape with 13 axes on 4095m² and slow retreat rate of 4.97my⁻¹ (2010-2013). The results show that thermo-erosional gullies have distinct characteristics depending on their environment; as they are landscape disturbances, implications of morphological and mechanistic studies of gullies for permafrost geosystem landscape modelling are discussed.

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EFFECT OF GRAIN SIZE DISTRIBUTION ON THE HYDRAULIC PROPERTIES OF UNSATURATED GRANITE SAND

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INTRODUCTION: The unsaturated hydraulic conductivity and water retention curve have become key functions to characterize the unsaturated soils. These parameters can be used to model flow of water in soils and fluctuation of negative pore water pressure. This paper presents the results of the multi-step outflow tests to determine the effect of grain size distribution on water retention curve of reconstituted samples of the Quebec Valcartier granitic sand. The experimental results were fitted by using van Genuchten (1980) and Fredlund and Xing (1994) models.

Unsaturated hydraulic conductivity is another important parameter for unsaturated soils. Different direct and indirect methods can be used to determine the unsaturated hydraulic conductivity. In this study, experimental water retention curves were used to determine the relative hydraulic conductivity functions of Quebec Valcartier sand. This parameter was estimated by using the van Genuchten (1980) and Fredlund et al. (1994) models. Fillion (2008) performed saturated hydraulic conductivity test on the same materials of this study. Using Fillion's (2008) saturated hydraulic conductivity test results and estimated relative hydraulic conductivities for the tested materials, the unsaturated hydraulic conductivity functions for Quebec Valcartier granitic sand were determined as a function of grain size distribution.

The effect of the effective grain size, d_{10} , and the coefficient of uniformity, C_u , on water retention curve behaviour was studied for each material. The analysis results indicated that soils with lower d_{10} and higher C_u reach the same volumetric water content at higher soil suctions (residual moisture content).

The results also showed a good agreement between the van Genuchten (1980) and Fredlund et al. (1994) models to predict the hydraulic conductivity functions. However, small differences may be observed at low suction where the estimated hydraulic conductivities from the van Genuchten (1980) model were lower than those obtained with the Fredlund et al. (1994) model. This trend was not observed at higher suctions.

CONCLUSION: Experimental water retention curves were used to determine the relative hydraulic conductivity functions of Quebec Valcartier sand. The analysis results showed that soils with lower d_{10} and higher C_u reach the same volumetric water content at higher soil suctions. The analysis results also showed a good agreement between the van Genuchten (1980) and Fredlund et al. (1994) models to predict the hydraulic conductivity functions.

INSTRUMENTATION MONITORING OF A TEST FILL CONSTRUCTED OVER PEAT AND SOFT CLAY DEPOSITS IN NORTHERN ALBERTA

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Instrumentation monitoring results of a full-scale, well-instrumented test fill constructed over peat and soft clay deposits in Northern Alberta are presented and discussed. The intent of this test fill was to better understand porewater pressure response and displacement behaviour of the foundation soils during and after fill placement to refine the geotechnical design of a proposed dyke with similar site conditions.

The construction rate of the test fill was approximately 0.8 m per day to a design height of 6 m and top dimensions of 50 m and 100 m. The north and south faces of the test fill had a side slope of 3H:1V, and the east and west faces had a side slope of 5H:1V. A total of 27 vibrating wire piezometers, 3 vibrating wire settlement cells, 4 slope inclinometers and 5 ShapeAccelArrays were installed along north-south and east-west sections under the test fill to monitor excess porewater pressure response, and vertical and lateral displacements in peat and soft clay layers during construction and for a period after construction.

The excess porewater pressure parameter $B\text{-bar}$ ($B\bar{}$) (i.e., the ratio of load induced excess porewater pressure to the applied vertical stress) was evaluated to assess requirement of construction rate constraint. As a typical trend, the maximum $B\bar{}$ value of approximately one generally occurred within the soft clay layer, shortly after the placement of each lift at the section with the side slope of 3H:1V.

The measured settlement mainly occurred during construction indicating the rapid primary consolidation of the peat layer. A dramatic drop of the settlement rate was observed when construction ended. Moreover, the maximum lateral deformation of 180 mm was observed at the section with the side slope of 3H:1V.

Based on the results of instrumentation, analyses were performed to calculate and confirm design values of compressibility parameters and hydraulic conductivity of the peat and soft clay soil units. Discussions of the measured excess porewater pressure response and displacements at the instrumented sections are presented.

PERMANENT DISPLACEMENT ANALYSIS UNDER EARTHQUAKE LOADS OF EARTH AND ROCKFILL DAMS LOCATED IN EASTERN CANADA

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Permanent deformation or permanent displacement analysis is now a widely accepted approach for studying the seismic stability of slopes or embankments built or composed of non-liquefiable soils. This approach is based on a concept put forward by Pr. N. Newmark in 1965 that the effects of earthquakes on slope stability should be based on the deformations they produced rather than on the factor of safety. The method has developed in two directions. Numerical simulations have evolved from assuming, in 1965, rigid plastic behavior and modelling the sliding mass as a single degree-of-freedom system to more complex flexible behavior and multi-degree-of-freedom systems. In parallel, several empirical formulas (Bureau, 1996; Swaisgood, 2003, etc.), based on the compilation of case histories, have been recently developed which relate vertical crest settlements of dams during an earthquake to the acceleration or the earthquake magnitude. However, as pointed out by Dobry (1994) the level of uncertainty associated with permanent ground deformation is still quite high and could be improved by calibrating analytical methods with empirical field correlations.

Studies on dams permanent displacements have been performed using Newmark's method or one of its variant using the ground motions predominantly from Western US. However, the seismological context of Eastern Canada, being characterized by an intra-plate seismicity and a distinct geology, is much different and produces seismic signals characterized by a strong high frequency content and a low attenuation of seismic waves. To date, no study has been carried out to develop and validate relationships of seismic displacement applicable to dams located in Eastern Canada. In this present study, seismically induced permanent displacements were calculated by the Newmark method using both a rigid and a flexible sliding block models. Overall, 317 seismic signals typical of Eastern Canada ground motions were used. New regression equations are proposed and predictions with Western US ground motions data are made and discussed. The paper concludes by a discussion of the implications of the high frequency ground motions in the analysis of seismic permanent displacement of earth and rockfill dams.

EFFECT OF AGEING ON STIFFNESS OF VERY LOOSE SAND

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The paper extends a previous study of the effect of ageing on the secant stiffness of very loose Fraser River sand in triaxial compression tests. The stiffness has been shown to be very dependent on the time of confinement prior to shearing and on the stress ratio at which the sample is aged. Higher stress ratios resulted in very soft initial moduli with no ageing but the moduli increased by several hundred percent during the first 1000 minutes of ageing. The data suggested that the effect of age on stiffness would be even greater as the strain increment level decreased. The test apparatus was modified to enable determination of shear stiffness at very small strain, G_0 , by measurement of shear wave velocity, V_s , using bender elements. The additional data showed that the effect of age on stiffness at very small strain was not as anticipated from the earlier work and was less than the resolution of the V_s measurement. The paper will present data showing the variation of G/G_0 versus shear strain with age in very loose Fraser River sand and discuss the implication of the results for interpretation of in situ stiffness.

TIRE-DERIVED AGGREGATES AS A BACKFILL FOR BRIDGE ABUTMENTS AND RETAINING WALLS

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Recycled materials that have been used as borrow materials for embankment construction and retaining wall backfills include recycled asphalt, recycled concrete, tire derived aggregates (TDA), blast furnace slag, steel slag, coal bottom ash/boiler slag, flue gas desulfurization scrubber, cullet glass, and roofing shingles. Some of these recycled materials offer potential environmental, technical, and economical benefits for retaining wall applications. For example, when compared to natural soils, many of them may offer the advantage of reduced lateral earth pressures and foundation settlement due to smaller unit weight, and potentially higher drainage capacity. However implicit in some of these options is the applicability of conventional soil mechanic principles in the design and technical assessment. In this paper we present experimental data from laboratory and model tests (centrifuge and model retaining walls) which highlight the challenges involved when trying to predict lateral pressures induced by a recycled wall backfill composed of tire derived aggregate. A key difference of this type of granular material is related to the nature of their particles which are deformable and that they can exhibit viscous behavior. The experimental results are compared with classical lateral earth theories for active, passive, and at-rest conditions.

CPT BASED METHODOLOGY TO PREDICT AXIAL CAPACITY OF POST GROUTED DRILLED SHAFTS

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CPT based methods for predicting the axial capacity of deep foundations are widely used in civil engineering design practice (e.g., LCPC method by Bustamante and Gianeselli, 1982). This paper presents an adapted CPT based method which can be used to predict axial capacity of the relatively new deep foundation system involving base post grouted drilled shafts. Conventional drilled shafts typically offer a suitable alternative to support high structural loads. Post stressing the tip of these foundations has been proposed as an effective alternative to address certain issues like strain-dependent side friction and construction disturbance at the bottom of the excavation that may reduce the achievable axial load capacity and affect the overall performance of the shaft. Furthermore, without tip post grouting, drilled shafts typically require large axial displacements to develop ultimate side friction and tip resistance simultaneously. Post-grouted drilled shafts (also known commercially in the U.S.A. as SynchroPiles) have been found to be a cost-effective solution to compensate for this capacity reduction and/or compressibility increase.

This paper presents a CPT based methodology that can be used to predict the capacity of Post Grouted drilled shafts. The method was developed based on a series of well instrumented full-scale axial load tests on these foundations where CPT soundings were available. Comparisons of measured capacity to predicted shows the methodology is reliable at least to similar levels reported for commonly used static methods used for estimating axial load capacity of deep foundations. In its current version the proposed methodology provides a useful design tool for post grouted drilled shaft foundations. However as more static axial load test case histories with CPT data become available the methodology can be updated and refined.

CARACTÉRISATION ET ÉVALUATION ÉCONOMIQUE D'ANCIENS RÉSIDUS MINIERS PAR MÉTHODES GÉOPHYSIQUES ET PÉTROPHYSIQUES

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La gestion et la valorisation des anciens résidus miniers sont aujourd'hui des enjeux majeurs au Québec et ailleurs dans le monde. Leur utilisation à des fins économiques est une des voies possibles d'aborder ce problème. Avec l'évolution des techniques métallurgiques et des prix des métaux, ces résidus peuvent représenter des sources de matières premières bon marché nécessitant peu de traitements supplémentaires. Le défi reste de faire l'évaluation économique de ces résidus qui présentent souvent de fortes hétérogénéités, compromettant l'efficacité d'une caractérisation géologique simple et classique. La géophysique, de par sa capacité à moyenniser l'ensemble des contributions de la zone investiguée, est alors un outil précieux. Alliée à la pétrophysique qui caractérise les propriétés physiques du matériau, définir des cibles et établir une évaluation économique est alors possible. Nous proposons ici une méthodologie accompagnée d'un cas d'application aux résidus miniers d'une ancienne mine du Québec ayant opéré de la fin du XIX^{ème} siècle jusqu'au milieu des années soixante-dix. Une première visite de terrain a été effectuée afin de s'assurer de la nature des résidus. On distingue deux grandes catégories : en premier des résidus de types gravats ou décombres, issus de dynamitage de roches jugés stériles afin d'accéder aux gisements; en second des résidus de type sables industriels, issus de l'usine d'extraction des métaux lors de l'exploitation. Des échantillons ont été prélevés et caractérisés au laboratoire afin de déterminer quelles méthodes géophysiques seraient les plus à même de mettre en évidence les concentrations économiques de métaux dans ces résidus. Ces tests ont inclus des caractérisations granulométriques, chimiques, minéralogiques, ainsi que des mesures de propriétés physiques telles que la résistivité ou la chargeabilité électrique. De par leur nature granulaire et la présence de minéraux économiques magnétiques ou ferriques, les méthodes magnétique, sensible principalement à la présence de magnétite, et de polarisation induite, sensible à la présence de particules chargeables telles que les oxydes métalliques, ont été préconisés. La méthode magnétique a permis de mettre en évidence des secteurs présentant de plus fortes concentrations en oxydes de fer, sans permettre de juger directement de leurs intérêts économiques dû à la sous-détermination intrinsèque à la méthode. Les levés électriques, plus coûteux à mettre en place, effectués sur les anomalies magnétiques, permettent de lever cette indétermination et de caractériser la structure et l'importance des zones de plus fortes concentrations.

THE FALL CONE METHOD AS AN ALTERNATIVE LAB METHOD TO ASSESS LIQUID LIMIT OF SOILS - WHERE DOES IT STAND IN CURRENT GEOTECHNICAL TEACHING PRACTICES

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This paper presents a summary of the state of teaching preferences in undergraduate geotechnical engineering courses regarding test methods recommended for assessing the liquid limit of soils. In the United States and Latin America the predominant methodology is based on the use of the Casagrande or percussion-based device (ASTM D4318). This test method developed in the 1900s has been reported as inherently subjective and cumbersome due to test processes such as spreading, grooving, point of test termination when groove reaches required closed length. Alternative the Fall Cone Method has been in practice in Canada, Europe and Asia with reports of little to no subjectivity. The paper will also present results of an experimental study carried out at UNC Charlotte to help students assess the differences and potential benefits of one method over the other. Finally the paper reviews a wide range of geotechnical textbooks commonly used in North America academia to assess the percentage of books that include the fall cone as an alternative testing method.

THE CURRENT STATE OF THE PRACTICE OF GEOSYNTHETIC BARRIERS: THE BEST WE CAN ACHIEVE

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In recent years, several developments and advances have been made in geosynthetic barriers, particularly barriers in exacting difficult and high risk applications. These advances have advanced the capabilities of geosynthetics and improved the performance of barrier systems. In particular, two applications have changed significantly. On December 19, 2014 the US EPA published the regulations that will be imposed on the storage of coal ash and coal combustion residuals in the United States. In the two years prior to that, a series of advances in leak detection methods and efficiency, leak location techniques and equipment and the materials that facilitate more accurate and rapid leak detection surveys have been fully commercialized and successfully applied to multiple installations around the world. This includes the ability to easily provide continuous monitoring for leakage through geosynthetic systems. This combination of regulations and technology has significantly improved the performance capabilities and potential for geosynthetic barriers. These technologies are reported. Case history examples are presented and projections are made for current and future usage of these materials and techniques.

THERMOKARST PROCESSES FORMATION ALONG LINEAR OBJECTS (AN EXAMPLE OF LONG DISTANCE OIL PIPELINE IN SIBERIA)

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Thermokarst phenomenon along the oil pipeline of 2500 km length in the South of the Eastern Siberia and the far East was analyzed. The width of the survey area is one kilometer, therefore the phenomenon has been investigated not only in the pipeline affected zone but also under natural conditions.

Initial data for the research represented by spatially determined (coordinate linked) images from helicopter visual survey. We got more than 7000 images during the aerovisual observations for 2010-2012.

Invariability of construction technology along the investigated object allowed to estimate the degree of the technogenic impact of pipeline on the factors and condition of thermokarst processes development. Three-year survey allowed to collect data about the dynamics of the process and to identify trends.

As a rule it is difficult to separate thermokarst natural flooding or bog formation.

Due to the high diversity of natural conditions along the pipeline lot of different morphological phenomenon of this process was discovered.

The study area location near the Southern border of the permafrost zone also affect on the specificity of phenomenon process. Coverage of thermokarst processes in landscapes of southern permafrost zone in modern scientific literature is weak and require further analysis and systematization.

Thermokarst phenomenon typification near the southern border of the permafrost zone was elaborated on the base of the results of the following analysis.

The obtained data allowed us to estimate the influence of environmental conditions on the dynamics and distribution of thermokarst processes and make the zoning on the leading factors and conditions.

Due to the high variety of morphological characteristics of the process it was suggested that different mechanisms of their formation, time of occurrence and stage of development occur. The problem of methodology for assessing the impact of different types of thermokarst processes for engineering objects rose.

Distribution graphs for thermokarst phenomena along the pipeline route in the zone of pipeline influence and in natural conditions were built.

The distribution regularity analysis of thermokarst allowed all the phenomena to be divided into two classes by their confinedness to relief elements. Landscape, climatic, tectonic and permafrost conditions were also analyzed. Natural and man-induced regularities of thermokarst processes were identified.

Different mechanisms of thermokarst formation, time of occurrence and stage of development were established.

Identifying of thermokarst processes is necessary for more accurate assessment of their hazard as well as for forecast of its development.

SOIL TEMPERATURE VARIATION AND THAW-FREEZING CYCLE IN NORTHERN TIBETAN PLATEAU IN CHINA

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Thaw-freezing cycle is the primary environmental character and land surface processes in the alpine cold region, such as northern Tibetan Plateau. The soil temperature variation and soil moisture underground during the thaw-freezing processes are of great significance to ecosystems. In this study, 19 soil moisture/temperature station and 3 automatic weather station in Gaize and Ritu county, Tibet, has been established to measure soil temperature and soil moisture at three soil depths(1, 10, 20cm) with their elevation varying over 4515-5172 m. The station-averaged soil temperature data at hourly to monthly scale are used to analyses the characteristics of soil temperature and thaw-freezing processes. Major finding are as follow: (1) For all three temperature layer, the daily-mean soil temperature show obvious seasonal variations, which is strongly correlated with that of air temperature, while the soil temperature varied in a more slowly amplitude with the depth increase. The annual range of daily-mean temperature is about 30°C and the spatial variability is less than 10°C (2)The soil temperature got strong coefficient of variation(CV) values during the thaw phase and freezing phase, indicating the effect of freezing-thawing processes on temperature that during the water phase change releases a great deal of energy. While the soil temperature got weak CV values during January/July, in which the monthly-mean temperature values is the minimum/maximum. (3) At the hourly scale, the soil temperature varied in sine waves style, with the waves smoothed and delayed gradually for the increase of depth. (4) The temperature lags change more early than season transfer. (5) The difference of 22 station may have relationship with elevation and latitude. This study will offer references for the scientific research such as ecology, soil, land cover, microclimate, microtopography on the northern Tibetan Plateau.

SELECTION OF ALLOWABLE LONG TERM REINFORCEMENT STRAINS FOR DEEP-MIXING-COLUMN SUPPORTED EMBANKMENTS REINFORCED BY VISCOUS GEOSYNTHETIC REINFORCEMENT

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Abstract:

The combined use of basal geosynthetic reinforcement and deep-mixing-columns is growing in popularity for embankment construction on difficult soils. This technique can control the embankment deformations and also increase the stability. Reinforcement viscosity has been shown to be significant for reinforced embankments without columns. The time-dependent performance of basal reinforced and column-supported embankments over soft clay is investigated for different maximum allowable long term reinforcement strains using fully 3D coupled finite element method that has been calibrated by successfully modelling the performance of reinforced and piled embankment in the field. The viscoelastic characteristic of geosynthetic reinforcement is considered. The other potential factors that may impact the behavior of basal reinforced and column supported embankments examined include column spacing, reinforcement type, and foundation soil profiles. The embankment performance is studied in terms of long-term service height, horizontal toe movement, maximum crest settlement and crest differential settlement. According to a series of finite element analyses, the favorable selection of allowable long-term reinforcement strains considering of reinforcement viscosity is suggested so that deformations of column supported embankments can be controlled to modest levels while its long term service height can be maximized.

Keywords: Viscosity, Geosynthetics, Column supported embankment, Three-dimensional, Deformation controlling, Soft soils, Numerical modeling

CHARACTERIZATION OF SPORADIC DISCONTINUOUS PERMAFROST OCCURRENCES IN NORTHEASTERN, BRITISH COLUMBIA

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Since the mid 2000's, the Horn River Basin, located in northeastern BC, has experienced a significant increase in the development of pipeline infrastructure to support development of natural gas deposits in this area. The region is primarily comprised of lowlands containing thick organic deposits. The area is located within the region of sporadic discontinuous permafrost, though minimal literature exist describing the permafrost in this area. Due to the sensitivity of permafrost within this area to disturbance due to its warm temperature (typically warmer than -1°C), the clearing of vegetation to permit construction and operation of the pipelines at temperatures above freezing results in thawing of the permafrost. Due to the potential for settlement associated with this thaw and the further potential to induce strain on the pipeline, it is critical to identify and characterize permafrost occurrences along the pipeline route to support the design of mitigation measures, if required.

A geotechnical assessment for a new pipeline project in the Horn River Basin was undertaken in 2009 and 2010. The project area is located approximately 70 km northeast of the town of Fort Nelson, BC within an area containing sporadic discontinuous permafrost. The objectives of the geotechnical assessment program included identifying areas underlain by permafrost and characterizing the permafrost conditions through terrain mapping, geophysical investigation, subsurface investigation and thermistor installation.

Based on the results of the characterization program, approximately 5.4 km (non-continuous) of permafrost in 19 separate occurrences were identified along the route. The permafrost occurrences were found to range from 80 to 710 m in length along the proposed pipeline. Approximately 2.1 km (or approximately 40%) of the identified permafrost occurrences were observed to be shallow and confined to the upper 3 m of the soil profile. The thickness of the permafrost was found to range from 2.1 to 7.6 m.

Thermistor were installed in select permafrost occurrences in 2010, during-construction of the pipeline. The permafrost temperature at the time of construction ranged from 0°C to -1°C . Temperatures of relict permafrost in areas where degradation of the top of the permafrost was noted, was at or near 0°C . Monitoring of the ground temperatures is on-going for the purpose of determining when the permafrost has degraded.

SEISMIC SITE EFFECTS AT SM-3 ROCKFILL DAM, QUEBEC

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Characteristic vibration frequency f_n is one of the most important dynamic parameter influencing site response as well as the seismic stability of a dam. This parameter could be determined by in situ measurements or assessed by artificial vibration shaking combined with dynamic numerical analysis of a dam section. In this paper, a spectral analysis of strong-motion data and ambient noise at the SM-3 dam is performed to evaluate possible site effects and the actual frequency of resonance (f_n) of this earth structure. SM-3 Dam is a rockfill embankment dam built on the Sainte-Marguerite River, a tributary of the lower Saint Lawrence River, in eastern Quebec North Shore. Standing 171 metres high and 378 metres long, SM-3 dam is the primary component of Hydro-Québec's Sainte-Marguerite 3 hydroelectric project. The dam is the highest in Quebec. Construction of this structure was completed in 1998. The dam is built in a narrow valley with its left and right abutments resting on gneiss rock foundations. Three-component digital strong-motion stations were installed on dam's crest and on bedrock, on the left abutment.

The spectral response of the accelerographic data is estimated from a series of three small earthquakes that have occurred in 1999 and 2002. The magnitudes M_w of these earthquakes varies between 4.0 and 5.1. f_n was estimated by calculating standard spectral ratios using the bedrock station as the reference site. For all three earthquakes, the spectral amplification curves show a clear peak between 2.0 and 2.2 Hz, in the transverse direction, and between 1.55 and 1.8 Hz, in the longitudinal direction. Amplification ratios range between 5.0 and 18.5 in the transverse directions and between 2.8 and 19.5 in the longitudinal direction.

When the site response is evaluated from ambient noise recordings and using the H/V technique of interpretation, the frequency of resonance f_n is about 2.1 Hz in the transverse direction and 1.8 in the longitudinal one. Relative ground motions at the two stations sites are presented and discussed. A strong amplification of the vertical motion component was also observed at both station sites.

TSUNAMIGENIC LANDSLIDES IN QUÉBEC

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This paper will summarize the various known cases histories in Québec where a tsunami wave was or could have been generated by a landslide, either subaerial or subaqueous. For example, the 1908 Notre-Dame-de-la-Salette slide is the one which has caused the greatest number of casualties (34). But others like the La Grande (1987) and Lac-des-Seize (2014) provide occasion to illustrate the destructive power of these events. It will be shown, in two cases, that the presence of an ice cover can be a significant aggravating factor associated with the generation of a tsunami wave. Finally, some discussion will be made regarding the approach which could be followed to take this hazard into account as part of a landslide hazard mapping procedure in Québec.

SHEAR STRENGTH AND CONSOLIDATION BEHAVIOUR OF RAW AND POLYMER AMENDED OIL SAND FINE TAILINGS EVALUATED IN SIMPLE SHEAR AND TRIAXIAL DEVICES

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Oil sands tailings deposition is regulated under Directive 74, which requires tailings deposits to achieve an un-drained shear strength of 5 kPa within 1 year after deposition and 10 kPa within 5 years. Operators are meeting these targets by improving dewatering and consolidation characteristics of fine tailings through various techniques, often involving addition of polymer or other flocculation-inducing treatment. However, the assessment of the strength performance of these technologies is typically quantified using a field vane. This gives one or two numbers, peak and residual strength. Element testing, while challenging for mature fine tailings, does give a richer description of strength behaviour. We compare shear behaviour of samples consolidated and sheared in simple shear and in triaxial element tests, and compare these findings to available field data on in-line flocculated mature fine tailings. Both unamended and amended tailings behave as a structured soil, showing very high shear strength to effective stress ratios. Shear strength values as a function of density show values comparable to measurements of residual strength by field vane at some field trials.

COMBINED EVAPORATION AND FREEZE-THAW EFFECTS IN POLYMER AMENDED MATURE FINE TAILINGS

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Both evaporation and freeze-thaw phenomena are known to contribute to dewatering and densification of fine tailings streams generated from oil sands bitumen extraction. This paper reports on studies of 1-D freezing of polymer-amended mature fine tailings that have different stress histories with respect to degree of desiccation by evaporation and consolidation. Freezing is accomplished using an electric cooler specially mounted in an insulated column. Polymer-amended tailings are placed at varying thicknesses, some of which have been allowed to desiccate, others which have not. Temperature is recorded using thermocouples, while the densification and dewatering is tracked by monitoring of water content, pore-water pressure, and cryo-suctions. After a number of freeze-thaw cycles are applied, the samples are cored to obtain profiles of density, pore-water chemistry, total suction, and ice content for those samples that are left frozen. Some samples are subsequently obtained and then loaded to examine differences in consolidation behaviour post-freezing.

MODELING BTEX CONTAMINANTS RELEASE FROM A GAS STATION

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The hydrocarbon contaminants are among the most important sources of contamination in the environment. Leakage from the underground storage tanks in gas stations which could occur due to aging, corrosion, and weak insulation, is considered as one of the groundwater contamination sources. The most common fuels in gas stations are gasoline and diesel. One of the major compounds in these fuels is the BTEX group which if released in the environment may cause critical treat to the human health. In this study, migration of light hydrocarbons leaking from underground storage tank in a gas station is simulated by a two-dimensional finite element method. Two sets of modeling were made. The first model is made with the emphasis on unsaturated zone in a low groundwater table. In this model, the effect of soil type, the contaminant type and soil layers on the transfer of contaminants were investigated. The results showed that Toluene in the BTEX has penetrated faster in the unsaturated zone but Xylene has the least penetration speed. Volume of the intake contaminant plays a major role in plume distribution. Moreover, in the case of soil heterogeneity, high hydraulic conductivity caused extensive plume distribution. The second model considered both saturated and unsaturated zones in a high groundwater table. In this model, distribution of four compounds of BTEX was examined. The results indicated that Benzene created more extensive plume in both water and gas phases.

A REVIEW OF SEISMIC SITE AMPLIFICATION BY CONSIDERING GEOMETRICAL AND GEOTECHNICAL CHARACTERISTICS OF SITES

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A seismic site effect manifests itself by the modification of the response of a site subjected to a seismic solicitation in comparison with a reference case. Unfortunately, the complete responses of movement taking into account the influence of topographical and geological conditions on seismic movement are not considered in normal engineering practice. The purpose of this paper is to contribute to establishment of a simple method to include complex site effects in a building code.

In this paper, acceleration response spectra of different empty, partially-filled as well as fully-filled valleys will be studied. Horizontal ground movements in various points of two-dimensional (2D) irregular configurations subjected to synthetic SV waves of vertical incidence are calculated. The parametric studies are achieved by means of HYBRID program combining finite elements in the near field and boundary elements in the far field (FEM/BEM). The results are shown in the form of pseudo-acceleration response spectra.

For the empty valleys, we can classify the spectral response according to a unique geometric criterion: the "surface/angle" ratio, where surface is the area of the valley opening, and angle denotes the angle between the slope and horizontal line in the above corner. To assess the influence of the 2D effect on the spectral response of fully- or partially-filled valleys, the response of alluvial basins is compared with the response of one-dimensional columns of soil. Finally, an offset criterion is proposed to choose a relevant computation method for the spectral acceleration at the surface of alluvial basins.

GEOFOAM NUMERICAL MODEL FOR REDUCED EARTH PRESSURE ON WALLS

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Expanded polystyrene (EPS) Geof foam has long been used as a lightweight and compressible alternative to backfills behind retaining systems to reduce the lateral earth pressure. The limitation of using local EPS Geof foam is the unavailability of material properties and the shortage in essential design parameters. In this study, the main goal was to characterise Geof foam and develop a finite element (FE) model that accurately captures the behaviour of rigid walls with Geof foam inclusions. A laboratory testing program was planned to measure the modulus of elasticity, shear and compressive strength, and interface properties of foam-soil and foam-concrete. Measurements were used to calibrate a FE model that utilises the hardening soil constitutive equations to represent Geof foam. A rigid wall was then simulated using the calibrated model to study the reduced earth pressure (REP) and the zero earth pressure (ZEP) concepts, and results were verified with measurements from a prototype. From the main outcomes, it was found that Geof foam inclusion with thickness divided by wall height, t/h , of 0.05 is enough to change rigid wall behaviour to act as flexible wall. Also coefficient of lateral earth pressure can be significantly reduced by more than 50% in REP cases.

GEOSUITE - A COMPUTERIZED MODULAR SYSTEM FOR GEOTECHNICAL DESIGN

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Remarkable advances in the analysis of for example slopes and embankments have happened since the 90s. Many are due to the information technology revolution in all aspects of geotechnical practice. Although the tools in use today are more sophisticated than earlier, experience, judgment and quality control remain the key to reliable foundation design. Experts agree that one should do calculations with two methods (or two codes) to check "that you have not missed anything of importance". It is not the software that differentiates consultants, but rather the knowledge and experience of the personnel and the appropriateness of the parameters and soil models used. In 2002, the geotechnical profession of Norway and Sweden entered an alliance to develop GeoSuite. The paper describes "GeoSuite", a code with a series of modules developed for the design of geotechnical foundations on land, with stability, settlement, bearing capacity, pile and excavation calculations. The objectives are to make the calculations as simple as possible for the user, and to provide assistance along the way. The first version of GeoSuite was issued in 2006. A new generation was completed in 2015. The code provides the practitioner with tools for one-, two- and three-dimensional calculations and visualization, and an integration of geotechnical input data, calculations and results. Consultants, research organizations, universities and government agencies worked together to develop GeoSuite. The paper presents the modules in GeoSuite and describes the calculation of stability and settlement, including examples and the user assistance provided for the selection of the parameters, for doing the analyses and for the interpretation of the results.

SOME PROPERTIES OF CRUSHED ROCK MATERIALS USED IN THE FROST PROTECTION LAYER (NORWAY)

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When the pavements are constructed over moisture and/or frost susceptible soils in cold and humid environments, the granular subbase and frost protection layers are also become a very important layer in the system together with base layer. The all thickness of granular material layers should be designed to limit or prevent frost penetration in frost susceptible subgrade layers. And in the case if frost heave occurs, these layers will dampen any differential movement that may result from frost action.

The winters of 2009/10 and 2010/11 were cold and gave frost heave problems on some newly constructed roads, especially in the south-eastern part of Norway. This gave rise to several reports in the newspapers and in the media which were of course negative for the national road authorities. To find the causes of the problems and to propose changes in the national frost design specifications, an expert group was established by The Norwegian Public Roads Administration.

In 2014 the Norwegian Public Road Administration came with new requirements for the frost protections layer presented in the new Handbook N200. According it the maximum stone size is up to 500 mm or half thickness of the layer and the maximum content in fine particles is 2-15% passing 0.063 mm calculated for the material passing 22.4 mm.

Field investigations in March 2014 were held for two county roads Fv26 and FV456 on the north of Norway around Alta and Bodø towns. Several excavations we made in the places where the frost heave was reported. Materials from the frost protection layer was collected and transported to the laboratory in NTNU. The main analyses for the sample included grain size distribution, quantity and mineralogy of fine particles, water content.

Series of experiments have been done at the laboratory to measure frost heave and segregation potential, and thermal conductivity of crushed rock material which is smaller than 22.4 mm.

In the paper we are going to discuss the results of field investigations as well as laboratory experiments.

FROST HEAVE BEHAVIOR OF UNSATURATED SOILS UNDER LOW OVERBURDEN PRESSURE AND ITS ESTIMATION

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In order to evaluate the dependency of frost heave behavior of soils, this study conducted laboratory frost heave tests on high and low frost susceptible geomaterials under different test conditions such as overburden pressure, degree of saturation, freezing velocity. Based on the test results, the difference in frost-heave behavior between low and high frost susceptible soils is discussed. As the result, it is revealed that the test conditions influence the frost susceptibility and heat capacity of soils. For example, under low overburden pressure and slow freezing velocity, soils exhibit high frost susceptibility and much amount of water are supplied to the freezing zone. Then, the heat capacity of soils changes depending on the supplied water volume. These test conditions enhance frost susceptibility of low frost susceptible soils and increase the frost heave ratio. On the other hand, low degree of saturation and closed-system frost heaving degrade the frost susceptibility of soils. In conclusion, overburden pressure, freezing velocity and water supply influence the freezing behavior strongly, irrespective of frost susceptibility of soils. Subsequently, this study proposes two kinds of estimation methods for the frost heave ratio of unsaturated frost-susceptible soils under low overburden pressure such as subgrade soils at the pavement structure in cold regions. One is the modified Takashi's equation in contemplation of matric suction of soils under low overburden pressure. The other is the simple frost heave model which evaluates the effects of initial water content, Bishop's effective stress and water absorption during freezing on the frost heave ratio. In addition, the applicability and the usefulness of both methods were discussed based on the results of frost susceptibility tests. As the results, it was revealed that the estimation methods proposed in this study have an excellent applicability to the precise prediction for the frost-heave phenomenon of unsaturated subsurface ground in cold regions.

EVOLUTION OF PILE SHAFT CAPACITY OVER TIME IN SOFT CLAYS (CASE STUDY: LEDA CLAY)

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This paper presents a comprehensive experimental investigation to examine the evolution of pile shaft capacity over time. This phenomenon is observed in pile foundations that are driven into soft clays, and is referred to as pile set-up. In this research, a series of pile load testing was performed on steel and concrete piles driven into Leda clay in Gloucester, Ontario. The piles were tested immediately after driving to measure their initial bearing capacities, and were tested repeatedly over different elapsed time to study the change in pile shaft capacity over time. The excess pore water pressure around the pile was also monitored by a piezometer. The average pile capacity measurements for steel and concrete piles indicate that there is approximately an 80% increase in the pile capacity after 30 days from the initial day.

THE DIVERSE IMPORTANT ROLES OF PERMAFROST AND PERIGLACIAL PROCESSES IN SHAPING THE HIGHEST MOUNTAINS ON EARTH

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Little is known about the interacting periglacial, cryogenic and atmospheric processes that shape high mountains and sustain massive glaciers and permafrost down to low latitudes in the Himalaya and other high alpine regions. Herein, we present new measurements of near surface temperatures within the rock debris covering much of the ablation zone of Khumbu glacier at the foot of Mt. Everest. These measurements enable us to define the current ground thermal regime, and by comparison with older measurements, its rate of change during the last few decades of warming. We also report on the important roles of permafrost on the maintenance of subsurface ice and ice-rich landforms in low-latitude regions, the response of debris-covered glaciers to climate warming, the rate of frost weathering, and the shaping of the highest ranges.

The temperature measurements complement our recent remote sensing work that will be briefly summarized. It uses satellite data as a means of monitoring icy landforms over broad regions to derive clues about the spatial extent and thickness of ice below the surface, and the rates at which the underlying processes operate. Interferometric synthetic aperture radar (InSAR) is a particularly useful tool as it measures the subtle surface deformation, with mm precision, that reflects deformation or changes in volume of ice within permafrost and debris covered glaciers. Although this ice has received much less attention than the more visible glacier ice, its volume may rival or exceed that of "clean" glaciers. Hence, it has considerable societal relevance; it is a critical water resource to communities in the Himalayas and other relatively arid alpine environments, and its demise is fundamental to increasing hazards (e.g. landslides and glacial lake outburst floods).

NUMERICAL MODELING OF STRESS REDUCING EFFECTS OF RIGID INCLUSIONS ABOVE BURIED FRP PIPES

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Buried FRP pipes are widely used in process industry, where, they are often subjected to large hauling loads. Few traditional protection approaches are in use. The inclusion of a precast reinforced concrete structural element above the crown of the pipe is a commonly adopted procedure. However, expansion of plants capacities dictates very large hauling operations exceeding few thousand tons over the FRP pipes buried few meters beneath the surface. Thus, the interaction mechanism between the buried pipe, surrounding soil and rigid inclusion that reach beyond the linear-elastic ranges of the material behavior emerge as a major knowledge gap.

This paper presents a series of numerical analyses that parametrically study the non-linear interaction between the FRP Pipe-Soil-Rigid Inclusion system. The interaction is highly complicated due to large stiffness changes as well as non-linear behavior. The geometric parameters, such as FRP pipe diameter, cover depth, rigid inclusion dimensions and location; material properties such as the stiffness of pipe, soil and rigid inclusion, quality of backfill compaction, as well as non-linear material behavior of soil and rigid inclusion are parametrically studied. An analytical approach that can be used to determine safe installation limits for the most common pipe dimensions and hauling loads is proposed. The results presented in this study are considered to be of interest to engineers and researchers.

EFFECT OF FLOCCULATING, THICKENING AND FREEZE/THAW ON CONSOLIDATION OF OIL SANDS FLUID FINE TAILINGS

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Oil sands tailings have been produced for 47 years and now cover an area of 176 km². The volume of fluid fine tailings store in tailings ponds is about 850 million m³ which require long-storage as the water is toxic and cannot be released. The reason for this accumulation is that the fluid fine tailings consolidates extremely slowly. Extensive research is underway by a number of organizations to develop methods to understand the reason for this slow consolidation and to design treatment methods for mine closure. The relationships of compressibility, hydraulic conductivity and shear strength with void ratio for fluid fine tailings are presented and these relationships are used in a consolidation model based on fine strain consolidation theory to model commercial scale tailings deposits. As the self-weight consolidation in the analyses was found to be limited, improvements in consolidation were determined by flocculation, freeze and thaw, and atmospheric drying by evaporation. Flocculation and freeze/thaw treatments increase the shear strength as a function of effective stress. This increase in consolidation was further explored by large strain consolidation modeling of the amended tailings and comparing the findings to those of the unamended tailings.

THE CASE FOR USING FINES VOID RATIO

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The Alberta Energy Regulator requires that oil sands companies annually dispose 50% of the fines in the tailings feed in dedicated disposal areas. The criteria for acceptable disposal is that the fluid fine tailings deposit have a minimum undrained shear strength of 5 kPa after one year. Companies are having difficulty in meeting this requirement and are adding flocculants to the fluid fine tailings and using thickeners or centrifuges to increase the solids content. As the tailings stream contains sand as well as fines the underflow from thickeners and centrifuges flowing to a dedicated disposal area contains sand as well as fines. The amount of sand varies depending on the thickening process and usually affects the measured properties of the tailings feed. Analyses and modeling of the long term behaviour of the tailings feed is based on the results of large strain consolidation and standpipe tests. The material relationships needed in modeling are void ratio as a function of effective stress, hydraulic conductivity as a function of void ratio and shear strength as a function of void ratio. Generally in geotechnical engineering these relationships are plotted as functions of total void ratio, but for oil sands and other tailings containing both fines and sand, it has been found that the sand does not significantly influence the compressibility, hydraulic conductivity and shear strength of sandy fluid fine tailings. The sand only functions as filler material that displaces the fines matrix. In plotting the relationships for the hydraulic conductivities and shear strengths, the fines void ratio, therefore, should be used not the total void ratio. The sand acts as an internal surcharge in the fines matrix and has some effect on the effective stress during self-weight compressibility, but once the effective stress is over 1 kPa, its effect is negligible. Therefore, for compressibility purposes, the fines void ratio should also be used for plotting the relationships for compressibility.

Test results proving the case for using fines void ratio not total void ratio is included using a Slurry Properties Diagram. This triangular diagram includes both total solids content and fines solid content which parameters are directly related to total void ratio and fines void ratio. As the sand content changes in the tailings feed the properties change as a function of fines solid content not total solids content.

SOLIFLUCTION IN INTERIOR ALASKA IMAGED WITH AIRBORNE LIDAR: RIFTING AND DIFFERENTIAL FLOW IN ICE-RICH SILT

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Airborne LiDAR imagery of the north-facing Glen Creek watershed just north of Fairbanks, Alaska reveals glacier-like shear flow characterized by rifting, similar to crevassing, and variable velocities, which caused the rifting. The area imaged is above the CRREL permafrost tunnels, is approximately 3 square km and has maximum slope of about 8 degrees. The area is mapped as undifferentiated silt and known to be ice-rich. Active layer thickness is about 70 cm. The image was obtained in March 2013, after light snow had fallen, which we think enhanced the rifting features. Slower motion is along the gentle valleys and faster motion is along the gentle ridges. The rifts appear like glacial crevasses, which is consistent with the ice-rich nature of this permafrost. Many rifts start at nearly 45 degrees to the likely flow direction, but soon curve in response to variable velocity gradients. Airborne photography reveals that the distribution of black spruce corresponds with the flow features. Velocities have not been measured but are estimated to be less than one meter/year. Ground-penetrating radar profiles recorded along a featureless slow-moving valley do not suggest regions of variable ice content, but profiles over the rifts are planned for 2015.

**EXPLORATION DE NOUVELLES MESURES D'ATTÉNUATION DE FORMATION DE GLACE EN PAROI –
EXEMPLE D'UNE TRANCHÉE COUVERTE QUÉBÉCOISE**

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Le contrôle des eaux souterraines est un problème majeur des excavations dans les massifs rocheux, que ce soit pour la réalisation de tranchées couvertes, de tunnels ou de fondations de bâtiment. En effet, il est fréquent que les excavations atteignent un niveau inférieur à celui de la nappe d'eau souterraine, ou qu'elle intercepte des aquifères superficiels qui n'ont pas toujours été localisés lors de la conception du projet. Il peut en résulter des problèmes d'infiltration lors de la réalisation des travaux ou durant la durée de vie utile de l'ouvrage.

Ainsi, le présent article se propose de décrire l'étude d'une tranchée couverte qui présente des approches rocheuses sur lesquelles des venues d'eau, parfois importantes, ont été observées durant l'été. En période hivernale, des quantités importantes de glace se forment à l'emplacement des venues d'eau estivales, à tel point que la glace vient à empiéter sur les voies de circulation. Des études antérieures ont été menées, elles préconisaient alors la mise en place de rideaux d'injection le long des approches afin de juguler l'infiltration des eaux souterraines. Cependant, des essais de faisabilité réalisés à la fin des années 90 soulignent la nécessité d'utiliser des volumes de coulis considérables lors de l'injection. Ainsi, il a été décidé, plutôt que de contrer les venues d'eau en paroi, d'analyser leur provenance la plus probable, en réalisant des essais de coloration et en observant les venues d'eau colorées sur les parois. Puis, un programme de gestion des eaux de surface et souterraines a été mis en place en accord avec les origines probables des venues d'eau. Il en résulte plusieurs solutions afin de contrôler les venues d'eau et qui sont réparties sur le site : la mise en place de puits de drainage verticaux afin de diriger les eaux de surface en profondeur avant qu'elles n'atteignent la roche affleurant aux approches, le captage et la dissipation des eaux de surface dans un caniveau situé en crête de la paroi et l'isolation de la paroi avec des rideaux d'uréthane afin de prévenir la formation de glace. Ces trois techniques sont d'un coût modéré par rapport à la réalisation d'un rideau d'injection et elles semblent être prometteuses pour le site à l'étude. De plus, certaines peuvent être transposées sur d'autres site avec succès.

IN-SITU TESTING IN CANADA'S WESTERN TILL

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The prairies of western Canada have been much affected by several sequences of Continental glaciation over the past two million years, covering the landscape with a blanket of soils overlying bedrock. The soils consist of Pleistocene deposits of till, glaciolacustrine and glaciofluvial sediments, and sometimes loess; varying in gradation, lateral homogeneity, engineering properties, and depth, including deep sediments in meltwater and buried channels. These factors lead to challenges in characterizing the engineering properties of these soils. This paper describes a program of in-situ soil testing that was undertaken in the prairies of western Canada to characterize the engineering properties of the region soils over a distance of several hundred miles. In-situ testing consisted of cone penetrometer and dilatometer soundings. Over 100 in-situ tests were performed to depths exceeding 120 ft. This paper describes the investigation program, and a summary of the engineering properties of the soils such as hydraulic, consolidation, strength, and wave propagation characteristics.

SUSTAINABLE APPROACHES TO OFFSHORE WIND TURBINE FOUNDATION DESIGN

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The challenges of ensuring the survival of wind farms operating in potentially aggressive offshore environmental conditions, e.g. with combined wind, wave, ice and current loadings, has so far driven the foundation design process; indeed the costs of foundations offshore can constitute 20-25% of the overall turbine cost, compared to 5% onshore for a similar turbine. Depending on the soil, environmental conditions and water depth, these costs can also vary widely. Options for foundation design typically include gravity base, large monopile and piled jacket structures to support the wind turbine self-weight and horizontal/overturning moment loads. Given current trends in other areas of engineering, it is likely that the basis for design of offshore wind farms will include the sustainability of the wind turbine and its foundation. Although many facets of geosustainability have been studied recently, quantitative indicators for assessing the sustainability of geotechnical practices, particularly those occurring during the planning and design stages, do not currently exist.

In this paper, three quantitative indicators: the resource use indicator, the environmental impact indicator and energy returned on energy invested ratio, are investigated to aid geotechnical engineers in the assessment of the comparative sustainability of different foundation types for offshore wind turbines. A life cycle thinking approach is adopted in developing these indicators, to account for the cumulative impacts of processes upstream and downstream of the foundation construction, including decommissioning of the wind farm. The numerical indicators are derived from a life cycle analysis (LCA) of two different pile foundation alternatives: gravity bases and monopiles. The inventory analysis of the LCA is used to judge the sustainability of the foundations from an accounting of the inputs, processes and energy outputs. The output inventory of the LCA is used to perform the environmental impact assessment. The resources used and the impact of emissions are categorized and normalized, and weights are applied across the categories to emphasize the relative importance of the categories. It is hoped that these indicators will serve as decision tools, by providing quantitative assessments of different aspects of offshore wind turbine foundation design and construction, on the basis of both the technical and non-technical criteria involved in sustainability.

TERRAIN ANALYSIS FOR HIGH VOLTAGE TRANSMISSION LINE ROUTING USING REMOTE SENSING TECHNIQUES

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Remote sensing techniques offer cost effective tools for assessing the broad range of terrain-related issues that may be encountered during identification and evaluation of linear infrastructure routes and for characterizing terrain conditions for geotechnical design and environmental assessment. A routing study for a high-voltage overhead transmission line in west-central Saskatchewan highlights the utility of remote sensing for identifying and evaluating terrain issues related to slope stability, staging and flood frequency at a major river crossing, and minimizing impacts to environmentally sensitive aeolian soils. Remote sensing tools used include various scales of black and white stereoscopic air photos, high-resolution colour aerial imagery, digital elevation data generated from photogrammetric analysis, and LiDAR digital elevation data. Interpretation of these data sets was aided by ground and helicopter field reconnaissance and publically available information including water well logs, soils maps, and hydrologic data. Terrain interpretation from stereoscopic air photos identified a number of recently active and historical landslides in the study area. The locations and nature of these landslides were confirmed by helicopter reconnaissance and ground observations, allowing routes to be selected that avoid areas of past slope movements. A desktop hydrometric study, supported by field observations, was conducted to estimate the magnitude of staging and flood frequency at potential river crossing sites, and was based on historical discharge data and rating curves obtained from Environment Canada, combined with topographic profiles generated from stereoscopic digital aerial imagery. Lands subject to flooding range from non-vegetated sandbars and low (1- 2m high) willow-covered terraces that often flood annually, to elevated terraces (up to 4 - 5m high) that flood approximately once every 5 to 10 years. Analytical results were also supported by field observations and anecdotal evidence from landowners. Wind-sensitive sandy soil exists extensively throughout the study area. Wind sensitivity soil polygons were extracted from published data sources and were further assessed using vertical air photos, field photographs, helicopter video and LiDAR data. With these data and methods the degree of soil sensitivity to disturbance and erosion was mapped based on relief, vegetation and soil texture. Imagery showing the location of existing access roads and trails was also used to assess the potential for impacts during construction.

RECLAMATION OF MATERIAL SITES IN CONTINUOUS PERMAFROST OF ALASKA: AN EXAMPLE OF GROUNDWATER FLOW BETWEEN PITS

eva stephani (1), Mark Musial (1), Steve Anderson (1)
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Development of material sites in areas with cold, continuous permafrost can result in multiple pits separated by a buffer zone. When sites are reclaimed the pit is sometimes allowed to fill with water. The reclamation concept is that permafrost prevents hydraulic connection between the new lake and any adjacent pits. However, mining operations and the presence of a water body that does not freeze trigger changes in the thermal regime. This paper presents an example of how groundwater flow through a buffer zone can be monitored with geophysical methods and borehole data, and suggests a way that these data can be used to manage pit refilling based on an observational approach.

The field assessment included drilling and geophysics surveying over a berm that forms a buffer between an operational pit and one that was being reclaimed. Electromagnetic induction and electrical resistivity imaging (ERI) surveys were completed along a series of boreholes. Soils geotechnical properties were tested in laboratory. Groundwater levels were measured in the boreholes and related to water level in the pit that was being refilled. Ground temperatures were monitored using an automated data acquisition system so that thawed zones could be related to water levels.

Subsurface materials were mainly composed of ice-rich gravelly and sandy soils, with some layers of clay and silty sand. The ERI profiles indicated a distinct two layer system; an upper layer with lower resistivity values and a deeper layer with higher resistivity values, except in one area where lower resistivity values extended to greater depths under the berm. Ground temperatures at depths were generally well below 0°C except in the lower resistivity values zone extending at depth. There ground temperatures were slightly above 0°C and groundwater was measured; this corresponded to the depth of surface water in the closing pit. Several months later, the near-isothermal conditions persisted.

Results indicate that the berm has zones opened to groundwater flow at depths. Preliminary results also suggest that there are possibly other zones opened for groundwater flow in the upper parts of the berm. Raising the water level in the closed pit will likely increase the potential for groundwater flow into the active pit. Therefore, refilling operations should be suspended to allow thermal conditions to stabilize and potentially refreeze the thawed zone. By monitoring conditions, data will be provided to help guide future reclamation activities.

THE PRACTICAL LIMITS OF COLD TEMPERATURE GEOMEMBRANE INSTALLATION IN NORTHERN CANADA

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Many industry specifications for geomembranes call for a low temperature installation limit of 0C. These limits were mostly set up for US installations and are rarely practical for more extreme northern Canadian installations. Short Canadian summers inevitably see projects extend into the fall where any day can slip below 0C. In recent years liner installations have been extended so that now it is common for geomembranes to be installed in all months of the year. If 0C is no longer a suitable low temperature limit then what is a suitable guideline for Canadian geomembrane installations?

This paper will look at a project completed in the winter of 2014 in the North West Territories. This triple-lined pond was installed in temperatures well below -30C. Cold temperature cracking of materials occurred during handling and deployment and one area of cracking developed in a unique area of the pond. Material samples were removed and tested by the manufacturer and were found to meet all project specifications. Back on the site the installers laid out special temperature monitoring stations at the top and the bottom of the pond slope and started compiling detailed records. Comparing field experience with the recorded temperatures allowed us to establish reasonable guidelines for northern Canadian low temperature installations. The paper also discusses the use of newer generation flexible polyolefin geomembranes which help to reduce the amount of field welding and overall installation costs.

EFFECTIVENESS OF JUTE GEOTEXTILE FOR HILL SLOPE STABILIZATION IN ADVERSE CLIMATIC CONDITIONS

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Efficacy of Jute Geotextiles (JGT) in hill slope management stands substantiated as a result of its unique attributes and structure. Its bio-degradability, hydrophilic property, and ability to moderate temperature extremes have hardly any parallel among natural fibres. The mechanism of containment of top soil erosion is the resultant effect of velocity of surface run-off propelled by gravity on the one hand, ground friction, hydraulic conductivity of the slope fill, absorption of a portion of run-off by jute yarns of open weave JGT (overland storage), and barrier effect posed by them on the other. Detachment of soil particles is caused by the impact of rain drops which depends on the erodibility of the top soil and coverage provided by JGT. In addition JGT acts as mulch and creates a congenial microclimate that fosters quick growth of vegetation on biodegradation. In fact, JGT plays an important role in bioremediation of slope-erosion problems. Considering the environmental aftermath, JGT is the preferred option in developed countries for surface soil conservation against erosion.

In India, JGT has not been tried in low temperature zones at high altitudes, where temperatures go below the freezing point (even below - 25° C) during winter. Mercury rises to even 30° during summer. The behaviour of JGT in such extreme temperature zones is not precisely known yet, making Canada ideal for testing. The 16th BRTF of Project Himank of Border Roads Organization undertook an initiative with the technology provided by National Jute Board, to try two varieties of JGT: 292 gsm and 500 gsm, at two different places for hill slope management in Leh, a high altitude area at about 2,660 and 4,900 m above MSL respectively, in Jammu & Kashmir where erosion is caused both, due to run-off, and high wind erosion. Soil particles in the region, formed naturally by weathering of fragile rocks, are usually loosely bonded (non-cohesive), undergo dissociation with rises in wind force and kinetic energy of rain drops, and are blown away by wind. Open weave JGT interestingly, was observed to contain the dissociated soil particles within its pores and lend stability to the affected soil mass to a great extent, thus preventing its movement by extraneous agents such as wind.

The paper delineates climatic factors, type of JGT used, and the prevailing site conditions with an attempt to analyze the mechanism of functioning of JGT in low temperature zones.

L'ALÉA CHUTES DE PIERRES : LA MODÉLISATION PRÉLIMINAIRE 3D DES TRAJECTOIRES LE LONG D'UNE INFRASTRUCTURE LINÉAIRE

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La caractérisation détaillée de vastes territoires pose un défi de taille et est souvent limitée par les ressources disponibles et le temps. Dans le cadre du développement d'outils reliés à l'aléa chutes de pierres, nous proposons une méthodologie pour cibler les secteurs problématiques et éliminer les autres comme aide à la planification des travaux de terrain le long d'infrastructures linéaires. Le secteur couvert débute à une dizaine de kilomètres de Port-Cartier (Québec) et s'étend sur 240 km jusqu'au nord des monts Groulx, le long du chemin de fer de la compagnie ArcelorMittal Infrastructures Canada. La modélisation des trajectoires de chutes de pierres sur l'ensemble d'un territoire permet de mieux cibler les secteurs où peuvent ensuite être réalisées les interventions plus poussées. La topographie des sites potentiellement problématiques, obtenue d'un levé LiDAR aéroporté est utilisée afin de modéliser les trajectoires en 3D à l'aide des logiciels Rocfall Analyst et RockyFor3D. Dans cet article nous proposons une approche pour caractériser les chutes de pierres le long d'un tracé linéaire, qui propose de faire des études de trajectoires préliminaires avant de raffiner les travaux sur le terrain. Les informations tirées de ces modélisations, même si elles sont réalisées avec des paramètres très conservateurs, permettent de cibler les secteurs problématiques et d'éliminer ceux qui sont non-susceptibles de générer des chutes de pierres ayant le potentiel d'atteindre les éléments à risque le long de l'infrastructure linéaire.

