22nd Vancouver Geotechnical Society Symposium
Friday, June 13, 2014 – The Vancouver Marriott Pinnacle

Foreshore Engineering

SYMPOSIUM PROGRAM

07:30 - 08:30	**Registration**
08:30 - 08:45	**Opening Remarks**
08:45 - 09:15	Keynote Presentation: "Geotechnical Design Challenges Associated with the Lower Fraser River Dikes "; Neil Peters
09:15 - 09:45	"New Performance-Based Seismic Design Guidelines for High Consequence Dikes in Southwestern British Columbia and Vancouver Island"; Upul Atukorala et al.
09:45 - 10:15	"On the mechanics of seepage induced soil slope instability as applied to foreshore engineering"; Charlie Harrison
10:15 - 10:45	**Coffee Break**
10:45 - 11:30	"Design of a Deep Soil Mixing Ground Improvement Scheme to Support Large MSE Walls for Kitimat LNG at Bish Cove, B.C."; Marina Li et al.
11:30 - 12:00	"Construction of a Seepage Cut-Off and Temporary Retaining Wall for an Excavation in Alluvial Soils using Cutter Soil Mixing Methods"; Jeff Scott et al.
12:00 - 12:30	"Modeling and Observations of Pile Installation Using Vibro Hammers in Fraser River Delta Soils"; David Tara et al.

12:30 - 13:30	**Lunch**

13:30 - 14:30	Keynote Presentation: "Assessment of Seismic Vulnerability of Earthen Levees"; Adda Athanasopoulos-Zekkos
14:30 - 15:00	"Geotechnical Seismic Design for a Marine Structure – UBCSAND Application in Plaxis 2D Dynamic Analysis"; George Gong Zuo Zhou
15:00 - 15:15	VGS Award
15:15 - 15:45	**Coffee Break**
15:45 - 16:15	"Design and Construction of the New Coal Harbour Shoreline, Vancouver, BC"; M. Yogendrakumar (Yogi) and Neil Wedge
16:15 - 17:15	Panel discussion on dikes moderated by John Clague of Simon Fraser University featuring Adda Athanasopoulos-Zekkos, Neil Peters, Upul Atukorala, and Carolyn Baron
17:15 - 17:30	**Closing Remarks**

ABSTRACTS

“Assessment of Seismic Vulnerability of Earthen Levees”
Keynote Presentation by Adda Athanasopoulos-Zekkos, Assistant Professor in Civil and Environmental Engineering, University of Michigan, Ann Arbor

Several regions worldwide are facing a great risk with regard to flooding as a result of potential failure of the system of levees that provides protection from high river runoff flows. In the wake of the unprecedented flooding of New Orleans during hurricane Katrina in 2005, this long-neglected risk is now being addressed by combined State and Federal efforts in California, as well as other places. Recent studies have shown that the annual risk of catastrophic levee failure due to seismically induced soil liquefaction is, in general, as great as the combined non-seismic risks associated with high water, levee settlement, overtopping, underseepage or through seepage, erosion and scour. This assessment creates a new class of engineering problems, as seismic levee vulnerability has only recently begun to be considered. This presentation will discuss a recently developed simplified procedure (Athanasopoulos-Zekkos and Seed, 2013) for the assessment of the seismic vulnerability of earthen levees based on dynamic analyses of select California levee sections. The importance of selecting the appropriate ground motions for the dynamic analyses of earthen structures will also be discussed and a procedure for selecting input ground motions for levees will be presented (Athanasopoulos-Zekkos and Saadi, 2012). Finally, preliminary results on the dynamic response of earthen levees with cutoff walls will be presented.

“Geotechnical Design Challenges Associated with the Lower Fraser River Dikes”
Keynote Presentation by Neil Peters, Inspector of Dikes, BC Ministry of Forests, Lands and Natural Resource Operations

500 kilometres of dikes (55 separate dikes) in the Lower Fraser River Valley and Delta protect roughly 70,000 hectares of floodplain lands, 500,000 British Columbians’ homes and jobs, and tens of billions of dollars worth of buildings and critical infrastructure. While many of these dike systems were upgraded during the 1970’s and 80’s, others were not and the extent and sufficiency of geotechnical design is highly variable. For the past 50 years flood risks have been magnified by intensive floodplain development and aging flood protection works. These factors will continue to increase flood risk in the decades ahead, but will also be exacerbated by climate change - through both sea level rise and potentially higher river flows. Because flood mitigation alternatives other than diking have significant limitations, the increased flood risks must be addressed primarily through higher and safer dikes. Due to the variability of dike geometry, foundation soils and dike fill materials over many kilometres of a specific dike, achieving the required high standards of geotechnical reliability will be a major challenge. Two key problems are preventing piping failures (particularly at structures through the dikes) and increasing the seismic resilience of diking systems. Examples of past piping failures and lessons learned are briefly described. The objectives and application of the ministry’s “Seismic Design Guidelines for Dikes” are also discussed.

"New Performance-Based Seismic Design Guidelines for High Consequence Dikes in Southwestern British Columbia and Vancouver Island"

Upul Atukorala, Randy Williams, Herb Hawson, and Brian Mylleville, Golder Associates Ltd.
Neil Peters & Jesal Shah, BC Ministry of Forests, Lands and Natural Resource Operations

Densely populated urban communities and regional infrastructure in British Columbia are protected from flooding by close to 300 km of river and sea dikes. The original dikes, constructed in the early years, were levees built with local fills and to very rudimentary standards. These dikes were upgraded in the 1970s and 1980s to design standards that existed at that time. During these upgrading works, although the potential for earthquake-induced soil liquefaction and associated potential for damage was reviewed, the cost to design for seismic loading was not judged to be commensurate with the consequences to the community. Over the past several decades, municipalities throughout the Lower Mainland have seen extensive population growth and the consequences to the communities and infrastructure has increased. The extent of damage resulting from large scale flooding resulting from breaches to the different diking systems has been estimated to reach upwards of $50 Bn (2013 dollars).

Dikes are almost always located along river banks and shorelines that have historically experienced considerable damage following earthquakes. Located in a region of high seismic hazard in Canada, they have a high geo-hazard exposure and need to be investigated in detail to allow identification and assessment of soil strata that are vulnerable to liquefaction, loss of shear strength, and displacement during seismic design.

This paper presents an overview of the basis and methodologies proposed for seismic design of High Consequence Dikes. The guidelines adopt a combination of traditional and performance-based design criteria for the seismic design of dikes. Dike performance is specified in terms of measureable criteria such as crest displacements of the dike structure. The methodologies and criteria were established following a review of practices currently followed in other regions of the world that are also prone to high seismic hazards. Guidelines are also provided on a) seismic ground motions to be considered for the analysis and design of dikes along with corresponding performance expectations, b) suitable geotechnical investigation methods to characterize and obtain engineering properties of the site-specific soils, c) commonly used methods for seismic analysis considered appropriate for dikes, d) seismic rehabilitation and strengthening measures, e) threshold seismic events that should trigger a post-event evaluation of the integrity of the dike system, and f) post-earthquake temporary emergency repair and permanent remediation measures.

"On the mechanics of seepage induced soil slope instability as applied to foreshore engineering"

Charlie Harrison, Golder Associates Ltd.
Oldrich Hungr, University of British Columbia

Bank instability is a common feature along rivers and coastal areas, owing to erosion by moving water. Further instability is likely to occur due to groundwater seepage exiting the slope at the face of the bank, either due to surface water infiltration, or changes in water elevation along the toe of the bank.

Observations of seepage induced soil slope instability have been made by numerous hydrologists, geotechnical engineering practitioners, and researchers. However, the mechanics of the mode of failure have not been quantified, or likely even fully understood.

A review of the available literature provides case histories for seepage induced bank and slope failures, and the factors affecting a slope's ability to resist the seepage forces. Although there is a significant amount of literature devoted to this topic, very little slope stability related literature discusses the failure mechanisms. Researchers studying the stability of zoned earth fill dams have published numerous papers, which discuss the stability of soil subjected to seepage. Applying this work to slopes provides insight into the mechanics of seepage induced slope instability.

The author provides further discussion regarding the susceptibility of natural soils to seepage induced slope instability by comparing natural soils to laboratory testing. A possible solution to seepage induced slope instability utilizing Critical State Soil Mechanics is also discussed.

"Design of a Deep Soil Mixing Ground Improvement Scheme to Support Large MSE Walls for Kitimat LNG at Bish Cove, B.C."

Randy R. Williams, Marina S.W. Li, and Roberto R. Olivera, Golder Associates Ltd.
Brian W. Wilson, Golder Construction Inc.

In 2012, Golder Associates Ltd. and Golder Construction Inc. formed a Design-Build team that completed the design and construction of an extensive, deep ground improvement scheme utilizing the Cutter Soil Mixing (CSM) technique to construct barrettes consisting of overlapping rectangular panels of in-situ cement-treated soils. The foreshore deep mixing scheme was designed and constructed to support up to 20 m high Mechanically Stabilized Earth walls and bulk earthworks for the development of the Kitimat Liquefied Natural Gas (LNG) facility at Bish Cove, British Columbia, covering an area of approximately 12,900 m2. The ground improvement design was performance-based and considered onshore and offshore static and seismic ground stability requirements as part of the project-specific design criteria.

The deep mixing scheme comprised of 1645 CSM panels constructed through discontinuous layers of varying thicknesses of very soft to soft fine-grained marine deposits consisting of clayey silt to silty clay interbedded with silt layers, embedding typically 2 m into the underlying dense silty sand to sand and gravel or bearing on Granodiorite bedrock. CSM panel depths ranged from 5 m to 30 m and were constructed by treating approximately 73,900 m3 of soil to consistently yield average unconfined compressive strengths exceeding 2.5 MPa.

This paper outlines the approach adopted for the design of the CSM ground improvement scheme in the highly variable subsurface conditions present at the site. The challenges associated with designing a deep mixed ground improvement scheme to support the MSE walls located upslope of Bish Cove are discussed in this paper. These challenges included constraints from a marine buffer zone and an existing tree line along the shore, a sloping ground profile of the intertidal areas immediately south of the ground improvement scheme, groundwater conditions, and variable offshore ground conditions. A discussion of a phased site-specific investigation consisting of boreholes, test pits, in-situ Cone Penetration Tests, piston tube sampling, advanced laboratory testing and groundwater monitoring is presented. Details of extensive geotechnical static and seismic analyses including Limit Equilibrium stability analyses, liquefaction assessments, Finite Element and Finite Difference analyses undertaken to assess various design load cases, and to optimize the design are also presented in this paper.

"Construction of a Seepage Cut-Off and Temporary Retaining Wall for an Excavation in Alluvial Soils using Cutter Soil Mixing Methods"

Jeff Scott & Dominique Jullienne, Geopac Inc.
Fabrice Mathieu, Soletanche Bachy
Keith Robinson, GeoPacific Consultants Ltd.

The Gardens (formerly known locally as Fantasy Gardens) is a residential and commercial development located in the municipality of Richmond, British Columbia, Canada. The development consists of five low to mid-rise buildings, with one of the buildings supported on two levels of underground parking structure. The typical alluvial soil and high groundwater conditions encountered in Richmond generally requires significant dewatering during the construction of excavations in addition to groundwater treatment prior to discharging to the storm sewer system.

The "Dry Box" solution was selected as the most appropriate technique to control the inflow of groundwater into the excavation and allow the safe construction of the two level underground parking structure. Cutter Soil Mixing (CSM) methods were used to construct a combined cut-off and retaining wall surrounding the excavation. This 28 metre deep CSM cut-off wall installation is recognized as one of the world's deepest applications of the technique. This paper presents a case history of the design, installation, QA/QC and performance related to the construction of the CSM cut-off /retaining wall at The Gardens development.

"Modeling and Observations of Pile Installation Using Vibro Hammers in Fraser River Delta Soils"

David Tara, Thurber Engineering Ltd.
Peter Middendorp, Allnamics Pile Testing Experts BV
Gerald Verbeek, President, Allnamics USA LLC

There has been significant recent interest in the use of vibratory drivers/vibro hammers to install piles in offshore and nearshore applications around the globe. Recent experience using vibratory drivers/vibro hammers is reviewed including lessons learned at the Riffgat Wind Farm project. Soil parameters derived for two local sites, based on the results of cone penetration test profiling and high strain dynamic testing conducted during and/or after completion of installation of piles by impact and/or vibratory methods, can be directly input into Wave Equation Analysis of Pile driving simulation software such as Allwave-PDP to model the vibratory installation process. The results of the analysis are shown to compare well with rudimentary observations during pile installation. Recommendations for better monitoring and analysis of vibro hammer projects are presented as are some of the advantages and challenges of using vibro hammers.

"Design and Construction of the New Coal Harbour Shoreline, Vancouver, BC"

M. Yogendrakumar & Neil Wedge, Golder Associates Ltd.

Construction of the new shoreline at Coal Harbour, extending from the Westin Bayshore Hotel to the west to the Vancouver Convention Centre to the east, required extensive land reclamation of Burrard Inlet. This Coal Harbour development consisted of many major elements including over 2 km of seawall and shoreline slope including fish benches, Harbour Green Park and Escarpment Wall, the Coal Harbour Marina and Restaurant, a saltwater intake structure associated with City of Vancouver's Dedicated Fire Protection System (DFPS), a floating walking and several roadway extensions. Imported fill, over 15 m high, was needed for the construction of the new shoreline. Fill placement over the soft marine sediments was carried out in stages to avoid failures. Various ground improvement techniques such as vibro compaction, viro-replacement and dynamic compaction were employed to treat both the existing fill and imported fill in order to meet the design criteria under the static and seismic loading conditions.

This paper will describe the geotechnical aspects of the design and analyses of the Phase 2 portion of the Coal Harbour Shoreline Development. This will include the various ground improvement techniques adopted including the rationale for their selection. Results of the ground improvement work along with results of the slope monitoring work during the construction will be presented. Challenges encountered during construction and lessons learned will also be presented.

"Geotechnical Seismic Design for a Marine Structure – UBCSAND Application in Plaxis 2D Dynamic Analysis"

George GongZuo Zhou, WorleyParsons

An existing rail barge ramp was constructed along the water front of Downtown Vancouver in the 1960s; the facility is currently being assessed for redevelopment as a bulk transportation terminal. The site is underlain by potentially liquefiable heterogeneous fills and marine deposits overlying glaciomarine till and bed rock in depth.

The Plaxis 2 dimensional models were used in a soil-structure interaction analysis, UBCSAND constitutive material model developed by Plasix for VIP users was used as user-defined model. Time–history of the Loma Prieta event was scaled to a PGA of 0.242g as input motion for an earthquake event with return periods of 475 years.

King pile wall deformations and load at static and dynamic stages were presented. Liquefaction trigging in the heterogeneous fills and marine deposits was analyzed, pore water pressure and liquefaction layers were presented. The pore pressure and liquefaction can be captured by UBCSAND constitutive model; generic parameters yields liquefiable zones that are reasonably consistent with NCEER 2001 simplified method.

Plaxis 2 dimensional model combined with UBCSAND constitutive material model can be used to predict soil-structure interaction at static and seismic load conditions. Plaxis dynamic has the advantages in model setup, and data process, as well as relatively short calculation time in dynamic stage.