GEO-INSTITUTE
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The Geo-Institute Soil Improvement Technical Committee will live-stream the session "*Ground Improvement for Liquefaction Mitigation*" on Thursday, December 7, at 2 PM EST. The topics include:

"Mitigation of Earthquake-induced Soil Liquefaction Using Bio-cementation Soil Improvement,"
Mike G. Gomez, Ph.D. A.M. ASCE

Bio-mediated soil improvement technologies leverage the capabilities of soil microorganisms to catalyze biological and chemical reactions in the geotechnical subsurface to generate a diverse range of products that can be used to improve the engineering behavior of soils. Microbially induced calcite precipitation (MICP), or biocementation, is arguably the most mature and well-researched bio-mediated soil improvement technology to-date. The process uses microbial urea hydrolysis to enable to precipitation of calcium carbonate minerals on soil particle surfaces and contacts with resulting improvements in soil shear strength and shear stiffness with minor reductions in soil hydraulic conductivity and porosity. The process has received significant attention as an earthquake-induced liquefaction mitigation technique; however, critical gaps have remained in our understanding of how liquefaction behaviors may shift as a function of applied loading magnitudes and cementation levels. This presentation will provide a brief introduction to biocementation soil improvement, highlight advances with respect to large-scale practical deployment of the technology, and share insights from recent laboratory experiments characterizing the liquefaction behaviors of bio-cemented loose sands. Presented outcomes are expected to improve our understanding of the liquefaction triggering and post-triggering behaviors of bio-cemented soils, the metrics by which these behaviors can be effectively characterized, and the specific mechanisms responsible for behavioral enhancements, ultimately furthering our understanding of how the technology may be employed for liquefaction mitigation purposes.

"Time Effect of CPT-Based Evaluations for Liquefaction Mitigation by Vibro Densification," **Adam Price**, PhD, P.E.; **Ryan Nagle, Tim Siegel**, P.E., and **Lisheng Shao**, Ph.D., P.E., G.E., M.ASCE

Vibro stone column treatment is a popular and cost-effective ground improvement method for soil liquefaction mitigations. To evaluate the liquefaction mitigation effectiveness, CPT tests are typically performed after the vibro stone column treatment. Post improvement liquefaction analysis is routinely undertaken in general accordance with the NCEER 1997 procedure (Youd et. al., 2001) or Boulanger and Idriss method (2014). During the installation of stone column, the vibrator generates cyclic shear in liquefiable sands, creating densification and building up excess pore water pressure. The excess pore water pressure dissipates slowly after the treatment, especially in the sand and clay layers interbedded soil profile. The authors performed extensive CPT, SPT, and soil sampling for a vibro-stone column project in San Francisco Bay Area. Five rounds of CPT tests were performed: prior to vibro-densification and one week, one month, 3 months, and 6 months after treatment at the same locations to evaluate the increase in cone tip resistance as a function of the time following vibro-densification. In situ soil samples in the potentially liquefiable soil were collected and tested for particle size distribution tests, Atterberg Limits tests, and nature moisture contents. The Ic values and fine contents of the soil were also compared before and after the ground improvement. The authors observed that the CPT tip resistance gradually increased in a slow pace and the calculated liquefaction induced settlement reduced as a function of the post-treatment duration. This paper presents the site geotechnical investigations, design and construction of vibro stone columns, time series of post improvement CPTs, and liquefaction evaluations.

"Modeling Vertical Reinforcing Effects of Columnar Ground Improvement for Post-Liquefaction Settlement Mitigation," **Jim Gingery**, PhD, P.E., G.E., M.ASCE

Contemporary design criteria for ground improvement supporting structures frequently specify a maximum post-liquefaction reconsolidation settlement value. Several methods are available and widely used for calculating post-liquefaction settlement, but they have been developed to represent free field conditions in the absence of ground improvement elements. Centrifuge and full-scale field tests have shown that arrays of dense gravel columns reinforce the ground and reduce post-liquefaction settlements relative to free field values. This presentation introduces a constitutive model that captures the development of post-liquefaction volumetric deformations with porewater pressure dissipation and its implementation in a finite difference numerical model. When combined with dense gravel columnar reinforcement the model can estimate post-liquefaction settlements consistent with centrifuge and field tests. The model has the advantage over more simplified approaches that it more rigorously captures many of the physical processes including porewater pressure dissipation, gradual regain of soil stiffness and strength, downdrag and stress redistribution. Practical applications of the model are presented to illustrate the effect of columnar reinforcement on post-liquefaction settlements.

"Evaluating the Effectiveness of Soil-Cement Columns for Liquefaction Mitigation in Liquefiable Sand," **Mohammad Khosravi**, PhD

A series of centrifuge experiments was conducted to investigate the reinforcing mechanisms of soil-cement (SC) columns in liquefiable sand. Crack detector sensors were used to identify the internal failure modes of SC columns under different loading conditions, including embankment loading and liquefaction-induced lateral spreading. The centrifuge experiments included models with level ground improved with SC columns and centrifuge tests of an embankment resting on liquefiable ground improved by SC columns with different flexural/shear strength. The models were subjected to earthquake base motions of varying intensities to observe acceleration, pore pressure, lateral displacement, and settlement responses. It was found that the shear reinforcement mechanisms of columns were not effective in reducing cyclic stress ratios in the treated soil. The results of the experiments suggested that during and after cracking of the SC columns, shear and tilting failure were the prominent failure mechanisms. Increasing the flexural/shear capacity of SC columns resulted in a reduction in the potential for earthquake-induced liquefaction and associated damage. It was observed that if the soil-cement columns remained intact, they would provide a means for supporting overlying structures even after liquefaction was triggered in the soil.

"Ground Freezing Standardization for Ground Improvement," **Joseph Sopko**, PhD, P.E., M.ASCE

Artificial Ground Freezing (AGF) has been used for temporary support of excavations since the late 1800s. It has routinely been used on specialized projects to provide groundwater control and/or temporary earth support for subsurface structures. The design ana analysis approaches to projects have been predominantly the choice of the ground freezing subcontractor. Recent steps have been taken to standardize the approach to the design of frozen earth structures to ensure continuity in the industry and provide approaches to verify safe and practical designs. This presentation highlights the required site investigation, laboratory testing, structural and thermal design, and requirements for guide specifications for both shafts and tunnels.