ASCE Geo-institute (G-I)
Soil Improvement Committee

Lectures on Offer from the Soil Improvement Committee (2018-2019)
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Introduction to Lightweight Fill Applications
Vernon R. Schaefer, Iowa State University
The presentation is offered as a ½ day short course.

This half-day course provides participants with general guidelines and recommended practices for the use of lightweight fills in geotechnical applications. The focus is on understanding the functions of lightweight fill and the available materials and construction practices. Design considerations and procedures, quality assurance, construction specifications, and cost data will be reviewed. An introduction to *GeoTechTools* will be provided and participants shown how to access the information on lightweight fills within *GeoTechTools*.

The following presentations can be offered at lunch or dinner meetings:

Leveraging multiple geotechnical construction techniques for one optimal solution*
James D. Hussin, Keller Foundations, LLC

Most geotechnical challenges can be resolved with a single ground improvement technique. However, taking advantage of the individual strengths of multiple techniques can often result in optimal solution for many projects. This lecture presents the strengths of different technique classifications and how to combine them into an integrated solution.

Tomorrow's Ground Improvement: Mechanics and Innovation*
Miriam Smith, Geopier

This presentation discusses the technical aspects of emerging ground improvement technologies being developed to meet tomorrow's market demand. Specifically, this presentation traces the evolution of ground improvement from aggregate columns to innovative rigid inclusions designed to support ever-increasing building loads on marginal sites (for both static and seismic conditions). Case histories will be presented that compare and contrast these ground improvement technologies to traditional foundation systems. The case histories will discuss these technologies from a basis of both mechanics and overall project cost. The aim of the presentation is to both equip and inspire our geotechnical engineers to embrace ground improvement innovations.

Wick Drain and Earthquake Drain Ground Improvement*
Martin G. Taube, Menard USA.

Wick drains, also referred to as prefabricated vertical drains (PVDs) have a long history of successful use in expediting consolidation settlement is compressible soils. The use of Earthquake Drains (EQDs) to mitigate the risk of liquefaction has become increasingly popular in recent years. This presentation will cover the background and history of both types of drains, applications, appropriate soil types, design concepts, installation methods, and case histories.

CMC Rigid Inclusion Design*
Brandon Buschmeier, Menard USA

CMC Rigid inclusions are generally designed without a direct, mechanical connection to the surface structure. The absence of this rigid linkage is an important conceptual difference between a traditional deep foundation and the rigid inclusion foundation solution, which greatly simplifies the structural components and improves the overall economy of the project. The high stiffness and minimal deformation components of the rigid inclusion at the surface are mitigated through the use of a 'cushion' load transfer layer between the top of the inclusion and bottom of the structural components. This load transfer layer is commonly referred to as a 'Load Transfer Platform' or (LTP) and is made up of a well-compacted dense-graded aggregate. As settlement of the compressible soil occurs between the inclusions, shear mechanisms engage in the LTP, creating an effective 'arching' of the load into the inclusions. The higher component stiffness of the rigid inclusion, combined with the complex load transfer mechanism located above the inclusion heads, requires complex design of the soil-structure interaction. This presentation provides an overview of the design approach and methodology used to apply CMC Rigid Inclusion ground improvement for a variety of project types.

Field trials on bio-based ground improvement
Leon A. van Paassen & Caitlyn Hall, Arizona State University

Bio-based ground improvement techniques are emerging as a sustainable alternative to a wide range of traditional ground improvement methods. Bio-based methods rely on biochemical processes that change pore water chemistry and can lead to the following products: precipitation (or dissolution) of inorganic minerals, formation of biogenic gas, or growth of biomass. Each of these products alters the hydro-mechanical behavior of soils and can be applied to a variety of geotechnical challenges. For example, microbially induced carbonate precipitation is being investigated for its potential to reduce permeability and increase strength and erosion resistance in granular soils to improve for oil wells and water retaining structures. Whereas, biogenic gas production and biomass growth has been proposed to control flow and seal leaks in water-retaining structures by reducing soil permeability. Further, biogenic gas has shown potential to mitigate earthquake-induced liquefaction, by dampening pore pressure build up during cyclic loading. Significant progress has been made to study these bio-based ground improvement methods in the laboratory, but applications and at field scale are still limited. Focus is now shifting to scale up these technologies and life cycle cost and sustainability analysis in order to identify the commercial potential of these methods, such that these processes can be applied in the near-term to address present challenges. This paper provides a review on reported and recent field-scale trials of these novel bio-based ground improvement methods. Lessons learned from these field trials and results from these field trials of these methods, including the factors which enable or limit commercialization, are discussed.

Ground Improvement and Liquefaction Mitigation using Driven Timber Piles
Armin W. Stuedlein, Oregon State University

Conventional driven timber pile ground improvement can provide a cost-effective liquefaction mitigation method, as it provides densification and reinforcement to an improved subgrade. The potential for drained timber piles to improve densification and potentially reduce in-earthquake pore pressures could allow densification, reinforcement, and drainage in one mitigation method. However, the soil densification possible with timber pile ground improvement is rarely incorporated into stability analyses of supported geostructures because of the current lack of understanding of the amount of densification possible. This study focuses on a field trial of driven conventional and drained timber piles to investigate the effect of pile spacing, time-since-installation, and drainage on the amount of soil densification. The test site consisted of clean to silty sands with a relative density ranging from 40 to 50 percent prior to installation. Following installation of the timber piles spaced at two, three, four, and five pile diameters, cone penetration tests were conducted to evaluate the degree of densification. These tests were performed at approximately 10, 50, 120, and 250 days following installation to evaluate the effect of time and to understand the role of fines content on the degree of densification. In general, the relative density of the soils improved to approximately 60 to 100 percent depending on the pile spacing and the presence of drainage elements. A controlled blasting test plan was also conducted at an un-improved control zone and in the improved timber pile test area to evaluate the effectiveness of this ground improvement alternative to reduce the excess pore-water pressures and mitigate liquefaction. The treated zones were shown to mitigate liquefaction by reducing the peak residual r_u values 10 to 25 percent and lowering the soil settlements by approximately 75 percent compared to the un-improved zone.

ASCE China Scan Tour - The State of Ground Improvement in China
Jie Han, University of Kansas and José LM Clemente, Bechtel Corporation

A team of United States based geoprofessionals sponsored by ASCE traveled to Shanghai, China in May 2018 to observe geotechniques, including ground improvement, commonly used in China. Team members consisted of practitioners and academicians, and the very well organized and successful trip was named the ASCE China Scan Tour. The team visited six job sites and observed the application of a wide range of geotechniques including diaphragm walls, recoverable/reusable anchors, soil mixing, different types of vacuum consolidation and electro-osmosis. The trip culminated with the 2nd China-US Workshop on Ground Improvement that was jointly organized with the Chinese Institution of Soil Mechanics & Geotechnical Engineering and held in connection with the GeoShanghai Conference. This presentation will include descriptions, including photographs of the sites visited and geotechniques observed at these sites. The team is tasked with the preparation of a report that will be made available by ASCE.

Pre-fabricated Vertical Drains for Reducing Liquefaction Potential Based on Full-Scale Shaking Table Tests
Kyle Rollins, Brigham Young University

Although small-scale testing suggests that vertical drains can be effective in mitigating liquefaction induced pore pressure and displacements, no full-scale drain installation has been subjected to an earthquake. This lack of performance data under full-scale conditions is an impediment to expanding the use of this technique. To address this problem, full-scale tests with vertical drains were conducted in loose liquefiable sand inside a 20 ft high laminar shear box with a high-speed actuator system to shake the base. Tests involved 3-inch diameter slotted plastic drain piles at 3 and 4 ft center-to-center spacing. The sand was deposited by water pluviation to a relative density between 35 to 45%. Base input motions consisted of 15 sinusoidal cycles at 2 Hz with peak accelerations increasing from 0.05g, to 0.10g, to 0.20g. This series of three tests was repeated three times. In contrast to tests with untreated sand, which liquefied completely after only a few cycles, the drains were successful in increasing the number of cycles to liquefaction. In addition, pore pressure dissipation at the end of shaking was dramatically increased. While liquefaction was not prevented in all cases, the ground surface settlement was reduced by 40 to 60% relative to that for the untreated sand case. This result is in agreement with centrifuge tests. Numerical modeling of the test results indicate that the behavior of the system can be predicted but accurate assessment of horizontal hydraulic conductivity and vertical compressibility are necessary. Compressibility should be estimated by back-calculation from available liquefaction settlement equations. Modeling also indicates that the better drain performance would be expected for longer duration earthquakes than was observed from the rapid loading on the shaking table.

Ground Improvement Techniques for Increasing the Lateral Resistance of Deep Foundations from Full-Scale Testing
Kyle Rollins, Brigham Young University

Ground improvement around a pile group can significantly increase the lateral resistance of pile group foundations with relatively little investment of time, effort, and expense compared to the cost for additional piles necessary to produce the same increased resistance. Comparative field testing conducted on full-scale pile groups before and after treatment of small soil volumes showed significant improvement in lateral resistance. A total of 16 full-scale lateral pile group load tests were performed after ground improvement with techniques such as soil mixing, jet grouting, excavation and replacement, flowable fill, and rammed aggregate piers in comparison to untreated soil. The lateral resistance of the pile group increased by 60% due to soil mixing and by 180% due to jet grouting. To provide additional understanding regarding the influence of the soil mix strength, depth of improvement and width of improvement, a series of parametric studies were performed using a 3D finite element model. This set of “virtual load tests” was then combined with the results from the actual field tests to help develop a simplified model to account for observed behavior. In general, the testing and analysis indicate the pile group and the surrounding improved soil block generally act as an equivalent “super pile”. The passive force, side shear and base shear on the improved soil surrounding the pile group itself increased lateral resistance. This increase in resistance from the soil block can be added to the lateral resistance of the pile group.

***GeoTechTools* – The First Place to Look**
Vernon R. Schaefer, Iowa State University

This presentation will introduce *GeoTechTools* – a knowledge system that provides a synthesis of critically important information about ground improvement and geotechnology techniques – and makes the information readily accessible. The two primary components of this comprehensive toolbox are a Catalog of Technologies and a Technology Selection Assistance System. For each technology, eight distinct products can be accessed through the Catalog of Technologies. Technology selection assistance is provided by use of an interactive selection system. This system aids the user in identifying a short-list of potential solutions for a particular project. *GeoTechTools* was developed to assist users to make more informed decisions on issues to reduce risk and minimize construction surprises. The value of this system is that it collects, synthesizes, integrates, and organizes a vast amount of critically important information about geotechnical solutions on a readily accessible website.

Introduction to Soil/Ground Improvement
Vernon R. Schaefer, Iowa State University

This presentation will provide a broad overview to soil and ground improvement methods. When difficult ground conditions are encountered several alternatives can be employed to achieve project objectives. Ground improvement/modification can be achieved using a large variety to geotechnical construction methods or technologies that alter or improve the ground. The functions of ground improvement and the alternatives available will be discussed. Guidance on selection of appropriate ground improvement for specific problems will be presented and sources of information on potential applications, applicability limits, feasibility evaluations, design guidance, QA and specifications, and costs will be provided.