The Geo-Institute Soil Improvement Technical Committee will live-stream the *session "Case Histories in Ground Improvement"* on Wednesday, December 10, at 2 PM EST. The talks include:

Talk #1: *"Lessons Learned on Caltrans' First Rigid Inclusion Supported Embankment Project in District 1"*, (presented by John Sims III, P.E., M.ASCE, Farrell Design-Build)

As part of a safety-enhancement project along U.S. Highway 101 between Eureka and Arcata, the California Department of Transportation (Caltrans) and the Project Development Team designed an undercrossing at Indianola Road with two bridge approach embankments, each with a length of approximately 1,000 feet and a maximum height of approximately 23 feet. Due to the challenging subsurface conditions of up to 70 feet of very soft and highly compressible bay clay deposits, special design considerations were required for the bridge structure and the approach embankments. The Project Development Team recommended using a Column Supported Embankment (CSE) system with unreinforced rigid inclusions in lieu of implementing a phased multi-year surcharge/embankment over wick drains. Kleinfelder, Inc. provided plans, calculations, and specifications for the CSE system, which included almost 5,000 columns with lengths ranging from 42 to 91 feet.

Farrell Design-Build (Farrell) was selected as the subcontractor to Granite Construction Company for the installation of the rigid inclusions. To meet the specification requirements, Farrell used its Drill Displacement Column™ (DDC) installation method to install the rigid inclusions. Farrell began installing the rigid inclusions in September 2023 and completed the scope in November 2024. During the first two phases of the project, 5 percent of the rigid inclusions were integrity tested by a third-party company using Low-Strain Impact Pile Integrity Testing (also known as Pile Integrity Testing) per ASTM D5882. Out of the 77 tests conducted, 41 tests detected probable defects and/or flaws from 5 to 20 feet below the top of the rigid inclusions. These findings would open a larger conversation between Caltrans and Farrell regarding displacement installation methods in low permeability soft clays, pad heave, installation sequencing, construction coordination, and the applicability of low-strain impact integrity testing for unreinforced rigid inclusions.

Farrell's presentation will explore the lessons learned by Farrell and Caltrans regarding the displacement effects on soft clay soils causing vertical and lateral heave around unreinforced columns, working pad stability, accounting for temporary effects of construction during design, the limitations of low-strain integrity testing, and a mid-project test program to evaluate how means and methods and design changes could mitigate against necking and cracking of the rigid inclusions.

Talk #2: *Reducing Trenchless Tunneling Risks: The Role of Permeation Grouting* (Presented by Mamoun Laraki, Nicholson Construction)

For many trenchless tunneling projects, there is no single solution that addresses all risks. Instead, each risk is conditioned on a variety of variables that lead us to make the best decisions possible. Knowledge and experience help us ensure outcomes that are both constructable and cost-effective. When Contractors work closely with Owners and Engineers, we can define and evaluate risks throughout a project's lifecycle. One effective tool in this process is permeation grouting, especially when used proactively during the design and pre-construction phases.

This presentation will highlight critical considerations when evaluating permeation grouting across design, bidding, and construction phases from the perspective of a specialty geotechnical contractor and will explore how early planning and real-time adaptability led to the successful execution of this risk mitigation strategy.

For the Jackson Street Storm Sewer Phase 2 project in Denver, Colorado, Nicholson Construction Company was engaged to perform chemical permeation grouting in advance of twin storm drain tunnel installations beneath Colorado Boulevard, a critical and high-traffic boulevard. The primary risk was the potential for loose alluvium soils above the tunnel alignment to unravel during tunneling, which could have led to ground loss, surface settlement, or sinkholes.

To mitigate this, Nicholson designed and executed a targeted treatment zone within the alluvium, between 13 and 18 feet below ground, seated just above the sandstone layer. The zone extended 3 feet above the tunnel crowns and 24 feet across the tunnel cross section along a 140-foot alignment. Grouting provided a stabilized ground mass that reduced risk to surface infrastructure and allowed tunneling operations to proceed without disruption to traffic or public safety.

Talk #3: ***<u>Optimizing Foundation and Retaining Wall Design Through Enhanced Subsurface Investigation and Ground Improvement</u>*** *(***Presented by Patrick Granitzki, P.E., BC.GE, M.ASCE, Dynamic Earth)**

This presentation will highlight a case study from a construction project in North Bergen, New Jersey, where significant geotechnical challenges arose due to the presence of compressible soils and the need to raise site grades to meet updated flood regulations. During construction, differential settlement during construction of a retaining wall raised concerns about the initial geotechnical recommendations and the potential for future settlement of a planned building. A critical review of the limited subsurface data and settlement monitoring led to the recommendation for more comprehensive geotechnical investigation, including deeper soil borings and laboratory testing including consolidation testing. The supplemental data revealed a greater susceptibility to settlement than previously indicated. Based on this refined analysis, the project team implemented a value-engineered solution involving a more flexible retaining wall system and coordinated with a specialty contractor for the design and installation of ground improvement elements (rigid inclusions). This approach allowed the existing mat shallow foundation system for the building to be utilized, avoiding expensive redesigns and reducing long-term settlement risks.

Talk #4: ***<u>A Comparative Assessment of Polymer and Nano-Based Soil Improvement and Stabilization: Techniques for Enhancing Gravel Road Infrastructure in the Free State</u>*** **(Presented by J.D. Steenkamp, Ph.D., Central University of Technology, South Africa)**

This study focused on the application of advanced soil improvement technologies-specifically polymer-based and nano-based stabilizers to enhance the performance of gravel roads in the Free State, South Africa. Recognizing the urgent need for sustainable and cost-effective road upgrades in regions dependent on gravel networks, the research evaluated how these innovative stabilizers improve the underlying soil's mechanical properties and durability.

A detailed case study was conducted on Haasbroek Road in Roodewal, Bloemfontein, where a polymer stabilizer was applied to assess improvements in key soil characteristics, including unconfined compressive strength (UCS), California Bearing Ratio (CBR), and resistance to environmental degradation through freeze-

thaw cycle testing. To further investigate, a comparative analysis was carried out on a 210-meter section of gravel road in LHP, divided into segments treated with varying rates of both polymer and nano-based stabilizers.

The study's assessment protocol included laboratory testing for UCS, moisture susceptibility via indirect tensile strength (ITS) testing, and long-term durability through accelerated weathering simulations. A cost-benefit analysis was also performed, weighing material and application costs against anticipated reductions in maintenance needs.

A statistical framework was used to determine the optimal application rates, ensuring the most effective use of stabilizers for maximum soil improvement. Performance enhancements were precisely measured using geospatial data from drone imagery and ground surveys, focusing on reduced surface deformation, decreased dust generation, and improved ride quality.

The findings demonstrate that polymer and nano-based stabilizers significantly improve the strength, resilience, and longevity of gravel road soils. The study offers clear, evidence-based recommendations for incorporating these soil improvement technologies into road maintenance programs, supporting more resilient and sustainable gravel road infrastructure throughout the Free State.

Talk #5: *Explainable Machine Learning Application on Soilcrete Unconfined Compressive Strength (UCS) Predictions* (Presented by Katherine Cheng, Ph.D., EIT, M.ASCE, Keller North America)

Soil mixing is a ground improvement method that consists of mixing cementitious binders with soil in-situ to create soilcrete, a material that is used for liquefaction mitigation, soil strengthening, and more. A key parameter in the design and construction of this method is the Unconfined Compressive Strength (UCS) of the soilcrete after a given curing time. However, estimating UCS can be challenging due to the numerous factors influencing the results, including soil type, soil moisture content, binder content, soil chemistry, soil heterogeneity, and mixing means and methods.

A database of soilcrete UCS and site/soil/means/methods metadata is compiled from recent Keller projects in the western United States and leveraged to explore UCS prediction with the eXtreme Gradient Boosting (XGBoost) ML algorithm. With the SHapley Additive exPlanations (SHAP) algorithm wrapper, mathematically backed explanations can be fit to the model to track input feature influences on the final prediction. Three XGBoost models were created from variations of the dataset to explore feature importances and influences for the final UCS prediction value from different angles. The first model included time-based features to examine the influence of construction timelines on the UCS prediction. The second model removed the time-based features to create a timeline-unrestricted UCS prediction model. The third model tested the abilities of XGBoost to predict future UCS values on fully unknown sites by alternating each site as the sole "test" set for the models. Each of these models were then explored with SHAP to further examine the relationships between the feature inputs and UCS predicted values. Both the influences of soil and human interactions with the final UCS were identified by the SHAP analysis and a Keller-specific FHWA-based UCS predictive equation was produced.

From this ML application, a blueprint of how to scaffold, feature engineer, and prepare soilcrete data for Explainable ML is showcased. Furthermore, the insights obtained from the SHAP models can be further pursued in traditional geotechnical research approaches to expand soil mixing knowledge.