Transportation Research Board

80th Annual Meeting

Pre-Meeting Workshop:

Doctoral Student Research in Transportation Geotechnics

Sunday, January 7, 2001, 1:30 – 5pm
Cotillion Room North
Marriott Wardman Park Hotel
Washington, DC

Sponsored by TRB A2 Sections on Soil Mechanics, Geology and Properties of Earth Materials, and Geomaterials

Transportation Research Board -- 80th Annual Meeting
Pre-Meeting Workshop:
Doctoral Student Research in Transportation Geotechnics

PRESENTATIONS:

I. MATERIAL PROPERTY CHARACTERIZATION:

1. Constitutive Modeling of WesTrack Pavement Materials
Jo Sias Daniel -- North Carolina State University

2. Development of a 3D Imaging System to Characterize Size and Shape Properties of Coarse Aggregates
Chetana Rao -- University of Illinois at Urbana Champaign

3. Changes in the Mechanical Behavior of Non-Plastic Silt Due to Drained Aging.
John Zarling -- Michigan Technological University

4. Total Suction-Moisture Content Characteristics for Expansive Soils
William J. Likos - Colorado School of Mines, Engineering Division

5. Determination of Finite Element Parameters for Florida Soils
J. Brian Anderson -- University of Florida

6. Degradation of Triassic Basin Rock
David W. Parish -- North Carolina State University

II. PREDICTING EARTHQUAKE RESPONSE:

7. Fabric and Stress State Effects on Liquefaction Susceptibility of Sands
Sivapathasundaram Sivathayalan -- University of British Columbia, Canada

8. Seismic-Compression of Compacted Fills
Daniel Whang -- University of California, Los Angeles

9. Seismic Zonation of Soils Susceptible to Ground Motion Amplification
Salome Romero -- Georgia Institute of Technology

III. PREDICTING WHOLE SYSTEM RESPONSE:

10. In-Situ Cavity Development due to Compaction Grouting in Cohesionless Soils
Silas C. Nichols -- University of Maryland

11. Use of Porous Steel Soil Nails For Enhancing Dynamic Stability of Earthdams
Saad A. Farag -- University of Missouri-Rolla

12. Anchored Geo-Support Systems for Landslide Stabilization
Wayne G. Jensen -- University of Wyoming

13. Use of EPS-Filled Tires as a Lightweight Construction Material ***Sethapong Sethabouppha -- Old Dominion University***

14. Cyclic Large Deflection Testing of Shaft Bridges
Kerop D. Janoyan -- University of California, Los Angeles

15. Experimental and Analytical Investigations of Piles and Abutments of Integral Bridges
Sami Arsoy -- Virginia Polytechnic Institute and State University

16. Prediction of Bearing Capacity and Settlement of Overconsolidated Clay Deposits
Nader Khodadoust -- New Jersey Institute of Technology

1. Constitutive Modeling of WesTrack Pavement Materials

Mixtures subject to various levels of laboratory aging were evaluated using an existing uniaxial cyclic fatigue and healing constitutive model to ensure that the viscoelasticity and continuum damage mechanics theories upon which the model are based apply to aged mixtures. Eight mixtures from the WesTrack Pavement Test Track Facility were tested to verify the model using field performance data. The relationship between the model coefficients for both cyclic fatigue and healing and mixture properties such as air void content, asphalt content, and gradation is investigated to establish a method of predicting the field performance from laboratory testing. Any relationship between the existing model coefficients and mixture properties can be used to simplify the model. Additionally, constant crosshead-rate to failure testing is performed to develop a simplified testing method that does not sacrifice the accuracy of the cyclic model while maintaining a sound theoretical basis. The effect of moisture on the fatigue performance of mixtures with different air void content and gradation is also investigated. Finally, fatigue testing is performed at a lower temperature to make certain the model and theory are valid at different temperatures.

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2. Development of a 3D Imaging System to Characterize Size and Shape Properties of Coarse Aggregates

Size and shape properties of coarse aggregates are very critical factors influencing permanent deformation and fatigue resistance of the asphalt concrete mixtures. Cubical and angular particles are preferred over flat and elongated or spherical particles. Particle size distribution affects the packing density and porosity of an aggregate mix. The amount of crushed particles, or angularity, is also important because it determines the level of internal shear resistance that can be developed in the aggregate structure. SUPERPAVE has developed a set of consensus properties and tests for coarse aggregates to optimize particle size and shape distributions.

SUPERPAVE tests involve very tedious procedures that can be automated using image analysis to increase time and labor efficiency. A new image analyzer system developed as a part of this doctoral research, known as the University of Illinois Aggregate Image Analyzer, uses a three camera setup to view each aggregate particle from orthogonal directions. Volume (and therefore weight), the flat and elongated ratio and particle size can be accurately determined for each particle based on image analysis and geometric principles. An angularity index, based on imaging principles, was developed to quantify angularity objectively. Tests conducted on 10 aggregate samples along with repeatability tests validate the accuracy of the Image Analyzer in automating the manual flat and elongated ratio testing and gradation in a rapid manner. Angularity index values determined from imaging for samples have been verified with the shear strength of the mixes. The robustness of this index in separating gravel from crushed aggregates has been demonstrated.

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3. Changes in the Mechanical Behavior of Non-Plastic Silt Due to Drained Aging

For the past 20 years researchers at Michigan Technological University have observed the aging phenomenon in non-plastic silt size material. No studies until now, have been performed to investigate the effects of this phenomenon on the pore size distribution and the shear strength of the soil.

Samples were consolidated at pressures of 100, 240 and 500 kPa for 1 hour and 5 days. From these samples pore size distributions were determined in both the horizontal and vertical direction with the aid of image processing. It was shown that the pore size distribution of a sample is shifted, an increase in smaller pores and a decrease in larger pores, due to drained aging. Samples were also tested in triaxial compression where it was shown that the undrained shear strength increases with drained aging time. It was also shown that the liquifaction potential decreases with drained aging time. The triaxial tests were run at consolidation stresses of 100, 240 and 480 kPa and aged for 1 hour, 1 day and 5 days.

Due to drained aging the pore size range decreased and the strength of non-plastic silt size material increased. Drained aging also caused an increase of the internal friction of the material due to decrease pore size range which caused an increase in contact areas of the particles.

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4. Total Suction-Moisture Content Characteristics for Expansive Soils

A computer-automated measurement technique is mobilized to measure total suction characteristic curves for suction values ranging from approximately 600 MPa to 10 MPa. Characteristic curves are measured using the system for four types of clay, including Na^{+}-smectite, Ca^{2+}-smectite, mixed layer illite/smectite, and kaolinite. A concurrent testing program using the non-contact filter paper method (ASTM D5298) is conducted to extend the measured characteristic curves to values of suction as low as 100 kPa.

Features in the behavior of the characteristic curves from the combined measurement techniques are analyzed to develop a series of conceptual models describing the sequential adsorption of water by the four types of clay. At relatively low values of water content, it is shown that mechanisms related to the hydration of particle surfaces and exchangeable interlayer cations are likely to dominate the swelling behavior of the smectite clays. At increased values of water content ($\approx$ 20%), osmotic swelling mechanisms become important for the Na^{+}-smectite but not for the Ca^{2+}-smectite.

Transitions in the relationship between volumetric strain and total suction obtained from a series of shrinkage tests are shown to coincide with observed transitions in the relationship between total suction and water content. Both relationships are marked by a distinct change in behavior occurring at a total suction value of approximately 10,000 MPa, interpreted to indicate the transition out of the regime where volume change is dominated by hydration-induced swelling mechanisms.

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5. Determination of Finite Element Parameters for Florida Soils

Finite Element programs such as Plaxis employ constitutive models in an attempt to model the complex behavior of soil. These models range in complexity from those that define the failure characteristics of the soil, to models that attempt to define strength, hardening, and plasticity. The development of these models depends upon knowing some material properties of the soil. Traditionally, such parameters are either tested for in the lab (ie. Mohr Coulomb constitutive model – triaxial) or signal matched by simulating a laboratory test until the inputs fit the results. Little, if any, guidance is available for the determination of these parameters based on insitu testing.

The purpose of this research was to develop some recommendations for the determination of constitutive model parameters from insitu tests. The scope included determination of the soil properties by laboratory testing in order to develop a known set of constitutive model parameters for use in analyzing insitu tests. Cone pressuremeter and triaxial tests were performed on soils at three research sites. The triaxial and pressuremeter tests were analyzed with the FEM codes Plaxis and PlasFEM (University of Florida). Results and comparison of the analyses are forthcoming.

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6. Degradation of Triassic Basin Rock

The quality of the bedrock in the Triassic Basins of North Carolina has been difficult to assess for durability. Most rock in the basins is of sedimentary nature, hard resilient sandstone interlayered with partially durable and non-durable siltstone and claystone (shales). To determine the durability of Triassic Basin rock, this work examines the strength and plasticity of weak sedimentary material and provides a qualitative correlation to the slake-durability index. Results from the experimental program were then compared to existing studies on like materials. Strength parameters for 50 separate samples from the region were analyzed using uniaxial compression, split-tensile strength and point-load strength tests. To ascertain the plasticity of the sediment, standard Atterberg limits were incorporated along with a determination for the activity of the clay matrix as defined by Skempton (1953). All tests results were presented as a comparison to the two-cycle slake durability index (Id2). Details of the experimental program and a discussion on the comparison of measured results are presented as well as a recommendation for future research.

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7. Fabric and stress state effects on liquefaction susceptibility of sands

An experimental study aimed at improving the understanding of the mechanics of liquefaction is presented. The influence of the initial stress state and fabric on static, cyclic and post cyclic behaviour of sands were studied in a systematic manner using triaxial, simple shear and hollow cylinder torsional shear apparatuses.

The influence of soil fabric was determined using reconstituted and undisturbed sand specimens. It is shown that in-situ sands and those water pluviated in the laboratory are inherently anisotropic, and their behaviour is similar under static and cyclic loading. The domain of states in void ratio-effective stress space accessible to the sands in-situ is shown to be similar to those that ensue on pluviation.

The initial effective stress state plays a dominant role on the subsequent undrained behaviour at a given void ratio. The behaviour due to an increase in deviator stress alone, and that due to simultaneous changes in deviator stress and the direction of principal stresses is investigated. A larger inclination of major principal stress to vertical results in a softer behaviour. Even a small undrained perturbation may trigger flow failure in a sand that is otherwise stable if drained, in the event the initial stress state is highly anisotropic together with larger inclination of major principal stress to the vertical. It is demonstrated that flow failure may be triggered by a mere rotation of principal stress directions only.

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8. Seismic-compression of compacted fills

Earthquake-induced ground deformations resulting from contractive volumetric strains in unsaturated compacted soil have been observed in numerous earthquakes. This process, termed seismic-compression, did not cause life-threatening damage to structures but did result in significant economic damage. The current state of practice for evaluation of seismic-compression in fills uses procedures based on the laboratory test results of Silver and Seed (1971) and Pyke and Seed (1975) for clean uniform sands. However, these procedures do not consider several factors such as fines content, fines plasticity and soil structure, thought to be influencing seismic-compression.

A key objective of this study is to evaluate the adequacy of existing design procedures for soils containing significant fines. Cyclic simple shear testing will be performed on both reconstituted soil specimens and manufactured soils to investigate several factors thought to be influencing the susceptibility to seismic-compression of compacted fills, such as gradation, fines content, and fines plasticity, relative compaction and water content relative to the modified Proctor standard. Results of the laboratory testing on manufactured soils and actual fill specimens will be compiled to evaluate the effects of RC, wc (relative to optimum), fines content and fines plasticity on seismic-compression. >From the collective results of this testing, general qualitative recommendations will be made for the design of fills to resist seismic-compression.

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9. Seismic Zonation of Soils Susceptible to Ground Motion Amplification

Current methods of site classification are based on studies conducted in the Western United States where the seismic hazard is significant. However, these studies may not accurately reflect the geological site conditions in other regions particularly in the Central Unites States. Therefore, analyses of site response analyses are performed based on the geology and seismicity of the Central United States to establish regional site amplification factors.

The near-surface shear wave velocity is a key parameter in estimating amplification factors for site response analyses. Unlike the Western United States, in situ measurements of shear wave velocity are not as extensive in the Central United States. However, based on the efforts of various researchers, a large database of shear wave velocity measurements has been compiled for the Central United States. Based on the collected profiles in this region, generic profiles were created for several geologic environments. The profiles were used for site response analyses to assess the effects of geology and near-surface shear wave velocity on ground motion amplification. Response spectra were determined for several earthquake moment magnitudes and hypocentral distances. Finally, site amplification factors were developed based on the conducted analyses.

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10. In-Situ Cavity Development due to Compaction Grouting in Cohesionless Soils

Over the past 50 years, compaction grouting has developed into an efficient and economical alternative for site improvement, structural support and rehabilitation. Despite success in practice, due essentially to contractor experience, a firm understanding of the primary parameters and mechanisms controlling grout bulb development and soil compaction is lacking.

This research presents the results of centrifuge compaction grouting tests to investigate the effects of grout composition, injection depth, injection rate, soil type and surcharge loads on cavity shape and expansion. The one-stage injection tests use real compaction grout injected into a dry, cohesionless soil. The full-scale, whole system soil response is evaluated with respect to the degree of compaction in the surrounding soil and final in-place volume and dimension of the grout bulb.

The results of the experimental program indicate that the final shape and volume of the grout bulb is dependent primarily on injection depth and grout composition, and to a lesser degree, injection rate, and soil type. The research has also shown that the permeability of the grout has a significant effect on the range of effective injection rates, the degree of volume reduction during injection and set-up, and the minimum overburden above which compaction grouting is no longer efficient.

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11. Use of Porous Steel Soil Nails For Enhancing Dynamic Stability of Earthdams

Many failures of earth structures, slopes and foundations supported on saturated sands have been attributed to liquefaction of the sands. Recent studies have shown that many embankments and earth dams are seismically vulnerable.

An innovative retrofit technique combining the advantages of in-situ strengthening and improving drainage is the use of small diameter (5 cm) porous pipes containing highly permeable geotextile driven vertically into the embankment. The shear force due to an earthquake is counteracted by the shear capacity of the soil nails' cross-section. The excess porewater pressure is dissipated through the geotextile thereby increasing the effective stresses within the embankment and dramatically improving its stability. The feasibility of the Porous Soil Nailing (PSN) technique to seismically retrofit embankment dams was the objective of this research. A case history of a failed road embankment on Highway 94 in Michigan has been selected as a study model. Vibratory tampers conducting a seismic reflection survey on a roadway embankment in Michigan's Upper Peninsula triggered a liquefaction failure. The embankment was then subjected to the El-Centro earthquake time history and its response evaluated.

The two-dimensional finite difference computer program, FLAC 3.4, was selected to analyze the problem. The study has illustrated the viability of the Porous Soil Nailing (PSN) technique for seismically retrofitting dam embankments. The use of the PSN technique to increase shear strength and reduce liquefaction potential has the advantages of rapid construction, use of light equipment, and low cost.

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12. Anchored Geo-Support Systems for Landslide Stabilization

Two landslide stabilization systems were instrumented and monitored for the purpose of evaluating overall performance and to facilitate comparisons between design assumptions and field observations. The Blue Trail Landslide involved the use of walls consisting of both micropiles and permanent ground anchors. Field measurements of axial load and bending in micropiles and measured anchor loads were used to evaluate how this type of system resists landslide driving forces. The field measurements were compared to loads assumed for design and to the results of finite element analysis. These analyses form the basis for recommendations to improve design methodology for this type of anchored geo-support system. The second project, stabilization of the Elbow Landslide, involved the use of a combined soil nail-MSE wall to control localized sliding within an old fill section. Measured axial loads of instrumented nails are compared to nail forces assumed for design. Comparisons of field performance with FEM and other analytical analyses are summarized.

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13. Use of EPS-Filled Tires as Lightweight Construction Material

The purpose of this research is to establish a means of re-using discarded automobile tires. In this research, EPS (expanded polystyrene) was molded inside the hollow space inside several discarded tires by an EPS molder. Under compressive load, the tire wall bent inward. This deformation was expected to increase the confining pressure to the EPS filled inside. However, due to the capability of the molding accessory, EPS could not
completely filled inside the hollow space of the tires. To fill those voids, expandable foam sealant, polyurethane base, was injected through drilled holes.

Compression tests of individual and stacks of EPS-tire units were performed along with computer simulation. A commercial software named Universal Distinct Element Code (UDEC) was used for this purpose. This software is also used to evaluate the performance of pavement systems on EPS-tire units.

Results of compression tests reveal that the stiffness is lower than the expectation. This is because the expandable foam sealant was apparently softer than the desired EPS. Stack tests and computer analysis imply that, the pavement systems must be very rigid in order to reduce traffic stress on the EPS-tire units, otherwise, a relatively thick subgrade soil is required. It could also be implied that this system might not be economical. However, this research will, hopefully, encourages the re-use of large amount of discarded tires. It could be more practical if EPS could be completely filled. Furthermore, used tires filled with other suitable materials could be used following the guideline created from this research.

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14. Cyclic Large Deflection Testing of Shaft Bridges

Cast-in-drilled-hole (CIDH) shaft/columns consist of a single shaft which has the same approximate section and reinforcement as the above ground column. The use of CIDH shaft/columns has become increasingly popular because of their economic and space saving characteristics. Previous tests have established lateral capacity and strength-deformation relationships for small diameter piles, however testing of large diameter (i.e. greater than 1 m or 3 ft) shafts subjected to representative lateral deflections has been limited.

The current research project includes field testing a full-scale large-diameter CIDH shaft/column undergoing cyclic large lateral deflections. The principal objective of the testing is to characterize the soil-shaft interaction across a wide displacement range to gain insight into the adequacy of existing design guidelines (which are based principally on the testing of small diameter piles) for the large diameter shafts commonly used to support highway bridges in California. The shaft is extensively instrumented to enable high precision, redundant section curvature measurements, measurements of pressure at the soil-shaft interface around the shaft perimeter, and in situ measurements of concrete quality. The measured data is then compared to existing design parameters and guidelines. Also of interest is the failure mechanism of the shaft-column, since most previous tests of large-diameter shaft-columns do not test the column to large levels of ductility.

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15. Experimental and Analytical Investigations of Piles and Abutments of Integral Bridges

Bridges without expansion joints are called "integral bridges." Eliminating joints from bridges crates concerns for the piles and the abutments of integral bridges because the abutments and the piles are subjected to temperature-induced cyclic lateral loads.

This research project includes experimental and analytical studies. The ability of piles and abutments to withstand cyclic loads is investigated by conducting large-scale cyclic load tests. Three pile types and three semi-integral abutments are tested in the laboratory. Experiments simulated 75 years of bridge life for each specimen by applying over 27,000 displacement cycles. Numerical analyses are conducted to investigate the interactions among the abutment, the approach fill, the foundation soil, and the piles.

The data from the experimental program indicates that steel H-piles are the best pile type for support of integral abutment bridges. Concrete piles and stiff pipe piles are not recommended. The first two semi-integral abutments tested showed fracture of concrete at the abutment/pile cap interface. A revised detail was developed by Staunton office of VDOT. The revised detail tolerated cyclic loads without damage.

Numerical analyses indicate that the interactions between the approach fill and the foundation soil create favorable conditions for stresses in piles supporting integral bridges.

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16. Prediction of Bearing Capacity and Settlement of Overconsolidated Clay Deposits

Stress history, mechanism of excess pore pressure generation / dissipation, anisotropy and stress dependency of settlement, introduce complexity to the analysis of the settlement for overconsolidated clays. In order to study the settlement characteristics of the subject soil deposits, field and laboratory test data have been collected from a project site in Hightstown, New Jersey. The project consists of about 3.6 miles of bypass highway, including seven (7) bridges. The samples were obtained from the borings performed at the location of the abutments and piers of the bridges. These tests include, pressuremeter, piezocone sounding, soil classification, unconfined compression, consolidated undrained (with pore pressure measurement) triaxial and consolidation (oedometer) testing. Advanced finite element technique is employed to study the behavior of the soil under the applied laboratory tests. Nonlinear behavior of the soil is being considered in the analysis. Also, generation and dissipation of the excess pore pressure is being studied. Construction history of the bridges in terms of major loading stages have been collected. A finite element environment is created to model the staged construction phases to study the immediate and consolidation settlement and the time history of excess pore pressure. Results from the analysis will be compared with monitoring data on the bridge foundations settlement. Recommendations to improve the accuracy of predicting the settlement and time of consolidation is the anticipated outcome of this research.

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