Transportation Research Board
83rd Annual Meeting

Doctoral Student Research in Transportation Geotechnics

Sunday, January 11, 2004
2:00 p.m. – 5:30 p.m.
McKinley Room
Marriott Wardman Park Hotel

The workshop is cosponsored by TRB sections: A2K00, Soil Mechanics, A2L00, Geology and Properties of Earth Materials, and A2J00, Geomaterials

Organizer: Sarah L. Gassman, *University of South Carolina*
Moderator: Susan Burns, *University of Virginia*

The primary objective of this new workshop series initiated at the 2001 Annual Meeting is to integrate recent and upcoming geotechnical PhD's into the TRB research community by providing them with an opportunity to showcase their research at the Annual Meeting. The workshop will consist of reports on geotechnical engineering research related to transportation facilities that will be of interest to both practitioners and researchers.

2:00 pm - 2:05 pm	**Introduction** Susan Burns*, University of Virginia*
2:05 pm – 2:20 pm	**Physical and Mathematical Modeling of Coarse-Grained Soils** Changho Choi, *University of Washington*
2:25 pm - 2:40 pm	**The BCT: a New Instrument for Quick Evaluation of Compaction** Yanfeng Li, *Texas A&M University*
2:45 pm - 3:00 pm	**Cyclic Constitutive Modeling of Granular Materials** Louis Yu-Ning Ge, *University of Colorado at Boulder*
3:05 pm – 3:20 pm	**Full Scale Field Testing Examination of Pile Capacity Gain with Time** Edward L. Hajduk, *University of Massachusetts-Lowell*
3:25 pm - 3:40 pm	**Mechanical Behavior of Silty and Clayey Sands** J. Antonio H. Carraro*, Purdue University*
3:45 pm - 4:00 pm	**BREAK**
4:00 pm - 4:15 pm	**Development of a Micromechanical Model to Predict Mixture Stiffness through Discrete Element Analysis for Asphalt Paving Mixture** Zhanping You, *University of Illinois*
4:20 pm - 4:35 pm	**Influence of Material Properties and Environmental Conditions on Electromagnetic Wave Propagation in Soil** Xiong Yu, *Purdue University*
4:40 pm - 4:55 pm	**Development of a Methodology for Highway Pavement Need Analysis and Maintenance Project Selection** Bo Gao, *Georgia Institute of Technology*
5:00 pm - 5:15 pm	**Formulation and Implementation of a Constitutive Model for Soft Rock** Randall Hickman, *Virginia Polytechnic Institute and State University*
5:30 pm	**ADJOURN**

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Abstracts:

Title: Mechanical Behavior of Silty and Clayey Sands

Author: J. Antonio H. Carraro, *Purdue University*

Abstract:
Static and Dynamic response of a sand containing different percentages of plastic and non-plastic fines is investigated. Static monotonic consolidated isotropically drained triaxial tests have been performed to determine the stress-strain response and intrinsic variables of these non-ideal soils. Cyclic undrained triaxial tests have been performed to study the effect of fines on the liquefaction resistance of sand. Bender elements instrumentation has been developed and is being used to evaluate small strain stiffness properties. The results of this investigation will provide new insights into the evaluation of liquefaction resistance of non-ideal soils and the design of foundations on silty and clayey sands.

Title: Physical and Mathematical Modeling of Coarse-Grained Soils

Author: Changho Choi, *University of Washington*

Abstract:
A fundamental characterization of engineering properties for gravelly soils is presented through an experimental and analytical study. The experimental study involves testing gravels in a recently developed 9.5 inch cubic multiaxial device. This cubic multiaxial device can accommodate geologic materials up through gravel size, and can test such materials under three independently controlled principal stresses, along with controlled backpressure. Drained and undrained, and static and cyclic loading conditions are possible. As part of this study, capabilities and limitations of the multiaxial device are assessed, and a preliminary database on gravels under general loading conditions is developed. The analytical study involves the evaluation of a recently developed constitutive model for granular soils as a suitable model for the simulation of gravelly soil behavior, the implementation of the model using robust implicit integration techniques, the development of efficient computational tools applicable to constitutive models based on object oriented programming techniques, and the calibration of the constitutive model parameters based on the results obtained in the experimental study. Attributes of the research are to better characterize the stress-strain behavior of gravels under general loading conditions, and to implement, verify, and calibrate an advanced constitutive model capable of reproducing the behavior of gravels under general loading conditions.

Title: Development of a Methodology for Highway Pavement Need Analysis and Maintenance Project Selection

Author: Bo Gao, *Georgia Institute of Technology*

Abstract:
A pavement management system (PMS) provides valuable tool for cost-effective management of long-term pavement performance maintenance. Although much has been written about PMS, there are many challenging issues, including balancing funding or performance among different subdivisions, linking project-level results and network-level results, improving the utilization of Geographic Information Technology (GIS), validating PMS with real data, and incorporating engineers' experiences. This thesis presents a methodology to address these issues. This methodology was incorporated in the PMS to develop two major modules. The first module is a GIS-enabled multi-year pavement rehabilitation and maintenance planning module that can perform multi-year, project-linked network pavement rehabilitation need analyses subject to funding availability, minimum performance requirements, and balancing funding or performance among jurisdiction boundaries, such as working and congressional districts. The second module is an annual pavement rehabilitation project selection module that can simulate and improve project selection practice, especially the interaction between district and central offices, by incorporating engineers' experience and judgment and balancing needs among different jurisdictions. This methodology was validated and calibrated with historical data provided by Georgia Department of Transportation (GDOT). These two modules were implemented by GDOT.

Title: Cyclic Constitutive Modeling of Granular Materials

Author: Louis Yu-Ning Ge, *University of Colorado at Boulder*

Abstract:
Cyclic behavior of pavement materials under traffic loading is a challenging task for geotechnical engineers. A typical example is railroad ballast, which is used to fill in irregular surface topology, distribute and transfer loads from a surface structure to the subgrades as uniformly and widely as possible in order to provide stable and stiff long-term embankment support for railways.

The research focuses on the development of a cyclic constitutive model based on fuzzy set concepts, its numerical integration, and finite element implementation. Unlike conventional elasto-plastic hardening models, the fuzzy set model is physically intuitive and easy to visualize. It provides analytical and simple geometrical interpretation to formulate hardening, hysteresis features, material memory, and kinematic mechanisms without invoking a complex analytical formulations in terms of kinematic hardening rules.

The cyclic constitutive model developed in this study accounts for: realistic stress-strain behavior under repeated load cycles, nonlinear dilatancy behavior, material memory, accurate reverse loading features, critical state soil mechanics concepts, density and mean effective stress dependence, features concerning long-term cyclic effects (fatigue, damage, and shakedown), and non-proportional loading. The implicit integration scheme for the fuzzy set plasticity model is also described and implemented in a finite element analysis computer code.

Title: Full Scale Field Testing Examination of Pile Capacity Gain with Time

Author: Edward L. Hajduk, *University of Massachusetts – Lowell*

Abstract:
It has long been established that piles driven into low permeability soils gain capacity over time. This capacity gain, often called "set-up" or "freeze", is believed to be controlled by two mechanisms: (a) the increase of effective stresses due to the dissipation of excess pore pressures built up during driving and (b) stress independent phenomena such as strength increase due to thixotropic bonding. However, only recently have efforts been made to quantify time dependent pile capacity and develop a methodology of incorporating it into pile design through use of insitu testing. As the final stage of a research initiative into time dependent pile capacity gain, three instrumented test piles and an accompanying ground piezometer field were installed and tested in a deposit of Boston Blue Clay in Newbury, Massachusetts. Measurements of excess pore pressures and radial stresses along the piles and in the insitu soils were measured with time and relationships were developed with overall and segmental pile capacity gain. These relationships were compared to those developed by previous research efforts within this initiative, such as collection and analysis of several data sets of previous instrumented pile programs and the use of a Multiple Deployment Model Pile (MDMP).

Title: Formulation and Implementation of a Constitutive Model for Soft Rock

Author: Randall Hickman**,** *Virginia Tech*

Abstract:
Goal is to develop and implement a constitutive model for soft rock, including time-independent stress-strain behavior, time-dependent behavior, and effect of rock-fluid interaction. Affiliated with the development of the model is the ability to implement the equations which comprise the numerical model into a numerical simulation package and obtain results which are robust, accurate, and efficient. The petroleum reservoirs of the North Sea are composed of a single solid phase (chalk) and three fluid phases (water, oil, and natural gas). Interaction of the solid and fluid phases during petroleum recovery operations has led to unexpected geomechanical behavior in the reservoir. Laboratory testing of chalk behavior have yielded results which indicate that the observed field behavior of chalk is due to interaction between solid chalk and pore fluid. Some aspects of chalk behavior are unique among geomaterials. A model is being developed which sufficiently general to apply to any soft rock, but the emphasis is on chalk. An elastoplastic model with several yielding mechanisms is being refined and implemented into a computer code. Much laboratory data has been gathered to correlate behavior to geomechanical properties. Calibration of the model is ongoing.

Title: The BCT: a New Instrument for Quick Evaluation of Compaction

Author: Yanfeng Li, *Texas A&M University*

Abstract:
Compaction of soil is essential in the construction of highways, airports, buildings, and bridges. Typically compaction is controlled by measuring the dry density and the water content of the compacted soil and checking that a target value has been achieved. There is a very strong trend towards measuring the soil modulus instead or in addition to density because the density measurements are made using Nuclear Density Gauge, an undesirable tool in today's political environment. BCT (Briaud Compaction Tester) is a portable device which can measure the soil modulus fast and accurately. The idea of BCT is to use the bending of a plate resting on the ground surface as an indicator of the modulus of the soil below. Numerical simulations show that within a certain range, soil modulus is proportional to the plate bending. BCT tests in parallel with plate tests of the same size also show a very good correlation between the bending strains measured with strain gauges glued to the top of the plate and the soil modulus.

Title: Development of a Micromechanical Model to Predict Mixture Stiffness Through Discrete Element Analysis for Asphalt Paving Mixture

Author: Zhanping You**,** *University of Illinois at Urbana-Champaign*

Abstract:
A microfabric discrete element modeling (MDEM) approach is presented for modeling asphalt concrete microstructure. The technique is a straightforward extension of a traditional discrete element modeling (DEM) analysis, where various material phases (e.g., aggregates, mastic) are modeled with clusters of very small discrete elements. The MDEM method has all the benefits of traditional DEM, e.g., the ability to handle complex, changing contact geometries, large displacements and crack propagation, and the ability to simulate specimen assembly (e.g., laboratory compaction of the asphalt mixture). By modeling inclusions such as aggregates with a "mesh" of small discrete elements, it is also possible to model complex aggregate shapes and the propagation of cracks around or through aggregates during a strength test. The MDEM approach is used herein to predict asphalt mixture complex modulus in extension/compression across a range of loading times and test. The method allows various constitutive models to be employed to describe particle and interface properties, such as normal and shear stiffness and strength. An uncalibrated 2D model was developed, and complex modulus predictions were compared to theoretical bounds on moduli. As expected, when insufficient coarse aggregate structure is in the MDEM model, the uncalibrated 2D model underestimates the significant stiffening effects of the coarse aggregate skeletal structure and predictions are found to reside near the lower theoretical bounds, well below experimentally determined moduli. Some technique was developed to calibrate the MDEM model to experimental results. The calibration is shown to provide better modulus estimates compared to more traditional calibration methods. The follow-up modeling efforts will be extended to three-dimensions.

Title: Influence of Material Properties and Environmental Conditions on Electromagnetic Wave Propagation in Soil

Author: Xiong Yu, *Purdue University*

Abstract:
The purpose of the presented study is to simplify the testing procedures for using TDR technology to measure soil water content and dry density, which are two important indicators for compaction quality control. This dissertation developed a new method for determining soil water content and dry density using a single Time Domain Reflectometry (TDR) test, which is an improvement over that designated by ASTM D6780. This new method utilizes the information of electrical conductivity in addition to apparent dielectric constant measured by TDR on the same soil sample. Calibration equations correlate these two parameters with soil gravimetric water content and dry density, which are imultaneously solved after adjusting field-measured conductivity to a standard conductivity. Effects of environmental temperature on the measurement results were investigated and compensated. Software was developed to automate the process of data acquisition and analyses. TDR Testing using this new method can be conducted in field as well as in the laboratory using the apparatus developed at Purdue. The amount of time required for making measurement is significantly reduced compared with the procedure in ASTM D6780. Preliminary laboratory and field investigations show this One-Step TDR method is a fast, accurate and safe method for construction quality control. The dissertation also made investigations on unconventional materials such as fly ash, lime stabilized soil which identified new application areas for using TDR technology to characterize civil engineering materials.