Geotechnical Engineering at the Waterways Experiment Station

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The Geotechnical Laboratory at the U.S. Army Engineer Waterways Experiment Station (WES) was founded in 1932 and currently employs approximately 250 engineers, engineering geologists, geophysicists, scientists, and support personnel. Research funding is developed through Civil and Military projects and has grown from less than 1 million dollars in the early 1940's to over 35 million dollars in the 1990's. A recent article in *Ground Engineering* (1991) provides a brief history of the Geotechnical Laboratory (GL). The GL is presently divided into four divisions, Earthquake Engineering and Geosciences, Soil and Rock Mechanics, Pavement Systems, and Mobility Systems. The major activities of each of these Divisions follow:

Earthquake Engineering and Geosciences Division

A major activity of the Earthquake Engineering and Geosciences Division (EEGD) is safety re-evaluations of Corps dams. This seismic dam safety research includes evaluation of design ground motions, advanced methods of site characterization, liquefaction potential of fine-grained and gravelly soils, large deformation effective stress dynamic analysis, and the design of remedial measures to control deformations to acceptable levels. The GL is also preparing seismic design guidance for Naval waterfront structures and a Corps geotechnical seismic design manual for embankments and foundations.

GL also contributes to the Department of Defense (DOD) Environmental Restoration Program and has developed a state-of-the-art Site Characterization and Analysis Penetrometer System (SCAPS) to accelerate the mapping and identification of soil and groundwater contamination. The system is mounted in a special truck (Figure 1) designed with protected workspaces for safe access to toxic and hazardous sites. A special trailer carries grouting pumps, water tank, and closed loop steam cleaner.

A unique fiber-optic flurometric contaminant sensor has been developed with SCAPS and was successful in detecting and delineating petroleum, oil, and lubricant contaminants in situ at Jacksonville Naval Air Station, Tyndall AFB, and Savannah River Demonstration site. Optical spectral measurement techniques are being developed. These developments will extend the utility of the fiber-optic sensors to include solvents, metals, and explosive contaminants. All penetrometer sensors output in real time and post processing of the data includes three-dimensional visualizations of site conditions to a concentration level of 1000 ppm (0.1%).

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Another part of GL's participation in the DOD Environmental Restoration Program involves the development and use of groundwater flow models, groundwater control systems, and techniques for artificial recharge of aquifers. GL designed gravel-filled trenches for recharging treated groundwater at the Rocky Mountain Arsenal to improve the containment/treatment system at the North boundary. Ten trenches were installed in 1988 and are performing successfully. GL is studying the factors that affect groundwater recharge efficiency.

Engineering geology studies are also conducted in EEGD to provide Corps Districts with geologic engineering parameter maps for construction sites. Similar maps are provided with spatial and temporal data portraying geologic age and environment of deposition necessary for the planning of cultural site surveys and investigations.

Soil and Rock Mechanics Division

Problems in classical soil mechanics currently being addressed by the Soil and Rock Mechanics Division include the development of design procedures to estimate the compaction and shear strength properties of earth-rock mixtures without resorting to large-scale laboratory testing. This research has

shown that sieved fractions can be used in the compaction control of soils containing large particles. Another recently concluded study has determined that erosion leading to the oversteepening of underwater slopes is the cause of troublesome "flow failures" which endanger flood control works and revetments along the lower Mississippi River. An extension of this study seeks to predict where these slides will occur.

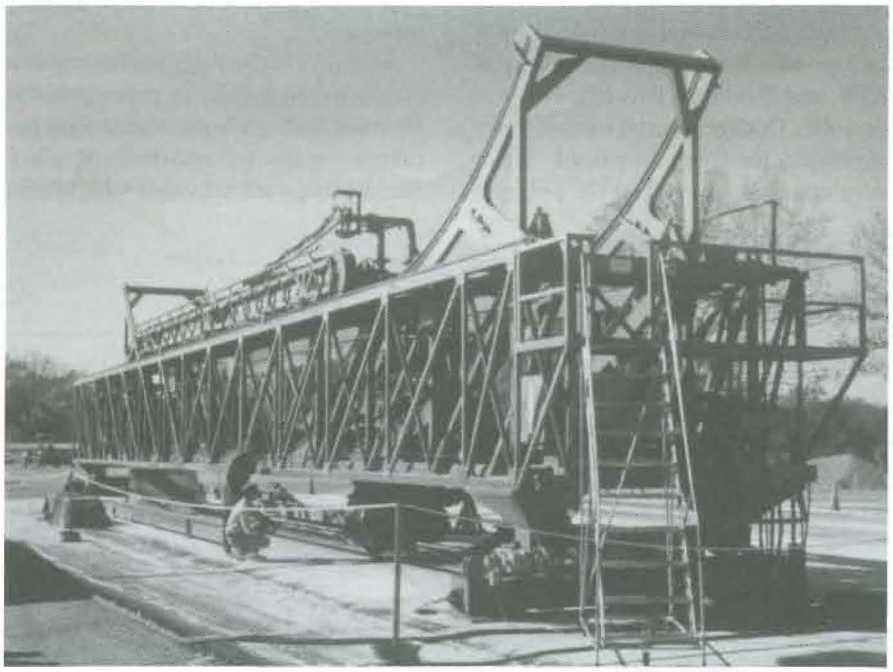

Figure 2..A 50-by-50m RMP test section was load tested using the Automated Load Facility (ALF) which applies dynamic traffic loads to the pavement.

Research within GL also includes the development of shallow foundation design procedures using wave mechanics to estimate heave exerted on mat foundations by expansive soils. A field test section at Fort Sam Houston, Texas is being developed to test heave prediction methods and preventive treatment measures for expansive soils.

Use of synthetic material in earthwork construction is another area of GL research. Projects involve the use of geosynthetics in embankment reinforcement, earth retaining structures, construction over soft ground, and in military barriers. Using prefabricated strip drains to accelerate consolidation of confined dredged material is under study. Use of large polystyrene blocks in permanent earthwork construction is being studied in cooperation with a private firm under the Corps' Construction Productivity Advancement Research Program.

Economical methods of repairing or renovating 40 to 50 years old structures such as dams, navigation locks, pumping stations and flood control structures is a major concern of the Corps of Engineers. For this reason methods of rehabilitation of relief wells and foundation drains, embankment repair through the use of jet grouting, lime injection, and soil nailing are being studied.

GL's Soil Research Center performs engineering property tests on undisturbed, reconstituted, and compacted soils using multiple automated controlled-strain direct shear apparatuses and consolidated undrained triaxial compression chambers. Susceptibility to liquefaction under seismic loadings, dynamic modulus, and dampening characteristics of foundations are determined by cyclic triaxial testing. Consolidation/settlement is determined using conventional and back pressure consolidometers with automated data acquisition. Special consolidation tests are conducted on clay-shales to 500 tsf; and large particle (up to 3 inches) soils are tested in a 15 inch diameter triaxial apparatus capable of applying 250,000 pounds of force. A 6-station MTS closed loop electrohydraulic loading system with state-of-the-art instrumentation provides capability for variable function stress or strain-controlled shear tests in axial or axial-torsional mode. A unique directional shear cell permits duplication of complex stress paths permitting solution of complex soil deformation problems. This shear cell is currently being used to confirm constitutive relationships and develop mathematical expressions that predict how failure planes develop and propagate.

Another GL focus is the characterization of rock masses and addressing problems in design and construction on rock foundations and underground excavations. It conducts field and laboratory investigations in the full range of rock mechanics, in situ measurements, large scale physical modeling, numerical modeling, fluid flow in fractured rock, and interaction of rock mechanics with a full range of engineering applications. An example of this research is the use of the world's largest polyaxial load frame, 3m square in plan and 1m deep, to investigate the influence of rock bolt length on the performance of tunnel support systems. The results indicate that the optimum bolt length to tunnel diameter ratio is between a third and a sixth. Additional activities include geological and geophysical material mass evaluations for preliminary design, and analysis of proposed designs; development, fabrication and installation of specialized instrumentation; data analysis, modeling and model validation.

In cooperation with the Trenchless Excavation Center at Louisiana Tech University and equipment manufacturers, GL will begin extensive research in "trenchless technology". The research will be performed under the Construction Productivity Advancement Research program, a cost shared program authorized by Water Resource Development Act. The 2-year study will develop guidelines and selection criteria for future users of trenchless technology.

Pavement Systems Division

The Pavement Systems Division (PSD)

is the pavements research organization for the U.S. Army Corps of Engineers and has been recognized as the lead pavements research facility for the DOD. The PSD develops new and improved methods for the design, construction, evaluation, rehabilitation, and maintenance of structure systems for pavements and other transportation facilities; development of models for improved performance predictions, identification of deterioration rates and failure modes and mechanisms, determination of failure criteria, management, and cost.

The PSD performs research and development studies for new and improved materials for pavements and other transportation facilities; procedures for pavement mixture designs, construction processes, performance requirements for surface materials, and maintenance materials and procedures. GL's state-of-the-art research laboratory is used to evaluate pavement materials and mixtures and field performance by conducting in situ tests and sampling of existing pavement systems. A typical example of GL's research is the evaluation of resin modified pavement (RMP) to resist damage due to abrasion and fuel spillage. The RMP consists of an open-graded asphalt mixture containing 25 to 30 percent voids, which are filled with a resin modified cement slurry grout. The slurry grout is poured onto the open-graded asphalt after cooling and then vibrated into the voids. The process is continued until all voids are filled with grout. A 50-by-50m RMP test section, Figure 2, was load tested using the Automated Load Facility (ALF) which applies dynamic traffic loads to the pavement. The test section was also subjected to six hundred 180 degree pivot steer turns and 5000 passes of a M-1 and M-60 tank and the pavement did not suffer any significant damage. In addition, the RMP resisted jet aviation fuel, gasoline, diesel, synthetic soil, and hydraulic oil spills. Based on this study, RMP has been determined to be a cost-effective method to construct and rehabilitate civil and military pavements and has been recommended as an alternative pavement surfacing material by the U.S. Army.

The GL is also responsible for criteria development, criteria applications and technology transfer through preparation of technical manuals, guide specifications, and engineer technical letter demonstration projects of new technology, construction materials, and practices; and training programs. Criteria relate to design, construction materials and practices evaluation, rehabilitation, maintenance, geometric requirements and safety of roads, airfields, railroads, and drainage facilities.

Mobility Systems Division

The Mobility Systems Division conducts research, testing, and evaluations to ensure that the U.S. military forces maintain superior ground mobility in all environments. This is accomplished through systematic studies involving experimental testing, terrain descriptions, modeling of vehicle-terrain interaction, and operations research methods to meet the increasing demands of technological advancements. This diverse research provides timely results which support wargamers, force developers, material developers, trainers, and soldiers in the field. This research encompasses engineering disciplines such as soil mechanics, soil dynamics, engineering geology, pavement technology, and soil-structure interactions.

Acknowledgment

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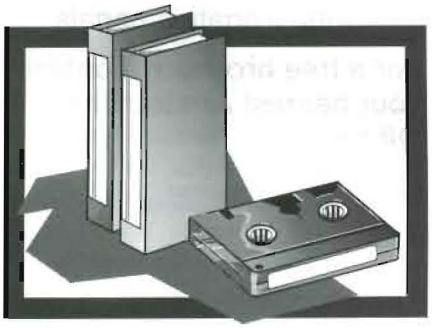
Reference

Ground Engineering, (1991). "Well of Learning," Vol. 24, No. 5, pp. 21-23.

VIDEO REVIEW



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ISSMFE Video Lectures: Leaders of Geotechnical Engineering Ralph B. Peck - Engineering Judgment

Video 1

BiTech Publishers Ltd., 903 - 580 Hornby Street, Vancouver, B.C., Canada V6C 3B6.

Date: 01/05/91 Length: 39 minutes

Available in VHS NTSC, VHS SECAM, or VHS PAL.

"Judgment in Geotechnical Engineering, the Professional Legacy of Ralph B. Peck", edited by John Dunnicliff and Don Deere providing some of the wisdom of this great engineer in written form.

Now, BiTech Publishers Ltd. have produced a video and we can experience the personality of Dr. Peck coupled to his understanding of the science and art of engineering.

Dr. Peck believes judgment in engineering is dependant upon an engineer's sense of proportion: an intuitive understanding of the sizes and relationships of things. It also requires an ability to identify a problem correctly and set reasonable criteria for determining its solution. Finally, it includes the use of both theoretical and empirical relationships and, hopefully, a recognition of the difference.

Dr. Peck expects a structural engineer of judgment to know approximately the span of a major bridge, say, the Golden Gate Bridge, the history of significant engineering works such as the Quebec Bridge, and the order of magnitude of a column load in a conventional industrial building.

Dr. Peck believes that judgment can be both taught and cultivated and this is the principal theme of his lecture. Those who have learned judgment should teach it and pass it to the next generation. Those who have not should study the literature and be prepared to learn at the feet of those who have al-