The Exploratory Advanced Research Program Fact Sheet

Real-Time Measurement of Soil Stiffness During Static Compaction

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Is continuous sensing of soil properties during static pad foot roller compaction achievable? A new pad-based, roller-integrated system for real-time measurement of the elastic modulus of fine- and mixed-grain soils is the goal of "Development of Soil Stiffness Measuring Device for Pad Foot Roller Compactor," a project of the Federal Highway Administration's (FHWA's) Exploratory Advanced Research (EAR) Program. Initiated in 2008, the study is being conducted by the Colorado School of Mines with the participation of roller manufacturers and the Colorado and Minnesota Departments of Transportation.

New Approach to Intelligent Compaction

Most embankment and subgrade soils are best compacted statically using pad foot rollers, yet none of the intelligent compaction systems in use measures stiffness or elastic modulus during static compaction. The estimation of soil modulus is important because subgrade modulus is the key parameter used in pavement design and in performance-based quality assurance. In this study, researchers are modeling a breakthrough approach and developing a prototype system to continuously measure soil modulus through its relationship with the contact force–displacement response of individual roller pads. Such a system, if accurate and reliable, would be significantly superior to the current practice of spot testing perhaps less than 1 percent of a compacted area.

Measuring Pad Contact Force and Soil Deflection

The system under development employs the changing relationship between pad contact force and deflection that occurs as soil is compacted. This change is illustrated in roller "walk out": as the soil stiffens, individual pads on the roller penetrate the soil less, causing the roller to "walk" out of the soil. Individual pads bear more contact force relative to the drum but are in contact with the soil for less time. By fitting several adjacent pads on standard pad foot rollers with load cells to gather data and by fusing the contact force–time history data from multiple pads, researchers can infer deflection. These contact force and deflection data feed into an algorithm that extracts soil modulus.

During the research, tactile pressure sensors on the pads and ultra-sonic proximity sensors on the roller frame are being used to verify pad deflection calculations and further develop the measurement approach. Small-scale tests, using rollers from different manufacturers, are collecting data from three soil types at three moisture levels. Analysis of these field data will inform and refine the model.

Continuous, Comprehensive, Accurate Data for Operators and Inspectors

Ultimately, information from the system will be integrated via wireless communication with onboard global positioning system mapping software and documentation systems, enabling the roller operator to "see" the state of the soil. Real-time graphical feedback offers many benefits: documented quality control over 100 percent of the compacted area; elimination of unnecessary passes; identification of "weak" spots; accelerated (less costly) construction. The quality assurance team will have documentation of soil modulus throughout the compaction area on which to base its decisions.

U.S. Department of Transportation
Federal Highway Administration

Real-Time Measurement of Soil Stiffness During Static Compaction

Future Efforts

Following development and validation of the measurement system and the modulus extraction algorithm, an integrated (or pad-based) power source and data communications capabilities will be designed and installed. The completed prototype will undergo full-scale demonstration and evaluation at a Colorado Department of Transportation construction site. As part of the evaluation, the responses of the roller operator, quality assurance contractor, and State highway engineers will be gathered.

When the project concludes in 2010, the system will be near ready for commercial production, subject to individual roller manufacturer specifications. The involvement of manufacturers throughout the project will expedite implementation. "If this pad-based technology is a success," says Mike Adams at FHWA's Highway Research Center, "it will represent a significant leap forward in quality assurance during earthwork construction. Highway agencies will benefit from improved compacting practices. The attainment of higher quality and more uniformity during soil compaction will lead to longer pavement life and lower life-cycle costs."

Learn More

To learn more about this project, contact Mike Adams, FHWA Office of Infrastructure Research and Development, at 202-493-3025 (mike.adams@fhwa.dot.gov).

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@fhwa.dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@fhwa.dot.gov).

Publication No. FHWA-HRT-09-047
HRTM-04/06-09(1M)E