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RESEARCH
SERVICES SECTION

TECHNICAL SUMMARY

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PROJECT COST:
$110,000

Current test rolling equipment is cumbersome and unsuitable for testing lifts less than 30 inches thick.

LRRB
LOCAL ROAD RESEARCH BOARD

Developing Improved Test Rolling Methods for Roadway Embankment Construction

What Was the Need?

Before pavement construction, crews test roll the soil that will act as the pavement subgrade by towing a two-wheeled vehicle of known weight over the soil and measuring the depth to which its wheels penetrate the soil. If this depth exceeds a Mn/DOT-specified limit, the subgrade must be further compacted before it is considered acceptable for placing the road's aggregate base.

The weight of Mn/DOT's current test rollers makes them impossible to use for projects that are not intended to support very heavy loads, and they use wheels that are no longer manufactured. The current test rolling procedure is also very time- and labor-intensive, and involves safety risks: One or two inspectors must walk alongside roller tires, which are prone to exploding.

To best redesign this system, Mn/DOT had to address limitations of the current test. Test rolling measurements using flexible pneumatic tires can vary due to coupled deformation of the wheel and soil. Crews often infer wheel penetration by measuring the distance between the wheel axle and the soil level surface, but this measurement can be misleading because of the effect of tire flexibility.

Moreover, there was no available means to relate test roller wheel penetration to basic soil mechanical properties. Without a theory linking sinkage to soil properties and acceptable mechanistic parameters, test rolling remains a visual, empirical tool rather than a quantitative way to obtain material characterizations for use in mechanistic design.

What Was Our Goal?

The objective of this project was to better understand the deformation of soils and tires in test rolling as well as the relationship between test roller measurements and soil strength properties in order to recommend improvements in test rolling equipment and procedures.

Investigators aimed to formulate a theoretical model for roller wheel penetration and then validate this model via experiments in which the various parameters influencing test rolling results—including test roller weight, wheel type and size, soil mechanical properties and soil layering—were well-controlled.

What Did We Do?

Investigators first evaluated existing research on processes involving soil-wheel interaction, as well as current test rolling specifications. Then they developed theoretical models for soil-wheel interaction. This modeling consisted of both comprehensive, three-dimensional numerical simulation and an analytical method that provided mathematical expressions relating wheel weight, size and flexibility to soil properties and sinkage.

The next step was to apply the theories developed during the modeling phase by evaluating the effects of test rolling variables such as wheel weight and size, soil layer depth and strength, and soil type on roller penetration. Investigators compared theoretical predictions of soil mechanical properties determined from laboratory testing to the results of field and lab-scaled rolling and indentation tests.

continued

"For a host of reasons, the old test roller system was no longer sustainable. This study served to better define the soil mechanics related to the new system we are building."

–John Siekmeier,
Mn/DOT Senior Research Engineer

"Test rolling has great potential as a tool for characterizing in situ subgrade strength over a broad area. Though test rolling in current practice is somewhat crude, the relationship between rolling wheel penetration and material strength parameters is quantifiable."

–James Hambleton,
University of Minnesota Department of Civil Engineering

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Evaluating test-rolled soil using current test rolling procedures: passing inspection (left), near failing (center) and failing (right).

What Did We Learn?

This study established relationships between sinkage in cohesive and granular soils and the variables most important to test rolling, including wheel weight and geometry, wheel type, and soil layering. Test rolling proved more sensitive to weak soil layers underneath the tested layers than to strong layers beneath.

Poor conditions at selected sites prevented effective field evaluations. However, scaled lab tests of rigid and flexible wheels on cohesive and granular soils verified the theoretical models and showed that test rolling results can be predicted from soil properties. The study showed that sinkage and rut depth from rolling can be used to determine soil properties.

This study produced several recommendations helpful to designing a new test roller system:

- Use rigid rather than flexible wheels, and offset test roller wheels from driving wheels.
- Use two or more offset wheels with different weights or geometries to measure both friction angle and cohesion of a soil.
- When rolling soils display a uniform strength (such as clean sand or moist clay), use single wheel types to determine friction angle or cohesion, but for mixed soils, use two wheels of different sizes or carrying different weights.
- Reduce the test roller weight by half (without changing wheel geometry) to reduce the sinkage by roughly one-half in granular soils and one-fourth in cohesive soils.

What's Next?

This study demonstrated that test rolling can effectively determine subgrade strength during construction. Validation of the accuracy of this study's theoretical models will require field testing at multiple sites over various representative subgrade materials.

A $253,000 implementation effort by investigators at Minnesota State University, Mankato, is under way to develop a new automated test roller system that is more mobile and adaptable to a wide variety of projects. This new system will include specifications that account for variations in projects such as the thickness and type of subgrade materials.

This Technical Summary pertains to the LRRB-produced Report 2008-08, "Development of Improved Test Rolling Methods for Roadway Embankment Construction," published February 2008. The full report can be accessed at http://www.lrrb.org/PDF/200808.pdf.