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LRRB
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TECHNICAL SUMMARY

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LRRB PROJECT COST:
$126,042

The TONN program processes falling weight deflectometer results, which can be used to evaluate pavement stiffness.

RESEARCH SERVICES
OFFICE OF POLICY ANALYSIS, RESEARCH & INNOVATION

Allowable Axle Loads on Pavements

What Was the Need?

One measure of the durability of a road is the degree to which its pavement sections bend under a given load. These deflections can be an indication of both the strength and stiffness of the layers composing the pavement. A falling weight deflectometer, or FWD, is often used to measure these deflections by dropping a large weight onto a pavement and recording its consequent deformation.

Investigators developed a more accurate software program for estimating pavement axle load capacities on Minnesota low-volume roads. It is expected to be widely used and will save money by avoiding the over- and underdesign of Minnesota roads.

Minnesota currently interprets FWD measurements of asphalt pavements on low-volume roads using a computer program called TONN (referring to the tonnage pressing down on a pavement). This software processes deflection measurements to determine whether a pavement section—given its thickness and expected traffic—is stiff enough to carry vehicles up to a certain weight per axle, or axle load, without incurring undue amounts of damage.

However, the TONN program uses a simple and outdated method to correlate FWD displacements and stiffness, accounting only for the properties of the top pavement layer. Since FWD deflections are greatly affected by the stiffness of the subgrade layers of soil and rock that support the top asphalt layer, TONN may underestimate the allowable axle load for soft clay subgrades but overestimate it for stiff sand or granular subgrades. These errors can lead either to the overdesign of pavements and unnecessary construction costs, or to underdesign and subsequent rehabilitation costs. Research was needed to update the TONN program in light of more current and accurate methods for interpreting FWD measurements.

What Was Our Goal?

The goal of this project was to improve the accuracy of Mn/DOT's existing program for estimating axle load capacities on Minnesota low-volume roads by taking into account the stresses on pavement subgrade layers and incorporating mechanistic-empirical design to predict the resulting damage.

What Did We Do?

Researchers developed an update to TONN called TONN2010. Where TONN relies on a less rigorous empirical system using performance data collected by AASHTO-sponsored road tests in the 1950s to correlate deflections and stiffness, TONN2010 incorporates mechanistic-empirical design, which uses a pavement's materials, structure, expected traffic and surrounding environment to predict pavement performance.

Researchers then calibrated TONN2010 by comparing its analyses of FWD measurements performed on two sections of MnROAD's low-volume road to the observed performance of these sections over three years. They further evaluated TONN2010 by applying it to 8,400 deflection measurements taken in nine Minnesota counties and comparing its results to those of TONN.

What Did We Learn?

Calibration and evaluation of TONN2010 showed it to be more conservative and accurate than TONN for the majority of analyzed FWD data. TONN2010, delivered as a FORTRAN-based program that can be run in an MS-DOS environment, is simple and easy

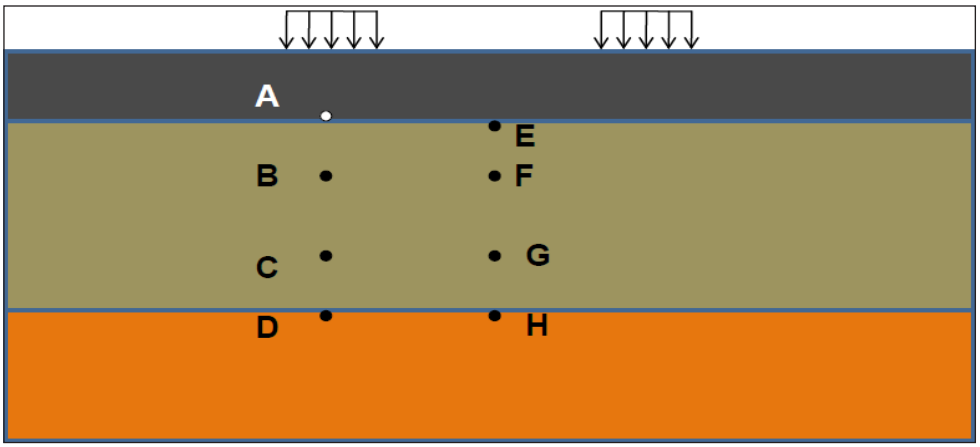
continued

"This is one of the most important research projects with which I've been involved, and a big step forward in giving us a more accurate assessment of pavement load capacities."

—Jerry Geib,
Research Project Engineer, Mn/DOT Office of Materials & Road Research

"TONN2010 will save costs by helping to avoid unnecessary construction and rehabilitation costs associated with over- or underdesigning pavements."

—Lev Khazanovich,
Associate Professor, University of Minnesota Department of Civil Engineering



This diagram shows the eight points across three layers of a pavement whose structural responses to loads are used by TONN2010 to calculate pavement stiffness. The previous program only took into account deflections in the asphalt layer.

to use; it is expected to be widely used by local agencies, Mn/DOT staff and consulting engineers. Its calculations are based on a wider range of inputs than TONN, including pavement layer thickness, FWD deflections, air temperature, pavement surface temperature, pavement location and anticipated traffic. Using these inputs, TONN2010:

- Back-calculates resilient modulus (a measure of stiffness) from FWD deflection measurements. This is accomplished by iteratively determining which resilient modulus value is calculated to yield the measured FWD deflections in an identical pavement receiving the same load.
- Adjusts resilient modulus calculations based on season and temperature at the time of testing using factors developed within MnPAVE, the version of the mechanistic-empirical design procedure calibrated for Minnesota low-volume roads.
- Derives from adjusted resilient modulus values the stresses and strains at various points in the pavement base layer using Mn/DOT's MnLAYER software.
- Derives from MnLAYER results the anticipated pavement damage caused by a vehicle axle of a given weight, including asphalt layer cracking, subgrade rutting, base shear failure and base deformation. If this anticipated damage is greater than the damage expected at the end of the pavement's design life, then either rehabilitation should be required before this point or vehicle axle weights should be restricted, especially during seasons when the damage would be greatest.

What's Next?

Researchers will soon be developing a graphical user interface for TONN2010. Additional testing is needed to verify TONN2010 predictions for a wide range of pavement structures and site conditions by comparing TONN2010 ratings with actual pavement performance. The program can be recalibrated as necessary based on these results to improve its predictions.

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