2007-25TS
Published 4-6-08

RESEARCH
SERVICES SECTION

TECHNICAL SUMMARY

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TOTAL PROJECT COST:
$149,000

Laboratory stiffness testing involves recording the response of a sample of base material in a pressure vessel to a series of loads.

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Measuring the Material Properties of Aggregate Base Containing Recycled Materials

What Was the Need?

Minnesota road reconstruction projects are increasingly incorporating recycled paving materials into the pavement base, due both to the cost of landfilling old material and to the scarcity of virgin aggregate. This may involve bringing in recycled material and/or using full-depth reclamation, where the original pavement and some of its underlying aggregate is pulverized and reused in the new base.

To establish the viability of these practices, we need to quantitatively show how base layer stiffness, measured by resilient modulus, changes after reconstruction, including its performance over subsequent seasonal changes. To optimize full-depth reclamation procedures, we need to know how varying the balance between reused aggregate and recycled pavement affects the material properties of the base. Values for these properties are needed to update Mn/DOT's pavement design specifications.

There are well-established procedures for measuring base stiffness and strength for both the field (falling-weight deflectometer testing) and the laboratory (the NCHRP 1-28A protocol), but it is rare for a study to employ both of these. Moreover, the current method of analyzing FWD data involves inconsistencies that can produce inaccurate modulus values.

What Was Our Goal?

The overall objective of this research effort was to quantify material properties of aggregate base and subbase containing recycled asphalt or concrete pavement materials and/or shredded tires. This would improve the quality of pavement design by telling us more about the relationship between laboratory and field measurements of base material properties.

The focus was narrowed to evaluating only bases and subbases incorporating recycled asphalt. The project was split into two studies, performed by the same research team:

- One study compared resilient modulus test results from the field and the laboratory. Researchers aimed to develop a method for calculating modulus values from FWD data that was more accurate than the current practice.
- The other focused on the effects on base material properties when recycled asphalt is added to the aggregate unearthed during full depth reclamation.

What Did We Do?

Researchers surveyed other states' specifications for measuring resilient modulus in the design of virgin and recycled aggregate bases. They used this information to focus the study and select three recent Minnesota reconstruction projects that employed recycled asphalt paving materials in the base and that had undergone FWD testing prior to construction: County State Aid Highway 3, Trunk Highway 23 and Trunk Highway 200.

The investigators took new FWD measurements and performed laboratory modulus tests on extracted samples from each site. They analyzed the FWD data using not only conventional methods, but also a new method that estimates the static response of the pavement based on the time histories of load-deflection readings. They also analyzed FWD readings already available for three MnROAD test sections in order to determine the influence of seasonal changes on resilient moduli.

continued

"We needed to know how recycled material compared with virgin material, and we can now look at the relative stiffness values between the two."

–Shongtao Dai,
MnROAD Research Operations Engineer

"We had qualitative information about the performance of these pavements, but it was difficult to compare projects. Falling-weight deflectometer testing gave us the quantitative measure we needed."

–Joseph F. Labuz,
Professor, University of Minnesota Department of Civil Engineering

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A falling-weight deflectometer tests stiffness by dropping a weight onto a loading plate on the pavement surface and recording the pavement and base response with sensors.

During the full-depth reclamation of the County Highway 3 site, researchers also took samples of the unearthed aggregate alone and of the recycled pavement that was added to it. They blended these in the lab at ratios of 0/100, 25/75, 50/50, 75/25 and 100/0. These mixtures, as well as the mixture actually used for reconstruction, were compacted and tested for modulus, shear strength, recoverable and permanent deformation (using cyclic triaxial testing), and other properties.

What Did We Learn?

The material property values from this effort can be used as input for a mechanistic-empirical pavement design guide. The field tests produced modulus readings comparable at a given stress state to the corresponding laboratory values. Comparisons before and after reconstruction for the three projects showed that pavement bases reconstructed with recycled asphalt displayed increased stiffness under dynamic loading.

Mixtures with a 50/50 ratio of reused aggregate base to recycled asphalt exhibited at least as much stiffness and strength as 100 percent aggregate material. However, permanent deformation behavior under cyclic loading increased as recycled asphalt was added.

The MnROAD data analyses revealed that pavement base material exhibits a considerable increase in stiffness from thawed to frozen months. Frozen pavements produced such small reactions to FWD loads that no modulus readings could be gathered.

What's Next?

The new method of analyzing FWD values and the software designed as a part of this study will provide additional tools to pavement designers, enabling more accurate stiffness measurements for a greater variety of pavement systems.

The material property values measured in this study will improve current practice and will be used in an upcoming update of the Mn/DOT Pavement Design Guide. This will require further research on other types of recycled materials beyond asphalt and additional field testing to confirm the benefits of using recycled materials. An implementation project has been proposed that would employ Mn/DOT's research test site database to track the performance of pavements using recycled materials statewide.

This Technical Summary pertains to Report 2007-25, "Resilient Modulus Development of Aggregate Base and Subbase Containing Recycled Bituminous and Concrete for 2002 Design Guide and Mn/Pave Pavement Design," published June 2007, and the LRRB-produced Report 2007-05, "Resilient Modulus and Strength of Base Course with Recycled Bituminous Material," published January 2007. The full reports can be accessed at http://www.lrrb.org/PDF/200725.pdf *and* http://www.lrrb.org/PDF/200705.pdf.