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RESEARCH
SERVICES SECTION

TECHNICAL SUMMARY

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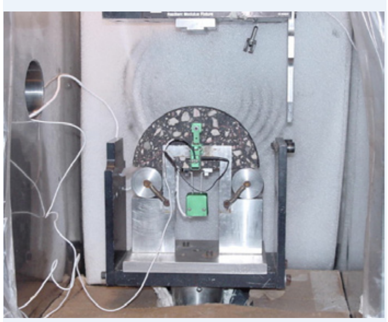
TOTAL PROJECT COST:
$905,000

MINNESOTA COST:
$380,000



The semi-circular bend test is used to measure the fracture energy of mixture specimens, which is related to resistance to crack propagation.

Investigation of Low-Temperature Cracking in Asphalt Pavements

What Was the Need?

Extreme cold triggers the most common type of distress of asphalt pavements in Minnesota and other northern states: low-temperature cracking. As temperatures drop, the pavement contracts, building up tensile stresses that lead to cracking. Fractures occur every 20 to 30 feet across the lane, allowing water to penetrate the structure, which further weakens the pavement layer and the base beneath. Traffic loads worsen these cracks, leading to shorter pavement life, increased maintenance requirements and rougher roads.

Currently, Mn/DOT attempts to limit asphalt pavement cracking by specifying Superpave performance-graded asphalt binders that have favorable properties at very low temperatures. However, more factors contribute to cracking than just the binder. The various aggregates that make up more than 90 percent (by weight) of a typical asphalt mix may each respond differently to low temperatures. Crude oils from different geographic locations produce asphalt binders that interact differently with aggregates, and asphalt binder grades and contents can also vary from mix to mix.

There is a need to understand more clearly the complex process of low-temperature cracking and to develop laboratory tests that predict a particular asphalt pavement mixture's overall resistance to low-temperature stress.

What Was Our Goal?

The goal of this 10-state pooled fund study (TPF-5(080), "Investigation of Low Temperature Cracking in Asphalt Pavements") was to develop the best combination of experiments and analysis for improving the low-temperature fracture resistance of asphalt pavements. Specific objectives included three major tasks:

- Develop new and traditional tests to evaluate and predict thermal cracking.
- Evaluate the laboratory test results with comparisons to field performance.
- Develop updated models for predicting thermal fracture behavior of asphalt materials and mixtures.

The study represented a unique partnership between Mn/DOT and four universities: the University of Minnesota (lead university), University of Illinois at Urbana–Champaign, University of Wisconsin at Madison, and Iowa State University.

What Did We Do?

Investigators began with a literature search to identify potential test methods and modeling approaches. Following this research, the investigators' tasks included:

- Field investigation of 13 hot-mix asphalt pavement sites, documenting performance (good vs. poor), mix properties and traffic, and taking samples (both cores and beams) for laboratory testing.
- Comprehensive laboratory study using traditional and new testing of both the asphalt binders and the complete mixtures, including fracture properties of mixtures. The field samples were tested along with the laboratory-prepared samples, which included two aggregate types, 10 binders from multiple crude oil sources and of multiple grades, two levels of air voids, and two levels of binder content.
- Modeling of low-temperature cracking based on field and laboratory findings.

continued

Low-temperature cracking (transverse cracks) may occur when asphalt pavements contract in cold temperatures.

What Did We Learn?

Investigators found that standard specifications do not include a specific test for measuring the potential fracture behavior of mixtures. Another key finding was that asphalt binder testing alone does not reliably predict low-temperature cracking. Mixture testing revealed that aggregate type affected resistance to fracture (granite outperformed limestone), as did the use of asphalt binders modified with polymers (modified PG 64-34 binders outperformed PG 58-34 binders).

An important outcome of the study was that investigators developed two laboratory fracture toughness tests that corresponded to field performance for mixtures that show fracture potential. These simple fracture tests can be used to select asphalt pavement materials and to replace the empirical inputs currently used in the Mechanistic-Empirical Pavement Design Guide. Results from these tests correlated well with field performance. Testing must be done at low temperatures, matching expected field conditions.

The models developed in this study for predicting the fracture performance of mixtures in the field were also effective. Investigators found that an accurate model requires determining how the mixture contracts with changes in temperature, as measured by its coefficient of thermal contraction.

What's Next?

This study provided an excellent start to a full understanding of asphalt's low-temperature susceptibility to fracture, as well as improved design approaches for fracture resistance. Key recommendations to develop further fracture toughness testing include:

- Expand fracture testing to a wider range of mix design types, including stone matrix asphalt, warm mixtures, recycled mixes and porous mixes, as well as to more aggregate sources.
- Create a database of coefficient of thermal contraction values for different types of binders, mixtures and aggregate sources.
- Develop a specification for selecting mixtures with increased fracture resistance.

A new pooled fund study (TPF-5(132), "Investigation of Low Temperature Cracking in Asphalt Pavements, Phase II") was recently approved to validate the laboratory procedures, models and pavement design procedures recommended by this report by constructing and monitoring seven MnROAD test sections.

This Technical Summary pertains to Report 2007-43, "Investigation of Low Temperature Cracking in Asphalt Pavements—A Transportation Pooled Fund Study," published October 2007. The full report can be accessed at http://www.lrrb.org/PDF/200743.pdf. *More information on the pooled fund study can be found at* http://www.pooledfund.org/projectdetails.asp?id=311&status=23. *The Web site for Phase II is* http://www.pooledfund.org/projectdetails.asp?id=395&status=4.

"This was an excellent start to developing ways to predict and combat low-temperature cracking. The fracture toughness test gave us good results that matched pavement performance."

–Benjamin Worel,
Operations Engineer,
Mn/DOT

"Asphalt binder properties are a good starting point for predicting low-temperature behavior, but our binder selection systems need to be refined by a better understanding of mixture behavior at low temperatures."

–Mihai Marasteanu,
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