



TECHNICAL SUMMARY

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TOTAL PROJECT COST:

\$515,000

CONTRIBUTIONS:

MnDOT: \$100,000

LRRB: \$50,000

PARTICIPATING STATES:

CT, IA, MN, ND, NY, WI



The SCB determines the energy required to cause or propagate cracking in specimens.



RESEARCH SERVICES

OFFICE OF POLICY ANALYSIS,
RESEARCH & INNOVATION

Pooling Our Research: Designing Asphalt Pavements That Resist Cracking at Low Temperatures

Why a Pooled Fund Study?

Building long-lasting asphalt pavements in cold climates can be a challenge. Low temperatures cause pavements to contract, creating internal tensions that lead to cracking. To help prevent cracking, MnDOT has established specifications that include laboratory tests designed to help select the asphalt materials that will perform best at low temperatures. Nevertheless, MnDOT has continued to have problems with low temperature cracking in asphalt pavements.

To address this problem, MnDOT and several other states formed [pooled fund study TPF-5\(080\)](#) in 2004 with the goal of developing methods to better characterize the behavior of asphalt at low temperatures. They evaluated a number of tests that involve measuring how materials respond to certain stresses, including the traditional indirect tensile (IDT) test, which measures deformation, as well as newly developed fracture mechanics tests, which characterize how well materials resist the formation and propagation of cracks. Fracture tests included the semi-circular bend (SCB) test and disk-shaped compact tension (DCT) test.

Completed in 2007, TPF-5(80) showed that fracture mechanics tests were best at predicting field performance and with further research should be incorporated into specifications. To accomplish this goal, TPF-5(80) was extended to a second phase, TPF-5(132).

What Was the Pooled Fund Study's Goal?

The objective of this pooled fund study was to continue the development of fracture mechanics-based specifications for determining the low temperature properties of asphalt mixtures; continue Phase I testing of additional samples using recycled and other materials; investigate the physical hardening effects for modified asphalt binders; and continue to develop computer models that make use of fracture mechanics properties.

What Did We Do?

As a continuation of the Phase I study, researchers conducted laboratory tests—including the IDT, SCB and DCT—on nine asphalt mixtures modified with recycled asphalt pavement, polyphosphoric acid and polymers. They compared these with specimens taken from MnROAD test sections and evaluated the effects of aging by conditioning laboratory mixtures for five days at 85 degrees Celsius. Researchers also investigated the physical hardening of asphalt binders and developed a comprehensive model for predicting this hardening without lengthy tests.

Researchers proposed a thermal cracking specification using the DCT and SCB tests, and validated the proposed DCT specification by using it with 11 mixtures from pavement sections constructed in Olmsted County, Minnesota, during the 2006 construction season. They proposed and validated a method for obtaining mixture creep compliance (how a material deforms permanently when subjected to stresses) from DCT and SCB

TPF-5(132): Low

Temperature Cracking, Phase II. The specifications developed in this study will help MnDOT design asphalt pavements that are less susceptible to cracking at low temperatures, leading to longer service life, lower maintenance costs and better ride quality for Minnesota drivers.

“Preliminary use of the DCT for in-service pavement projects shows that it will be a very good tool for accurately predicting the low temperature cracking performance of asphalt pavements.”

—**Tim Clyne**,
Senior Research Engineer,
MnDOT Office of
Materials and Road
Research

“The thermal model developed in this study represents a significant step forward in accurately quantifying the cracking mechanism in pavements.”

—**Mihai Marasteanu**,
Associate Professor,
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The DCT (left) involves loading cylindrical asphalt specimens that have been cooled and notched with a table saw. A gauge placed at the mouth of the notch (right) is used to measure crack propagation in response to loading.

results. They also explored the feasibility of predicting mixture creep compliance from asphalt binder creep compliance.

Finally, researchers developed a thermal cracking computer model called ILLI-TC and conducted a comprehensive experimental and modeling investigation into the contraction and expansion of asphalt mixtures due to thermal cycles.

What Did We Learn?

Laboratory tests on asphalt mixtures showed that fracture tests could distinguish between different mixtures, with the DCT and SCB generally providing similar results. Research into the physical hardening of asphalt binders showed that it causes significant changes in their creep response at temperatures below or near the glass transition (the temperature below which a polymer becomes brittle). The rate of physical hardening decreases rapidly with the amount of time the binder is stored at a constant low temperature and is not significantly changed by using various polymer additives. This hardening affects material stresses caused by contraction from cooling.

The DCT specification proposes a 15 percent increase in fracture energy to account for mixture aging and suggests a higher fracture energy threshold to limit thermal cracking to lower levels on critical projects. DCT test validation showed that the test reasonably predicted the initial field performance data available at the conclusion of the project.

The new ILLI-TC thermal cracking model significantly improves current models in handling fracture simulations. Researchers also developed a thermal stress model that accounts for the glass transition and physical hardening of asphalt mixtures, providing a foundation for developing mixtures that resist cracking through multiple temperature cycles.

What's Next?

MnDOT is conducting a follow-up study, “DCT Low Temperature Fracture Testing Pilot Project,” in which the DCT will be used as part of the specification during the mix design process for several pavements. A related project, “Laboratory Performance Test for Asphalt Concrete,” will compare the historical performance of in-service pavements to that predicted by DCT and other laboratory tests, helping MnDOT to refine its low temperature cracking specification.

This Technical Summary pertains to Report 2012-23, “Investigation of Low Temperature Cracking in Asphalt Pavements National Pooled Fund Study—Phase II,” published in August 2012 and funded through pooled fund study TPF-5(132), which continued a project initiated under TPF-5(080). The full report can be found at <http://www.lrrb.org/PDF/201223.pdf>, with pooled fund study information at <http://www.pooledfund.org/Details/Study/395> and <http://www.pooledfund.org/Details/Study/311>. For information about the follow-up studies, contact Tim Clyne at Tim.Clyne@state.mn.us.

For more than 25 years, FHWA’s Transportation Pooled Fund Program has been providing state DOTs and other organizations the opportunity to collaborate in solving transportation-related problems. The TPF Program is focused on leveraging limited funds, avoiding duplication of effort, undertaking large-scale projects and achieving broader dissemination of results on issues of regional and national interest.