

## Identifying the Problem

Low temperature cracking occurs when cold weather temperatures cause the upper part of a pavement section to contract, while the pavement's bottom section is held in place by its granular base and prevented from contracting.

To relieve stress, cracks are formed at semi-regular intervals, thus degrading the pavement and reducing riding comfort. Low temperature cracking is the main cause of pavement roughness and reduced service life in northern climates.

A theoretical view of major factors influencing transverse cracking was provided by University of Minnesota Civil Engineering Professor Mihai Marasteanu. They include:

- Highly variable natural materials
- Materials interaction
- Varying construction practices
- Complex interaction of traffic and temperature loading
- Differential aging of the HMA pavement layers
- Moisture infiltration and drainage

To design a pavement that is resistant to thermal cracking, it is important to understand crack initiation and propagation. Thermal cracks can be initiated by a large drop in temperature and propagated by traffic loading or temperature cycles.

## Solving the Issues

### SUPERPAVE

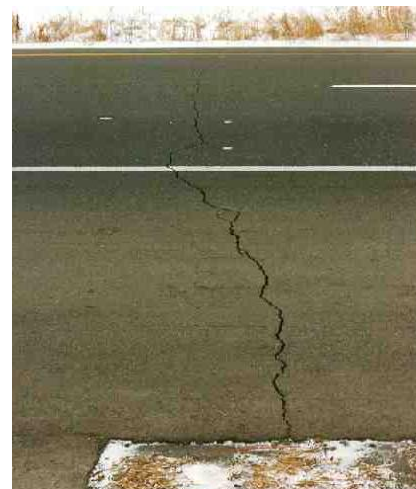
An important advance has been the Superpave (SUPERior Asphalt PAVement) Binder Specification, a product of the Strategic Highway Research Program (SHRP). First published in 1992, the Superpave specification allows engineers to specify binders and mix designs to fit anticipated temperature and traffic conditions.

Superpave binder specifications are referred to as "performance-grade" (PG), because they relate physical binder properties to field conditions—specifically, air temperature.

The current Superpave specification considers only the asphalt binder, attempting to address low temperature cracking by identifying a limiting low temperature for the binder.

Specifications must also be developed for the asphalt mixture. A performance-based specification for the asphalt mixture should account for:

- Binder grade
- Aggregate type
- Asphalt-aggregate interaction
- Mix design
  - Air voids
  - Asphalt content
  - Film thickness



While data from MnROAD confirms asphalt binder grade is more important than all other factors in cracking, MnROAD researchers determined crack severity is worse in:

- Full-depth test sections
- Mixes employing stiffer binders
- Leaner asphalt mixes

#### SAW AND SEAL

Saw-and-seal is a post-installation method used to prevent transverse cracking in pavement. Saw-and-seal attempts to alleviate stress in new pavement by cutting the pavement transversely at regular intervals and filling the cuts with crack sealant. The following recommendations are based on field results:

- Specifying a Superpave binder rated at -34° C (such as PG 58-34) is more cost-effective than using the saw-and-seal method.
- Saw-and-seal is recommended for curb-and-gutter pavements because of the higher stresses resulting from impingement.
- In bituminous-over-concrete overlays, saw cuts should be placed within one inch of old concrete joints.
- Saw-and-seal is not recommended in bituminous-over-bituminous overlays.

#### CRACK REPAIR

When thermal cracking does occur, repairing cracks can be costly. Using results from several research projects, MnROAD researchers have made recommendations on crack repair methodology.

Relatively ineffective methods include:

- Stress-absorbing membranes and interlayers (SAMIs)
- Spray injection patching (with a blow patcher)
- Slurry crack leveling (with a MiniMac)

Two methods found to show promise in providing lasting repairs include using thicker HMA overlays and mill and fill (removing the cracked surface and replacing it with a new HMA layer). Both methods outperform the repair methods discussed above, but are more expensive.

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## MnROAD Phase I Study

The Minnesota Department of Transportation (Mn/DOT) initiated and is leading a two-phase pooled fund research effort aimed at developing nationally accepted specifications for asphalt binder and mixtures. The ultimate goal is to eliminate low temperature cracking in new and rehabilitated Hot Mix Asphalt (HMA) pavements.

Since the original PG binder specifications developed during the SHRP program considered only neat binders and national trends indicate using more modified binders, it is necessary to re-evaluate the way asphalt binders and mixtures are specified.

Phase I of MnRoad's study developed a fracture mechanics-based specification. It was designed to better select asphalt binders and mixtures with respect to crack formation and propagation resistance.

The fracture mechanics approach will also help investigate the detrimental effects of aging and moisture on asphalt materials' fracture resistance.

The work performed in Phase I resulted in the following findings and recommendations:

1. Field performance correlates best with fracture behavior for both asphalt mixtures and binders. These results clearly indicated that, while the current properties such as creep and strength are needed for stress calculations and pavement design, the selection of fracture resistant binders and mixtures should be based on simple fracture tests.



2. PG specifications for binders are a good start to eliminating cracks. However, other factors such as aggregate type and air voids need to be considered. Asphalt mixture specification criteria similar to the current binder PG system need to be developed.
3. At low temperatures, asphalt mixtures are complex viscoelastic composite materials significantly dependent on temperature and loading rate. Any new specification should be based on test results at multiple temperatures and loading rates similar to the rates experienced by real pavements.
4. While selecting materials with good fracture properties will significantly improve pavement performance, it is critical to understand the role of all pavement system components. The pavement mechanics models developed in Phase I need to be further refined.

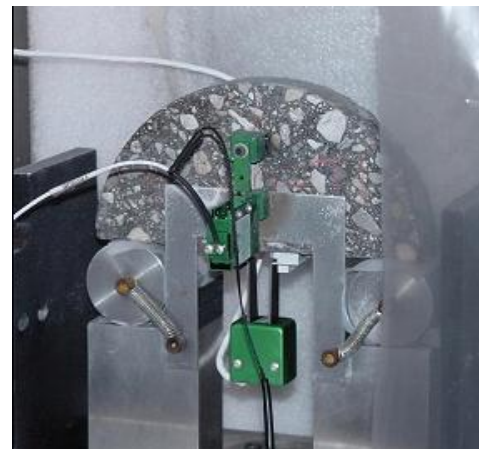
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## MnROAD Phase II Study

The specific recommendations of the Phase I study are contained in a comprehensive report. They provide clear direction on additional studies needed to improve asphalt binder and asphalt mixture specifications and the low temperature cracking model included in the current Mechanistic-Empirical Pavement Design Guide.

Phase II of the research effort needs to:

- Develop specifications selecting asphalt mixtures similar to the PG system for binders.
- Improve the current PG system for asphalt binders.
- Improve the modeling approach developed in Phase I by providing a mechanics-based model through additional experimental data and pavement performance data.
- Apply test methods and analyses to asphalt pavements built with recycled asphalt pavement.
- Validate study findings by constructing instrumented field test sections and evaluating additional existing field sections. This may result in revised binder and mixture design specifications.



Phase I developed new models for intrinsic material properties, laboratory testing behavior, and mixture performance in an in-service pavement. Phase II will combine laboratory materials testing with numerical modeling and pavement performance prediction. Three test sections at MnRoad will be constructed to validate the aforementioned tests and models.

The research proposed in this field study will build on previous research of low temperature cracking performed in Minnesota and around the country.

The models being developed for top-down cracking and reflective cracking may be of use for modeling thermal cracking. New asphalt materials, including modified PG binders, can be tested according to the principles developed in past research. Updated testing methods and important factors impacting low temperature cracking are being realized.

Although this research is primarily used to investigate low temperature cracking, the approach can be extended to a wide variety of issues that many states have in common including fatigue, reflective, and top down cracking.

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## References Related to MnROAD Efforts

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