Investigation of Low Temperature Cracking in Asphalt Pavements

National Pooled Fund Executive Summary

May 2007

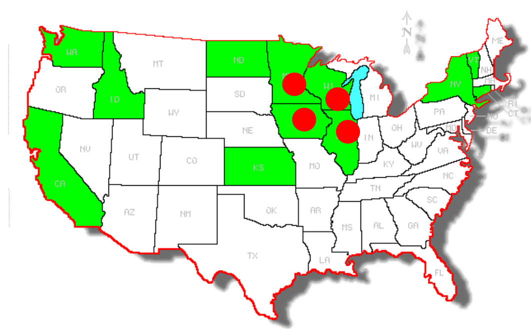
The Minnesota Department of Transportation (Mn/DOT) is leading pooled fund research efforts aimed at developing nationally accepted specifications for asphalt binder and mixture testing. The ultimate goal is the elimination of low temperature cracking in both new and rehabilitated Hot Mix Asphalt (HMA) pavements. Low temperature cracking is the main cause of pavement roughness and reduced service life in Northern climates. The original PG binder specifications developed in the 1990's during the SHRP program considered only neat binders, and the current national trend toward using more and more modified binders necessitates re-evaluating the way we specify asphalt binders and mixtures.

Currently engineers are expecting better performance if a modified PG (PG = Performance Grade) binder is specified instead of unmodified PG binder. This extra protection for low temperature cracking costs Mn/DOT alone <u>$5.7 million annually</u> based on binder costs and paving done in 2005, but is it as simple as using the correct binder for Minnesota and the nation? Coming up with updated testing methods and discovering the important factors that impact low temperature cracking is being realized through our combined efforts.

Investigation of Low Temperature Cracking in Asphalt Pavements – Phase I

TPF-5(080) -- http://www.pooledfund.org/projectdetails.asp?id=311&status=4

Participation from 12 states has made this national project possible by contracting top researchers from the Universities of Minnesota, Illinois, Wisconsin, and Iowa State. The study was comprised of three major components:



1) Statistically designed comprehensive laboratory study that examined ten different asphalt binders of multiple crude sources and PG grades, two aggregate types, two levels of air voids, and two levels of asphalt binder contents.
2) Evaluation of 13 pavement sections, consisting of laboratory performance testing and development of correlations to field performance.
3) Advanced modeling of low temperature cracking based upon the field and laboratory components.

Based on the work performed in phase I, the following main accomplishments and findings can be stated:

- **The current specifications for low temperature cracking for both asphalt binders and mixtures are based on static creep tests and do not include a fracture test. It is strongly recommended that the selection of fracture resistant binders and mixtures be based on simple-to-perform true fracture tests.**
  - In this study two simple mixture tests were investigated and were successfully used to provide relevant fracture properties. The statistical analysis indicated that the fracture

toughness and energy obtained from these new tests correlate best with the field distresses measured in the selected pavement sections.
  - These tests can be used to select materials with better fracture resistance and provide input parameters needed in an improved thermal cracking analysis that would replace the empirical analysis part of the current Mechanistic Empirical Pavement Design Guide
  - The current binder direct tension test protocol also provided a fracture parameter, the failure strain, which is highly correlated to thermal cracking occurrence in the selected pavement section. This test can be further improved, as shown in this research, to obtain binder characteristics needed for more accurate ranking at low temperature.
  - The current indirect tensile test provides useful information for the complete evaluation of low temperature behavior of asphalt mixtures, but is not the best choice for a simple screening test.
  - The current thermal stress restrained specimen test can become a useful research tool to analyze the stress development and fracture mechanism in asphalt mixtures at low temperatures if further refined.
- **Asphalt binder properties represent a key factor in designing asphalt mixtures resistant to low temperature cracking. However, the current asphalt binder testing does not provide sufficient reliability to predict low temperature cracking of asphalt pavements**
  - The aggregate type has a significant effect on the fracture properties of similar types of mixtures made with the same asphalt binder.
  - The volumetric properties also influence the low temperature cracking of asphalt mixtures.
  - The PG system provides a good starting point in the selection of asphalt binders. However, this study showed the need for further refinement of the current AASHTO M320 specification which seems to be "blind" to improved fracture properties at low temperature due to polymer modification.
  - Physical hardening has a significant effect on measured binder properties and appears to be an important variable for bending beam rheometer and fracture testing.
- **Even at low temperatures asphalt mixtures are complex viscoelastic composite materials that are significantly temperature and loading rate dependent**
  - This study clearly demonstrated that the effect of temperature is significant as the behavior changes from brittle-ductile to brittle; therefore, when conducting low temperature tests on asphalt mixtures, testing temperatures should be established relative to the expected low pavement temperature and/or relative to the low temperature Superpave PG grade for the location of interest.
  - The mixture and binder test temperatures should be matched as much as possible to better understand the contribution of the binder to the fracture properties of mixtures. This contribution needs to be further investigated and modeled.
  - The effect of loading rate also needs to be further investigated to better match true field cooling rates.
- **The mixture coefficient of thermal contraction is a critical parameter for estimation of field performance for low temperature cracking.**
  - This study showed that the coefficients are affected by binder grades and by mixture variables.
  - The tests level of difficulty warrants the creation of the database of values for different types of binders and mixtures that can be used for future analyses.

The specific recommendations of this study are contained in a comprehensive report and represent a very good start in the quest for developing improved asphalt binder and asphalt mixture specifications as well as improving the low temperature cracking model that is included in the current Mechanistic-Empirical Pavement Design Guide. However, this research effort needs to be continued to address the following key issues:

- **Develop a specification for selecting asphalt mixtures with increased fracture resistance similar to the PG system for binders.**
  - Low temperature cracking performance cannot rely entirely on the PG of the binder. There is a critical need for an asphalt mixture specification.
  - Phase I of this work identified test protocols that can be used to obtain fracture parameters that control the fracture resistance of the mixtures.
  - These test methods need to be applied to a wider range of mix designs (SMA, warm mixtures, porous mixtures) and aggregate size, since in phase I only one type of mix was used.
  - These methods need to be used to test cored samples from top performing pavements to develop limiting criteria for fracture energy and fracture toughness in order to obtain limiting temperatures at which these materials will perform well.
- **Improve the current PG system for asphalt binders.**
  - Phase I of this work identified a number of issues not included in the current PG specification that can influence the performance of asphalt binders significantly
  - The analysis indicated that the failure strain at the minimum pavement temperature obtained with the direct tension test correlated best with field occurrence of thermal cracking. It becomes important to have a fracture parameter as part of criterion to obtain the critical low temperature and therefore, there is a critical need to develop a robust fracture test for asphalt binders. This process was started in phase I and needs to be further investigated as part of phase II.
  - Physical hardening needs to be further investigated to understand its role in predicting pavement performance.
- **Improve the modeling approach developed in Phase I.**
  - The work performed in phase I clearly indicated that the empirical model that is used to predict low temperature cracking in the mechanistic empirical pavement design can be successfully replaced with a robust mechanics based model that can significantly increase the accuracy of the prediction model.
  - This work needs to be continued in order to improve the models developed in phase I by providing additional experimental data and additional pavement performance data.
- **Apply test methods and analyses to asphalt pavements built with RAP.**
  - Most of the pavements built today contain various degrees of RAP. It becomes therefore important to investigate the fracture resistance of RAP mixtures using the set of tools developed for “clean” mixtures
  - The fracture properties will most likely represent the controlling factors that will dictate the amount of RAP and the type of binder to be used since the addition of RAP influences the most the fracture properties of the resulting mixture.
- **One key recommendation is that the construction of instrumented field test sections under well controlled conditions and the evaluation of additional existing field sections are needed to validate the findings of this study. Based on such a study, the development of revised binder and mixture design specifications could be achieved.**

Although this research approach is primarily used in this work to investigate low temperature cracking, it can be easily extended to a wide variety of issues that many states have in common including fatigue, reflective, and top down cracking, since it is based on fundamental test procedures and mechanics-based analyses that significantly reduce the empiricism of the previous test methods.

Investigation of Low Temperature Cracking in Asphalt Pavements – Phase II
TPF Solicitation (1044) -- http://www.pooledfund.org/projectdetails.asp?id=1044&status=1

Mn/DOT has recently proposed Phase-II of this study. The main objective planned is to validate the laboratory test procedures, models, and pavement design procedures that are being developed in Phase-I of this study, but the states participating in the next phase will ultimately determine the research direction. MnROAD will also be utilized with the development of field test sections per the participating states direction. Actual construction will not be funded through this pooled fund, only research ideas.