RESEARCH PROBLEM STATEMENT
"Investigation of Low Temperature Cracking in Asphalt Pavements"
Minnesota Department of Transportation
April 24, 2003

Overview

A pooled fund research project is proposed to improve our understanding of low temperature cracking in asphalt pavements. The ultimate goal is the elimination of low temperature cracking in both new and rehabilitated hot mix asphalt pavements. The following points provide the basis of the study.

- Utilize a national Technical Advisory Panel (TAP) to assist in the selection and development of testing methods that measure fundamental material properties related to low temperature cracking.
- Collect samples and mix designs from participating states and industry and run all recommended new testing methods.
- Correlate the test results with documented field performance.
- Develop and refine the most promising new testing methods for low temperature cracking.
- Calibrate and validate the thermal cracking model in the 2002 AASHTO design guide.
- Select mix designs for the reconstruction of MnROAD. Construction and field validation at MnROAD will be completed in the next phase of the study.

Problem Statement

Low temperature cracking is the most prevalent distress found in asphalt pavements built in cold weather climates. As the temperature drops the restrained pavement tries to shrink. The tensile stresses build up to a critical point when a crack is formed and partial stress relief occurs. The current Superpave specification attempts to address this issue by specifying a limiting low temperature for the asphalt binder. The specification does a reasonable job predicting performance of conventional asphalt cements, but this does not hold true for polymer-modified asphalt binders that are manufactured to reach very cold temperature grades needed in cold climates. Typically the base asphalt binder controls the low temperature properties. As an example a PG 58-34 is made with an xx-34 grade asphalt and polymer is added to achieve the high end (58). Currently the low temperature specification considers only the asphalt binder. Specifications must be developed for the complete asphalt mixture. Although low temperature cracking appears to be controlled by a single-event mechanism, it is very important to understand the mechanism of crack initiation and propagation. These cracks can be initiated by traffic loading, cycles of temperature changes, and then propagated by a large drop in temperature. In addition, the significant effects of aging and moisture on crack formation and propagation is also not fully understood and needs investigation.

MnROAD has provided us with valuable data about the damaging effect the environment has on our HMA pavements in cold regions. The initial mainline experiment (1994 to the present) was designed as a structural experiment, however the primary distress to date has been low temperature cracking with little load induced fatigue cracking. The low volume road at MnROAD also demonstrates our lack of knowledge on low temperature cracking. Three different cells were constructed in 1999 using the current Superpave asphalt binder grading system. Each cell was designed with a 4" Superpave HMA layer, 12" crushed stone base over a clay subgrade. The only variable was the asphalt grade used PG 58-28, PG 58-34, and PG 58-40. The PG 58-40 should be least susceptible to low temperature cracking. It was expected the –28 and –34 materials would crack before the –40 material. Preliminary data indicate that after four winters the –40 cell has experienced the most cracking, -34 no cracking, and the –28 only a minimal amount of cracking, not as predicted from the current Superpave grading system. This demonstrates the need to improve the current accepted standards used to select asphalt binders and mixtures used in cold weather climates. More information about MnROAD or the research that is being conducted can be obtained from the MnROAD web page: http://mnroad.dot.state.mn.us/research/Mnresearch.asp

Objectives

The development of a fracture-mechanics-based specification is one of the objectives of this study. It will allow for a better selection of asphalt binders and mixtures with respect to their resistance to crack formation and propagation. This fracture mechanics approach will also be used to investigate the detrimental role of aging and moisture to fracture resistance of asphalt materials.

The PG grading system currently uses the Bending Beam Rheometer (BBR) and the Direct Tension (DT) tests to determine the asphalt binders low temperature properties. For the asphalt mixtures, the Indirect Tension Test (IDT) is used to perform creep and strength tests. However, none of these tests directly produce fracture properties of the materials, which is essential when characterizing the initiation and propagation of these cracks. Information gained through testing can help us address other important issues such as the combined effect of temperature and traffic has on crack formation and propagation (relation between fatigue cracking and low-temperature cracking) and the healing potential of certain asphalt mixtures. Some of the most recent research efforts are based on the use of fracture mechanics concepts to characterize the fracture properties of asphalt materials. Some of these efforts indicate that the use of certain polymer additives in the asphalt binders improve dramatically the fracture properties of the pavement without significantly changing the PG grade.

Research Approach

A number of tests both traditional, such as strength and creep, as well as newer tests, such as the semicircular bend, hollow cylinder test, and notched beam test will be the primary candidates for the development of a specification procedure to determine fracture resistance properties for both the asphalt binder and the asphalt mixture. Samples, of both binders and mixtures, will be tested to determine the relationship of fracture resistance to various factors such as binder type (type of modifier), aggregate type including recycled materials, asphalt-aggregate interaction (surface free energy), aggregate gradation, air voids, and film thickness. Various aging and moisture conditions will be included in the experimental design. Material parameters obtained from the fracture mechanics analysis will be correlated to conventional mechanical and rheological properties. The top performing mix designs will be used to develop up to 25 test cells in the next phase of MnROAD.

Research Plan
The research plan will work toward developing updated tests to define the asphalt binders and mix designs needed to eliminate low temperature cracking. The steps are summarized below and will be further defined into tasks once the formal contract is approved.

Step 1 (Develop a Technical Advisory Panel)
A low temperature asphalt binder Technical Advisory Panel (TAP) will be developed to assist this pooled fund effort, see initial membership list. This TAP will consist of State, FHWA, academia, and industry representatives. An initial meeting will be held in the summer of 2003 to help define the testing program and another in the fall of 2004 to review the results of the work completed to date (see step 5).

Step 2 (Refine Research Needs)
This will include literature searches along with working with the participating states and TAP members on the materials needed and the types of tests required.

Step 3 (Material Sampling & Data Collection)
Participating States and industry will provide the samples needed for testing. Samples will include pavement cores of existing roads and new materials that have shown promise in the elimination of low temperature cracking. When field cores are provided, it is expected that States will include associated performance data (distress surveys) to provide the initial link between material testing and performance. MnROAD will also be used to develop and calibrate the link between field performance and lab testing. Promising new materials will be another source of data from both participating States and Industry partners. It is expected that a large number of these new "miracle" materials will be submitted. The research team and the TAP will sort out the candidates based on funding and the potential for success.

Step 4 (Lab Testing/Data Analysis)
It is anticipated that the core research team will complete the majority of the lab testing based on their individual expertise and available resources. The testing protocol for each new test will be refined as needed during the laboratory investigations of the samples collected. Comparisons will be made from lab testing results to the observed performance in the field for both the cores and new mix designs. This may include using the FHWA Superpave test trailer and other contractor's equipment and expertise. Participating state and industry partners will be informed of all the testing results in the final report.

Step 5 (Review of Lab Testing Methods & Results)
The TAP will meet to review the preliminary report developed by the University of Minnesota that shows the results of the testing and data collected in Steps 3&4 and gives recommendations on what test methods and which mix designs should be field validated.

Step 6 (Final Report)
A final report will summarize all the work and findings into one document. The report will include all the steps covered above including the testing and testing protocols used, samples collected, summary of results found, along with recommendations for the MnROAD reconstruction.

Quarterly updates will be written to keep the participants updated on the progress. An 18-month contract is expected to start September 1, 2003 and be completed by April 1, 2005.

Schedule	**2003**		**2004**				**2005**
	July	**Oct**	**Jan**	**Apr**	**July**	**Oct**	**Jan**
Step 1 (Develop a Research Team)	■						
Step 2 (Refine Research Needs)		■					
Step 3 (Materials Sampling & Data Collection)		■	■				
Step 4 (Lab Testing/Data Analysis)			■	■	■	■	
Step 5 (Review of Lab Testing Methods & Results)					■		
Step 6 (Final Report)							■

Research Team
The core research team is responsible for this investigation include:

Minnesota DOT	Lead state
Mihai Marasteanu	University of Minnesota
Hussain Bahia	University of Wisconsin
Bill Buttlar	University of Illinois
Chris Williams	Michigan Technological University

The low temperature cracking Technical Advisory Panel (TAP) consists of the core research team plus the following members. The TAP serves as an advisory role to the core research team. This team was developed from their past expertise in the field of low temperature cracking.

David Anderson	Penn State University
Mike Anderson	Asphalt Institute
Ray Brown	NCAT
Mike Heitzman	Iowa DOT
Gerry Huber	Heritage Research Group
David E. Newcomb	NAPA
Gerald Reinke	MTE Services, Inc
Carl Monosmith	U of California, Berkeley
Ray Robertson	Western Research Institute
Ray Roque	University of Florida
John D'Angelo	FHWA (Turner Fairbanks)
Jack Youtcheff	FHWA (Turner Fairbanks)
Keith Herbold	FHWA (Mid-Western Resource Center)
Kai Tam	Ontario Ministry of Transportation

Participating Agencies will review and comment on all TAP recommendations made before they are implemented into the project this problem statement is describing.

Anticipated Costs
The anticipated cost of this proposal is expected to be $750,000. The majority of the costs will be spent on lab testing, analysis and coordination, which will provide the basis for the products that will be developed. Please note that the TAP and core research team will establish the number and type of samples needed along with the testing needs for this study. It is anticipated that each state will contribute $50,000 for this project. The funds can be transferred per the agencies discretion into three possible fiscal years 2004, 2005, and 2006.

Cost Breakdown	Cost
Step 1 (Develop a Research Team)	10,000
Step 2 (Refine Research Needs)	10,000
Step 3 (Materials Sampling & Data Collection)	40,000
Step 4 (Lab Testing/Data Analysis)	600,000
Step 5 (Review of Lab Testing Methods & Results)	30,000
Step 6 (Final Report)	60,000
Total Costs =	$ 750,000

Products
The direct products of this proposal include:

<u>Development of a testing protocol to better determine asphalt *binder* resistance to low temperature cracking</u>
The current PG binder grading system does not reasonably characterize polymer modified asphalt binders fracture properties. The previous studies have shown that two asphalt binders with the same PG grade have different fracture toughness, which is a true measurement of material resistance to crack propagation. A new testing method based on true material fracture resistance properties at low temperatures will be proposed from this research.

<u>Development of a testing protocol to better determine asphalt *mixture* resistance to low temperature cracking</u>
Currently, indirect tensile test is recommended by SHRP to characterize HMA mixtures for predicting thermal cracking. However, the recent NCHRP 9-19 study has shown that "In general, the correlation between the response parameters from the indirect tensile test and cracking was poor and site dependent", (NCHRP report 465). This research will propose a new testing protocol to characterize mixture for thermal cracking.

<u>Calibrated thermal cracking model in the 2002 design guide</u>
The performance prediction models in the 2002 design guide were calibrated using LTPP test sections. Unfortunately, many of the HMA fundamental properties required to support the performance prediction equations were not available in the LTPP and AASHTO database and had to be estimated from regression equations. Currently indirect tensile creep tests are needed at test temperatures of 0, -10, and –20^{o}C for calibrating and validating the thermal cracking model. However, these low temperature indirect tension tests were not preformed to validate and calibrate the thermal cracking model selected for the 2002 design guide. As a result, no further validation of the thermal cracking could be accomplished under NCHRP 1-37A. NCHRP 1-37 recommends that the local agencies should further validate the thermal cracking model. This project will conduct extensive laboratory testing to obtain all necessary

fundamental material properties required to further validate the thermal crack model in the 2002 design guide.

Establish the mix designs for the 2005 reconstruction of MnROAD

Approximately 25 test cells will be reconstructed at MnROAD in 2005. The results from this study will be used to develop the mix designs that require further field validation. Preference will be given to mixes that have shown the most resistance to low temperature cracking. The costs related to the next phase are not included in this pooled fund effort.

Anticipated Benefits

The combined effects of improved material selection mix design, and new low temperature crack prevention techniques will result in significant benefits. The reduction in these cracks will translate into improved overall ride, longer pavement life and substantially reduced maintenance costs. It is anticipated that practitioners will be able to develop improved asphalt mix designs that take full advantage of new technology and wiser use of materials. It is also anticipated that this study will lead to significant progress in the prevention of other types of cracking such as reflective, top-down, and fatigue cracking.