Quarterly Project Report

Center for Transportation Studies

Project Title: **Investigation of Low Temperature Cracking in Asphalt Pavements: National Pooled Fund Study Phase II**

Quarter: **April 01 - June 30, 2010**

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Funding Source(s):

State Pooled Funds

Task Update:

1 Update on low temperature cracking research

A brief literature review will be performed to document any new research in the area of low temperature cracking, including the work performed by the Asphalt Research Consortium research team. Details of the MnROAD test cells constructed in 2007 and 2008 in relation to low temperature cracking will be provided. In addition, test specifications from Canada & Europe that may be similar to the current DCT and SCB tests will be documented, as well as any modifications to the SCB and DCT tests that have been done since the end of Phase I.

Deliverables : Quarterly task reports
Task Budget : $16,785.00
Task Due Date : 12/17/2008 *(Calculated)*
Date Delivered : 1/8/2010 *(Reported by PI)*
Date Approved : 2/8/2010 *(CTS received task approval)*
Task Approved : Yes
Progress:

% Task Complete: 100

2 Expand Phase I test matrix with additional field samples

Nine new asphalt mixtures used in field studies will be tested and analyzed with respect to their low temperature cracking resistance. The research team is proposing the following seven mixtures plus two additional mixtures from Wisconsin and New York. The tests will consists of IDT creep and strength tests as well as SCB and DCT fracture tests. The experimental variables that are important in differentiating low temperature cracking mix performance are test temperature, long-term aging or mix conditioning, and mix air voids. The proposed experimental plan for establishing the proposed low temperature cracking criteria is shown in the table below.The initial validation plan detailed in the table above consists of performing 54 tests per mixture for a total of 486 tests. All nine mixtures will be DCT tested at UIUC laboratory, and SCB and IDT tested at UMN laboratory, respectively. For three of the nine mixtures, DCT tests will be also performed at UMN and SCB test will be also performed at UIUC; Iowa State will perform a limited number of tests (SCB and/or DCT), if equipment becomes available. All laboratories will provide a detailed QA plan to ensure the accuracy of the test results. The progress of this work will be presented periodically at the Expert Task Group meetings, and it is expected that, at the end of Task 2 or subtask II of Task 3, a round robin will be initiated through ETG mechanisms, at no cost to the current project, to obtain precision and bias information on the fracture test methods. The laboratory test results will be correlated to the low temperature cracking field performance of the MN/Road mixes. This plan will determine which device is best and the best temperature, mix conditioning, and air void level for establishing the low temperature specification criteria. The research team envisions that there will be two levels of specification consisting of simply a mix criteria and a more advanced one using models. The more advanced specification will consist of additional mix testing beyond that of the mix design criteria for use in the developed advanced models.

Task Update:

Subtask on Physical Hardening (See work plan for details)

Deliverables : Quarterly task reports

Task Budget : $116,785.00

Task Due Date : 5/17/2010 *(Calculated)*

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Progress:

All testing has been finished except for DCT testing of MnROAD cores. The cores will be shipped to Illinois at the beginning of July and testing will be completed by the end of July.

For the subtask on physical hardening, the research team focused on the development of a prediction model for physical hardening. The analysis showed that the rate of physical hardening is highly dependent on the source and type of base binder. Different types of polymer modification did not significantly change the rate of physical hardening. It was also shown that the rate of physical hardening does not increase indefinitely as temperature decreases, but rather it peaks at the intersection of the volume-temperature curve asymptotes above and below the glass transition, and approaches zero as the temperature increases or decrease toward the limits of the glass transition region.

It is expected that this task will be completed at the end of August, 3 months later than scheduled.

% Task Complete: 95

3 Develop low temperature specification for asphalt mixtures

The main objective of this work is the development of low temperature performance specification for asphalt mixtures. Currently, the simple performance test provides the parameters needed to predict the intermediate and high service temperature performance. There is a need for a similar test to fill the gap in the low temperature range. In order to accomplish this goal the following subtasks will be performed:
Subtask 1 ¿ develop test method (see work plan for details)
Subtask 2 ¿ develop specification (see work plan for details)
Subtask 3 ¿ propose simplified method to obtain mixture creep compliance (see work plan for details)
The primary outcome of task will be the development of a simple mixture design specification, based upon mixture fracture testing and Superpave low-temperature binder test data, to control thermal cracking. It is not anticipated that the specification will involve the use of a computer program as part of routine design. However, the improved TCMODEL program to be developed under Task 4 will be used to choose specification parameters and to set specification thresholds. An optional, more rigorous specification, which will require running the TCMODEL program, will be developed under Task 4.

Deliverables : Quarterly task reports

Task Budget : $123,286.00

Task Due Date : 11/17/2010 *(Calculated)*

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Progress:

Work has continued in all three subtasks. A number of modifications to the current SCB method were analyzed. More data was gathered and analyzed for specification development. Work has started to investigate if creep compliance can be obtained from other current test methods.

% Task Complete: 75

4 Develop Improved TCMODEL

TCMODEL is a computer program developed under SHRP and later revised and adopted for the M-E PDG that predicts transverse cracking versus time based upon hourly air temperatures, HMA creep compliance and tensile strength from the IDT (AASHTO T 332), HMA thermal coefficient, and other pavement layering information. Phase I of the study demonstrated the benefits of the mixture fracture energy measurement as compared to mixture tensile strength, particularly for polymer-modified mixtures.

Task Update:

TCMODEL will be enhanced in Phase II (¿NewTCMODEL¿) to better capture the true fracture properties of hot-mix asphalt. The resulting program will be used to guide the specification design team in the development of a simple specification for the control of thermal cracking based upon a mixture fracture test and standard Superpave binder test results. The program will also be delivered as part of an optional rigorous thermal cracking design specification, where the running of NewTCMODEL is part of the design specification. This system will bear similarity to the M-E PDG, although it will use mixture fracture tests instead of tensile strength and will have an improved fracture model (cohesive zone fracture model instead of the Paris law model). Climatic files for participating states (3 climatic zones per state) will be developed and included in the software for a range of asphalt layer thicknesses. The TCMODEL program will be made available as a freeware program, to be posted on University, FHWA, and State DOT websites. The program and an accompanying user¿s manual will be bundled with the final report.

In addition, UIUC researchers will work with other university team members to conduct a preliminary calibration and validation of the new model at the end of the second year of the study. Data from phase I project, along with new data generated from the Mn/ROAD project will be used to calibrate and validate the accuracy of the new model. Direct comparisons to the existing TCMODEL code will also be made.
Subtasks will be performed if additional funding becomes available (see work plan for details).

Deliverables : Quarterly task reports

Task Budget : $81,786.00

Task Due Date : 5/17/2011 *(Calculated)*

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Progress:

During the current quarter a major task of code integration, debugging and verification was undertaken for the new thermal cracking model. The viscoelastic material modeling code is now fully integrated with the cohesive zone based fracture model within the finite element framework. The analysis code has now been verified against the commercially available software ABAQUS. Further verification cases are currently underway. On the pre-processing side, the input file generator has been implemented and verified. This code takes the data from a user-friendly graphical user interface (GUI) and generates a series of files for the main analysis engine. Three main input files are generated by the pre-processor, which includes the geometric information (finite element mesh and boundary conditions), material property information and the temperature boundary conditions (temperature vs. depth vs. time, as generated by the Integrated Climatic Model).
The next and final step prior to deployment of the thermal cracking prediction software will be fine-tuning of the code to minimize the analysis run times and to make the GUI even more user-friendly and intuitive.

% Task Complete: 85

5 Modeling of Asphalt Mixtures Contraction and Expansion Due to Thermal Cycling

The main objectives of this task are:
1. Expand the data base for thermo-volumetric properties of asphalt binders and mixtures to a wider range of modified asphalts and types of mixtures to fully quantify the effects of binders and aggregates in the asymmetrical thermo-volumetric behavior (glass transitions and coefficients).
2. Develop a micromechanics numerical model that can be used to estimate the glass transition temperatures and coefficients from mixture variables commonly measured for binder grading and for mixture design.
3. Conduct thermal cracking sensitivity analysis to determine which of the glass transition parameters (6 parameters) are statistically important for cracking, which ones need to be measured, and what is the effect of used estimated values rather than measured values.

This task will be coordinated with the WRI Asphalt Research Consortium (ARC) project. The ARC is currently involved in modifying the TG instrument to make it more user friendly. The ARC project is also looking at the effect of aging and effect of cooling rates. Although different mixtures are used, the concepts remain the same and the effect of aging and cooling/heating rates will be used to define what the critical factors for thermal cracking are and which material properties need to be used in modeling and in specification.

Deliverables : Quarterly task reports

Task Budget : $48,804.00

Task Due Date : 5/17/2011 *(Calculated)*

Task Update:

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Progress:

the research team continued efforts for Task 5 on modeling and testing the thermo-volumetric behavior of asphalt mixtures. Emphasis is been paid on the effect of thermal cycles on the glass transition temperatures and coefficients of thermal expansion/contraction of asphalt mixtures. The effect of the spatial distribution of aggregates on the thermal-volumetric behavior of mixtures after thermal cycles is currently been studied by means of Finite Element modeling (FEM).

% Task Complete: 55

6 Validation of new specification

Based upon the outcomes of the testing of the preliminary validation experimental plan, the best test device and method of conditioning mixes for long-term aging will be selected for the final validation. The final validation will be based upon testing of the 11 Olmstead County, Minnesota mixes placed in the 2006 construction season. The testing will be at the low performance grade temperature as well as at 10¿C above the low temperature performance grade. The mixes will also be tested in triplicate at both 4 and 7 percent air voids. Based upon the outlined test parameters and the two air void contents for the 11 mixes, a total of 132 samples will be tested in the final validation component of this study.

The other test sections that will be used as part of the validation process in year 3 of the project are listed below. The IDT will be performed only in this task and IDT creep compliance data will be used to develop and validate new method to predict mixture creep compliance from Bending Beam Rheometer (BBR) binder creep compliance, as described in task 3.

Deliverables : Quarterly task reports

Task Budget : $63,804.00

Task Due Date : 5/17/2011 *(Calculated)*

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Progress:

Testing of the validation sections will start at the beginning of next quarter.

% Task Complete: 5

7 Development of draft AASHTO standards and Final Report

A final report containing the updated reports from task 1 to 5 will be delivered at the end of this task. The report will also contain the following:
-Access database containing all the experimental results as well as additional information on the field samples and laboratory prepared specimens
-Proposed test protocols (experimental set up and data analysis) for selecting asphalt binders and mixtures with enhanced fracture resistance to low temperature thermal cracking
-Software and documentation describing a new fracture mechanics-based thermal cracking program (improved TCMODEL). Stand alone program and user manual will be provided.

Deliverables : Draft final report

Task Budget : $23,750.00

Task Due Date : 10/17/2011 *(Calculated)*

Date Delivered : *(Reported by PI)*

Date Approved : *(CTS received task approval)*

Task Approved : No

Project Title: **Investigation of Low Temperature Cracking in Asphalt Pavements: National Pooled Fund Study Phase II**

Quarter: **April 01 - June 30, 2010**

Task Update:

Progress:

Nothing to report.

% Task Complete: 0

Future Plans:

Problems Encountered/Actions Taken: