

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, 2011

CTS Project # : 2008077

Contract # : 89261

Work Order # : 103

Project Authorization Date : 6/17/2008

Project Expiration Date: 1/31/2012

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Funding Source(s):

State Pooled Funds

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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 consist 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.

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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 : 12/1/2010 (*Reported by PI*)

Date Approved : 12/8/2010 (*CTS received task approval*)

Task Approved : Yes

Progress:

% Task Complete: 100

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 $\hat{}$ develop test method (see work plan for details)

Subtask 2 $\hat{}$ develop specification (see work plan for details)

Subtask 3 $\hat{}$ 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:

The work in this task is almost completed and it will be delivered by the end of August 2011. Both UIUC and UMN team have developed methods to obtain creep from DCT or SCB test samples. A specification for fracture and for stiffness is in the process of being finalized. The rests of the subtasks are completed and are being incorporated into the task report.

% Task Complete: 95

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.

TCMODEL will be enhanced in Phase II ($\hat{}$ NewTCMODEL $\hat{}$) 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

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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, progress was made in coordinating the final compilation of the combined TCMODEL code, which includes a user-friendly interface, a climatic file database, a viscoelastic bulk response model, a cohesive-zone based fracture model, and a crack distribution model. Climatic files for 3 locations (denoted as ϵ_{Cold} , $\epsilon_{Average}$, and ϵ_{Warm}) within each participating state in the pooled fund study for a range of pavement structures are now being generated, with a scheduled completion in late July 2011. TCMODEL will be completed in the next quarter, and model calibration and validation are also slated for completion in the next quarter.

% Task Complete: 98

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*)

Date Delivered : (*Reported by PI*)

Date Approved : (*CTS received task approval*)

Task Approved : No

Progress:

The effect of thermal cycling on the stress buildup and thermo-volumetric properties of MnROAD mixtures was investigated experimentally by means of the Asphalt Thermal Cracking Analyzer (ATCA). Furthermore, analytical modeling was conducted to determine the effect of physical hardening, relaxation, and glass transition behavior on the thermal stress buildup of asphalt mixtures.

The following efforts were completed this quarter:

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- Development of database of mixture volumetric properties in cooling/heating.
- Development of thermal stress buildup model accounting for non-linear coefficient of thermal expansion (CTE) and glass transition temperature (T_g) in heating and cooling.
- Development of model to predict T_g and CTE based on mixture and binder common properties.
- Sensitivity analysis of developed model to determine which of the CTEs and T_g (i.e., in heating or cooling) are significantly in thermal cracking prediction.
- Validation of thermal stress and physical hardening model with WRI samples (i.e., validation mixture samples from task 6).

The analytical model for the calculation of thermal stress buildup in mixtures was derived using relaxation modulus master curves, the WLF equation for time-temperature superposition of thermo-rheological simple material, Boltzmann's superposition principle, and a model describing the isothermal contraction of asphalt as a continuous function of conditioning time and temperature. The key idea behind this model is that the input thermal strain can be divided into small step increments for which the relaxation response can be easily computed and added in time to obtain the total thermal stress.

% Task Complete: 95

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:

The UIUC research team received additional lab and field cores for testing in the past quarter, totaling approximately 90 specimens for testing in the disk-shaped compact tension test. A summary is provided in Table 2. All tests will be completed by the end of August, 2011, and summarized in the next quarterly report. A slight delay in testing was caused by a malfunction in the load cell of the Instron test machine at the Advanced Transportation Research and Engineering Laboratory. However, the repaired load cell has been received and calibrated and testing resumed in early July. In addition, UIUC researchers are working with Mr. Richard Stegar, Chair of the ASTM D04.26 subcommittee, which oversees asphalt mechanical tests, to conduct ruggedness and round-robin testing to establish precision and bias statistics for the D7313-07 specification for the DC(T) test. A report on the progress of these tasks will be provided at the next LTC meeting.

% Task Complete: 80

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.

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Task Update:

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

Progress:

Initial work in the development of the draft AASHTO has started based on input from the other tasks.

% Task Complete: 10

Future Plans:

The research team will do its best to finish the project on time. Task 3, 4, and 5, will be finalized and delivered by August 30th.

Problems Encountered/Actions Taken:

Students:

Name

E-Mail

Degree Program

Degrees

Graduation Date