

QUARTERLY REPORT 4/1/2006 - 6/30/2006
CENTER FOR TRANSPORTATION STUDIES

Project Title: Investigation of Low Temperature Cracking in Asphalt Pavements - National Pooled Fund Study 776

CTS Project # 2005008 **Contract #** 81655 **Work Order #** 128 **Authorization Date:** 8/9/2004

Funding Source:

Mn/DOT

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Technical Liaison: Ben Worel

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Task Update

1 Literature review

A comprehensive literature review of previous and current research efforts in the area of low temperature performance of asphalt pavements will be conducted at the beginning of the project. The review will include research performed in asphalt materials characterization, experimental results analysis and modeling, pavement system analysis and modeling and pavement performance related to low temperature behavior of asphalt pavements.

Deliverables: Literature Review-summary report

Task Budget \$15,000.00

Task Due Date (calculated): 12/9/2004

Date Delivered (reported by PI):

Task Approved: Yes Date Approved (CTS received task approval) : 4/14/2006

Progress: Task submitted and approved.

2 Identify pavement sites and laboratory materials

The University will investigate two sets of materials in this study. The first set consists of materials that have been used in already built pavements for which performance information is well documented and readily available. The second set consists of laboratory prepared specimens following a statistically designed test matrix.

Deliverables: Description of field sites, field specimens and laboratory materials used in the analysis-summary report

Task Budget \$20,000.00

Task Due Date (calculated): 12/9/2004

Date Delivered (reported by PI):

Task Approved: Yes Date Approved (CTS received task approval) : 4/14/2006

Progress: Task submitted and approved.

3 Laboratory specimen preparation & experimental testing; Part I

The University will complete laboratory preparation and transport of the asphalt mixture gyratory specimens used for fracture testing and IDT creep and strength testing.

Deliverables: Letter Report

Task Budget \$40,000.00

Task Due Date (calculated): 2/9/2005

Date Delivered (reported by PI):

Task Approved: Yes Date Approved (CTS received task approval) : 6/28/2006

Progress: Task submitted.

4 Laboratory specimen preparation & experimental testing; Part II

The University will complete laboratory preparation and transport of the asphalt mixture slab compacted specimens used for fracture testing , for dilatometric measurements and for TSRST testing.

Deliverables: Letter Report

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Task Budget \$30,000.00
Task Due Date (calculated): 4/9/2005
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :

Progress: Completed: 20%
Expected completion of task: end of July.

Iowa State took delivery of a slab compactor. The compactor has been installed and the personnel have been trained by the manufacturer. The research team compacted numerous slabs in order to develop correction factors for the slabs to be compacted as part of the research program. Iowa State began compacted slabs that will be used in subsequent testing by the University of Wisconsin and the University of Minnesota.

Iowa State delivered batch materials for making slabs to the University of Illinois as they would like to mix and compact slabs for their research testing.

Work for Next Quarter
Iowa State will complete compacting and the delivery of the slabs in the upcoming quarter and continue to work on the database.

5 Laboratory specimen preparation & experimental testing; Part III

The University will extract and recover asphalt binders from the field asphalt mixture samples.

Deliverables: Letter Report

Task Budget \$10,000.00
Task Due Date (calculated): 6/9/2005
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :

Progress: Work completed: 10%
Expected completion date: mid August.

Iowa State has received samples from the top layers of the field cores and is in the process of extracting the binders.

6 Laboratory specimen preparation & experimental testing; Part IV

The University will complete laboratory aging of asphalt binders used in preparing the laboratory asphalt mixtures specimens.

Deliverables: Letter Report

Task Budget \$5,000.00
Task Due Date (calculated): 8/9/2005
Date Delivered (reported by PI):
Task Approved: Yes Date Approved (CTS received task approval) : 7/14/2006

Progress: Task submitted.

7 Laboratory specimen preparation & experimental testing; Part V

The University will perform Fracture and IDT testing of the asphalt mixture field samples

Deliverables: Letter Report

Task Budget \$100,000.00
Task Due Date (calculated): 10/9/2005
Date Delivered (reported by PI):
Task Approved: Yes Date Approved (CTS received task approval) : 7/14/2006

Progress: Task submitted.

8 Laboratory specimen preparation & experimental testing; Part VI

The University will perform Fracture and IDT testing of the asphalt mixture field samples

Deliverables: Letter Report

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Task Budget \$50,000.00
Task Due Date (calculated): 12/9/2005
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Completed: 50%
Expected completion date: end of August.

9 Laboratory specimen preparation & experimental testing; Part VII

The University will perform TSRST testing of the slab compactor specimens and of the field beams samples.

Deliverables: Letter Report

Task Budget \$25,000.00
Task Due Date (calculated): 2/9/2006
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Completed: 10%
Expected completion date: end of next quarter.

Beams were cut from the top layer of the field beam samples and were packaged for transportation to Turner Fairbanks.

On July 24 graduate students from Minnesota will pick up the slab compacted specimens from Iowa State and will drive to Turner Fairbanks Highway Research Center to perform the TSRST tests.

10 Laboratory specimen preparation & experimental testing; Part VIII

The University will perform Dilatometric testing of the asphalt mixture slab compactor specimens and field beams samples.

Deliverables: Letter Report

Task Budget \$40,000.00
Task Due Date (calculated): 4/9/2006
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Completed: 30%
Expected completion date: mid August.

Main activities on mixture T_g determination (University of Wisconsin) was the development of software and calibration of the equipment. Both LDVT and temperature for the new equipment were calibrated for asphalt mixture. As part of the calibration a dummy asphalt beam was calibrated to determine temperature gradient within the asphalt mixture.

Initial measurements were collected for a trial specimen to shake down the system. Some work needs to be done on the Teflon (non-stick) strip and on the type of glue to keep the LVDT pads at extreme low temperature. It is expected that mixture T_g will be reported within the month of July.

11 Laboratory specimen preparation & experimental testing; Part IX

The University will perform Dilatometric testing of the asphalt binder specimens and of the extracted asphalt binders from the field samples.

Deliverables: Letter Report

Task Budget \$20,000.00
Task Due Date (calculated): 6/9/2006
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Completed: 80%
Expected completion date: end of August.

The University of Wisconsin has performed most of the tests. Work is in progress to finalize testing the remaining binders that will be extracted by Iowa State.

12 Laboratory specimen preparation & experimental testing; Part XI

The University will perform Rheological testing of the asphalt binder specimens and of the extracted asphalt binders from the field samples.

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Deliverables: Letter Report

Task Budget \$30,000.00

Task Due Date (calculated): 8/9/2006

Date Delivered (reported by PI):

Task Approved: No Date Approved (CTS received task approval) :

Progress: Completed: 50%
Expected completion date: end of September.

University of Minnesota has performed 100% of the BBR, 30% of the DTT and 20% of the DENT tests on the original binders. Once the extracted binders are delivered from Iowa State work will start on these binders as well.

13 Analysis of experimental results

All experimental results from testing field samples and laboratory specimens will be incorporated into an Access database that will be delivered at the end of the project as part of the final report. The database will also include any relevant information about the material tested, such as construction information, pavement system information (layer thickness, granular materials and soil information, etc), and environmental information for the field samples, as well as volumetric, sample preparation and aging and any other relevant information for the laboratory prepared specimens. University of Minnesota and MTU will be primarily responsible for developing the database. The analysis of the test results will involve all four universities. The analysis will focus on finding the most promising experimental parameters for selecting the most crack resistant materials and for correctly analyzing the crack propagation mechanism in the pavement system and predicting performance. The comprehensive test matrix detailed in Table 2 will allow investigating the effect of the test method on material parameters, such as the fracture toughness obtained in the SENB and SCB configurations. It will also allow developing useful correlations between the different material parameters obtained from the different test methods include in the test matrix. For example correlations between the rheological and the fracture properties of asphalt materials will be investigated. Particular emphasis will be placed on the role of temperature on the mechanical properties of asphalt materials. An important priority will be given to investigating the contribution of each of the asphalt mixture components and their interactions to the fracture resistance of the mixture, with emphasis on the role played by the asphalt binder and the binder-aggregate interaction. A series of statistical analyses will be done consistent with the developed experimental plan. The analyses will include means tests, such as Student-Newman Keuls and Duncan's Multiple Range Test, to examine the effects of the independent experimental variables on thermal cracking for the various performance tests. The analyses will also provide a relative ranking of importance of the independent variables on thermal cracking potential. Additional statistical methods such as Ridge Regression will also be considered as appropriate. It is expected that this task will result in testing protocols that will improve the current selection process of asphalt binders and mixtures with enhanced low temperature cracking resistance. They will also provide better temperature dependent material parameters that will be incorporated in the analysis tools developed in task 5 to reasonably predict the field performance of asphalt pavements exposed to low temperatures.

Deliverables: Analysis of test results-summary report

Task Budget \$113,700.00

Task Due Date (calculated): 10/9/2006

Date Delivered (reported by PI):

Task Approved: No Date Approved (CTS received task approval) :

Progress: Completed: 50%
Expected completion date: mid October.

The four universities have performed the analyses of the data generated so far. Work is in progress to compare the results generated using different test methods and to select the method that provides the most significant information related to the fracture resistance properties of mixtures and binders.

14 Development of Baseline Thermal Cracking Models

In developing a rigorous understanding of thermal cracking mechanisms, an integrated study involving bench-scale laboratory fracture testing and full-scale experiments and field sections is essential. Fracture modeling is a critical element to this approach, as it provides two critical "links," namely: 1) the ability to properly interpret bench-scale laboratory test results (to obtain fundamental material properties/minimize size effects), and; 2) the ability to accurately extend fracture models to full scale, in order to develop an accurate and complete description of thermal cracking mechanisms. A key component of this study will involve the reexamination of the mechanisms of thermal cracking by applying modern computational fracture mechanics models. As a short summary, discrete fracture and damage tools will be utilized to model crack initiation and propagation in pavement systems using the finite element method code I-FRANC2D (Illinois Fracture Analysis Code in Two Dimensions). The research team will also utilize cohesive fracture models and damage models in specially designed subroutines developed for the commercially available finite element code ABAQUS. These models can predict crack nucleation, initiation, and propagation in 2D or 3D, and have been applied recently to examine mixed-mode crack propagation (tension and shear), which would obviously be present if traffic loads were to combine with thermal loads to create a critical condition. This work will also include refining a simple model recently developed at the University of Minnesota to predict the crack spacing and the lateral movement of the crack using 2D (or 3D if necessary) viscoelastic analysis based on the cohesive-frictional characteristics of the subgrade, the constitutive properties of the asphalt mixture and the thermal history of pavement system. Once the mechanisms of thermal cracking are better understood, the researchers will be in a much better position to determine the best approach for recalibration and/or modifying the existing TCMODEL program in the 2002 Design Guide and to recommend appropriate testing protocols to support this approach. One area where considerable emphasis will be placed is in the evaluation of the current crack propagation model in

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TCMODEL. While thermal fatigue cracking might be a contributor to pavement deterioration in some areas, the control of single event thermal cracking must remain a top priority due to its devastating effect on pavements in cold climates. Furthermore, the control of single-event thermal cracking in many cases should provide an inherent factor of safety against thermal fatigue cracking. It is anticipated that the new analysis tools proposed herein will allow researchers to: Apply a true fracture propagation model in the study of thermal cracking mechanisms, Improve response modeling to include 3-D effects (current model is 1D), Utilize data from low-temperature fracture tests, Allow consideration of multiple AC layers, and material property gradients within layers (both temperature and aging related should be considered), Combine thermal and mechanical loads (thermo-mechanical analysis), integrate testing and modeling program

Deliverables: Letter Report
Task Budget \$70,000.00
Task Due Date (calculated): 10/9/2006
Date Delivered (reported by PI):
Task Approved: Yes Date Approved (CTS received task approval) : 7/14/2006
Progress: Task submitted.

15 Application of the Models to the Experimental and Field Data

Once the mechanisms of thermal cracking are better understood, the researchers will be in a much better position to determine the best approach for recalibration and/or modifying the existing TCMODEL program in the 2002 Design Guide and to recommend appropriate testing protocols to support this approach. One area where considerable emphasis will be placed is in the evaluation of the current crack propagation model in TCMODEL. While thermal fatigue cracking might be a contributor to pavement deterioration in some areas, the control of single event thermal cracking must remain a top priority due to its devastating effect on pavements in cold climates. Furthermore, the control of single-event thermal cracking in many cases should provide an inherent factor of safety against thermal fatigue cracking.

It is anticipated that the new analysis tools proposed herein will allow researchers to: Apply a true fracture propagation model in the study of thermal cracking mechanisms, Improve response modeling to include 3-D effects (current model is 1D), Utilize data from low-temperature fracture tests, Allow consideration of multiple AC layers, and material property gradients within layers (both temperature and aging related should be considered), Combine thermal and mechanical loads (thermo-mechanical analysis), integrate testing and modeling program.

Deliverables: Letter Report
Task Budget \$43,000.00
Task Due Date (calculated): 10/9/2006
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Completed: 80%
Expected completion date: mid October.

Work is in progress at University of Illinois. Once the experimental data is finalized the models will be adjusted with the new parameters and the final analysis will be completed.

16 Draft Final Report

The University will deliver a draft final report detailing the work performed in the previous five tasks at the end of this task. The University will prepare the draft final report following the Mn/DOT publication guidelines documenting the project activities, findings, and recommendations. The University will submit the draft final report through the publication process for technical and editorial review. The report will also contain the following: a) Access database containing all the experimental results as well as additional information on the field samples and laboratory prepared specimens, b) 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).

Deliverables: Draft final Report
Task Budget \$20,000.00
Task Due Date (calculated): 2/9/2007
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: A draft final report will be delivered by the end of 2006.

17 Final Report Completion

The University will incorporate the technical and editorial comments from the review process into the final report as appropriate. The University will consult the reviewers for clarification or discussion of comments. The University will prepare and submit the revised, final, report for publication.

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Deliverables: Final Report
Task Budget \$33,300.00
Task Due Date (calculated): 4/9/2007
Date Delivered (reported by PI):
Task Approved: No Date Approved (CTS received task approval) :
Progress: Nothing to report.

Future Plans:

Problems Encountered/Actions Taken: