

# Quarterly Project Report

Center for Transportation Studies

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

**Quarter:** July 01 - September 30 2006

**CTS Project # :** 2005008

**Contract # :** 81655

**Work Order # :** 128

**Project Authorization Date :** 8/9/2004

**Project Expiration Date:** 4/30/2007

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**Funding Source(s):**

Mn/DOT

**Administrative Liaison:** Jim Klessig

**Technical Liaison:** Ben Worel

**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 :** 12/9/2004 (Calculated)

**Date Delivered :** (Reported by PI)

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

**Task Approved :** Yes

**Progress:** Completed

**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 :** 12/9/2004 (Calculated)

**Date Delivered :** (Reported by PI)

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

**Task Approved :** Yes

**Progress:** Completed

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**Task Update:**

**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* : 2/9/2005 (*Calculated*)

*Date Delivered* : (*Reported by PI*)

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

*Task Approved* : Yes

*Progress*: Completed

**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

*Task Budget* : \$30,000.00

*Task Due Date* : 4/9/2005 (*Calculated*)

*Date Delivered* : (*Reported by PI*)

*Date Approved* : (*CTS received task approval*)

*Task Approved* : No

*Progress*: Work was finalized at the end of this quarter.  
A task report describing the preparation of the mixture slabs will be delivered by the end of October.

**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* : 6/9/2005 (*Calculated*)

*Date Delivered* : (*Reported by PI*)

*Date Approved* : (*CTS received task approval*)

*Task Approved* : No

*Progress*: Iowa State won't be able to perform the extraction. MnDOT chemical laboratory has been contacted and they will perform the extraction of the binder from the field samples.  
It is expected that this task will be finalized by the middle of November.

**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

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**Task Update:**

Task Due Date : 8/9/2005 (Calculated)  
Date Delivered : (Reported by PI)  
Date Approved : 7/14/2006 (CTS received task approval)  
Task Approved : Yes  
Progress: Completed

**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 : 10/9/2005 (Calculated)  
Date Delivered : (Reported by PI)  
Date Approved : 7/14/2006 (CTS received task approval)  
Task Approved : Yes  
Progress: Completed

**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  
Task Budget : \$50,000.00  
Task Due Date : 12/9/2005 (Calculated)  
Date Delivered : (Reported by PI)  
Date Approved : (CTS received task approval)  
Task Approved : No

Progress: The testing has been finalized and a task report will be completed and delivered by the end of October.

**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 : 2/9/2006 (Calculated)  
Date Delivered : (Reported by PI)  
Date Approved : (CTS received task approval)  
Task Approved : No

Progress: University of Minnesota has sent Raul Velasquez to Turner Fairbanks facility to perform TSRST test during the month of August. At the end of the month only a limited number of tests have been completed. FHWA kindly agreed to loan the TSRST equipment to the U of M research group to finalize all testing. It is expected that testing will be finished by the end of November.

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**Task Update:**

**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 :* 4/9/2006 (*Calculated*)

*Date Delivered :* (*Reported by PI*)

*Date Approved :* (*CTS received task approval*)

*Task Approved :* No

*Progress:* Testing has begun on asphalt mixture samples prepared at Iowa State University. A total of 27 combinations of mixtures were delivered (each with one replicate sample), from which two samples were prepared for testing in the Tg apparatus.

Due to high noise in measurements that was attributed to icing at the ends of specimens and possible temperature fluctuations, steel end connection rods were changed to a polymeric, thermally non-conductive material. In addition, a dummy sample of an asphalt mixture was placed in chamber with a thermocouple inside the mixture to directly measure temperature inside the sample.

Two operators are working two shifts to complete testing in a timely manner. Each sample requires about six hours of testing and with two replicates, it will take approximately 12 hours to complete. For each replicate the testing includes 30 minutes conditioning, 120 minutes cooling, 30 minutes waiting at minimum temperature and 120 minutes heating. Cooling and heating rate is 1.0 C/ minute. Completion of all test results is expected by mid October with a target date of end of October for analysis of results and a brief report.

**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 :* 6/9/2006 (*Calculated*)

*Date Delivered :* (*Reported by PI*)

*Date Approved :* (*CTS received task approval*)

*Task Approved :* No

*Progress:* Not started. It is expected that all binders will be extracted by the end of October and Tg measurements will be finalized by the end of November.

**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.

*Deliverables :* Letter Report

*Task Budget :* \$30,000.00

*Task Due Date :* 8/9/2006 (*Calculated*)

*Date Delivered :* (*Reported by PI*)

*Date Approved :* (*CTS received task approval*)

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## **Task Update:**

*Task Approved :* No

*Progress:* All BBR, DTT and DENT testing of the laboratory prepared samples were finalized. Work is in progress to finish the DSR testing of the RTFOT binders to generate master curves.

Once the extracted binders become available, the same tests will be performed. IT is expected that this task will be completed by the end of November.

### **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 :* 10/9/2006 (Calculated)

*Date Delivered :* (Reported by PI)

*Date Approved :* (CTS received task approval)

*Task Approved :* No

*Progress:* The analysis of the data is in progress. As more data is generated the analysis is progressing to incorporate the new results. It is expected that the data analysis will be completed by mid December.

### **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

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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 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), ntegrate testing and modeling program

*Deliverables :* Letter Report

*Task Budget :* \$70,000.00

*Task Due Date :* 10/9/2006 (Calculated)

*Date Delivered :* (Reported by PI)

*Date Approved :* 7/14/2006 (CTS received task approval)

*Task Approved :* Yes

*Progress:* Completed.

## **15 Application of the Models to the Experimental and Field Data**

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*Deliverables :* Letter Report

*Task Budget :* \$43,000.00

*Task Due Date :* 10/9/2006 (Calculated)

*Date Delivered :* (Reported by PI)

*Date Approved :* (CTS received task approval)

*Task Approved :* No

*Progress:* The UIUC team continues to develop finite element meshes and input properties for the field sections under investigation in this study. Verification runs have been performed to check the newly developed models against existing benchmarks. UIUC researchers have been in contact with the other university research teams to collect the required laboratory testing data on field specimens to complete the modeling runs. In addition, the requisite inputs for running the mechanistic-empirical design guide thermal cracking model are being collected and organized. All modeling runs will be completed in the next quarter.

## **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

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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* : 2/9/2007 (*Calculated*)

*Date Delivered* : (*Reported by PI*)

*Date Approved* : (*CTS received task approval*)

*Task Approved* : No

*Progress*: A draft final report will be completed by the due date. Many components of the report are already completed and some are half way waiting for the completion of the experimental work and analyses.

**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.

*Deliverables* : Final Report

*Task Budget* : \$33,300.00

*Task Due Date* : 4/9/2007 (*Calculated*)

*Date Delivered* : (*Reported by PI*)

*Date Approved* : (*CTS received task approval*)

*Task Approved* : No

*Progress*: NA

**Future Plans:**

**Problems Encountered/Actions Taken:**

Iowa State will subtract the amount of funding required for performing the extraction of the field binders from their award. The money will go to MnDOT chemical laboratory to cover the extraction work.