State Planning and Research Program
Quarterly Report

PROJECT TITLE:
TPF-5 (132) Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II (MnROAD Study)

OBJECTIVES: The main objective of this study is to validate the laboratory test procedures, models, and pavement design procedures that come out of Phase I of this study. This will be accomplished by monitoring two new test sections at the Minnesota Road Research Facility (MnROAD). Phase I was aimed at developing a fracture mechanics-based specification 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 effects of aging and moisture on the fracture resistance of asphalt materials.

PERIOD COVERED:
January 1, 2008 – March 31, 2009

PARTICIPATING AGENCIES:
CT, IA, MN, ND, NY, WI, LRRB

PROJECT MANAGER:	**SP&R PROJECT NO**:	PROJECT IS:
Benjamin Worel **LEAD AGENCY**: Mn/DOT **PRINCIPAL INVESTIGATOR**: TBD by TAP	TPF-5 (132)	____ Planning __X__ Research & Development

ANNUAL BUDGET:	**PROJECT EXPENDITURES TO DATE**:
$525,000 Total Funding = $475K Contract + 26K Admin (meetings) + 24K Admin (Agency Discretion)	• First State Meeting held March 11, 2008 (Travel expenses from CT, ND, NY, WI were processed) • No other expenses

WORK COMPLETED:
1 - December 2007 - Project was just work plan developed and approved
2 - March 11, 2008 Agency Kickoff meeting held in Minnesota
3 – June 17, 2008 - Contract finalized between University of Minnesota and Mn/DOT – work starts. University of Minnesota has subcontract with Iowa State and working on the other two universities.
4 – MnROAD Test cells are completed on the mainline for this study.
5 – See the University Report following this cover sheet for individual task completions. To date no tasks have been fully completed and approved.
6 - State meeting (20 minutes) in Minneapolis March 19th at AAPT (Handout attached).

SUMMARY OF ACTIVITIES EXPECTED TO BE PERFORMED NEXT QUARTER:
1. Contractors continue to work this quarter and get started on their tasks.
2. More work will be completed this quarter when students become more avalible.
3. NY and

STATUS AND COMPLETION DATES:
1. Contract is posted on the pooled fund web site. The contractor will follow the schedule posted.

Handout at the AAPT Meeting (March 2009)

Location	Construction Date	Description	Mix	Binder
MnROAD 33	September 2007	58-34 Acid only no RAP	X	Sent
MnROAD 34		58-34 SBS + Acid no RAP	X	To
MnROAD 35		58-34 SBS only no RAP	X	Mihai
MnROAD 77		58-34 Elvaloy + Acid no RAP	X	Ben
MnROAD 20	August 2008	58-28, 30% non-fractionated RAP, level 4 SP, wear & non-wear	X	X
MnROAD 21		58-28, 30% fractionated RAP, level 4 SP, wear & non-wear	X	X
MnROAD 22		58-34, 30% fractionated RAP, level 4 SP, wear & non-wear	X	X
Wisconsin 9.5 mm SMA	2008	Wisconsin will provide materials	X	X
New York "Typical Mix"	2008	New York with PG 64-22 binder and an aggregate other than limestone and granite.		

Loose Mixture Inventory

A. Minnesota Received Sept- 08

	Labeled	buckets	kilogram
cell 33	cell 33 layer…	6+3*	180
cell 34	cell 34 layer…	6+3*	180
cell 35	cell 35 layer…	6+3*	180
cell 77	cell 77 layer…	6+3*	180
cell20	cell 20 SPWEB 440B	6+3*	180
cell21	cell 21 SPWEB 440B	6+3*	180
cell22	cell 22 SPWEB 440C	6+3*	180

3* buckets are for Urbana, but will be compacted at U of M

B. Wiscosin loose mix received 12/1/2008

Mix design number	% of Binder	% of Rap	Bags
506607	5.3	6	12
506607	5.3	9	3
506607	5.2	7	3
506607	5.1	7	1
506607	5.0	7	1
		Total	**20**

C. NY loose mix

none

A. Minnesota binder

PG 58-28 1 bucket 10/15/2008
PG 58-34 1 bucket 10/15/2008

B Wisonsin binder

unlabeled 4 quarts 12/1/2008

Quarterly Project Report

Center for Transportation Studies

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

Quarter: **January 01 - March 31, 2009**

CTS Project # : 2008077
Contract # : 89261
Work Order # : 103
Project Authorization Date : 6/17/2008
Project Expiration Date: 1/31/2012

Principal Investigator
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AL: Bruce Holdhusen
TL: Ben Worel

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 : *(Reported by PI)*
Date Approved : *(CTS received task approval)*
Task Approved : No
Task % Complete : 95%

Progress: The literature review was updated with new references from TRB meeting in January and AAPT meeting in March.
A task report will be delivered by the end of April.

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.

Task Update:

The more advanced specification will consist of additional mix testing beyond that of the mix design criteria for use in the developed advanced models.
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

Task % Complete : 20%

Progress: All mixture samples were received and work is in progress to compact specimens used for testing by the four universities.

Subtask on Physical Hardening
During the SHRP project studies showed that isothermal storage time has a significant effect on the creep response of asphalt binders, known as physical hardening. The main practical difficulty of measuring magnitude and rate of physical hardening is the length of the isothermal conditioning, which can extend to 48 or 96 hours. During the project it was shown that the effect of isothermal conditioning is similar to that of temperature change, causing a shift of the stiffness-loading time curve.
In this project the approach will be adopted to study if testing at shorter time (2-6 Hours) can be used to predict longer time hardening.
This quarter, discussion on using this approach has started and an experimental plan is under development. The main objective of the research effort in the next quarter will be to estimate the relation between the physical hardening shift factor and the isothermal storage time, in order to extrapolate the stiffening effect over long periods of time by measuring the rate only for relatively short conditioning times.

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

Task % Complete : 5%

Progress: Discussions on how to address the development of a low temperature specification for mixtures were held by the four universities at TRB and AAPT.

4 Develop Improved TCMODEL

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

Quarter: January 01 - March 31, 2009

Task Update:

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 (¿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

Task % Complete : 15%

Progress: The primary objective of task four is to enhance the existing TCMODEL (¿NewTCMODEL¿) to better capture the true fracture properties of hot-mix asphalt (HMA). The following reports progress on the two subtasks, dealing with the development of the model interface and model analysis engine.

Progress on Model Interface
Specifically, work has been done in creating the graphical user interface (GUI) which will allow for easy use of the NewTCMODEL. Once completed, the GUI will collect data input from the user, pre process data for input into NewTCMODEL, execute NewTCMODEL, and post process NewTCMODEL outputs.

Currently, the GUI is programmed for use with the existing TCMODEL and will be updated accordingly when the NewTCMODEL is complete. The layout and format of the GUI is similar to that of the Mechanistic Empirical Pavement Design Guide (ME-PDG), however it requires much less user input. The GUI only requires inputs related to the structure of pavement and thermal properties of the asphalt concrete, whereas the ME-PDG requires several additional traffic inputs that are not pertinent to the thermal cracking analysis.

Progress on Model Engine
Significant progress has been made in the past quarter towards the development of the analysis engine for the new thermal-cracking prediction model (NewTCMODEL). The model engine is being developed in form of a viscoelastic finite element analysis code with a recursive time-integration scheme. A cohesive fracture model capable of capturing the crack nucleation, initiation and propagation is being utilized in the stand-along thermal cracking prediction model. Generalized Maxwell model (Prony series form) is being used for the viscoelastic representation of asphalt concrete. Similar to current AASHTO MEPDG procedure the bulk material property inputs to this new procedure will be in form of creep results from the AASHTO-T322 tests. The key material inputs for the cohesive zone fracture model are the tensile strength and the fracture energy measured using AASHTO-T322 and ASTM-D3717 test specifications respectively. Several key parameters for the implementation of the software code have been narrowed down and the implementation work is currently in progress. The broad development items for the task are listed as follows along with their current status:
-Built-in mesh generator (development complete)
-Thermo-viscoelastic analysis using recursive time-integration scheme (formulation completed and verified, implementation in-progress)
-Bi-linear cohesive zone fracture model (formulation completed and verified, implementation in-progress)

Task Update:

-Integration of the finite-element engine with the pre- and post-processing software (to be performed in Q2 and Q3 of 2009)

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

Task % Complete : 5%

Progress: This quarter preliminary testing of samples used for measurement of glass transition temperature of mixtures using the modified and refined system was conducted. A dummy asphalt mix specimen is placed at the bottom of the insulated chamber to estimate the interior temperatures of the mixture specimen during testing. Also, the procedure followed included conditioning by holding the chamber temperature at 20¿C for 40 minutes before cooling to -80¿C at the rate of -0.5¿C/min. After the temperature inside the chamber reached -80¿C, the mixture specimen is held at this constant temperature for 40 minutes before re-heating to 20¿C at 0.5¿C/min rate.
Data collected were analyzed using a regression analysis method and curve fitting.

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 Update:

Task Approved : No

Task % Complete : 0%

Progress: Nothing to report.

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

Task % Complete : 0%

Progress: Nothing to report.

Future Plans:

Problems Encountered/Actions Taken: