**TRANSPORTATION POOLED FUND PROGRAM**

**QUARTERLY PROGRESS REPORT**

Lead Agency (FHWA or State DOT): Minnesota Department of Transortation

**INSTRUCTIONS:**

*Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.*

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| **Transportation Pooled Fund Program Project #**  *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)*  TPF-5(132) | | **Transportation Pooled Fund Program - Report Period:**  □Quarter 1 (January 1 – March 31)  □Quarter 2 (April 1 – June 30)  □Quarter 3 (July 1 – September 30)  C:\Program Files\Microsoft Office\MEDIA\OFFICE14\Bullets\BD21301_.gif□Quarter 4 (October 1 – December 31) | |
| **Project Title:**  Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II | | | |
| **Name of Project Manager(s):**  Tim Clyne | **Phone Number:**  651-366-5473 | | **E-Mail**  [tim.clyne@state.mn.us](mailto:tim.clyne@state.mn.us) |
| **Lead Agency Project ID:**  Contract 89261 | **Other Project ID (i.e., contract #):**  WO # 103 | | **Project Start Date:**  6/17/08 |
| **Original Project End Date:**  1/31/12 | **Current Project End Date:**  7/31/12 | | **Number of Extensions:**  1 |

Project schedule status:

C:\Program Files\Microsoft Office\MEDIA\OFFICE14\Bullets\BD21301_.gif□ On schedule □ On revised schedule □ Ahead of schedule □ Behind schedule

Overall Project Statistics:

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| **Total Project Budget** | **Total Cost to Date for Project** | **Percentage of Work**  **Completed to Date** |
| $505,000 ($475k research; $30k admin) | $133,570 (+ 6 TAP meetings) | ~75% |

***Quarterly*** Project Statistics:

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| **Total Project Expenses**  **and Percentage This Quarter** | **Total Amount of Funds**  **Expended This Quarter** | **Total Percentage of**  **Time Used to Date** |
| 0 | 0 | 83% |

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| **Project Description**:  The Minnesota Department of Transportation initiated this pooled fund study as a continuation of a long-standing  investigation of low temperature cracking. The Phase I pooled fund study 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.    The Phase I study has developed new models for intrinsic material properties, laboratory testing behavior, and mixture performance in an in-service pavement. An integrated approach that combines laboratory materials testing, numerical  modeling, and prediction of pavement performance is taken in Phase II of this study. Part of this approach will include  field validation of the aforementioned tests and models by constructing 3 test sections at MnROAD.    The main objective of this project is to develop test methods and specification criteria that will allow the selection of  fracture resistant asphalt mixtures and binders at low temperatures. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):**  A TAP meeting was held October 5th in conjunction with the October 4th MnROAD Research Conference. The  participants discussed the progress of the project, and the states gave further direction to the research team on  how to proceed. Expectations for final deliverables of the project were documented.  *Task 3, Develop low temperature specification for asphalt mixtures* - A project meeting was held in Minnesota to  discuss the framework for a low temperature cracking specification. Currently, we believe that a fracture energy  threshold of 400 J/m2 will be the recommended minimum fracture energy, based upon results from Phase I and  other related studies. This result will be validated in light of phase II test results and available field performance data.  A creep compliance requirement is also anticipated, which will identify overly stiff mixtures which may also happen to  have borderline fracture energy (for instance, mixture containing high amounts of oxidized RAP). Since the IDT  creep test may not be available in many labs due to its relatively high cost and complexity, a surrogate tests that can  be run in conjunction with the DC(T) is under investigation (creep results obtained prior to running fracture test).  Experimental trials are nearly complete, with final results expected next quarter.  *Task 4, Develop Improved TCMODEL* - The majority of time on this task this quarter involved increasing the  computational efficiency of the new thermal cracking code (ILLI-TC). A routine, which has been under development  over the past three quarters, is being finalized to render ILLI-TC much more computationally efficient. The finite  element calculations are relatively time consuming, since iterations are needed to handle the nonlinearities caused  by the viscoelastic material model and the presence of the crack propagation model (cohesive zone). Mesh  refinement in the area of the crack tip also requires additional computational expense. The time-saving algorithm  developed uses a simple 1-D viscoelastic stress prediction at the surface to indicate non-critical cooling events.  During long consecutive periods of these events, the crack will not propagate and therefore the finite element  calculations can be skipped, thereby reducing computational time. This important algorithm is currently being  optimized and verified for accuracy and reliability.  *Task 5, Modeling of Asphalt Mixtures Contraction and Expansion Due to Thermal Cycling* - As part of  Task 5 experiments, asphalt binders and mixtures were subjected to cooling and heating cycles, during which the  thermo-volumetric response was measured. A micro-mechanical model based on aggregate structure, volume fraction,  relative stiffness of the mixture phases, and thermo-volumetric properties of the mastic was developed, allowing for the estimation of mixture coefficients of contraction. Furthermore thermal stress buildup during cooling, and the subsequent reduction during heating were investigated for by using a calculation model capable of accounting for time dependent  strain (i.e., physical hardening). By varying the thermal volumetric properties in heating and cooling, a sensitivity  analysis on these parameters was performed. The following notable conclusions were derived last quarter:  • The liquid phase coefficient of thermal expansion/contraction (CTE), αl and the glass transition temperature, Tg,  showed the most influence on the rate and trend of thermal stress buildup; the later becoming more prominent when  accounting for the time dependency of strains in the glass transition region.  • Assumption of a constant CTE at low temperatures can lead to significant error in calculation of thermal stress.  • The limited sensitivity of thermal stress to changes in magnitude of αg indicates the possibility of using a  typical value for αg in place of experimental measurements.  • Typical average values for thermo-volumetric parameters during heating can be used due to the relatively low  sensitivity of thermal stress to these parameters (e.g., CTE, Tg).  • Overall, it is concluded that accurate calculation of thermal stress needs reliable measurements of the αl, Tg,  and the transition geometry.  • The coefficient of thermal expansion/contraction (CTE) of the asphalt mixture is strongly depended on the  modulus of its constituents and the variation of this ratio as temperature varies.  • The CTE has a notable dependency on the micromechanical properties of the mixture aggregate skeleton. It  is observed that there is a good correlation between number of aggregate contact zones and αl of the mixture and a  model have been proposed to evaluate this term based on micromechanical properties of the mixture. Also it has been  shown that for temperatures below Tg the effect of microstructure on thermal expansion is not notable.  • A semi-empirical model based on the Hirsch model and common composite theories was proposed with the  ability to take into account the mixture aggregate skeleton, the glass transition, and the stiffness ratios of the phases,  for the estimation of the total CTE, rather than simply relying on the volume fractions of each phase.  • The input needed for the proposed mixture CTE model is the stiffness, and the glassy and liquid CTE of the  mastic phase as well as the number of aggregate to aggregate contact points and volume fraction. The later properties  can be derived very easily using the iPas image analysis software. No mixture testing is needed for the estimation of  the mixture CTE, with the use of the proposed model. |
| **Anticipated work next quarter**:  Task 3 is almost completed and it will be delivered by the end of January 2012. The delay is mostly due to assembling  the many different components of this task and to some delay with completing the experimental part of obtaining creep compliance from DC(T) and SCB test specimens.  Sample results from ILLI-TC (Task 4) should be available next quarter and can be presented at the next TAP meeting.  Task 5 is under final review by the research team at University of Madison and it will be delivered by January 31.  The research teams are waiting for additional results obtained in Tasks 3, 4, and 5 to finalize Task 6. It is anticipated  that the task will be delivered by the end of February.  Once task 6 is delivered, then Task 7 work will be finalized in a short period of time, expected by the end of March. |

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| **Significant Results:**  Researchers are narrowing in on specification limits for the chosen asphalt mixture fracture test, the DCT. These  spec limits will differentiate between good and poor performers in terms of low temperature cracking. AASHTO  standard test methods have been proposed for the SCB and BBR mix tests.    Significant improvements have been made to ILLI-TC. This model will be a stand-alone program with a graphical,  user-friendly interface.    The University of Wisconsin has developed sophisticated testing and modeling techniques to account for thermal  stress buildup in asphalt mixtures.    Statistical analyses performed by ISU have shown that the DCT test does a good job differentiating between mixtures  and their different parameters. |
| **Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that**  **might affect the completion of the project within the time, scope and fiscal constraints set forth in the**  **agreement, along with recommended solutions to those problems).**  The State of Minnesota endured a 3-week shutdown in July 2011, during which time the research team was not  Permitted to work on the research project. This caused delays in the project, but the Universities should be able to  catch up and complete the project on time.    The Universities also were delayed in obtaining some of the field test specimens, which delayed their laboratory  testing and data analysis. |

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| **Potential Implementation:**  MnDOT and the other participating states may potentially revise their bituminous paving specifications to include a low temperature fracture test based on the results of this study. Iowa is in the process of developing performance  specifications around the DCT test this year.    The states need to decide for themselves how the results of the study will be implemented. MnDOT is in the process  of developing our “HMA Implementation Plan” through discussions between the Research Section and Bituminous  Office. |