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Asphalt Research Consortium

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INTRODUCTION

This document is the Quarterly Report for the period of July 1 to September 30, 2014, for Federal Highway Administration (FHWA) Contract No. DTFH61-07-H-00009, the Asphalt Research Consortium (ARC). The Consortium is coordinated by Western Research Institute with partners Texas A&M University, the University of Wisconsin-Madison, the University of Nevada Reno, Advanced Asphalt Technologies, and the National Center for Asphalt Technology.

This report is presented as a progress report on the 83 anticipated project deliverables. The project deliverables are grouped into three areas, Reports, Test Methods/Practices, and Models/Software. The deliverables consist of 34 Reports, 42 Test Methods/Practices and 7 Models/Software. Of the 83 deliverables, 20 Draft Reports and 41 Test Methods/Practices and/or Models/Software have been submitted for review. Proposed work in this contract is nearing completion, therefore, original Work Elements and Subtasks have coalesced into the 83 anticipated project deliverables. A Table of Deliverables is presented following this introduction which identifies the title of the deliverable, expected draft delivery date, expected final delivery date, and comment of status. This Table of Deliverables is updated each quarter. In addition, this Quarterly Report reports on Other Research Activities which may develop deliverables as the work progresses. The project deliverables result from research that was grouped into seven areas, Moisture Damage, Fatigue, Engineered Paving Materials, Vehicle-Pavement Interaction, Validation, Technology Development, and Technology Transfer.

The Quarter of July 1 to September 30, 2014, is the second quarter of the Year 7.5 of the contract. A six-month, no-cost extension to this contract was granted by FHWA to begin July 1, 2014, and to end on December 31, 2014. Reviewers may reference previous Annual Work Plans and other documents that are posted on the ARC website, www.ARC.unr.edu.

SUPPORT OF FHWA AND DOT STRATEGIC GOALS

The Asphalt Research Consortium research is responsive to the needs of asphalt engineers and technologists, state DOT's, and supports the FHWA Strategic Goals and the Asphalt Pavement Road Map. More specifically, the research reported here supports the Strategic Goals of safety, mobility, and environmental stewardship. By addressing the causes of pavement failure and thus determining methods to improve asphalt pavement durability and longevity, this research will provide the motoring public with increased safety and mobility. The research directed at improved use of recycled asphalt pavement (RAP), warm mix asphalt, and cold mix asphalt supports the Strategic Goal of environmental stewardship.

TABLE OF ASPHALT RESEARCH CONSORTIUM DELIVERABLES

Deliverable	Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Description/Note
Report AD	Executive Summary Report: ARC History, Participants and Accomplishments	11/15/2014	12/31/2014	All	All	Report outline has been prepared
Report A0	Summary Report of Asphalt Research Consortium Research at Texas A&M University	Completed 2/28/2014	5/31/2014	TAMU	All	Reference level 2 and 3 deliverables for details, 508
Report A	Moisture Damage of Asphalt Pavements: Mechanisms, Characterization, Prediction and Numerical Modeling	Completed 3/21/2013	9/30/2013	TAMU	Masad	Sent to FHWA for review, Reference level 3 deliverables for details, NTIS
Report B	Characterization of Fatigue Damage and Relevant Properties in Asphalt Binders and Composites	Completed 8/22/2013	10/31/2013	TAMU	Bhasin	NTIS
Report C	PANDA: Pavement Analysis Using Nonlinear Damage Approach	Completed 9/26/2013	11/30/2013	TAMU	Darabi	Summary of PANDA methodology including descriptions of methods for indentifying model parameters, 508
Report D	Microstructural Characterization of the Chemo-Mechanical Behavior of Asphalt in Terms of Aging and Fatigue Performance Properties	Completed 7/26/2013	10/31/2013	TAMU	Little	Summary report on methodology for characterizing the phases of asphalt binder with description of composite implications NTIS

Deliverable	Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Description/Note
Report E	A Multiscale Virtual Fabrication and Lattice Modeling Approach for the Fatigue Performance Prediction of Asphalt Concrete	Completed 9/30/2013	9/30/2013	NCSU	R. Kim	Submitted to FHWA for review, Comprehensive report on lattice model.
Report F	Microstructure Cohesive Zone Modeling for Moisture Damage and Fatigue Cracking	Completed 3/21/2013	8/31/2013	UNL	Y.R. Kim	Sent to FHWA for review, Comprehensive report on cohesive zone model
Report G	Design System for HMA Containing a High Percentage of RAP Material	9/30/2014	4/30/2015	UNR	Sebaaly Hajj	5 month extension of draft report deadline requested.
Report H	Rutting Performance of Asphalt Mixtures Under Critical Conditions	Completed 06/30/2014	9/30/2014 Pending Review	UNR	Hajj Sebaaly	Comprehensive report describing the developed mechanistic-based approach for critically designed mixtures
Report I	Thermal Cracking Resistant Mixes	9/30/2014	11/30/2014	UNR	Hajj Sebaaly	3 month extension of draft report deadline requested.
Report I-A	Study of Pavement Temperature Rates in HMA Layers	Completed 09/26/2013	12/26/2013 Pending Review	UNR	Hajj Sebaaly	Received MS Word and Hardcopy
Report I-B	Low Temperature Cracking Characterization of Asphalt Binders	2/15/2014		UWM	Tabatabaee	Recently separately from report I on 1/5/2014
Report J	Pavement Response Model to Dynamic Loads 3D Move	9/30/2014	11/30/2014	UNR	Hajj Sebaaly	3 month extension of draft report deadline requested.

Deliverable	Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Description/Note
Report K	Development of Materials Database	Completed 05/30/2014	8/30/2014 Pending Review	UNR	Hajj Ekedahl	Draft submitted to FHWA for review
Report L	Development and Validation of the Bitumen Bond Strength Test (BBS)	Completed 10/31/11	Completed 10/31/13	UWM	Hanz	Extended to incorporate new information from NCHRP 9-50
Report M	Development of Test Procedures for Characterization of Asphalt Binder Fatigue and Healing	Completed	Completed 3/31/2014	UWM	Tabatabaee	Received MS Word version and tech brief. Section 508 and image descriptions needed.
Report N	Guideline for Selection of Modification Techniques	Completed 3/31/2014	6/30/2014 Pending Review	UWM	Tabatabaee	3 month extension of draft report deadline approved by FHWA
Report O	Characterization of Binder Damage Resistance to Rutting	Completed 9/30/2013	Completed 3/31/2014	UWM	Tabatabaee	Complete 508 formatting, Tech Brief, etc.
Report P	Quantifying the Impacts of Warm Mix Asphalt on Constructability and Performance	10/01/2014 (from 9/30/2013, 12/31/2013)	11/01/2014 from (12/31/2013, 3/31/2014)	UWM	Roohi	3 month extension of draft report deadline requested
Report Q	Improvement of Emulsion Characterization and Mixture Design for Cold Bitumen Applications	10/01/2014, from 11/01/2013, 12/31/2013	11/01/2014 (from 3/31/2014)	UWM	Roohi	3 month extension of draft report deadline requested
Report R	Studies on Tire-Pavement Noise and Skid Response	Completed 12/31/11	Completed 7/30/2013	UWM	Roohi	Received MS Word version and tech brief
Report S	Molecular dynamics results for multiple asphalt chemistries	11/15/2014 (from 3/30/2014)	12/31/2014 (from 5/31/2014)	URI	Greenfield	3 month extension of draft report deadline requested.

Deliverable	Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Description/Note
Report T	Progress Toward a Multi-scale Model of Asphalt Pavement- Including Test Methods for Model Input Parameters	10/31/2014	12/31/2014	WRI/VT/ URI/TUD	Pauli	508 Format
Report U	Design Guidance for Fatigue and Rut Resistance Mixtures	7/21/2014	12/15/2014	AAT	Bonaquist Christensen	3 month extension of draft report deadline requested. NTIS format report with Technical Brief
Report V	Continuum Damage Permanent Deformation Analysis for Asphalt Mixtures (Level 2)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Draft submitted to FHWA Reference appropriate level 3 deliverables NTIS
Report W	Characterization of Fatigue and Healing Properties of Asphalt Mixtures (Level 2)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Draft submitted to FHWA Reference appropriate level 3 deliverables NTIS
Report X	Characterization of Field Cores of Asphalt Pavements (Level 2)	Completed 07/26/2013	10/30/2013	TAMU	Lytton/Luo	Draft submitted to FHWA Reference appropriate level 3 deliverables NTIS
Report Y	Water Vapor Diffusion in Pavement and Its Effects on the Performance of Asphalt Mixtures (Level 2)	Completed 07/26/2013	10/30/2013	TAMU	Lytton/Luo	A revised version of this report is submitted to FHWA for review
Report Z	Effect of Extraction Methods on the Properties of Aggregates in Reclaimed Asphalt Pavement (NTIS format)	Completed 3/1/2013	10/30/2013	UNR	Hajj Sebaaly	Draft submitted to FHWA Final pending receipt of peer review comments
Report AA	Laboratory Assessment of Asphalt Mixture Long Term Aging	3/31/2014	6/30/2014	UWM	Tabatabaee	3 month extension of draft submittal requested

Deliverable	Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Description/Note
Report AB	Summary Report on ARC Comparative Pavement Test Sections	11/15/2014		WRI	Farrar	Report summarizing progress of establishing and maintaining the WRI-ARC and FPIII comparative pavement test sections.
Report AC	Summary Report on NCAT Warm-Mix Pavement Test Sections	8/30/2014		NCAT	Nam	Report summarizing progress of establishing and maintaining the NCAT test sections.
Report AE	Superpave Mix Design for Cold In-Place Recycling	4/30/2015	6/30/2015	UNR	Sebaaly	

TABLE OF ASPHALT RESEARCH CONSORTIUM PRODUCT DELIVERABLES

Deliverable/ Product	Description/Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
AASHTO Method	Simplified Continuum Damage Fatigue Analysis for the Asphalt Mixture Performance Tester	7/21/2014	12/15/2014	AAT	Bonaquist Christensen	Development documented in Report U. Test method included in Report U
AASHTO Method	Using a Wilhelmy Plate Device to Determine Surface Energy Components of Asphalt Binders (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Bhasin	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Using a Sorption Device to Determine Surface Energy Components of Aggregates (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Bhasin	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Conducting Dynamic Mechanical Analyzer (DMA) Tests (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Kassem	Draft submitted to FHWA Referenced in Reports A & B
ASTM Method	Automated Flocculation Titrimetric Analysis	Completed		WRI	Pauli	ASTM D-6703
AASHTO Method	Determination of Polymer in Asphalt	Completed		WRI	Harnsberger	
AASHTO Method	Preparing Dynamic Mechanical Analyzer (DMA) Specimens (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Kassem	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Quantifying Intrinsic Healing of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)	Completed 03/07/2013	9/30/2012	TAMU/ UT	Bhasin	Draft submitted to FHWA Referenced in Report B
AASHTO Method	Calibration of the Pavement Analysis using Nonlinear Damage Approach (PANDA) Constitutive Relationships (Level 3)	Completed 09/26/2013	2/28/2014	TAMU	Kassem Darabi	Referenced in Report C
Test Method & Model	Continuum Damage Permanent Deformation Analysis for Asphalt Mixtures (Level 3)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report V

Deliverable/ Product	Description/Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Test Method & Model	Characterization of Fatigue and Healing Properties of Asphalt Mixtures (Level 3)	Completed 07/26/2013	9/30/2013	TAMU	Lytton/Luo	Appendix in Report W
Test Method Analysis Program	Nondestructive Characterization of Tensile Viscoelastic Properties of Undamaged Asphalt Mixtures (Level 3)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report W
Test Method & Model	Characterization of Field Cores of Asphalt Pavements (Level 3)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report X
Test Method Analysis Program	Nondestructive Characterization of Anisotropic Viscoelastic Properties of Undamaged Asphalt Mixtures under Compressive Loading (Level 3)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report V
AASHTO Practice	Mix Design for Cold-In-Place Recycling (CIR)	4/30/2014		UNR	Sebaaly Hajj	Detailed in Report Q
AASHTO Practice	Mix Design for Cold Mix Asphalt	10/01/2014 (from 9/30/2013)	11/01/2014 (from 3/31/2014)	UWM	Roohi	Extension requested to coincide with submittal of draft for Report Q
AASHTO Practice	Evaluation of RAP Aggregates	12/31/2012		UNR	Sebaaly	Detailed in Report G
AASHTO Practice	Determining Asphalt Mixture Critical Conditions for Rutting Evaluation by Means of Dynamic Repeated Load Triaxial (RLT) Test	Completed 5/31/2013		UNR	Hajj Sebaaly	Detailed in Report H
AASHTO Method	Determining Thermal Crack Properties of Asphalt Mixtures Through Measurement of Thermally Induced Stress and Strain	Completed 5/31/2012		UNR	Hajj Tabatabaee	Detailed in Report I
AASHTO Method	Determining Asphalt Binder Bond Strength by Means of the Bitumen Bond Strength Test (BBS)	Completed	Completed 6/30/13	UWM	Hanz	Complete, no additional work planned.
AASHTO Method	Measurement of Asphalt Binder Elastic Recovery in the Dynamic Shear Rheometer (DSR)	Completed 1/31/2013	Complete 6/30/2013	UWM	Tabatabaee	Complete, no additional work planned.
AASHTO Method	Estimating Fatigue Resistance of Asphalt Binders Using the Linear Amplitude Sweep (LAS)	Completed	Completed 9/30/2013	UWM	Tabatabaee	Complete, no additional work planned.
AASHTO Method	Binder Yield Energy Test (BYET)	Completed 1/31/2013	Complete 6/30/2013	UWM	Tabatabaee	Complete, no additional work planned.

Deliverable/ Product	Description/Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
AASHTO Method	Measurement of Rigden Voids for fillers	Completed 1/31/2013	Completed 6/30/2013	UWM	Hanz	Complete, no additional work planned.
AASHTO Method	Measurement of Asphalt Binder Lubricity Using the Dynamic Shear Rheometer (DSR)	10/01/2014 (from 9/30/2013)	11/01/2014 (from 12/31/2013)	UWM	Roohi	3 month extension requested to coincide with submittal of draft final Report P
AASHTO Method	Procedure for Evaluation of Coating for Cold Mix Asphalt	Completed 4/30/2013	Completed 9/30/2013	UWM	Hanz	Complete, no additional work planned
AASHTO Method	Cold Mix Laboratory Specimen Preparation Using Modified SGC Molds	Completed 8/30/2013	Completed 12/31/2013	UWM	Hanz	Pending comments from FHWA/ETG
AASHTO Method Software	RAP Binder PG True Grade Determination	Completed 9/30/2012	Completed 6/30/2013	UWM	Hanz	Complete, no additional work planned
AASHTO Method	Measurement of Asphalt Binder Fracture Properties Using the Single Edge Notch Bending Test	Completed 9/30/2012	Completed 9/30/2013	UWM	Tabatabaee	Complete, no additional work planned
AASHTO Method	Test Method for Measurement of the Glass Transition Temperature of Asphalt Binders	Completed 1/31/2013	Completed 6/30/2013	UWM	Tabatabaee	Action pending FHWA/ETG comments
AASHTO Method	Test Method for Measurement of the Glass Transition Temperature of Asphalt Mixtures	Completed 4/30/2013	Completed 6/30/2013	UWM	Tabatabaee	Refer to UNR TSRST procedure for additional information
AASHTO Method Software	Analysis of Asphalt Mixture Aggregate Structure through Use of Planar Imaging and Image Processing & Analysis System (IPAS)	Completed 4/30/2013	Completed 9/30/2013	UWM	Roohi	Action pending ETG comments
AASHTO Method	Determining the Resistive Effort of Asphalt Mixtures during Compaction in a Gyrator Compactor using an Internal Device	Completed ASTM	Completed ASTM	UWM	Hanz	Complete, no additional work planned.
AASHTO Method	Micromechanical Properties of Various Structural Components in Asphalt using Atomic Force Microscopy (AFM) (Level 3)	Completed 03/07/2013	8/31/2013	TAMU	Little	Draft submitted to FHWA, Referenced in Report D

Deliverable/ Product	Description/Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
AASHTO Method	Test Method for Fatigue of Binder and Mastics: A cyclic direct tension test that can provide direct evaluation of fatigue for binder and mastic. It can also provide model validation and model parameter inputs.	10/30/2014	12/15/2014	VT	Wang	Draft data extension requested
AASHTO Method	AASHTO Method: Method to Quantify (Self) Healing in Asphalt Composites Based on Viscoelastic Continuum Damage Theory (Level 3)	Completed 08/22/2013	8/31/2013	TAMU/ UT	Bhasin	Appendix in Report B
Test Method & Analysis Program	Self-Consistent Micromechanics Models of Asphalt Mixtures	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report W
AASHTO Method & Analysis Program	AASHTO Method: Prediction of Apparent Viscosity of Asphalt Binders Using a Generalized Oldroyd-B Model	Completed 10/16/2013	9/30/2013	TAMU	Little	Draft submitted to FHWA for review
AASHTO Method	Test method to determine surface roughness of aggregate and fines based on AFM	11/15/2014	12/31/2014	WRI	Grimes	Will be subject of Tech. Pub., Discussed in Report T
AASHTO Method	Test method to determine ductile-brittle properties via AFM measurements	10/31/2014	12/31/2014	WRI	Grimes	Will be subject of Tech. Pub., Discussed in Report T
AASHTO Method	AFM-based micro/nano-scale cyclic direct tension test	Completed 3/31/2013	10/31/2013	WRI	Grimes	Draft submitted to FHWA Will be subject of Tech. Pub., Discussed in Report T
AASHTO Method	Measurement and Texture Spectral Analysis of Pavement Surface Profiles Using a Linear Stationary Laser Profiler (SLP)	Completed 9/30/2012	Completed 6/30/2013	UWM	Roohi	Complete, FHWA decided not to pursue draft standard.
Model	HMA Thermal Stresses in Pavement	3/31/2014		UNR	Hajj	Detailed in Report I
Software	Dynamic Model for Flexible Pavements 3D-Move	3/31/2014		UNR	Hajj Siddharthan	Detailed in Report J

Deliverable/ Product	Description/Title	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Model & Test Method	Improved Oxygen and Thermal Transport Model of Binder Oxidation in Pavements (Level 3)	5/31/2013	10/31/2013	TAMU	Glover	Part of Report B & Summary Report References to Dissertations and Journal Papers
Model & Test Method	Pavement Air Voids Size Distribution Model for use in an Oxygen and Thermal Transport Model of Binder Oxidation in Pavements (Level 3)	5/31/2013	10/31/2013	TAMU	Glover	Part of Report B & Summary Report References to Dissertations and Journal Papers
Model	Approaches to interpret MD simulation results and experimental data to quantify the composition and temperature dependence of free energy.	8/15/2013		URI	Greenfield	Detailed in Report S
Model and Software	Phase-Field Model of Asphalt Binder Fracture and COMSOL Code for Model	5/15/2014	5/31/2014	VT	Hou/Wang	Extension Requested Appendix in Report T
Software	PANDA Software (Pavement Analysis using a Nonlinear Damage Approach)	11/15/2014		TAMU	Sun-Myung Kim	This software supports the PANDA constitutive models(UMAT) used in conjunction with Abaqus FE software. This includes the PUI and PPI software

REPORTS

REPORT A0: ARC TAMU COMPREHENSIVE SUMMARY REPORT

Status: The report is completed and submitted to FHWA for review.

ARC Database
Researchers at TAMU will have two more batches of experimental data for UNR to upload into the database. The first batch of data should be sent to UNR by October 31st, while the second batch should be available by the end December 2014.

REPORT A: SUMMARY REPORT ON MOISTURE DAMAGE

Status: The report is completed and submitted to FHWA for review.

REPORT B: CHARACTERIZATION OF FATIGUE DAMAGE AND RELEVANT PROPERTIES

Status: The report is completed and submitted to FHWA for review.

REPORT C: PAVEMENT ANALYSIS USING A NONLINEAR DAMAGE APPROACH (PANDA)
Status: The report is completed and submitted to FHWA for review.

The main progress of this quarter can be outlined as follows:
After our teleconference with Mr. Eric Weaver on July 21st, our team discussed capabilities and status of PANDA. We prepared a white paper that was delivered to Mr. Weaver. The white paper discussed: capabilities of PANDA in its current form, format of final PANDA deliverables (UMAT, PUI, and PPI), plan to move toward implementing PANDA in a multi-scale standalone platform that is no longer dependent upon use of the Abaqus FE framework, and a business plan that will provide support for PANDA in the stand-alone form for the future.

We continued to further validate PANDA against lab and field experiments.

- **PANDA chapter**

The PANDA chapter in the comprehensive summary report was completed and delivered to FHWA.

- **PANDA Parameter Identifier package (PPI)**

During this quarter, ARC team finalized the PANDA Parameter Identifier (PPI) package. PPI package is ready and will be delivered along with PUI and UMAT to the FHWA by November 15 2014.

- **Further validation of PANDA**

During this quarter, PANDA was further validated against: a) laboratory test results conducted on ARC mix #1;these test results were used to further validate viscoelastic, viscoplastic, damage, and aging constitutive relationships; b) lab experiments and full-scale tests conducted at Waterways Experiment Station. The lab experiments were used to calibrate and validate viscoelastic, viscoplastic, and hardening-relaxation constitutive relationships. The full-scale tests were conducted using HVS (Heavy Vehicle Simulator) at high temperatures subjected to C-17 and F-15E wheels. It was shown that PANDA can be used effectively to predict the responses observed in full scale testing.

The focus of the next quarter will be on further calibration and validation of PANDA against ARC test results as well as the other available and on-going experimental data (Waterways Experiment Station data, ARC lab experiments on selected asphalt mixtures, and Ohio test sections) and previously collected data from the Accelerated Loading Facility at Turner-Fairbanks, the Nottingham facility at Nottingham University.

We continued to incorporate the effect of realistic tire contact stresses in PANDA for more accurate analysis of pavement structures. Dr. Imad Al-Qadi and his team from University of Illinois-Urban, Champaign is assisting in this task by predicting the contact pressures from different types of tires at different temperatures. Those predictions will be used as inputs into the realistic rutting and fatigue damage simulations using PANDA. This work is still undergoing and will be the focus of the current quarter.

- **Effect of layer properties on performance of pavements**

During this quarter, PANDA was used to conduct a comprehensive analysis on the effect of geometry, material properties, and applied load on rutting performance of pavements. Several simulations were conducted to investigate the effects of layer thickness, wheel load, and properties of asphalt layer on the rutting performance. A paper was drafted to report the results.

- **Identification of future directions of PANDA**

After our teleconference with Mr. Eric Weaver on July 21st, our team discussed capabilities and status of PANDA and prepared a white paper, that was delivered to Mr. Weaver, that discusses capabilities of PANDA in its current form, format of final PANDA deliverables (UMAT, PUI, and PPI), plan to move toward implementing PANDA in a multi-scale standalone platform that is no longer dependent upon use of the Abaqus FE framework, and a business plan that will provide support for PANDA in the stand-alone form for the future.

Within this theme, our research group has been working closely with Dr. David Allen, Adjunct Professor at TAMU and former dean of engineering at the University of Nebraska at Lincoln who is well-known in the fields of constitutive modeling and mechanics with extensive experiences with Schapery's non-linear viscoelatic and viscoplastic models and computational modeling of asphalt and composites, and Dr. Masoud Darabi, Assistant Professor at University of Kansas who is an expert in constitutive modeling and computational mechanics of asphalt concrete and is considered as one of the main contributors in development of PANDA, to:

a) critically examine the constitutive relations implemented in PANDA and identify potential areas that may need more refinements and enhancements,
b) evaluate the efficacy of implementing PANDA into a standalone package that is no longer dependent upon use of the Abaqus FE framework,
c) carefully evaluate different techniques to extrapolate the PANDA simulation results to large number of loading cycles,
d) propose a plan and suggest future directions of PANDA.

Items "a-c" will not be done within ARC, but the final PANDA report will include a plan to move forward in that direction.

We will focus our future efforts on the following subjects:

- Finalize PUI, PPI, and UMAT packages to be delivered to FHWA.
- Further validate PANDA against ARC data, Waterways Experiment Station data, and Ohio test sections.
- Incorporate realistic tire contact stresses in PANDA.
- Investigate the effect of layer properties on performance of pavements.
- Investigate the efficacy of incorporating PANDA into a standalone package.
- Investigate the efficacy of enhancing PANAD by implementing a robust extrapolation technique in order to predict the performance under large number of loading cycles.

REPORT D: CHARACTERIZATION OF ASPHALT BINDERS USING ATOMIC FORCE MICROSCOPY

Status: The report is completed and submitted to FHWA for review. The work described below is beyond the original scope of our proposed AFM work, but successes with the AFM have prompted our continued effort in this area as described below.

Main progress achieved during this quarter and focus of future work

The rolling thin film oven test (RTFOT) aging can simulate the effect of short term aging while the pressure aging vessel (PAV) aging can simulate the effect of long term aging on asphalt binder. These tests in conjunction with the AFM can help us understand how the microstructure of the asphalt binder is affected by the aging process. Standard binder tests such as dynamic shear rheometer (DSR) reveal with aging has a profound effect on the elasticity and the viscosity of asphalt binder. However, the effect of aging on the damage response of asphalt binder at the micro scale is still a topic that requires significant research. Tensile testing using the custom made loading frame setup developed and described in previous reports may be able to reveal how aging can affect the formation of load induced phase separation (LIPS) zones at a small scale.

Experimental testing involving tensile loading of rolling thin film oven test (RTFOT) and RTFOT and pressure aging vessel (PAV) aged AAD and BI0002 samples have been completed. Preliminary results suggest that aging has a definitive effect on the formation of LIPS zones. Preliminary indentation testing suggests that aging increases the stiffness of asphalt binder and also has an effect on the time dependent response. Image analysis reveals that “bee” structures, “bee casing” structures, along with the interstitial phases are all present in both RTFOT and RTFOT+PAV aged samples. One interesting observation that is to be noted is that the resistance of the asphalt binder to the formation of the LIPS zones increases with aging. Most samples tested have shown little to no formation of LIPS zones after one percent strain. After five percent strain the density and the thickness of the LIPS zones are lower than of those forming in unaged binder samples. This suggests that multiple competing mechanisms may be at work during the oxidation process. Oxidation leads to the stiffening of the asphalt binder. However, at the same time the fracture toughness is also affected. The end result is an effect of both of these factors working together. This may become an interesting area of research to further this work.

Finite element modeling of asphalt binder AAD and BI0002 under aged conditions are currently in process. The geometries for both models will be are based on actual AFM images obtained during the tensile testing using the micro-loading frame previously designed. The material properties will be obtained through AFM creep indentation experiments.

In addition, with the aid of a mathematica script a numerical finite element sensitivity analysis will be performed using Abaqus finite element package. The objective of this analysis is to determine the effect of the orientation, size, density and composition of different constituents of the asphalt binder. Through this type of analysis different combinations of geometry and material properties can be simulated which have not necessarily been observed in the experimental trials that have already been completed.

A publication titled “EVOLUTION OF ASPHALT BINDER MICROSTRUCTURE DUE TO TENSILE LOADING DETERMINED USING AFM AND IMAGE ANALYSIS TECHNIQUES” has been accepted for publication by the International Journal of Pavement Engineering. This work investigates the damage mechanisms in asphalt binder at a small scale using tensile testing using a micro-loading frame and numerical analysis using the finite element method. In addition, this work has been submitted for presentation at the TRB Annual meeting has already been accepted by the committee of reviewers.

REPORT E: MULTISCALE VIRTUAL FABRICATION AND LATTICE MODELING.

Status: The report is completed and submitted to FHWA for review.

REPORT F: MICROSTRUCTURE COHESIVE ZONE MODELING FOR MOISTURE DAMAGE AND FATIGUE CRACKING

Status: The report is completed and submitted to FHWA for review.

REPORT G: DESIGN SYSTEM FOR HMA CONTAINING A HIGH PERCENTAGE OF RAP MATERIAL

Included Work Elements/Subtasks
Work Element E2b:Design System for HMA Containing a High Percentage of RAP Materials

Status and Work Planned
Behind Schedule. An extension of the draft report deadline is requested.

The following list describes the work items completed this quarter:

- Completed TSR testing for the mixtures with 1.36, 1.86 and 2.22 dust proportions. Based on the preliminary analysis, it is observed that the tensile strength ratio (TSR) reduces as the dust proportion increases.
- Completed flow number tests (AASHTO TP 79) for all three HMA mixes with 1.36, 1.86 and 2.22 dust proportions. Based on the preliminary analysis, it is observed that the resistance to rutting increases as the dust proportion increases.
- The delay was accompanied with a delay in conducting a parallel experiment on the impact of dust proportion on the filler portion of RAP mixtures conducted by University of Wisconsin, Madison.
- The sample preparation and testing are in progress for flexural beam fatigue test.

The following list the work planned for next quarter:

- Complete the beam fatigue tests on all three HMA mixes with different DPs.
- Continue the writing of the final report.

REPORT H: CRITICALLY DESIGNED HMA MIXTURES

Included Work Elements/Subtasks
Work Element E2c: Critically Designed HMA Mixtures

Status and Work Planned
The report has been completed and submitted to FHWA for technical and editorial review.

REPORT I: THERMAL CRACKING RESISTANT MIXTURES

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States

Status and Work Planned
Behind Schedule. The following list describes the work items completed this quarter:

- The analysis of all test results for laboratory-produced and validation mixtures were completed.
- Field core mixtures from WesTrack were tested using UTSST. The analysis of results have been completed.
- Writing of the E2d report on thermal cracking resistant mixture is underway by UNR with significant background and methodology information being established. Rough draft versions have been prepared for three of the proposed eight chapters of the report.
- The thermal cracking analysis package (TCAP) software has been finalized. The findings of the overall comprehensive model and the TCAP were presented at the FHWA Binder and Mix ETG meetings in Baton Rouge, LA, Sept 16-19, 2014

The following list the work planned for next quarter:

- Completion and submission of Report I.
- The alpha-version of the thermal cracking analysis package (TCAP) software will be released for initial evaluation.

REPORT J: PAVEMENT RESPONSE MODEL TO DYNAMIC LOADS 3D-MOVE

Included Work Elements/Subtasks
Work Element VP3a: Pavement Response Model to Dynamic Loads

Status and Work Planned
Behind Schedule.

The work on the report continued this quarter and it is 90% complete. Started the work on the new platform for the next version of 3D-Move. The effort is concentrating on the optimization of the code in order to increase the time efficiency of the software. Multiple options are currently being explored by the research team at UNR.

The following is a list work elements planned for next quarter:

- Complete the Final Report and the 3D-Move documentation;
- Continue the work on the new platform for next version of 3D-Move (Ver. 3).

REPORT K: DEVELOPMENT OF MATERIALS DATABASE

Included Work Elements/Subtasks

Work Element TT1d: Development of Materials Database

Status and Work Planned

In this quarter, no additional technical or editorial comments were requested from FHWA on Report K.

The following list summarizes the work items completed or in progress this quarter.

- Implementation of the Distress data subsystem (status)
- Deployment of the Announcements subsystem
- Development and Deployment of a database schema viewer
- Status of batch files uploads
- Status of the role system
- Development of a pavement site report
- Preparations and outcomes of the 10-1 10-2 PRDS meeting
- Miscellaneous enhancements

1. Significant Results (Implementation of the Distress Data Subsystem)

Last quarter, the development team created a prototype to record distress measurements in addition to test measurements. The infrastructure for the property groups and properties were modified to operate with distress measurements based on a pavement section, rather than a material. This quarter, most of the remaining tasks were completed.

The following tables were modified so as to connect a measurement with a distress record rather than a test run. Measurements are designed to be either test run measurements or distress measurements.

- **tblQNMeasure:** Added the field fldDistressID. There is a one-to-many relationship between tblDistress.fldDistressID and tblQNMeasure.fldDistressID.
  tblQLMeasusre: Added the field fldDistressID. There is a one-to-many relationship between tblDistress.fldDistressID and tblQLMeasure.fldDistressID.

The following views were created:

- Created the view **vAllDistressesJoined** which operates similar to vAllMeasuresJoined. The view selects all quantitative and qualitative measures for a distress record.

The following stored procedures were created:

- Created **spAllMeasuresByDistress** to mimic spAllMeasuresByTestRun.
  Created equivalent procedures InsertQNMeasure, InsertQLMeasure, UpdateQNMeasure, UpdateQLMeasure renamed measure to distress (InsertQNDistress, InsertQLDistress, UpdateQNDistress, UpdateQLDistress.

Enhancements continued on the form named MeasureEditDistress.aspx, which was created to edit distress records. Single factor distress records can be edited. Validation code was added to test for all required inputs and type compatibility. The pavement section has been extend such they can be associated with distress measurements.

The following tasks have yet to be completed:

- Add the role system into the form's user interface and implement the data approval process.
- The multi-factor measurement data entry features has been implemented. The system is undergoing final testing.

2. Significant Results (Deployment of the Announcements Subsystem)
Development of the announcements subsystem was completed last quarter. The user control that rendered the announcements was completed and deployed to some of the forms. The deployment of the user control to all forms is complete with the exception of forms that are or will be obsolete in the near future.

Eric Weaver has suggested that this system be extended so that users can use the announcement system as a means of information exchange between them. The development team is attempting to enhance the announcement system to achieve this end.

3. Significant Results (Development and Deployment of a Database Schema Viewer)
As the ARC is possibly migrated to become the foundation for the FHWA PRDS system, the FHWA requested a list of all tables in the database and a representative sample of that data. The development team suggested a form be built within the application to do this, rather than manually gathering this information.

The Database Schema Viewer contains a selector whereby the user can select either a table or a view to be displayed. The user can also select the number of rows to be displayed from the table or view. The following figure shows the selector:

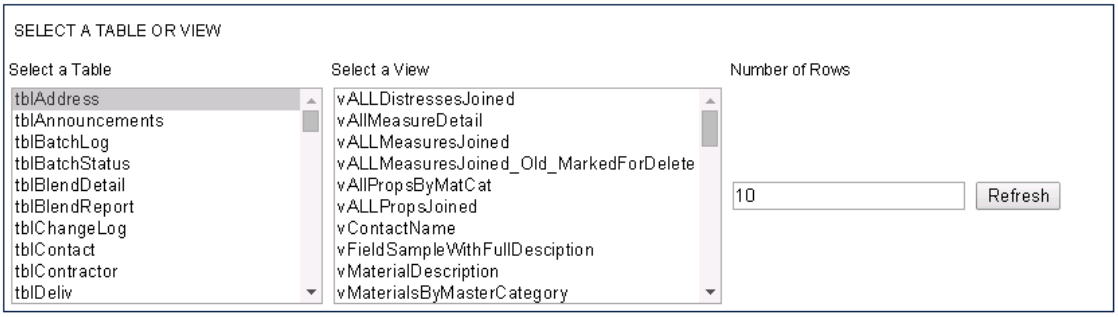
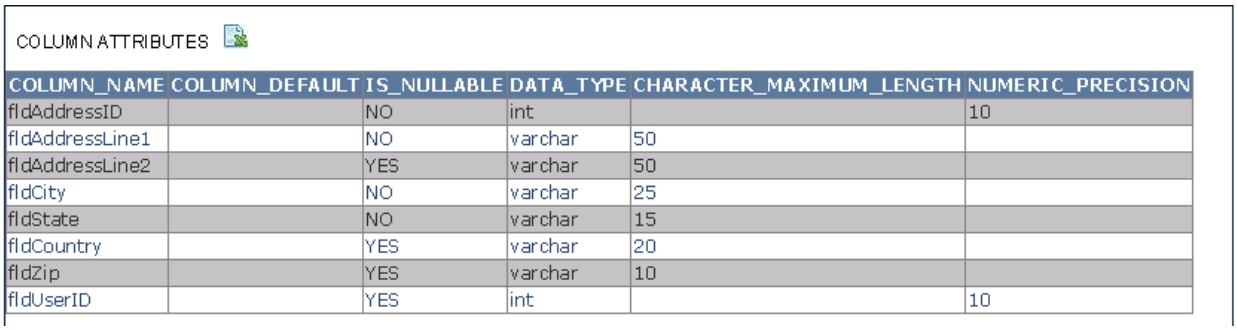


Figure TT1D.1: Database Schema Viewer – Selector

In the above figure, the table named tblAddress is selected. The default number of rows to display is 10. Once a table or view is selected, the COLUMN ATTRIBUTES grid is displayed listing the columns in the selected table, along with various attributes as shown in the following figure. Note that this information can be exported to Excel.

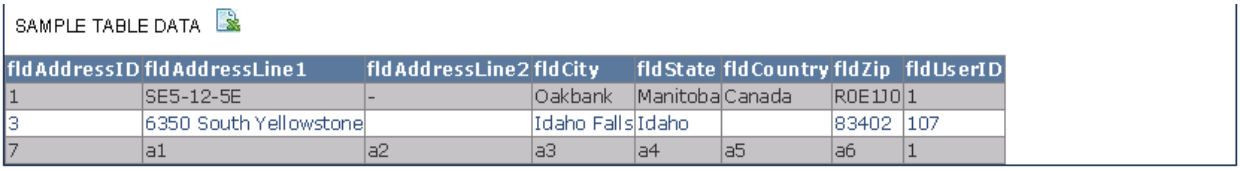


COLUMN ATTRIBUTES

COLUMN_NAME	COLUMN_DEFAULT	IS_NULLABLE	DATA_TYPE	CHARACTER_MAXIMUM_LENGTH	NUMERIC_PRECISION
fldAddressID		NO	int		10
fldAddressLine1		NO	varchar	50	
fldAddressLine2		YES	varchar	50	
fldCity		NO	varchar	25	
fldState		NO	varchar	15	
fldCountry		YES	varchar	20	
fldZip		YES	varchar	10	
fldUserID		YES	int		10

Figure TT1D.2: Database Schema Viewer – View table schema

The following figure shows the sample table data. In the following figure, the sample data is for the table named tblAddress. Three records appear because there are only three records in the table. The column header name is the same as the field name.



SAMPLE TABLE DATA

fldAddressID	fldAddressLine1	fldAddressLine2	fldCity	fldState	fldCountry	fldZip	fldUserID
1	SE5-12-5E	-	Oakbank	Manitoba	Canada	R0E1J0	1
3	6350 South Yellowstone		Idaho Falls	Idaho		83402	107
7	a1	a2	a3	a4	a5	a6	1

Figure TT1D.3: Database Schema Viewer – View table data

Note: At this time, only tables and views are displayed. The development team is considering adding support for the stored procedures and the execution of those stored procedures with parameters.

- The grids can be exported to Excel (.csv file).
- A Help page was created for the form.
- Using the default configuration, users with consortium access can use the form (resource).

4. Significant Results (Status of Batch File Uploads)

Texas A&M has three batches of data that need to be uploaded to the ARC application and ARC database. The first batch was fully imported and uploaded two quarters ago. A second batch was received this quarter. The upload was to be completed by 7/31/2014. Upon final review of the data, several inconsistencies were found by the upload program. The following changes were made to the template provided by Texas A&M:

- Texas A&M added an additional folder column (Column I) to account for an additional input folder. The upload application was modified accordingly. Note that subsequent input files should follow this revised structure. Added a new column (ColumnK) so that the input and output folders match. This column contains the folder PANDA.
- Updated Metadata ID to 26 (same as first batch metadata). This metadata extension might not be correct as these files have a suffix of .dat instead of .txt (used in the first batch). A new metadata type can easily be created.
- Updated Work elements M4C -> M4C-1, F3C -> F3C-2, FC3 -> FC3-1. This change is consistent with the changes in the first batch.
- Nearly all of the data files have a suffix of '.dat'. I modified the template to include the file suffixes.

Some folders and files were found that did not match the template and could not be reconciled by the UNR development team. The team at Texas A&M is reworking the file and template to correct errors. At this time, the third batch of data has not been received.

5. Significant Results (Status of the Role System)
At the time of this writing, all forms, with the exception of the following, have been converted to use the new role system:

- BatchApproval.aspx, BatchViewer.aspx, FieldSamples.aspx, FileApplyDefaultMetaData.aspx, FileLinker.aspx, FileMove.aspx, FileUpload.aspx, ListReports.aspx, Materials.aspx, MeasureApproveTestRun.aspx, MeasureEditTestRun.aspx, Measures.aspx, MeasureCreateTestRun.aspx, VerifyReports.aspx.

6. Significant Results (Pavement Site Report)
The development team has created numerous reports for materials, properties, users, and other data elements. This quarter, a report was created to list pavement sites, the pavement sections within those sites, and the pavement layers. As with most of the reporting elements, the resulting report can be exported to Microsoft Excel (.csv file). The following figure shows the filters that can be applied to the selector:

Figure TT1D.4: Pavement site list – Filter Properties section

As shown in the above figure, the data can be filtered by pavement site, pavement site type, or the user responsible for the pavement site. Once the filters are applied, the pavement site report can be displayed in a grid or exported to Excel.

fldValidationSiteID	fldContactID	fldContractorID	fldComment	fldSiteDescription	fldSiteCode	fldStateProvinceID	fldMembershipID	fldSiteURL	f
25	1	2		Chism Str_Reno-WMA Site	32	27	107		1
25	1	2		Chism Str_Reno-WMA Site	32	27	107		1

Figure TT1D.5: Pavement site list – output grid

7. Significant Results (Status of the Database Initialization Feature)
The database initialization feature was not completed last quarter although progress was made.

The form named ListUserOwnership.aspx was completed and has been deployed to the production ARC system. This form supports the following:

- List all data in the ARC database owned by a particular user.
- Delete all data owned by a particular user.
- Change ownership of data owned by a particular user.

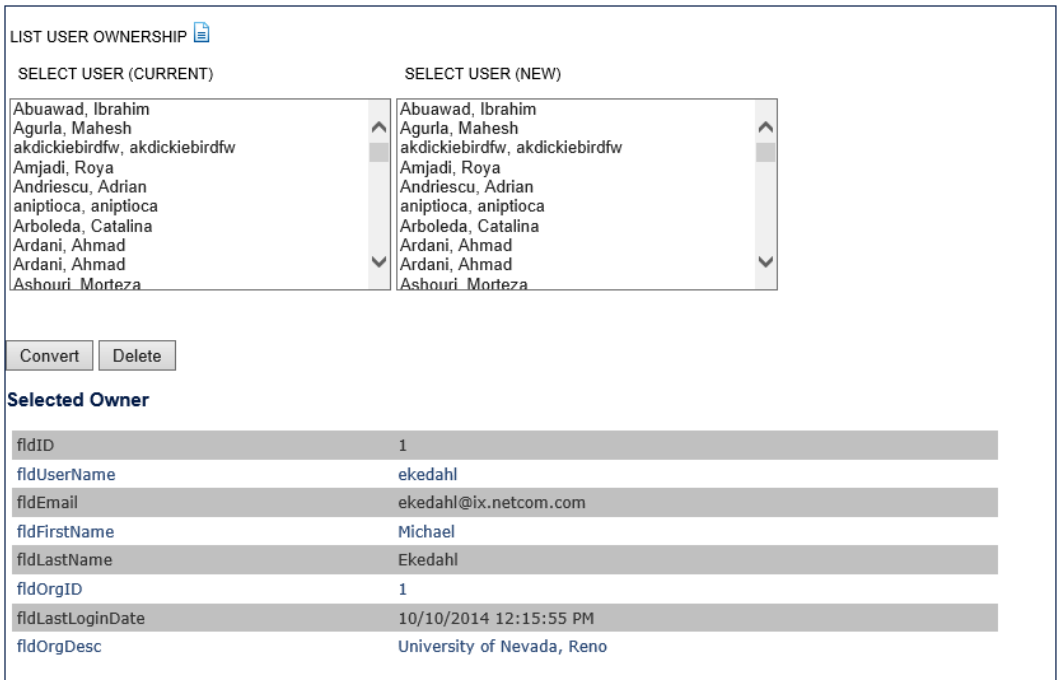


Figure TT1D.5: User ownership form

While testing the form, various test users were deleted along with some dummy data created by former students: Alex Fianacca, Jeremy Tweet, and Robert Dittmer.

A second script is being developed that will delete only transactional data for a particular user. Two more scripts are being developed.

- A script that will be delete all transactional data, and the transactional data for a specific user
- A script that will be delete all master data, and the master data owned by a particular user.

8. Creating of Testing Organization and Testing Standards

In the ARC project, members have expressed a need to associate data points with testing organizations and the standard tests defined by those organizations. The following tables were created to support testing:

- **tblTestOrganization** has fields named fldTestOrgID, fldTestOrgCode, and fldTestOrgDescription, and is designed to describe an organization that defines material and other tests and testing standards.
- **tblTestStandard** has fields named fldTestStdID, fldTestOrgID, fldTestCode, fldTestDescription, fldTestComment, fldTestValidFrom, and fldtestValidTo. Its purpose

store names and descriptions of the material or other tests applicable to a testing organization.

The form named TestOrganization.aspx is used to manage these two tables. The first section is used to add, change, and delete testing organizations. The second section is used to add, change, and delete the testing standards applicable to the selected testing organization. The following figure shows the TESTING ORGANIZATION section.

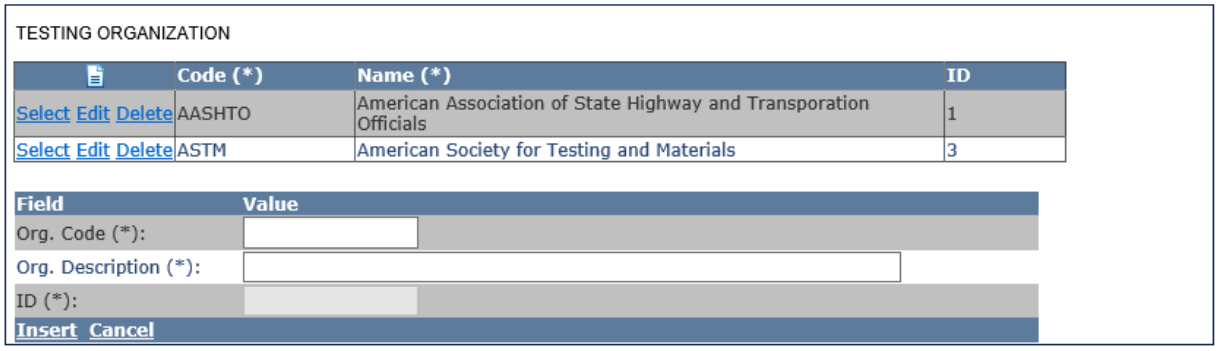


Figure TT1D.6: Test Organization Form – TESTING ORGANIZATION section

Validation is performed on the required code and description fields.

The second part of the form is used to display and edit testing standards applicable to the selected testing organization. The following figure shows the TESTING STANDARDS section:

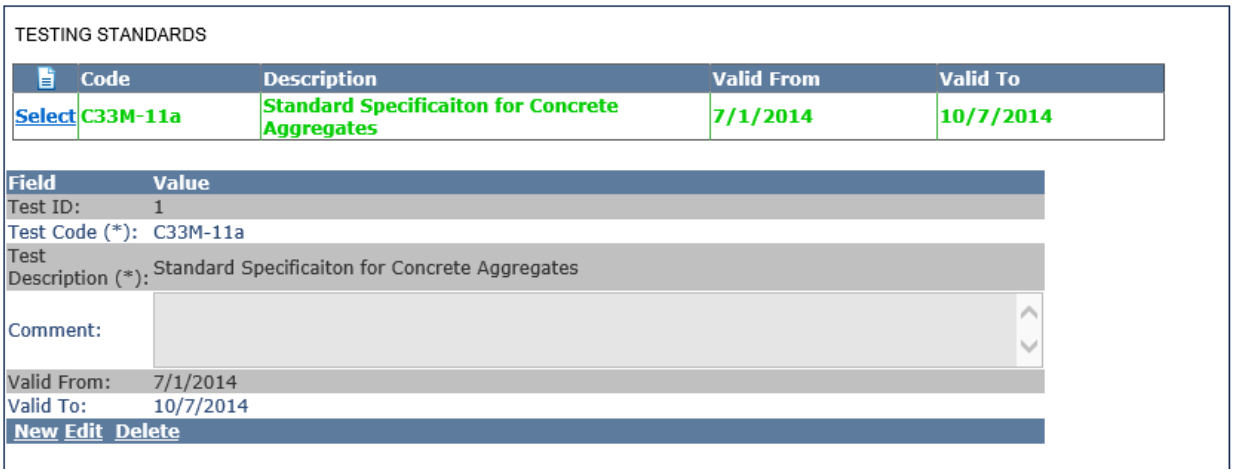


Figure TT1D.6: Test Organization Form – TESTING STANDARD section

At the time of this writing, associations between testing organizations and testing standards is being defined.

9. Preparations and outcomes of the 10-1 10-2 PRDS meeting

A meeting was held with the UNR ARC team, members of the Turner-Fairbanks lab staff, and IT personnel, to review the ARC database the functional specifications for the PRDS are developed. The two-day meeting was organized into four sessions. Each session was broken up into a

presentation, hands-on exercise, and round table discussion. The following list summarizes topics of the four sessions.

- Session 1: Summarize the technologies used in the ARC database and ARC application. Discuss the database schema and the tools designed to access it. Discuss the role and user management system.
- Session 2: Overview of the ARC master data system. Property groups, properties, material types and materials, pavement sites, and other data.
- Session 3: The file upload and management system was discussed.
- Session 4: The measurement system was discussed

The following list summarizes selected meeting outcomes:

Materials

Standardized material naming conventions will need to be developed so as to easily locate materials and mixes to support searching and reduce entry of duplicate materials.

Materials will need to be enhanced so as to store the ratio of material in mixes. A mechanism is needed to cope with material aging. Additional fields might need to be added to the material records including Lot number, date, truck, quantity-on-hand and original quantity delivered, and materials storage location. Note that there was some discussion of material inventory tracking. The general sentiment did not support this feature.

Material testing sample size was discussed. The system will need to handle small and large sample sizes.

The ARC system presently has tables listing testing methods. There was discussing of how to better integrate standard tests and testing methods with the PRDS system.

Projects

Most FHWA work is based on the notion of a project. The team did not decide the exact data points to be collected about a project. However, the following were suggested:

- Date project started and date completed.
- Keywords
- Which lab is working on the project?
- Fields to support searching for old projects were suggested.

Projects might link to:

- Materials used by the project.
- Measures for the project
- Support files relevant to the project.

Pavement site or test section related to the project.

Other items

- FHWA has PDF forms for some standardized tests. These forms generally correspond to AASHTO or ASTM tests. There was discussion of implementing these forms for data entry. However, not all labs use these PDF forms.

- The ARC notion of a work task will need to be reworked or might be abandoned entirely. The work task concept was unique to the ARC grant deliverables. The feature might be used to organize projects though.
- The design of the ARC system involved tests of materials and pavement sites. PRDS will center testing on projects. Some tests are not material or pavement site related. These types of tests might involve energy consumption data, bridge hinge determination, or other tests. The question was raised how to handle these unique test types and possible properties for these tests.
- The participants agreed with some form of data approval process. Suggests were made to create a notification system should be implemented indicating that data was awaiting approval. Possible solutions include e-mail to responsible supervisor or notification upon login to the system.
- The role system will need to be modified to support peer collaboration. That is, multiple people should be able to edit files in the same work group. How will the role system interact with UPACS (SP)?

10. Significant Results (Summary Lists for Measures and Reports)
The following table shows the reports uploaded this quarter and the total reports uploaded for the ARC project.

Table TT1D.1: Summary reports / files contained in the ARC database

Organization	Q3 2014	Q2 2014	Q1 2014	Q4 2013	Q3 2013	Total Yr. 1-7
Ohio University						508
Texas A&M University			640	503		1853
University of Illinois						419
University of Nevada, Reno	7		5	1	2	1757
University of Wisconsin Madison			83	750		1682
Western Research Institute	3877				579	5423

11. Significant Results (Miscellaneous Enhancements)
The following enhancements were made this quarter.

- The Materials page (Materials.aspx) was updated along with the table named tblMaterials. Two new fields were added to the tabled named fldPackageType and fldPackageWeight. The package weight is validated to ensure that it contains a positive whole number. The announcements control was added to the page. I bug was fixed in the material selector. When a master category was selected, the control did not update the material type to show only the material types applicable to the selected master category.

The data definition page was updated accordingly. The following figure shows the revised Material Detail Editor:

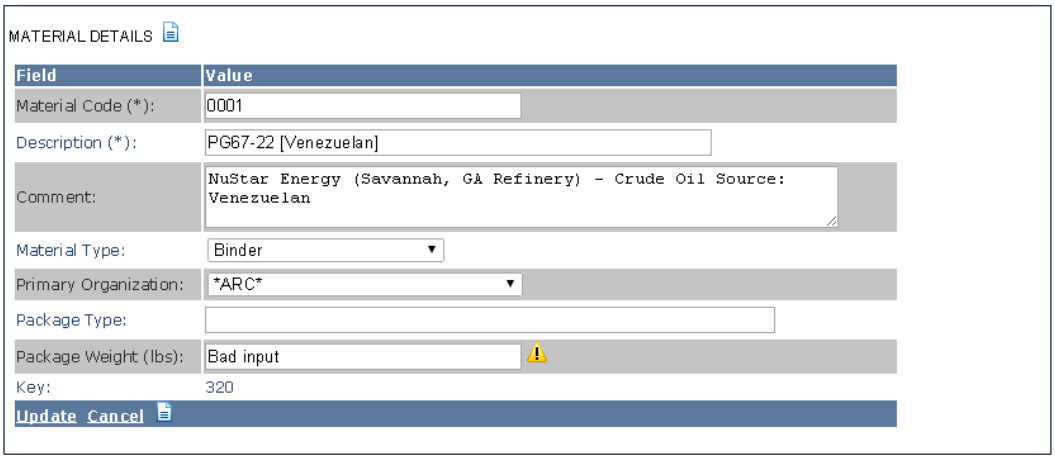


Figure TT1D.7: Revised material details

- Fixed a bug in the ManageUsers form. The form was not updating the failed password counter field properly.

12. Work planned for Next Quarter

The following work items are planned for next quarter:

- Complete the distress data subsystem
- Continue to work with the FHWA as they migrate to PRDS.
- Complete the role conversion for the remaining forms.
- Finish the SQL scripts to clean master and transactional data for the ARC database distribution backup.
- Import final batches of Texas A&M data.
- Revisit the FileLinker form and subsystem, as necessary (no activity reported this quarter)

REPORT L: DEVELOPMENT AND VALIDATION OF THE BITUMEN BOND STRENGTH TEST (BBS)

Included Work Elements/Subtasks

Work Element M1a: Affinity of Asphalt to Aggregate

Status and Work Planned

Complete

Work Completed: None. All work was completed in 2013Q3.

Work Planned: None.

Revised Delivery Dates
Draft Report: 10/30/11 (Submitted)
Final Report: 10/30/2013(Completed) (Revised – Extended from 6/30/2012, 9/30/2012, 3/30/2013, 6/30/2013, 9/30/2013)

REPORT M: DEVELOPMENT OF TEST PROCEDURES FOR CHARACTERIZATION OF ASPHALT BINDER FATIGUE AND HEALING

Included Work Elements/Subtasks
Work Element F1d: Healing
Subtask F1d-6: Evaluate Relationship Between Healing and Endurance Limit of Asphalt Binders
Work Element F2a: Binder Tests and Effect of Composition
Work Element F2e: Verification of the Relationship Between DSR Binder Fatigue Tests and Mixture Fatigue Performance

Status and Work Planned
Completed.

Work Completed: Addressed technical review comments and submitted final report. Section 508 document, Image Descriptions, and Tech Brief are also submitted.

Work Planned: None.

Revised Delivery Dates
Draft Report: 10/31/11 (Submitted)
Final Report: 3/31/2014 (Completed), (Revised from 10/31/13).

REPORT N: GUIDELINES FOR SELECTION OF MODIFICATION TECHNIQUES

Included Work Elements/Subtasks
Work Element E2a: Comparison of Modification Techniques
Work Element E3a: Effect of Extenders (such as Sulfur) and Alternative Binders (such as Bio-Binders) on Mixture Performance

Status and Work Planned
On Schedule

Work Completed: Submitted draft final report and Tech Brief. This is intended to be an NTIS report.

Work Planned: Address FHWA technical comments as needed.

Delivery Dates
Draft Report: 3/31/2014 (Complete), (revised from 9/30/2013, 12/31/2013)
Final Report: 6/30/2014, (revised from 3/31/2013), date pending receipt of technical review on draft report.

REPORT O: CHARACTERIZATION OF BINDER DAMAGE RESISTANCE TO RUTTING

Included Work Elements/Subtasks
Work Element E1b: Binder Damage Resistance Characterization (DRC)
Subtask E1b-1: Rutting of Asphalt Binders
Subtask E1b-2: Feasibility of Determining Rheological and Fracture Properties of Asphalt Binders and Mastics Using Simple Indentation Tests
Work Element V3f: Validation of the AASHTO MP-19 Specifications and Improvements of the TP-70 Procedure

Status and Work Planned
Completed.

Work Completed: Section 508 document and Image Descriptions to FHWA submitted.

Work Planned: None.

Delivery Dates
Draft Report: 9/30/2013 (Completed), extended from 6/30/2013
Final Report: 4/30/2014, (Revised from, 3/31/2014, 12/31/2013)

REPORT P: QUANTIFYING THE IMPACTS OF WARM MIX ASPHALT ON CONSTRUCTABILITY AND PERFORMANCE

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
Subtask E1c-1: Warm Mixes

Status and Work Planned
Behind Schedule

Work Completed: The draft report has been completed.

Work Planned: Submitting the draft final report after completion of internal review.

Reason for Delay
Additional time is requested to conduct internal review.

Delivery Dates
Draft Report: 11/01/2014 – extended from 9/30/2013, 3/31/2013, 12/31/2014
Final Report: 12/01/2014 – extended from 10/31/2013, 12/31/2013

REPORT Q: IMPROVEMENT OF EMULSION CHARACTERIZATION AND MIXTURE DESIGN FOR COLD BITUMEN APPLICATIONS

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
Subtask E1c-2: Improvement of Emulsions' Characterization and Mixture Design for Cold Bitumen Applications
Work Element E3b: Development of PG Specification for Emulsions used in Surface Treatments, Cold Mixes, and Cold-In-Place Recycled Mixes

Status and Work Planned
On Revised Schedule

Work Completed: The draft report is completed and will be submitted after internal revision.

Work Planned: Complete internal review of final report and submit.

Delivery Dates
Draft Report: 11/01/2014, from 9/30/2013, 12/31/2013
Final Report: 12/01/2014, from 3/31/2014

REPORT R: STUDIES ON TIRE-PAVEMENT NOISE AND SKID RESPONSE

Included Work Elements/Subtasks
Work Element VP2a: Mixture Design to Enhance Safety and Reduce Noise of HMA

Status and Work Planned
Complete.

Work Completed: Reviewer comments were addressed and final report was submitted to FHWA.

Work Planned: None, report considered complete.

Delivery Dates
Draft Report: 12/31/2011 (Submitted)
Final Report: 7/30/2013 (Submitted)

REPORT S: MOLECULAR DYNAMICS RESULTS FOR MULTIPLE ASPHALT CHEMISTRIES

This report will be delivered in non-508 format. A technical brief will be provided in section 508 format. Completing the report and uploading data into the ARC database has continued into the Oct-Dec quarter in part due to teaching pressures during overlap with the semester.

Included Work Elements/Subtasks

Subtask F3a-1: *ab initio* Theories, Molecular Mechanics/Dynamics and Density Functional Theory Simulations of Asphalt Molecular Structure Interactions
- Sub-subtask F3a-1.1. Specify desired asphalt compositions and chemistries for testing multiscale asphalt modeling effort (large cluster simulations) (URI, WRI)
- Sub-subtask F3a-1.2. Develop algorithms and methods for directly linking molecular simulation outputs and phase field inputs (URI, NIST)
- Sub-subtask F3a-1.3. Obtain temperature-dependent dynamics results for model asphalts that represent asphalts of different crude oil sources (URI)
- Sub-subtask F3a-1.4. Simulate changes in asphalt dynamics after inducing representations of chemical and/or physical changes to a model asphalt (URI)

Subtask F3a-4. Overall integration for multiscale modeling (VT, URI, and WRI)
Subtask F3a-5. Experimental verification and validation (VT, URI, and WRI)

Status and Work Planned

Sub-subtask F3a-1.1. Specify desired asphalt compositions and chemistries for testing multiscale asphalt modeling effort (large cluster simulations) (URI, WRI)

On Schedule.

Sub-subtask F3a-1.3. Obtain temperature-dependent dynamics results for model asphalts that represent asphalts of different crude oil sources (URI)

Continued delay during the past quarter with analyzing results for new systems.

Results from molecular simulations of model asphalts continued to be analyzed to obtain physical insights. A manuscript that described complex modulus results obtained from molecular dynamics simulation results was accepted and published in the *Journal of Chemical Physics* (M. Masoori and M.L. Greenfield, 141, 124504 (2014)). This paper compared calculated frequency-dependent modulus results for the new AAA-1 model system with results for an earlier AAA-1 model asphalt (pre-ARC) that contained molecules that are too small. The paper includes a direct comparison between molecular simulation results and the CAM model.

Uploading data to the ARC database was attempted during the Jul-Sept quarter. Appropriate data types and metadata were identified, but software compatibility issues with the Silverlight uploading tool (not available on the computers with the data) prevented uploading from occurring. That problem is being fixed, and data uploading will occur during the Oct-Dec

quarter. Communications with the ARC database group will occur to ensure appropriate metadata fields are in place.

Sub-subtask F3a-1.4. Simulate changes in asphalt dynamics after inducing representations of chemical and/or physical changes to a model asphalt (URI)

Continued delay during the past quarter.

Work to simulate additional asphalt systems continues to proceed more slowly than expected. These simulations are running during the new 6-month extension period.

Sub-subtask F3a-1.2. Develop algorithms and methods for directly linking molecular simulation outputs and phase field inputs (URI)
Subtask F3a-4. Overall integration for multiscale modeling (VT, URI, and WRI)
Subtask F3a-5. Experimental verification and validation (VT, URI, and WRI)

Technical work – Progress during past quarter.

These Subtasks and Sub-subtasks constitute the ARC Model Deliverable for obtaining free energy from a molecular perspective. The free energy will be obtained using an equation of state that balances chemical complexity with sufficient ease of use. Inputs include estimates of pure compound parameters. Estimates of some parameters will be obtained by comparing equation of state calculations to molecular simulation results.

Different correlations to estimate pure component boiling point and critical properties have been evaluated. The choice is being guided by results obtained by others for molecules for which pure component experimental data exist. That is not usually the case for molecules in asphalts.

The Model Deliverable itself will be a detailed description of the steps that can be taken to set up a model asphalt system, to run a molecular simulation, and to interpret the quantitative results. Report S focuses especially on interpreting the peer-reviewed publications in the asphalt chemistry and pavement literature into language and concepts that are most familiar to the asphalt pavement research community. The report will include detailed descriptions of the simulation data that will be included within the ARC database.

Results from the sequence of molecular simulations, interpretations, correlations, interpolations, and extrapolations will be incorporated into Report S. This includes relationships between the simulation conditions and the energy. Report T, entitled “Progress Toward a Multi-scale Model of Asphalt Pavement- Including Test Methods for Model Input Parameters”, will be written primarily by Troy Pauli of WRI.

REPORT T: PROGRESS TOWARD A MULTI-SCALE MODEL OF ASPHALT PAVEMENT

Included work elements/subtasks
Sub-subtask F3a-1.5. Molecular mechanics simulations of asphalt-aggregate interfaces (VT)
Sub-subtask F3a-1.6. Modeling of fatigue behavior at atomic scale (VT)
Sub-subtask F3a-1.7. Modeling of moisture damage (VT)
Sub-subtask F3a-1.8. *ab initio* Calculations of Asphalt Molecular Structures and Correlation to Experimental Physico-Chemical Properties of SHRP Asphalts (WRI-TUDelft)
Subtask F3a-2. Multiscale modeling based on phase field method and MD simulation (VT)
Sub-subtask F3a-2.1. Multiscale modeling of single mode cracking (VT)
Sub-subtask F3a-2.2. The generalized J – integral in multiscale modeling (VT)
Sub-subtask F3a-2.3. Multiscale modeling of Phase separation (VT)
Sub-subtask F3a-2.4. Potential multiscale applications (VT)
Subtask F3a-3. Phase-Field and Continuum Mechanical (Finite Element) Modeling of Asphalt Binder, a Unified Chemo-Mechanical Model of Asphalt Binder
Subtask F3a-4. Overall integration for multiscale modeling (VT, URI, TUDelft and WRI)
Subtask F3a-5. Experimental verification and validation (VT, URI, TUDelft and WRI)

Status and Work Planned for Work Element F3a:
Report T is delayed and requires an extension to the end of the next quarter.
Draft Report for Report T will be submitted in 508 format by October 31, 2014.
This report will include an appendix describing how to implement phase-field simulations in the software package COMSOL.

REPORT U: DESIGN GUIDANCE FOR FATIGUE AND RUT RESISTANCE MIXTURES

Included Work Elements/Subtasks
Work Element E2e: Design Guidance for Fatigue and Rut Resistance Mixtures

Status and Work Planned
Behind Schedule

Both the NTIS report and the FHWA Tech Brief were completed. The NTIS report was submitted 7/21/2014. The FHWA Tech Brief was submitted 10/7/2014.

The report and Tech Brief will be revised based on comments received.

REPORT V: CONTINUUM DAMAGE PERMANENT DEFORMATION ANALYSIS FOR ASPHALT MIXTURES

Status: The report is completed and submitted to FHWA for review.

REPORT W: CHARACTERIZATION OF FATIGUE AND HEALING PROPERTIES OF ASPHALT MIXTURES

Status: The report is completed and submitted to FHWA for review.

REPORT X: CHARACTERIZATION OF FIELD CORES OF ASPHALT PAVEMENTS

Status: The report is completed and submitted to FHWA for review.

REPORT Y: MODEL WATER VAPOR DIFFUSION IN PAVEMENT AND ITS EFFECTS ON THE PERFORMANCE OF ASPHALT MIXTURES

Status: A revised version of this report is submitted to FHWA for review after the authors addressed the comments provided earlier by FHWA.

REPORT Z: EFFECT OF EXTRACTION METHODS ON THE PROPERTIES OF AGGREGATES IN RECLAIMED ASPHALT PAVEMENT

Included Work Elements/Subtasks
Work Element E2b: Design System for HMA Containing a High Percentage of RAP Material
Subtask E2b-1: Develop a System to Evaluate the Properties of RAP Materials

Status and Work Planned
Completed.

In this quarter, no additional technical or editorial comments were requested from FHWA on Report Z.

REPORT AA: LABORATORY ASSESSMENT OF ASPHALT MIXTURE LONG-TERM AGING

Included Work Elements/Subtasks
Work Element E3c: Laboratory Assessment of Asphalt Mixture Long-term Aging

Status and Work Planned
Completed.

Work Completed: Submitted draft final report and Tech Brief to FHWA.

Work Planned: Address comments as needed.

Delivery Dates
Draft Report: 3/31/2014 (Completed), revised from 9/30/2013, 12/31/2013
Final Report: 6/30/2104

REPORT AB: SUMMARY REPORT ON ARC COMPARATIVE PAVEMENT TEST SECTIONS

Included Work Elements/Subtasks
Work element V1b, Construction and Monitoring of Additional Comparative Pavement Validation Sites

Status and Work Planned
Behind Schedule, The preparation of this report is in progress.
Draft delivery date for this report is scheduled for November 30, 2014.

REPORT AC: SUMMARY REPORT ON NCAT WARM-MIX PAVEMENT TEST SECTIONS

Included Work Elements/Subtasks
Work element V1a, Use and Monitoring of Warm Mix Asphalt Sections

Status and Work Planned
On Schedule, The preparation of this report is in progress.
Draft delivery date for this report is scheduled for November 30, 2014.

REPORT AD: EXECUTIVE SUMMARY REPORT: ARC HISTORY, PARTICIPANTS AND ACCOMPLISHMENTS

Included Work Elements/Subtasks
ALL

Status and Work Planned
Behind Schedule. The preparation of this report is ongoing.
Draft delivery date for this report is scheduled for November 15, 2014.

REPORT AE: (New Report) SUPERPAVE MIX DESIGN FOR COLD IN-PLACE RECYCLING (CIR)

Included Work Elements/Subtasks
Work Element E1c-2: Improvement of Emulsion Characterization and Mixture Design for Cold Bitumen Applications

Status and Work Planned
This report is a new addition to the deliverables. Due to the increase in the scope of work for CIR mix design and evaluation a separate and independent report from Report Q was deemed necessary.

TEST METHODS

DRAFT AASHTO METHOD/PRACTICE: SIMPLIFIED CONTINUUM DAMAGE FATIGUE ANALYSIS FOR THE ASPHALT MIXTURE PERFORMANCE TESTER

Included Work Elements/Subtasks
Work Element E2e: Design Guidance for Fatigue and Rut Resistance Mixtures

Status and Work Planned
Behind schedule

The draft practice was included in Task U Report.

No additional work is planned.

TEST METHOD AND MODEL: CONTINUUM DAMAGE PERMANENT DEFORMATION ANALYSIS FOR ASPHALT MIXTURES

Included Work Elements/Subtasks
Work Element F2c: Mixture Testing Protocol (TAMU)
Work Element E1a: Analytical and Micro-mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Model "Continuum Damage Permanent Deformation Analysis of Asphalt Mixtures" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Model has been attached to and referenced in the Level 2 Report V "Continuum Damage Permanent Deformation Analysis for Asphalt Mixtures" as an appendix.

TEST METHOD AND MODEL: CHARACTERIZATION OF FATIGUE AND HEALING PROPERTIES OF ASPHALT MIXTURES

Included Work Elements/Subtasks
Work Element E1a: Analytical and Micro-mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Model "Characterization of Fatigue and Healing Properties of Asphalt Mixtures" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Model has been attached to and referenced in the Level 2 Report W "Characterization of Fatigue and Healing Properties of Asphalt Mixtures" as an appendix.

TEST METHOD AND ANALYSIS PROGRAM: NONDESTRUCTIVE CHARACTERIZATION OF TENSILE VISCOELASTIC PROPERTIES OF UNDAMAGED ASPHALT MIXTURES

Included Work Elements/Subtasks
Work Element E1a: Analytical and Micro-Mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Model "Nondestructive Characterization of Tensile Viscoelastic Properties of Undamaged Asphalt Mixtures" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Model has been attached to and referenced in the Level 2 Report W "Characterization of Fatigue and Healing Properties of Asphalt Mixtures" as an appendix.

TEST METHOD AND MODEL: CHARACTERIZATION OF FIELD CORES OF ASPHALT PAVEMENTS

Included Work Elements/Subtasks
Work Element E1a: Analytical and Micro-mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Model "Characterization of Field Cores of Asphalt Pavements" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Model has been attached to and referenced in the Level 2 Report X "Characterization of Field Cores of Asphalt Pavements" as an appendix.

TEST METHOD AND ANALYSIS PROGRAM: NONDESTRUCTIVE CHARACTERIZATION OF ANISOTROPIC VISCOELASTIC PROPERTIES OF UNDAMAGED ASPHALT MIXTURES UNDER COMPRESSIVE LOADING

Included Work Elements/Subtasks
Work Element F2c: Mixture Testing Protocol (TAMU)
Work Element E1a: Analytical and Micro-mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Analysis Program "Nondestructive Characterization of Anisotropic Viscoelastic Properties of Undamaged Asphalt Mixtures under Compressive Loading" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Model has been attached to and referenced in the Level 2 Report V "Continuum Damage Permanent Deformation Analysis for Asphalt Mixtures" as an appendix.

DRAFT AASHTO PRACTICE: MIX DESIGN FOR COLD-IN-PLACE RECYCLING (CIR)

Included Work Elements/Subtasks
Work Element E1c-2: Improvement of Emulsion Characterization and Mixture Design for Cold Bitumen Applications

Status and Work Planned
The following list describes the work items completed this quarter:

- Using local material from a recently constructed project, a new mix design was conducted on Matterhorn RAP material using 0.5% Cement according to the proposed CIR mix design procedure.
- Moisture susceptibility test (AASHTO T283) was conducted on all selected combinations of emulsion and water content for the Matterhorn materials using 0.5% cement and without additives.

The following list describes the work planned for next quarter:

- Continue additional Moisture Susceptibility test (AASHTO 283) for the CIR Matterhorn at different freeze-thaw cycles for all three mixes using lime, cement and without additives.
- Continue the performance related tests for the mix design using 0.5% cement and without additives.

DRAFT AASHTO METHOD/PRACTICE: MIX DESIGN FOR COLD MIX ASPHALT

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
SubtaskE1c-2: Improvement of Emulsions' Characterization and Mixture Design for Cold Bitumen Applications
Subtask E1c2-Yr6-I: Protocol for Selecting Aggregates and Emulsions for CMA
Subtask E1c2-Yr6-II: Evaluation of CMA Laboratory Compaction Methods and Curing Conditions

Statusand Work Planned
Behind Schedule

Work Completed: All experimental work related to development of standard as well as the AASHTO standard are completed.

Work Planned: Performing internal review for submission.

Reasons for Delay:
Submission of standard was extended to coincide with revised delivery date of draft final report.

Delivery Dates
Draft AASHTO Practice: 11/01/2014, from 5/30/2014
Final AASHTO Practice: 12/01/2014, from 6/30/2014

DRAFT AASHTO PRACTICE: EVALUATION OF RAP AGGREGATES

Included Work Elements/Subtasks
Work Element E2b: Design System for HMA Containing a High Percentage of RAP Materials
Subtask E2b-1: Develop a System to Evaluate the Properties of RAP Materials

Status and Work Planned
On Schedule.

The findings from the report entitled: "Effect of Extraction Methods on the Properties of Aggregates in Reclaimed Asphalt Pavement," were considered in the final recommendations of NCHRP 09-46 study completed by NCAT.

DRAFT AASHTO PRACTICE: DETERMINING ASPHALT MIXTURE CRITICAL CONDITIONS FOR RUTTING EVALUATION BY MEANS OF DYNAMIC REPEATED LOAD TRIAXIAL (RLT) TEST

Included Work Elements/Subtasks
Work Element E2c: Critically Designed HMA Mixtures

Status and Work Planned
Completed.

DRAFT AASHTO METHOD: DETERMINING THERMAL CRACK PROPERTIES OF ASPHALT MIXTURES THROUGH MEASUREMENT OF THERMALLY INDUCED STRESS AND STRAIN

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States
Subtask E2d-3: Identify an Evaluation and Testing System

Status and Work Planned
On Schedule.

The draft AASHTO Standard has been completed. The following list describes the on-going and completed work items:

- Continue working with a manufacturer/supplier company to modify its TSRST setup to meet the UTSST requirements.
- Revise and refine the UTSST AASHTO draft as needed.

DRAFT AASHTO METHOD/PRACTICE: DETERMINING ASPHALT BINDER BOND STRENGTH BY MEANS OF THE BINDER BOND STRENGTH TEST

Included Work Elements/Subtasks
Work Element M1a: Affinity of Asphalt to Aggregate

Status and Work Planned
Completed

Work Completed: None, product was completed last quarter.

Work Planned: None planned, product considered complete.

Delivery Dates
Revised Standard: 6/30/2013 (Complete)

DRAFT AASHTO TEST METHOD: MEASUREMENT OF ASPHALT BINDER ELASTIC RECOVERY IN THE DYNAMIC SHEAR RHEOMETER (DSR)

Included Work Elements/Subtasks
Work Element F2a: Binder Tests and Effect of Composition

Status and Work Planned
Completed

Work Completed: Product combined with BYET procedure. Please see BYET report for details.

Work Scheduled: Please see BYET report for details

Delivery Dates
Completed, see BYET report for delivery dates.

AASHTO TEST METHOD: ESTIMATING FATIGUE RESISTANCE OF ASPHALT BINDERS USING THE LINEAR AMPLITUDE SWEEP

Included Work Elements/Subtasks
Work Element F2e: Verification of the Relationship between DSR Binder Fatigue Tests and Mixture Performance

Status and Work Planned
Complete

Work Completed: Presented update to Asphalt Binder ETG regarding new failure criteria and updated ruggedness testing results.

Work Planned: Work item is considered complete. Any comments by AASHTO or ETG for implementation will be addressed.

Delivery Dates

Submit Revised Draft AASHTO Method to ETG: Completed.
Presentation at FHWA Binder ETG Meeting: 5/02/2013 (Complete)
Presentation at FHWA Binder ETG Meeting: 9/17/2013 (Complete)
Final AASHTO Method: 9/30/2013 (Complete), based on new findings and ETG comments (Extended from 6/30/2013)

AASHTO TEST METHOD: BINDER YIELD ENERGY TEST (BYET)

Included Work Elements/Subtasks
Work Element F2e: Verification of the Relationship between DSR Binder Fatigue Tests and Mixture Performance

Status and Work Planned
Completed.

Work Completed: Draft of combined ER-DSR and BYET procedures were submitted to the AASHTO SOM by FHWA for consideration in the August 2013 meeting.

Work Scheduled: Product is considered complete. Comments from AASHTO will be addressed as necessary.

Delivery Dates
Draft AASHTO Method: 1/31/2013 (extended from 12/31/2012) (Complete)
Presentation at FHWA Binder ETG Meeting: 5/02/2013 (Complete)
Final AASHTO Method: 6/30/2013 (Complete)

DRAFT AASHTO TEST METHOD: MEASUREMENT OF RIGDEN VOIDS FOR MINERAL FILLERS

Included Work Elements/Subtasks
Work Element F2e: Verification of the Relationship between DSR Binder Fatigue Tests and Mixture Performance

Status and Work Planned
Completed

Work Completed: Response to comments received from AASHTO SOM was completed and sent to FHWA.

Work Planned: None. Product is considered complete.

Revised Delivery Dates
Draft AASHTO Method: Complete (1/31/2013).
Final AASHTO Method: Complete (9/30/2013).

DRAFT AASHTO TEST METHOD: MEASUREMENT OF ASPHALT BINDER LUBRICITY USING THE DYNAMIC SHEAR RHEOMETER (DSR)

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
Subtask E1c-1: Warm Mixes
Subtask E1c-1-Y6-I: Guideline for Determination of Mixing and Compaction Temperatures for Conventional HMA Mixes
Subtask E1c-1-Y6-II: Guideline for Determination of Acceptable WMA Production Temperatures

Statusand Work Planned
Behind Schedule

Work Completed: The draft AASHTO standard is completed.

Work Planned: Completing internal review, and submit to FHWA.

Reasons for Delay: Deadline extended to coincide with submittal of draft final report.

Delivery Dates
Draft AASHTO Method: 11/01/2014, from 6/30/2013, 3/31/2013, 9/30/2013, 12/31/2014
Final AASHTO Method: 12/01/2014 - from 9/30/2013, 12/31/2013

DRAFT AASHTO METHOD/PRACTICE: PROCEDURE FOR EVALUATION OF COATING FOR COLD MIX ASPHALT

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
SubtaskE1c-2: Improvement of Emulsions' Characterization and Mixture Design for Cold Bitumen Applications
Subtask E1c2-Yr6-I:Protocol for Selecting Aggregates and Emulsions for CMA

Status and Work Planned
Completed.

Work Completed: None. Product is considered completed.

Work Planned: None, product is considered complete. Address comments from FHWA/ETG as necessary.

Delivery Dates
Draft AASHTO Method: Completed 4/30/2013 – extended from 3/31/2013 and 12/31/2012
Presentation at FHWA Mixtures ETG Meeting (if necessary): N/A
Final AASHTO Standard: 9/30/2013 (Complete)

DRAFT AASHTO METHOD/PRACTICE: COLD MIX LABORATORY SPECIMEN PREPARATION USING MODIFIED SGC MOLDS

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
Subtask E1c-2: Improvement of Emulsions' Characterization and Mixture Design for Cold Bitumen Applications
Subtask E1c2-Yr6-II: Evaluation of CMA Laboratory Compaction Methods and Curing Conditions

Status and Work Planned
Completed.

Work Completed: None, product is considered complete.

Work Planned: None, product is considered complete.

Delivery Dates
Draft AASHTO Method: 8/30/2013 (Complete) – extended from 6/30/2012, 12/31/2012
Final AASHTO Standard: 12/31/2013 (Complete)

DRAFT AASHTO TEST METHOD: RAP BINDER PG TRUE GRADE DETERMINATION

Included Work Elements/Subtasks
Work Element E2b: Design System for HMA Containing a High Percentage of RAP Materials

Status and Work Planned
Completed.

Work Completed: Response to comments received from AASHTO SOM was completed and sent to FHWA.

Work Planned: None. Product is considered complete.

Delivery Dates
Draft AASHTO Test Method: Completed (9/30/2012)
Presentation at Mix ETG Meeting: Completed (4/30/2013).
Presentation at Binder ETG Meeting: Completed (9/20/2013)
Final AASHTO Test Method: Completed (6/30/2013)

AASHTO TEST METHOD: MEASUREMENT OF ASPHALT BINDER FRACTURE PROPERTIES USING THE SINGLE EDGED NOTCHED BENDING TEST

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States

Status and Work Planned
Completed.

Work Completed: None, this product is considered completed.

Work Planned: No additional work is planned this task is considered complete. Will address additional comments from ETG/FHWA as needed.

Delivery Dates
Draft AASHTO Method: Completed (9/30/2012)
Presentation at Binder ETG Meeting: 5/2/2013 (Completed)
Presentation at Binder ETG Meeting (if necessary): 9/20/2013
Final AASHTO Test Method: Completed (9/30/2013) (Extended from 6/30/2013)

DRAFT AASHTO TEST METHOD: TEST METHOD FOR MEASUREMENT OF THE GLASS TRANSITION TEMPERATURE OF ASPHALT BINDERS

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States

Status and Work Planned
Completed

Work Completed: None, no request for presentation was made by FHWA Binder ETG. Draft standard and context document were completed two quarters ago.

Work Planned: None, product is considered complete.

Delivery Dates
Draft AASHTO Test Method: Complete (1/31/2013)– extended from 12/31/2012
Presentation to Binder ETG (if necessary): 9/20/2013.
Final AASHTO Test Method: 6/30/2013, revisions pending ETG review and comment.

DRAFT AASHTO TEST METHOD: TEST METHOD FOR MEASUREMENT OF THE GLASS TRANSITION TEMPERATURE OF ASPHALT MIXTURES

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States

Status and Work Planned
Completed.

Work Completed: Combined ATCA/UTSST test method was completed and submitted to Mix ETG by UNR.

Work Planned: None planned under this product. UNR team has taken the lead in obtaining approval of combined test procedure from Mixture ETG.

Revised Delivery Dates
Draft AASHTO Test Method: 4/30/2013 (Completed)
Presentation to Mix ETG: 5/2/2013. (Completed)
Final AASHTO Test Method: 6/30/2013 (Completed)

DRAFT AASHTO TEST METHOD/PRACTICE: ANALYSIS OF ASPHALT MIXTURE AGGREGATE STRUCTURE THROUGH USE OF PLANAR IMAGING.
ARC MODELS AND/OR SOFTWARE: IMAGE PROCESSING AND ANALYSIS SYSTEM (IPAS^2)

Included Work Elements/Subtasks
Work Element E1b: Binder Damage Resistance Characterization (DRC)
SubtaskE1b-1: Rutting of Asphalt Binders

Status and Work Planned
Completed.

Work Completed: None, this product is considered completed.

Work Planned: None. This item is considered complete.

Delivery Dates
Draft AASHTO Method: 3/31/2013
Presentation to Mix ETG (if necessary): 9/20/2013
Final AASHTO Standard: 9/30/2013 (Complete)

DRAFT AASHTO METHOD/PRACTICE: DETERMINING THE RESISTIVE EFFORT OF ASPHALT MIXTURES DURING COMPACTION IN A GYRATORY COMPACTOR USING AN INTERNAL DEVICE

Included Work Elements/Subtasks
Work Element E1c: Warm and Cold Mixes
SubtaskE1c-1: Warm Mix Asphalt
Subtask E1c-2: Improvement of Emulsions' Characterization and Mixture Design for Cold Bitumen Applications

Status and Work Planned
Completed.

Work Completed: None, this product is considered completed.

Work Planned: None planned at this time.

Delivery Dates
Draft ASTM Standard: Complete
Finalize ASTM Standard: Complete 12/31/2013
Complete Precision and Bias StatementP&B Statement: 3/31/2014 (Completed) (extended from 6/30/2013, 9/30/2013, 12/31/2014).

TEST METHOD AND ANALYSIS PROGRAM: SELF-CONSISTENT MICROMECHANICS MODELS OF ASPHALT MIXTURES

Included Work Elements/Subtasks
Work Element E1a: Analytical and Micro-mechanics Models for Mechanical Behavior of Mixtures (TAMU)

Status and Work Planned
Status: Completed.

The Test Method and Analysis Program "Self-Consistent Micromechanics Models of Asphalt Mixtures" has been completed by the Research Team and has been edited by the Research Editor of the Texas A&M Transportation Institute.

The edited Test Method and Analysis Program has been attached to and referenced in the Level 2 Report W "Characterization of Fatigue and Healing Properties of Asphalt Mixtures" as an appendix.

DRAFT AASHTO METHOD: A METHOD TO DETERMINE SURFACE ROUGHNESS OF AGGREGATE AND FINES BASED ON AFM

Included Work Elements/Subtasks
M1b-2: Work of Adhesion at Nano-Scale using AFM

Status and Work Planned
A draft AASHTO method for the determination of micro-scale aggregate surface roughness by AFM has been completed and is currently being reviewed in-house. Development of the method which characterizes aggregate surfaces in terms of six standard roughness parameters was completed this quarter, and the method was subsequently used to characterize the micro-scale roughness for a set of four different aggregates. Based upon the work with these four aggregates the method was adjusted somewhat, mainly in terms of collecting and selecting images that are appropriate for this measurement. A draft AFM micro-scale surface roughness method has been developed, reviewed, tested, and revised. The method is currently undergoing a final review.

A draft AASHTO method for the determination of micro-scale aggregate surface roughness will be submitted next quarter.

DRAFT AASHTO METHOD: A METHOD TO DETERMINE DUCTILE-BRITTLE PROPERTIES VIA AFM

Included Work Elements/Subtasks
M1b-2: Work of Adhesion at Nano-Scale using AFM
M2a-2: Work of Cohesion at Nano-Scale using AFM

Status and Work Planned
A draft AASHTO method for the determination of ductile brittle transition temperature by AFM was reviewed in-house this past quarter. The in-house review brought up a question that required some additional experimental work. This experimental work was completed this quarter and the method has been modified based upon the results of this work. A draft AASHTO method for determining the ductile-brittle transition temperature using AFM has been developed, reviewed, tested, and revised. The method is currently undergoing a final review.

A draft AASHTO method for determining the ductile-brittle transition temperature using AFM will be submitted next quarter.

DRAFT AASHTO METHOD: AFM-BASED MICRO/NANO-SCALE CYCLIC DIRECT TENSION TEST

Included Work Elements/Subtasks
M1b-2: Work of Adhesion at Nano-Scale using AFM
M2a-2: Work of Cohesion at Nano-Scale using AFM

Status and Work Planned
A draft AASHTO method has been completed.

DRAFT AASHTO METHOD: CHIP ADHERENCE STABILITY TEST APPARATUS

Included Work Elements/Subtasks
New work element designed to generate apparatus for a scaled-up adhesion test based upon the micro/nano-scale AFM adhesion test

Status and Work Planned
A prototype adhesion test apparatus has been completed.

DRAFT AASHTO METHOD: CYCLIC DIRECT TENSION TEST FOR BINDER AND MASTIC FATIGUE

Included Work Elements/Subtasks
Sub-subtask F3a-1.6. Modeling of fatigue behavior at atomic scale (VT)
Sub-subtask F3a-2.1. Multiscale modeling of single mode cracking (VT)
Sub-subtask F3a-2.2. The generalized J – integral in multiscale modeling (VT)

Status and Work Planned
A cyclic direct tension test has been developed that can provide direct evaluation of fatigue for binder and mastic. This test provides parameter inputs for phase field models which simulate fatigue and healing in asphalt binders and mastics.
A draft AASHTO method will be submitted to FHWA for review by October 30, 2014.

DRAFT AASHTO METHOD/PRACTICE: MEASUREMENT AND TEXTURE SPECTRAL ANALYSIS OF PAVEMENT SURFACE PROFILES USING A LINEAR STATIONARY LASER PROFILER (SLP)

Included Work Elements/Subtasks
Work Element VP-2a: Mixture Design to Enhance Safety and Reduce Noise in HMA

Status and Work Planned
Completed

Work Completed: Standard was not pursued by FHWA. Test procedure has been used for other research projects.

Work Planned: None planned; AASHTO Standard was included in an Appendix in Report R.

Delivery Dates
Draft AASHTO Method: Complete (9/30/2012)
Final AASHTO Standard: Complete (6/30/2013), extended from 3/31/2013

MODELS AND SOFTWARE

MODEL: HMA THERMAL STRESSES IN PAVEMENT

Included Work Elements/Subtasks
Work Element E2d: Thermal Cracking Resistant Mixes for Intermountain States

Status and Work Planned
On Schedule.

The following list describes the work items completed or in progress this quarter:

- The alfa-version of the Thermal Cracking Analysis Package (TCAP) model has been finalized in MATLAB®. TCAP allows for the calculation of thermal stresses over years of a pavement in service while taking into consideration pavement temperature history and the aging effect of asphalt material properties.
- The stand-alone software TEMPS for predicting pavement temperature profile and history has been completed. The new time-efficient software program TEMPS allows for the prediction of the hourly temperature history at any depth in the asphalt pavement for any location in the United States. The software, called Temperature Estimate Model for Pavement Structures (TEMPS), make use of the Finite Control Volume Method (FCVM) with the fully implicit scheme to remedy some of the known limitations in the current pavement temperature profile models. TEMPS suggests the use of meteorological data such as solar radiation and considers monthly variation in pavement surface radiation properties (albedo, emissivity, and absorption coefficients). The implemented improvements led to accurate predictions of pavement temperature profiles as was validated for selected LTPP SMP sites. The TEMPS model is a unique software and can have numerous applications in pavement engineering. For instance, accurate prediction of pavement temperatures, over time and with depth, is critical particularly in mechanistic modeling of thermal cracking.
- The findings and both the TCAP and TEMPS software were presented at the FHWA Binder and Mix ETG meetings in Baton Rouge, LA on September 16-19, 20014.

The following list the work planned for next quarter:

- Refine the alfa-version of the Thermal Cracking Analysis Package (TCAP).
- Calibrate the TEMPS software using LTPP data and NCAT test track data for pavement temperature profiles.

SOFTWARE: DYNAMIC MODEL FOR FLEXIBLE PAVEMENTS 3D-MOVE

Included Work Elements/Subtasks
Work Element VP3a: Pavement Response Model to Dynamic Loads

Status and Work Planned
On Schedule. The work relative to 3D-Move Analysis Software during this period continued along two directions. One focused on continued modifications and corrections (bugs) for current version (Version 3). The other was devoted to preparing the Report J.

The following is a list work elements planned for next quarter:

- Completed the Final Report and the 3D-Move documentation;
- Assist users with issues ranging from usage questions, concepts clarifications, and bugs;
- Continue working the new platform for next version of 3D-Move (Ver. 3);
- Keep maintaining the 3D-move forum.

MODEL: PHASE FIELD SIMULATION OF FATIGUE AND HEALING

Included Work Elements/Subtasks
Subtask F3a-2. Multiscale modeling based on phase field method and MD simulation (VT)
Sub-subtask F3a-2.1. Multiscale modeling of single mode cracking (VT)
Sub-subtask F3a-2.2. The generalized J – integral in multiscale modeling (VT)
Sub-subtask F3a-2.3. Multiscale modeling of Phase separation (VT)
Sub-subtask F3a-2.4. Potential multiscale applications (VT)
Subtask F3a-3. Phase-Field and Continuum Mechanical (Finite Element) Modeling of Asphalt Binder, a Unified Chemo-Mechanical Model of Asphalt Binder

The commercial finite element code COMSOL Multiphysics is used to calculate the phase-field application in asphalt computational analysis. The system, simulated asphalt binder, is simulated as the coupling of phase-fields and stress fields, where the Phase-field is calculated by a Mathematics Module while stress field is calculated by a Structural Module in COMSOL.

Status and Work Planned
Completed.
This model will be published as an appendix in Report T: Progress Toward a Multi-Scale Model of Asphalt Pavement.

OTHER RESEARCH ACTIVITIES

Subtask E2b-2: Compatibility of RAP and Virgin Binders

Work Done This Quarter
Results from this work have been published.

Shin-Che Huang, Adam T. Pauli, R. Will Grimes & Fred Turner (2014): Ageing characteristics of RAP binder blends – what types of RAP binders are suitable for multiple recycling? *Road Materials and Pavement Design*, DOI: 10.1080/14680629.2014.926625.

Status and Work Done This Quarter
Complete

Work Planned Next Quarter
None

Work Element E3a: Effects of Extenders and Alternative Binders on Performance

Work Done This Quarter
Chapter related to extenders was included in Report N, which was submitted to FHWA in draft form this quarter.

Work Planned Next Quarter
Address comments as needed.

Proposed Research Product and Timeline
Results were added as a number of chapters to Report N: Guidelines for Selection of Modification Techniques.

Due Date for Draft Report Submittal: See Report N.
Due Date for Final Report Submittal: See Report N.

Significant Problems, Issues and Potential Impact on Progress
None.

Work Element E3b: Development of a PG Specification for Emulsions used in Surface Treatments, Cold Mixes, and Cold-In-Place Recycled Mixes

Work Done This Quarter
The report has been completed as part of the draft version of report Q which will be presented after internal review in the next month.

Work Planned Next Quarter
Completing internal review and deliver draft final report.

Proposed Research Product and Timeline
Results will be summarized as part of Report Q: Improvement of Emulsion Characterization and Mixture Design for Cold Bitumen Applications
Due Date for Draft Report Submittal: 11/01/2014, extended from 9/30/2013, 12/31/2103, 3/31/201
Due Date for Final Report Submittal: 12/01/2014

Significant Problems, Issues and Potential Impact on Progress
None, on revised schedule.

Work Element E3c: Laboratory Assessment of Mixture Long Term Aging

Work Done This Quarter
Completed draft final report.

Work Planned Next Quarter
See report AA.

Proposed Research Product and Timeline
Results will be summarized in a final report titled: "Laboratory Assessment of Long Term Aging of Asphalt Mixtures" it is proposed this deliverable be labeled as "Report AA."

Due Date for Draft Report Submittal: See Report AA.
Due Date for Final Report Submittal: See Report AA.

Significant Problems, Issues and Potential Impact on Progress

Work element V1a: Use and Monitoring of Warm Mix Asphalt Sections

Work Done This Quarter
Laboratory testing at NCAT has been completed, and test data have been compiled for all the field projects. A final report is being prepared for each test site.

Work was performed at WRI on preparing a compilation of the pavement distress data and material properties on all the test sites, which includes a number of WMA sites, for upload to the ARC database and for inclusion in an ARC final report summarizing the validation site study.

Work Planned Next Quarter
NCAT will continue to work on a final report for each test site constructed for this work element.

WRI presented a paper on the Universal Simple Aging Test (USAT) at the June 2014 ISAP conference. The paper reports a new method for simulating the short term aging of WMA binder in the laboratory. Part of the USAT study was performed with ARC validation site materials.

[Farrar, M. J., J-P. Planche, R. W. Grimes, and Q. Qin, 2014, The Universal Simple Aging Test (USAT): Simulating short- and long term hot and warm mix oxidative aging in the laboratory. Chapter 9 in *Asphalt Pavements*, Y. R. Kim, Ed., CRC Press, Taylor & Francis Group, London, pp. 79-87. http://www.crcnetbase.com/doi/abs/10.1201/b17219-17]

Work element V1b: Construction and Monitoring of Additional Comparative Pavement Validation Sites

Work Done This Quarter
WRI is continuing compilation of the pavement distress data and material properties on all the validation test sites, which includes a number of WMA sites, for upload to the ARC database and for inclusion in an ARC final report summarizing the validation site study.

Work Planned Next Quarter
WRI is finalizing the compilation of the pavement distress data and material properties on all the test sites, which includes a number of WMA sites, for upload to the ARC database and for inclusion in an ARC final report summarizing the validation site study. The validation site study will include an in-depth analysis of the thermal cracking that has occurred on the MN site (const. 2006) and the AZ site (const 2001)