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INTRODUCTION

This document is the Quarterly Report for the period of April 1 to June 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 33 Reports, 43 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, which constitutes 73% of the anticipated project deliverables. 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 April 1 to June 30, 2014, is the first 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	8/30/2014	9/30/2014	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	11/30/2014	UNR	Sebaaly Hajj	3 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	9/30/2014 (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	8/31/2014	9/31/2014	WRI/VT/ URI/TUD	Pauli	3 month extension of draft report deadline requested.
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	8/15/2014		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.

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	Hanz	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.	9/15/2014	10/15/2014	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	9/15/2014	9/30/2014	WRI	Grimes	Will be subject of Tech. Pub., Discussed in Report T
AASHTO Method	Test method to determine ductile-brittle properties via AFM measurements	8/31/2014	9/15/2014	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	Wang	Extension Requested Detailed in Report T
Software	PANDA Software (Pavement Analysis using a Nonlinear Damage Approach)	8/15/2014		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 August 29th, 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:

In a recent teleconference with Mr. Eric Weaver on July 21st, our team discussed capabilities and status of PANDA. We are preparing a white paper that will be delivered to Mr. Weaver by August 8, 2014. The white paper will discuss: 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.

- **PANDA chapter**

The PANDA chapter in the comprehensive summary report was completed during this quarter. The focus of the current and next quarter will be on addressing the FHWA comments on PANDA report and chapter.

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

During this quarter, ARC team finalized the PANDA Parameter Identifier (PPI) package. The focus of this quarter will be on making final refinements to PPI to be delivered to the FHWA.

- **Further validation of PANDA**

During this quarter, PANDA was further validated against laboratory test results conducted on ARC mix #1. These test results were used to further validate the aging and fatigue damage constitutive relationships.

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.

The effect of realistic tire contact stresses will also be incorporated 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.

The focus of the next quarter will be on finalizing these sensitivity analyses as well as finalizing the report that includes the results.

- **Auditing constitutive relationships of PANDA and evaluate different extrapolation techniques**

The ARC researchers have been collaborating closely with Dr. David Allen, Adjunct Professor at TAMU and former dean of engineering at the University of Nebraska at Lincoln. Dr. Allen is well-known in the fields of constitutive modeling and mechanics and will audit the constitutive relations implemented in PANDA. Because of his extensive experiences with Schapery's non-linear viscoelastic and viscoplastic models and computational modeling of asphalt and composites, we have asked Dr. Allen to critically examine the constitutive relations implemented in PANDA and provide us with the areas that may need more refinements and enhancements. Dr. Allen is also assisting our team to evaluate the efficacy of implementing PANDA into a standalone package that is no longer dependent upon use of the Abaqus FE framework. Development of the standalone package will not be done within ARC, but the final PANDA report will include a plan to move forward in that direction.

The focus of this quarter was to carefully evaluate the different techniques to extrapolate the PANDA simulation results to large number of loading cycles. The extrapolation techniques are necessary to predict the performance of pavements subjected to millions of traffic loading cycles. Development and implementation of the extrapolation technique will not be done within ARC. However, the final PANDA report will include a plan to move forward in development of a robust extrapolation technique.

We will focus our future efforts on the following subjects:

- Finalize PUI and PPI 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 is in progress. 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.

Finite element modeling of asphalt binder AAD and BI0002 under aged conditions will also completed. The geometries for both models will be 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.

A publication titled “EVOLUTION OF ASPHALT BINDER MICROSTRUCTURE DUE TO TENSILE LOADING DETERMINED USING AFM & 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.

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.

The following list describes the work items completed this quarter:

- The mix with higher dust proportion consistently failed to meet the VMA criteria and that lead us to choose completely new aggregate source. Initial mix designs for new source of aggregate were completed with corresponding all three dust proportions (DP) of 1.36, 1.86 and 2.22. Mixture with DP of 1.36 had a VMA of 13.4% while mixture with DP of 1.86 had a VMA of 12.18% and mixture with DP of 2.22 had a VMA of 11.37%. One out of three mixtures met the minimum VMA requirement of 13.0%. However, the research team decided to continue to do the performance tests without meeting the VMA criteria since the mix with lower VMA does not necessarily imply poor performance.
- Completed TSR test for the mix with 1.36 DP.
- Rest of the TSR and repeated load triaxial (RLT) tests are in progress.
- This 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 following list the work planned for next quarter:

- Start Phase II of the study including testing beam fatigue specimens at several factors against the DP levels.
- Complete 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 is underway and nearing completion.
- Writing of the E2d report on thermal cracking resistant mixture is underway by UNR with significant background and methodology information being established.
- Development of the thermal cracking analysis package (TCAP) software is being finalized.

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 80% complete.

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

- Complete the Final Report and the 3D-Move documentation;
- 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
- Implementation of the Announcements subsystem
- Summary Lists for Measures and Reports
- Google Maps added to pavement site form
- Status of batch upload of data from Texas A&M
- Review of functional requirements
- Status of the Database initialization feature
- Status of the role system
- Miscellaneous enhancements

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

Last quarter, the development team was tasked to develop an additional subsystem that would record pavement distress test results for pavement sites, based on the distress characteristics described in the Distress Identification Manual for The LTPP (Fourth Revised Edition). At this time, a prototype has been designed and the implementation has started. This prototype utilizes much of the existing ARC infrastructure. In general, the following enhancements are being made.

The PropertyGroup form (PropGroup.aspx) has been modified to account for different types of property groups. At this point AsphaltPavement Distress, Concrete PavementDistress, Test Property, and other have been defined. Property groups, in turn, apply to exactly one property type (category). Properties, in turn belong to a particular type (category) via their property group. To make this work with the existing data contained in the ARC database, all existing property groups have been assigned the group type of Test Property. Note that the Internal Cat (category) field is introduced so as to change the behavior of various property groups as follows:

- The internal category DD indicates that the property type is a distress type. Distress test results, are associated with a pavement section within a pavement site, rather than a material.
- The internal category named TR depicts a test property that is associated with a material, rather than a pavement section.

These internal category codes are used in numerous queries. The following figure shows the new segment of the PropertyGroup form, with sample data populated.

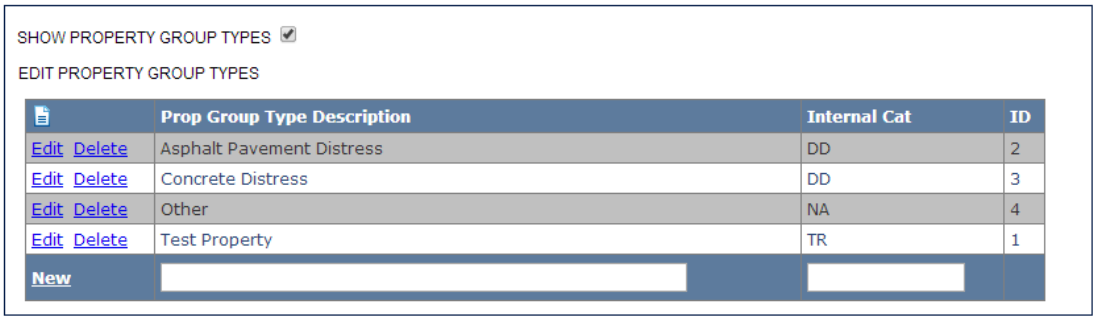

Figure TT1D.1: Revised Property Group form

This grid operates similarly to the grids on most other forms. The Edit and Delete buttons are used to edit and remove the current record, respectively. Completing the description and internal category and by clicking the New button causes a new property group type to be created. The master form to edit properties required modification so that before selecting property groups, they are first filtered based on their property group type. The following figure shows the property category selector on the Properties form.

Figure TT1D.2: Property Group Type Selector

Once the property group type (category) is selected, the form's user interface operates the same way as it did before. That is, the user can then select the desired property groups, and create quantitative and qualitative properties. Implementation of multi-factor properties has not changed either.

The second part of the implementation operates similar to the facility to create and edit test runs. The form named MeasureEditDistress.aspx was created for this purpose. Unlike a test run, however, a distress run is associated with a pavement section (place) instead of a material (thing). The following steps are required to create and edit distress data:

- First, a pavement site and pavement section must be selected. The same pavement selector is used for this task as the pavement selector used elsewhere in the application.
- Second, a distress record is created or edited.

- Finally, the distress measurements can be entered. The user interface designed to enter distress data is the same as the user interface to create ordinary measurement (test) data.

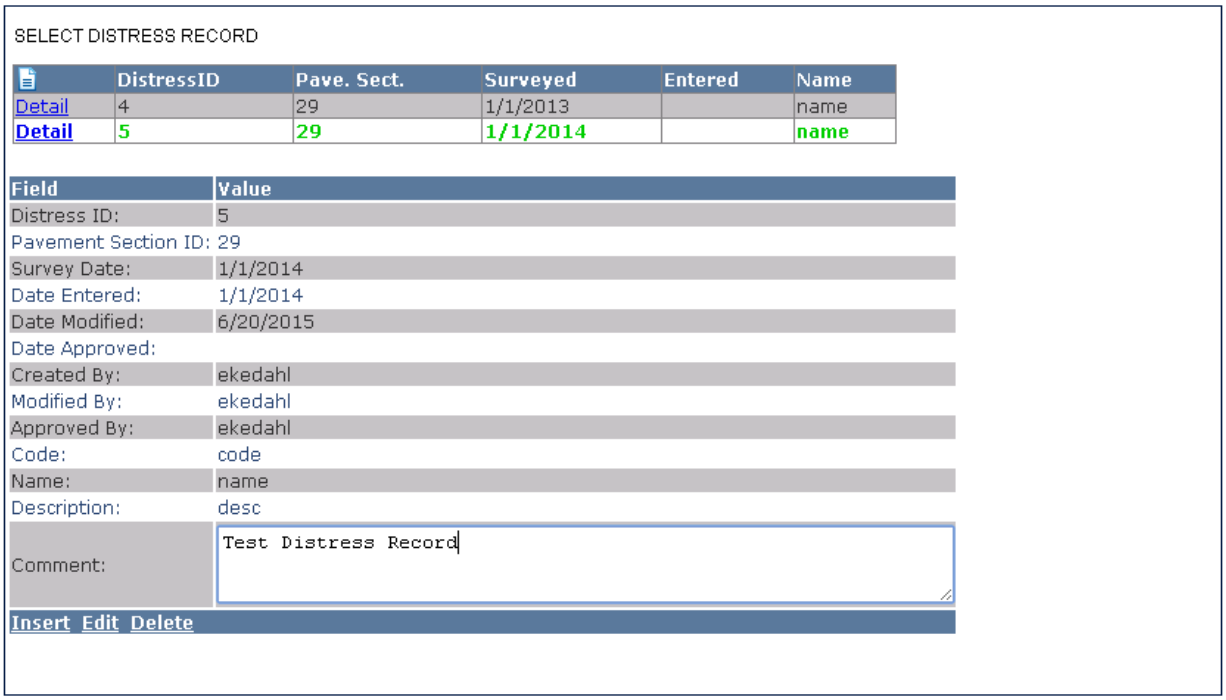

Figure TT1D.3: Create / Select distress record

Once the distress record is selected or created the user interface to enter single-factor and multi-factor measurement is the same as the user interface used to enter test run measurements.
The development team expects that the distress data subsystem will be fully operational and deployed next quarter. The remaining tasks need to be completed:

- Add the role system into the form's user interface and implement the data approval process.
- Extend queries, as necessary to filter based on property group type.
- Extend pavement section to be associated with a distress record.
- Validate required fields for data entry.

2. Significant Results (Announcements System)

Development continued on the announcement subsystem. The functionality of the original forms named Announcements.aspx and AnnouncementMaintenance.aspx have been combined in to a single form (Announcements.aspx). The menu system has been updated accordingly. The Announcements page appears on the Help menu. This form utilizes the ARC role system to grant users the rights to read announcements or to create and edit them. The following figure shows the revised Announcement form.

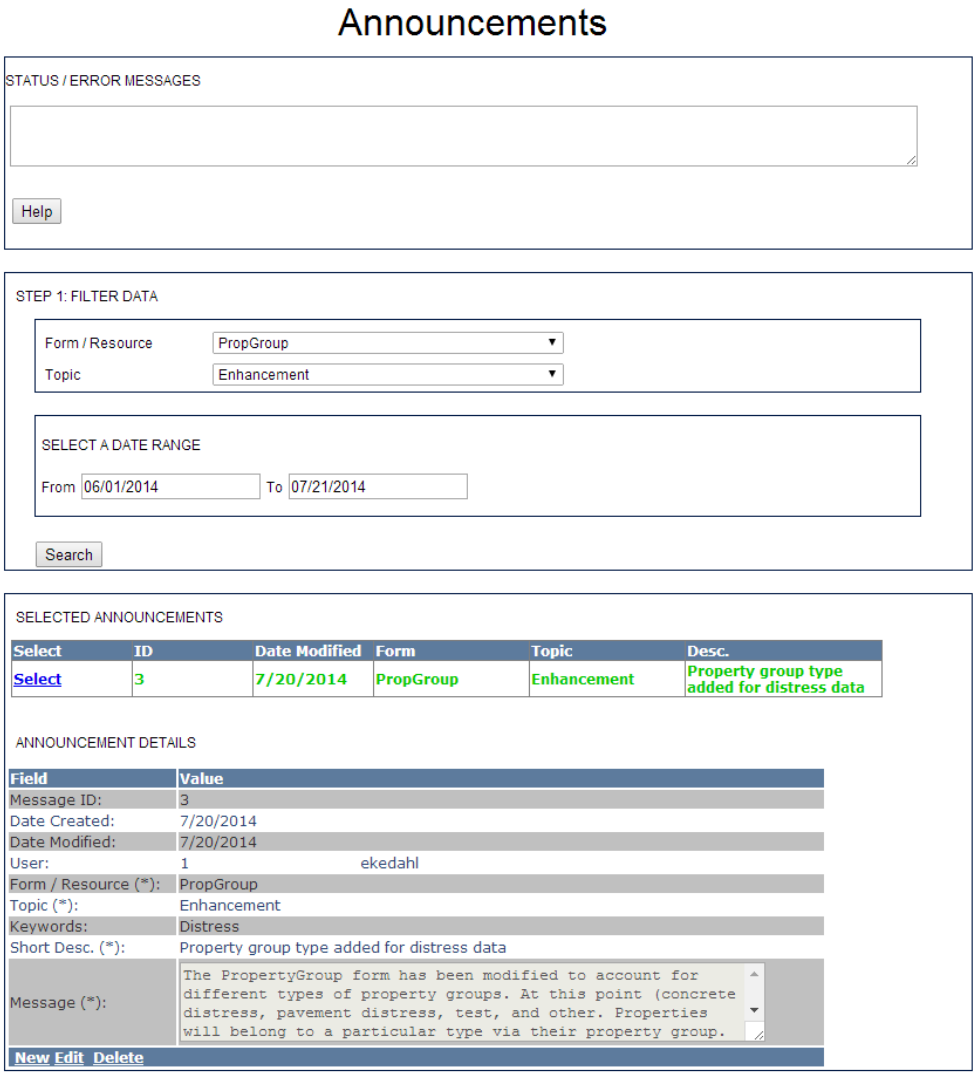

Figure TT1D.3: Revised Announcement form

The form's formatting and validation of required fields was completed this quarter. The form is controlled by the role subsystem. All users can read announcements. Consortium users can create and edit announcements.

The announcement user control (ucAnnouncements.aspx) was completed this quarter and is being deployed to various forms as time permits. The user control has the following characteristics:

- By default, announcement information is hidden. Clicking the SHOW ANNOUNCEMENTS check box causes the filtered announcements to be displayed
- The control uses AJAX so an entire page refresh is not required when the announcement content is rendered.
- When the control detail is displayed, announcements matching the criteria appear in a collapsed jQuery accordion control. Only one announcement can be expanded at a time.

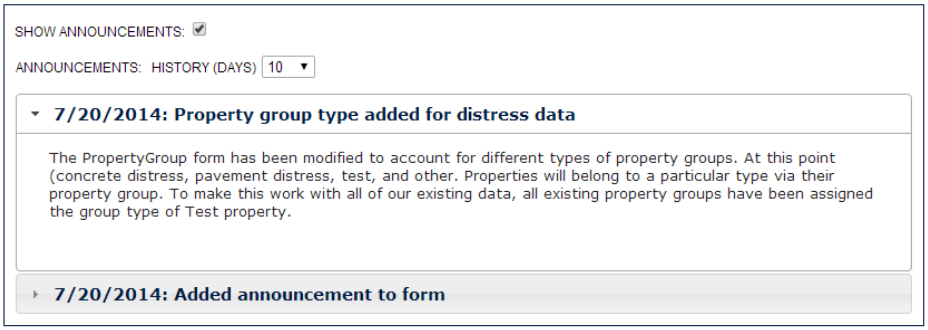

Figure TT1D.4: Completed Announcement user control

At the time of this report, the Announcement user control has been added to the following application forms: (BatchApproval.aspx ,BatchViewer.aspx, Default.aspx, ListMeasureCounts.aspx, MeasureEditDistress.apsx, PropEntry.aspx,PropGroup.aspx,) The announcements will be added to the remaining forms next quarter. 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 (Summary Lists for Measures and Reports)

Last quarter, the prototype queries were developed to extract record totals for reports and measurement data. These queries were to be embedded into the database application and forms this quarter so that they can be run by any user with appropriate privileges. This task has been completed. The following Figure TT1D.5 shows the output from the summary lists.

Note that bugs were reported on the form's prototype. The buttons were not labeled correctly. The steps were not numbered correctly. The query to filter quantitative single-factor measures did not restrict values by dates. These errors have been fixed. In addition, qualitative single-factor measures were added to the report.

Eric Weaver had requested that summary statistics of activity be reported each quarter. This information is contained in Table TT1D.1

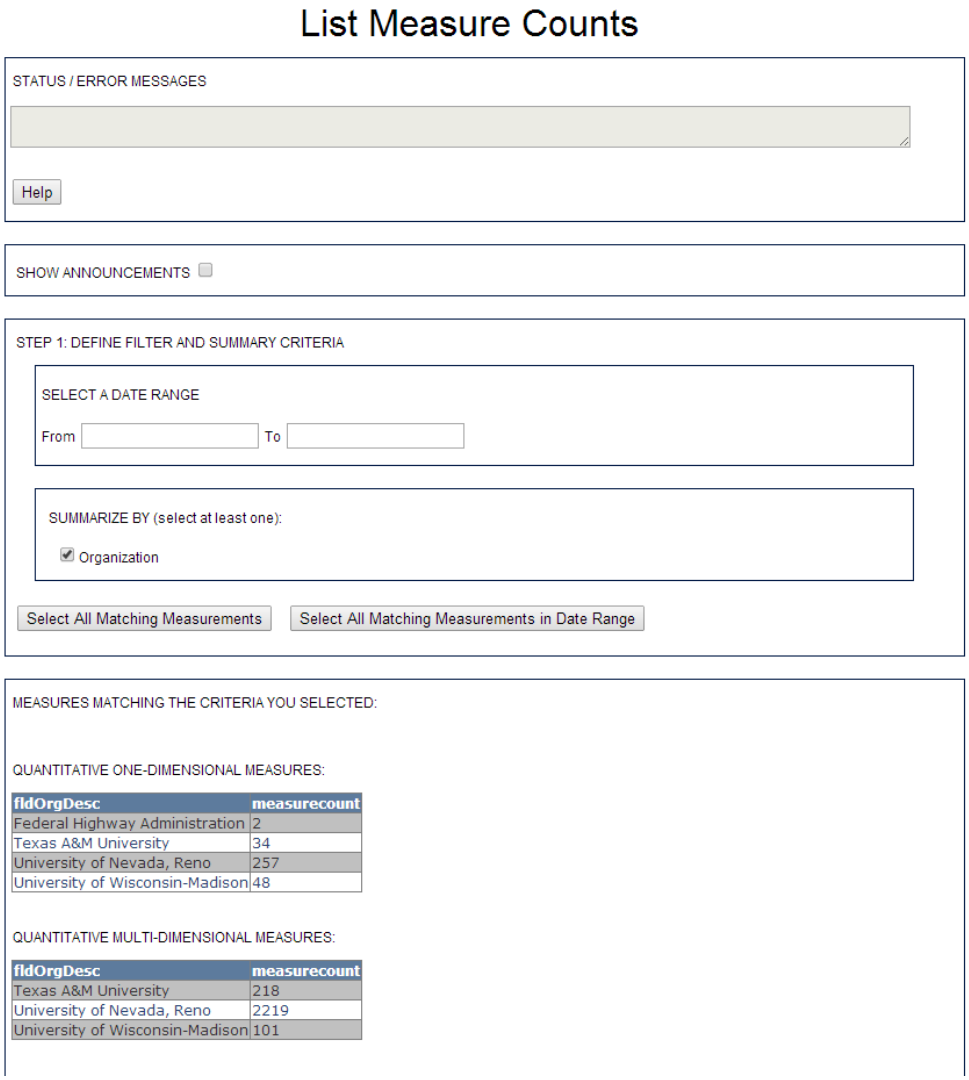

Figure TT1D.5: Summary Lists for Measures

Table TT1D.1: Summary of qualitative and quantitative measures contained in the ARC database.

Organization	**Single Factor (Quantitative)**		**Single Factor (Qualitative)**		**Multi-factor (Quantitative)**	
	Total Q1 2014	**Total Q2 2014**	Total Q1 2014	Total Q2 2014	Total Q1 2014	Total Q2 2014
FHWA		**2**		2		
Texas A&M University	34	**34**	27	27	218	218
University of Nevada, Reno	256	**257**	48	49	2219	2219
University of Wisconsin-Madison	42	**48**	25	31	101	101

The following table shows the progress of the uploaded files. These results were obtained by running the form named ListReportCounts. The following list describes the selection criteria for the report:

- All reports were selected, regardless of approval status. At the time of this writing, only two reports have been approved.
- All reports were selected, regardless of the metadata assigned.

Note that no new reports were uploaded this quarter by ARC members. Batch 2 of Texas A&M data has been uploaded to the test database and will be uploaded to the production database by 7/28/2014.

Table TT1D.2: Summary reports / files contained in the ARC database

Organization	Q2 2014	Q1 2014	Q4 2013	Q3 2013	Q2 2013	Total Yr. 1-7
Ohio University						508
Texas A&M University		640	503			1853
University of Illinois						419
University of Nevada, Reno		5	1	2	148	1750
University of Wisconsin Madison		83	750		514	1682
Western Research Institute				579	221	1522

4. Significant results (Google Maps Added to Pavement Site Form)

Last quarter, geographical coordinates were added to both the pavement site and pavement section. These coordinates include longitude, latitude, and elevation. This quarter, a feature was added to display pavement sites in a Google Map. Pavement sections within a site can also be rendered. The pavement site map displays a pin at these coordinates. The pavement section map displays a pin for the starting and ending coordinates of the section. The site or section description is stored in the pin tool tip description. The following figure shows the Google Maps enhancement.

Note that Google Maps requires a key to display maps. The development team at UNR has created a key and this key is used in the application. Implementors will need to request their own key to use Google maps. Presently, the key is embedded in the JavaScript code appearing in the user control named ucValidationFV.ascx. This key will be moved into the application's Web.config file for ease of maintenance.

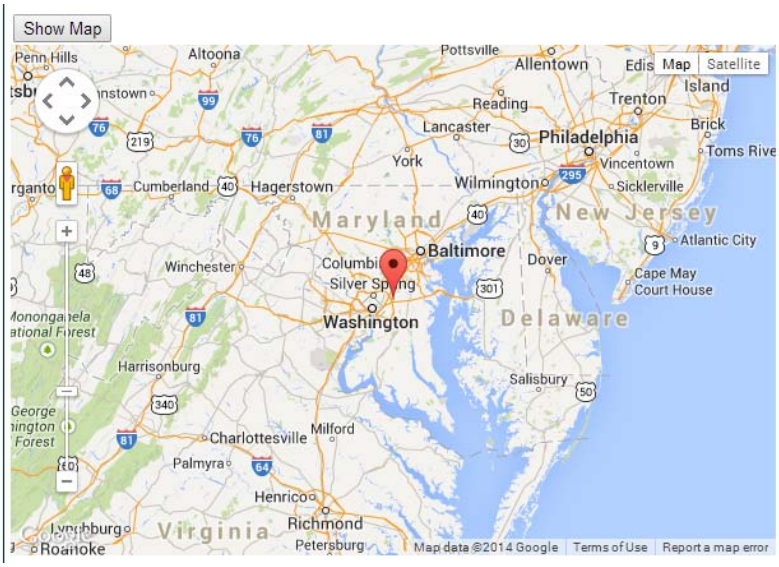

Figure TT1D.6: Google Maps display

Two buttons named btnShowMapValidationSite and btnShowMapValidationSection contain the code to generate and render the maps. The following list summarizes the functionality of this code:

- For the pavement site, the longitude and latitude are gathered.
- For the pavement section, the longitude and latitude of each pavement section is gathered.
- The JavaScript initialize function is dynamically created. For the pavement site, a single balloon is created. For a pavement section, a balloon is created for each pavement section in the pavement site.
- The .net ScriptManager.RegisterStartScript function is called to register the client script created previously. The script is run when the control is rendered.
- Note that the script uses AJAX so that the form need not be rendered again when the map is displayed.

5. Significant Results (Status of batch upload of data from Texas A&M)

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 last quarter. A second batch was received this quarter. The batch has been validated and uploaded to the test database. Final upload of batch two will be completed by 7/31/2014. The development team expects receipt of the third batch this quarter. The data upload should be completed this quarter too.

6. Significant Results (Review of PRDS Functional Requirements)

As the FHWA moves toward its goal of implementing the Pavement Research Database System (PRDS), FHWA ITS produced a first document (2014.07.08) defining the “High Level Functional Requirements” of the PRDS system. The document is presently under review by FHWA researchers. These functional requirements, as presently defined, closely mirror the implementation of the ARC application on a menu-by-menu basis. The ARC development team has made comments in the document for general review. These comments are summarized in the following list:

- The functional requirements push the entire role system to the internal FHWA credentialing system. While the topic is really not part of the functional specifications but more of a design problem, it would be good to know the specific programmatic interface to the FHWA credentialing system.
- Eric Weaver alluded to a more critical analysis of fields to make sure that the FHWA is capturing everything that needs to be captured. The UNR development team agrees with this suggestion.
- The UNR development team is trying to best fit the ARC application and database so as to match the objectives of the proposed PRDS system.

In addition to the PRDS document, the ARC development team has provided the following to the FHWA to help them design their requirements:

- A test copy of the ARC application and ARC database have been provisioned for use by the ITS team and others. The database is an identical copy of the production ARC database. The URL for this site is http://business.unr.edu/ARCFHWA.
- A .zip file was created from the ARC master source code directory tree and uploaded to the FHWA secure file exchange server to help the ITS staff review the application.
- An ERD was reverse engineered from Microsoft SQL Server into Visio 2010 for review by the FHWA.
- All users have been disabled except for those explicitly designated by the FHWA.

The test application and database will be updated as necessary to reflect changes to the production ARC application and database.

7. Significant Results (Status of the Database Initialization Feature)

The database initialization feature was not completed last quarter although progress was made. A form named ListUserOwnership.aspx was created and the initial prototype is being tested now. This form will support 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.

A second script is being developed that will delete all transactional data for all users.
A final script is being developed that will be delete all master data.

8. Significant Results (Status of the Role System)

At the time of this writing, all forms, with the exception of the following, have been converted: BatchApproval.aspx, BatchViewer.aspx, FieldSamples.aspx, FileApplyDefaultMetaData.aspx, FileLinker.aspx, FileMove.aspx, FileUpload.aspx, ListReports.aspx, Materials.aspx, MeasureApproveTestRun.aspx, MeasurEditTestRun.aspx, Measures.aspx, MeasureCreateTestRun.aspx, VerifyReports.aspx.

9. Significant Results (Miscellaneous Enhancements)

The following miscellaneous enhancements / fixes were made to the ARC application and database this quarter.

- The database home page now displays the data base version, build number and build date applicable to the current instance. This information is stored in the web.config file for the application in the keys ArcBuildVersion, and ArcBuildDate. The online configuration manual was updated to document these changes. The corresponding help file was added. The database name is obtained from the sqlserver database instance and displayed in the version number. Figure TT1D.7 shows the information displayed on the application's home page.

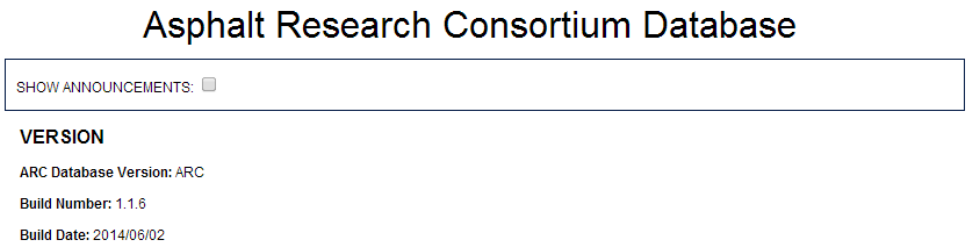

Figure TT1D.7: Version information on home page

- The e-mail notification system was modified so that different e-mails can be used for new user account requests and other system logs. The web.config and the RequestAccount page were modified accordingly. Also reformatted the page so that it appears similar to the rest of the application.
- As final edits are made to the application pages, required fields are being marked as such by adding a field name suffix (*) to depict a required file. This change is being made to GridView and FormView controls.

10. 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.
- In some cases, the request was made to make record descriptions searchable. The development team will add a description search on a table by table basis, based on the number of table records.
- Complete the role conversion for the remaining forms.
- Finish the SQL scripts to clean master and transactional data for the ARC database distribution backup.
- Integrate measure queries into the user interface for the ARC application.
- 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: Incorporated some of comments related to ETG discussion regarding optimum binder content selection for WMA.

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

Reason for Delay

Additional time is requested to complete the draft report and conduct internal review.

Delivery Dates
Draft Report: 10/01/2014 – extended from 9/30/2013, 3/31/2013, 12/31/2014
Final Report: 11/01/2014 – 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: 80% of report is done.

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

Delivery Dates
Draft Report: 10/01/2014, from 9/30/2013, 12/31/2013
Final Report: 11/01/2014, 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 been extended into the 3rd and 4th quarters 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.

Results from molecular simulations of model asphalts continued to be analyzed to obtain physical insights. Revisions were completed to a manuscript that described complex modulus results obtained from molecular dynamics simulation results. It was resubmitted to the *Journal of Chemical Physics* at the very end of the quarter. Both of these papers have focused on the new AAA-1 model system, with results for other model asphalts set aside as the methods and understanding are refined.

Uploading data to the ARC database will initiate during the upcoming Jul-Sept quarter. Appropriate data types and metadata will be identified in the 1st half of the quarter. Uploading will begin in the second half of the quarter and will be completed during the Oct-Dec quarter.

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 – Progressing during past quarter.

These Subtasks and Sub-subtasks constitute the ARC Model Deliverable for obtaining free energy from a molecular perspective. Developing models to interpret molecular simulations to parameterize free energy models is proceeding. The calculation inputs are the simulation outputs, i.e. molecule positions, velocities, and stress fluctuations that are obtained during the atomistically detailed molecular simulations.

Work has continued on formulating an equation-of-state approach that incorporates the chemistry of the model asphalt system into composition-dependent computations of the free energy. Inputs include some direct molecular simulation outputs and some group contribution correlations. Calculations and interpretations are underway.

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

This report will be delivered in non-508 format. A technical brief will be provided in section 508 format.

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, the 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:
Preparation of Report T is in progress with an anticipated draft completion date of August. 31, 2014.

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

Work on the NTIS report continued this quarter. The report is receiving editorial review before being submitted to FHWA.

The report will be submitted next quarter. An FHWA Tech Brief referencing the availability of Report U through NTIS will be prepared and submitted. 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 August 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 has not been set.

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 in progress.
Draft delivery date for this report is scheduled for August 31, 2014.

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 majority of the draft practice has been completed.

The draft practice will be submitted next quarter with the Task U Report.

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:

- Moisture susceptibility test (AASHTO T283) was conducted on all selected combinations of emulsion and water content for designed CIR mixes from Redrock, Alturus, and Matterhorn. The graded-CIR with 0.5% cement from Alturus did not meet the minimum TSR criteria of 70%, therefore it was decided not to further evaluate its performance.
- The cohesion and raveling tests were conducted on all three CIR mixtures and they all met the raveling criteria of maximum mass loss of 2.0% after meeting the cohesion test criteria.
- The dynamic modulus test was also completed on all three CIR mixtures.
- As a part of evaluating CIR technology for regional transportation agency, a new mix design was conducted on Matterhorn RAP material without any additives according to the proposed CIR mix design procedure.

The following list describes the work planned for next quarter:

- Continue the performance related tests
- Complete the draft AASHTO Practice and supporting document.

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

Status and Work Planned
Behind Schedule

Work Completed: All experimental work related to development of standard is completed.

Work Planned: Completing the AASHTO standard and perform 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: 10/01/2014, from 5/30/2014
Final AASHTO Practice: 11/01/2014, 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

Status and Work Planned
Behind Schedule

Work Completed: Work on draft AASHTO standard continued.

Work Planned: Complete draft of AASHTO standard, complete internal review, and submit to FHWA.

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

Delivery Dates
Draft AASHTO Method: 10/01/2014, from6/30/2013, 3/31/2013, 9/30/2013, 12/31/2014
Final AASHTO Method: 11/01/2014 - 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
Due to conflicting demands for personnel, completion of this work element has been delayed. We are currently testing the method using archival data. The draft method should be ready for in-house review by the end of August 2014.

This work is currently scheduled to be completed by 9/31/14.

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 has been completed and is currently being reviewed in-house.

We expect to address in-house comments and submit the completed draft before 8/31/14.

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/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:

- MATLAB® code has been developed to calculate the thermal stresses over years of a pavement in service. The code account for the evolution of relaxation modulus with oxidative aging (CA) as well as temperature and possible aging dependency of coefficient of thermal contraction (CTC).
- The alfa-version of thermal cracking analysis package (TCAP) is being finalized and will be released in the next quarter.
- The stand-alone software for predicting pavement temperature profile and history has been completed and will be release in the next quarter. The software performance has been optimized and the rum time was decreased to few seconds for a 20 year analysis period.

The following list the work planned for next quarter:

- Releasing the alfa-version of the temperature profile prediction stand-alone software.
- Releasing the alfa-version of the Thermal Cracking Analysis Package (TCAP).

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 Software Manual.

Topic 1: Modifications and Corrections
The list of the work done continued with the work started during last quarter.

- Establishment of new framework to handle multi-projects ;
- Site/Project Identification;
- Static / Dynamic Analysis; and
- Axle Configuration/Contact Pressure Distribution

Topic 2: Preparation of Manual
Work Completed:

- Preparation of Outline of Manual
- Introduction
- Features of 3D-Move Analysis
- Formulation of 3D-Move Analysis
- Adaptation of 3D-Move to Software

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.

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.

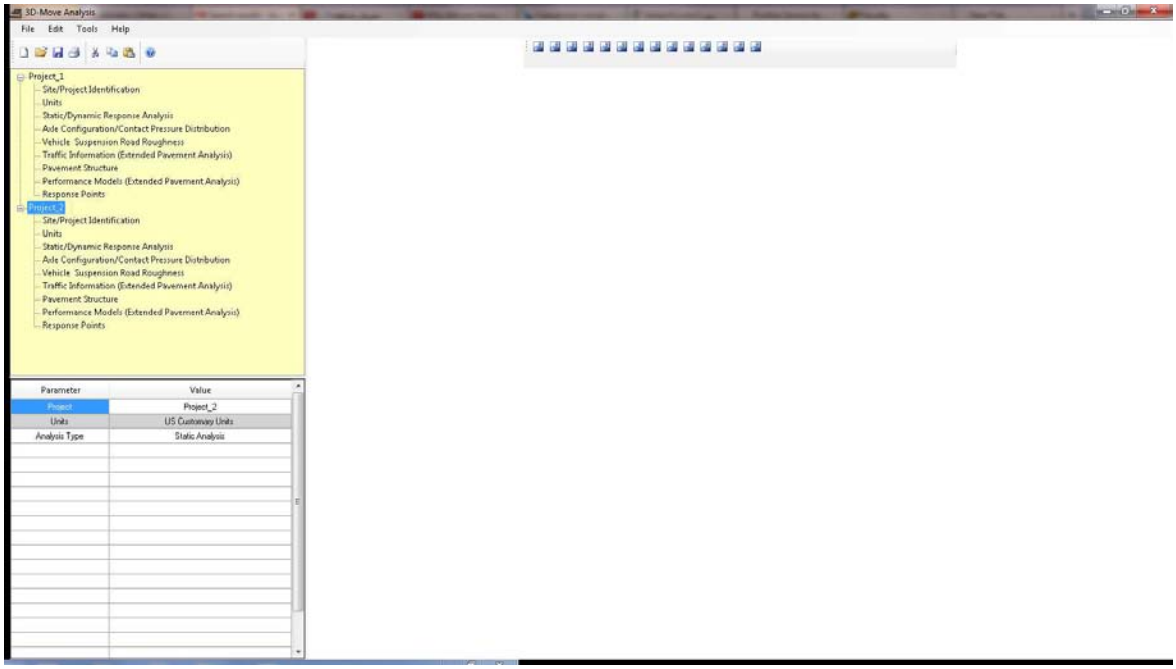

Figure VP3a.1: Multi-projects feature (ver. 3)

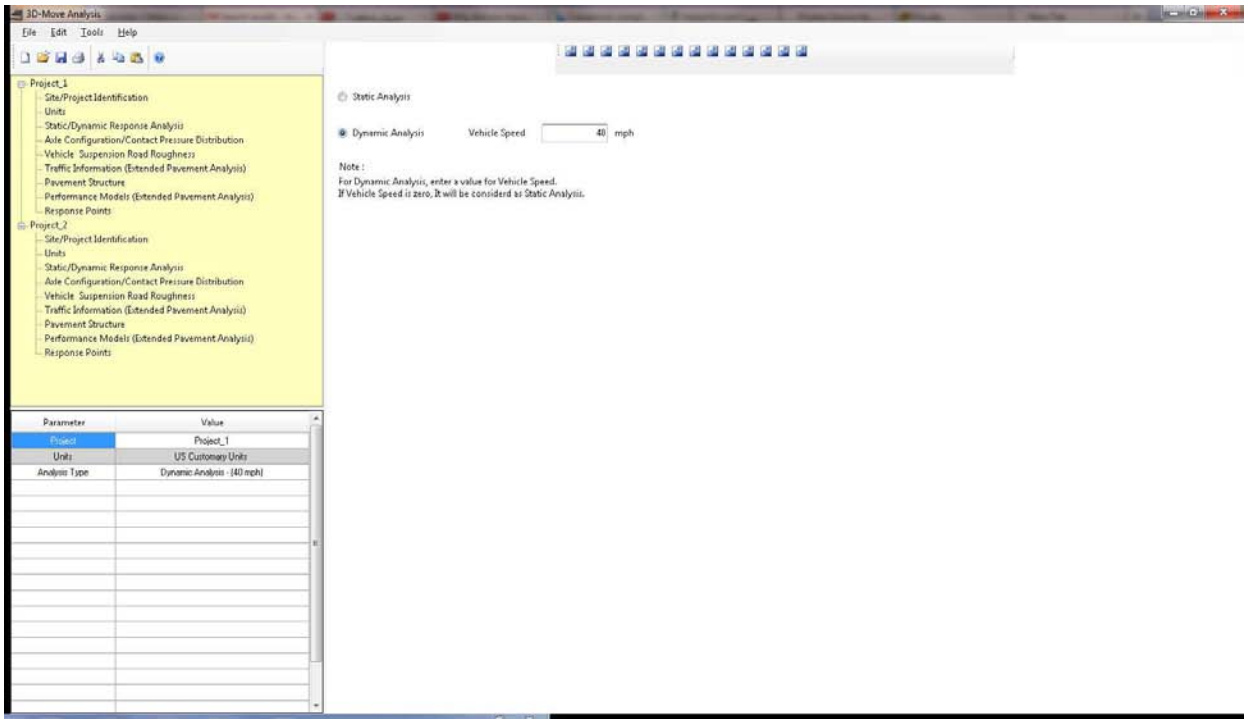

Figure VP3a.2: Analysis type section(ver. 3)

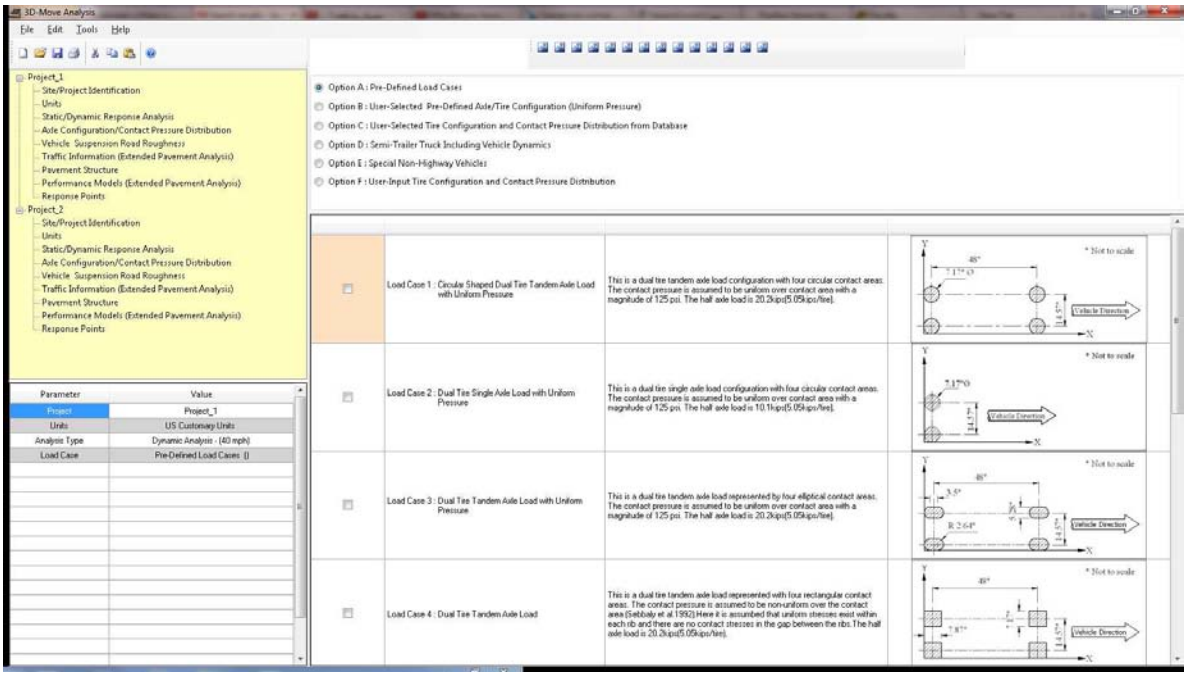

Figure VP3a.3: Axle configuration/contact pressure distribution, Option A(ver. 3)

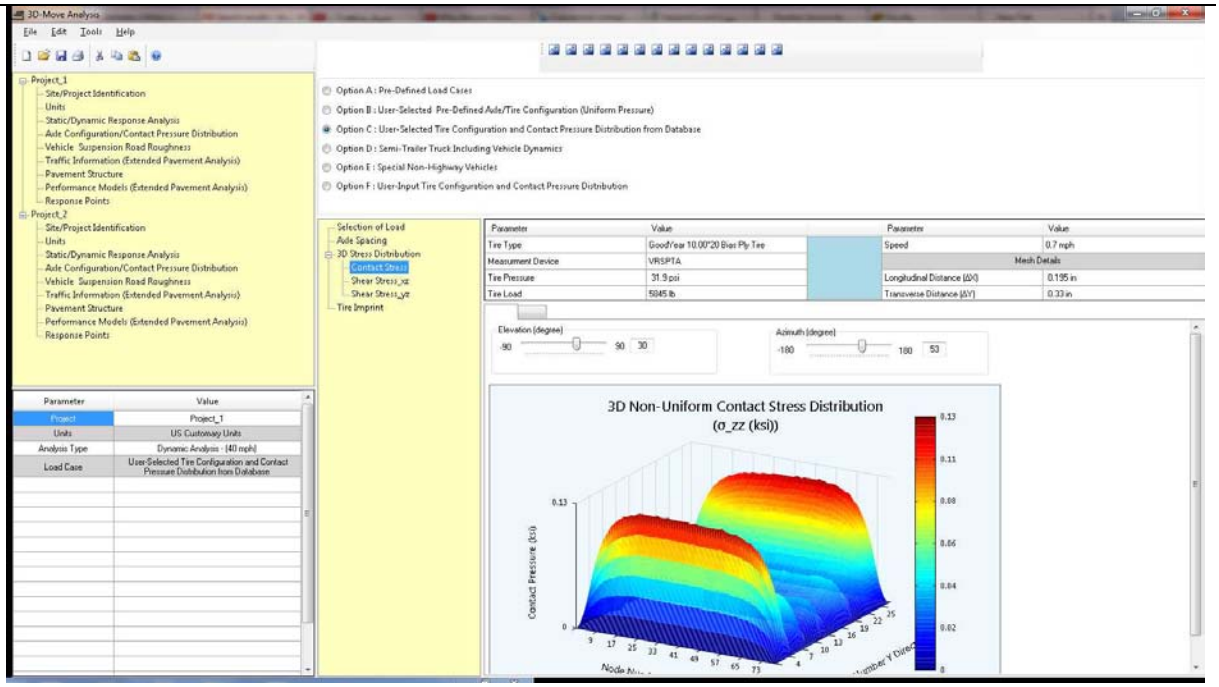

Figure VP3a.4: Axle configuration/contact pressure distribution, Option C (Tire Database)(ver. 3)

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
Revisited WI Chip Seal sites in spring to collect final data point for field performance comparison. The data will be presented in report Q.

Work Planned Next Quarter
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: 10/01/2014, extended from 9/30/2013, 12/31/2103, 3/31/201
Due Date for Final Report Submittal: 11/01/2014

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 for all the field projects. Information is being compiled to upload to the ARC database.

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 compile data and work on a final report 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., Jean-Pascal Planche, R. William Grimes, Qian Qin, The Universal Simple Aging Test (USAT): Simulating Short- and Long Term Hot and Warm Mix Oxidative Aging in the Laboratory, accepted for presentation to the June 2014 ISAP conference at NCSU.]

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

Work Done This Quarter
WRI is 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
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.

Work this quarter also included evaluating the Linear Amplitude Sweep (LAS) in terms of an alternate approach to fatigue in the non-linear regime employing the application of large amplitude oscillatory shear (LAOS). LAOS testing will be conducted with binder material retain from the Arizona comparative test sections where fatigue performance data has been compiled.

Nonlinear mechanical properties play an important role in the LAS test. However the current LAS test only applies the “viscoelastic moduli” corresponding to the first harmonic Fourier coefficients G1' (ω), G1" (ω), and that can be misleading in describing the nonlinear phenomena. Our approach has been to demonstrate the application of LAOS within the framework of Lissajous curves and Fourier harmonics. This approach is much more fundamental than the current LAS test.