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Asphalt Research Consortium

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INTRODUCTION

This document is the Quarterly Report for the period of October 1 to December 31, 2013, for the Federal Highway Administration (FHWA) Contract 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.

The report is presented as a progress report on the 79 anticipated project deliverables. The project deliverables are grouped into three areas, Reports, Test Methods/Practices, and Models and/or Software. The deliverables consist of 30 Reports, 42 Test Methods/Practices, and 7 Models and/or software. Of the 79 deliverables, 15 draft reports and 33 test methods/practices have been submitted for review. Most of the planned work is completed or nearing completion, therefore, many of the original Work Elements and Subtasks have coalesced into a larger product(s), as planned. The Table of Deliverables is presented following this introduction and identifies the title of the deliverable, expected draft delivery date, and expected final delivery date. The table 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 October 1 to December 31, 2013, is the third quarter of the Year 7 contract year. Reviewers may want to reference the previous Annual Work Plans and many other documents that are posted on the ARC website, www.ARC.unr.edu. The more detailed information about the research such as approaches to test method development, data collection, and analyses have been and will continue to be reported in research publications as part of the deliverables.

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	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Overall Report	Summary Narrative Report on ARC members and accomplishments	4/15/2014	5/31/2014	All	All	
Report A0	Comprehensive Summary Report (Level 1) (Report summarizing all work elements in significant detail to provide a single source documentation of ARC accomplishments)	2/15/2014	5/31/2014	TAMU	All	Reference level 2 and 3 deliverables for details, 508
Report A	Summary report on Moisture Damage (Level 2)	Completed 1/31/2013	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 (Level 2)	Completed 8/15/2013	10/31/2013	TAMU	Bhasin	NTIS
Report C	PANDA: Pavement Analysis using a Nonlinear Damage Approach (Level 2)	Completed 8/31/2013	11/30/2013	TAMU	Darabi	Summary of PANDA methodology including descriptions of methods for indentifying model parameters, 508
Report D	Characterization of Asphalt Binders using Atomic Force Microscopy (Level 2) Microstructural Chemo-Mechanical Behavior of Asphalt Aging and Fatigue	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	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Report E	Lattice Model and Continuum Damage to Fracture (Level 2)	Completed 9/03/2013	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 (Level 2)	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	4/30/2014	6/30/2014	UNR	Sebaaly Hajj	
Report H	Critically Designed HMA Mixtures	12/31/2013	3/31/2014	UNR	Hajj Sebaaly	Comprehensive report describing the developed mechanistic-based approach for critically designed mixtures
Report I	Thermal Cracking Resistant Mixes	2/15/2014	5/31/2014	UNR	Hajj Sebaaly	
Report I-A	Study of Pavement Temperature Rates in HMA Layers	9/26/2013		UNR	Hajj Sebaaly	Received MS Word and Hardcopy
Report I-B	Low Temperature Cracking Characterization of Asphalt Binders	2/15/2014		UNR	Hajj Sebaaly	Recently separately from report I on 1/5/2014

Deliverable	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Report J	Pavement Response Model to Dynamic Loads 3D Move	2/28/2014	5/31/2014	UNR	Hajj Sebaaly	Delayed. Research team focused on addressing and solving the various bugs reported by the users for newly released Ver. 2 of the software
Report K	Development of Materials Database	2/28/2014	5/31/2014	UNR	Hajj Ekedahl	Outline only
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	3/31/2014 (from 10/31/2013)	UWM	Tabatabaee	Received MS Word version and tech brief. Section 508 and image descriptions needed.
Report N	Guideline for Selection of Modification Techniques	3/31/2014 (from 9/30/2013, 12/31/2014)	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	3/31/2014 (from 12/31/2013)	UWM	Tabatabaee	Received draft MS Version
Report P	Quantifying the Impacts of Warm Mix Asphalt on Constructability and Performance	3/31/2014 (from 9/30/2013, 12/31/2013)	6/30/2014 from (12/31/2013, 3/31/2014)	UWM	Hanz	3 month extension of draft report deadline requested

Deliverable	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
Report Q	Improvement of Emulsion Characterization and Mixture Design for Cold Bitumen Applications	12/31/2013 from 12/31/2013	3/31/2014 from 3/31/2014	UWM	Hanz	3 month extension of draft report deadline requested
Report R	Studies on Tire-Pavement Noise and Skid Response	Completed 12/31/11	7/30/2013	UWM	Roohi	Received MS Word version and tech brief
Report S	Molecular dynamics results for multiple asphalt chemistries	3/30/2014	5/31/2014	URI	Greenfield	3 month extension of draft report deadline requested.
Report T	Progress Toward a Multi-scale Model of Asphalt Pavement- Including Test Methods for Model Input Parameters	3/30/2014	5/31/2014	WRI/VT/URI	Pauli	3 month extension of draft report deadline requested.
Report U	Design Guidance for Fatigue and Rut Resistance Mixtures	3/15/2014	6/30/2014	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

Deliverable	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
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	Draft submitted to FHWA Reference appropriate level 3 deliverables NTIS
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

TABLE OF ASPHALT RESEARCH CONSORTIUM PRODUCT DELIVERABLES

Deliverable/ Product	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
AASHTO Method	Simplified Continuum Damage Fatigue Analysis for the Asphalt Mixture Performance Tester	3/15/2014	6/30/2014	AAT	Bonaquist Christensen	Development documented in Report U
AASHTO Method	Wilhelmy Plate Test (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Bhasin	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Universal Sorption Device (Level 3)	Completed 03/07/2013	6/30/2013	TAMU	Bhasin	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Dynamic Mechanical Analysis (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	A Method for the Preparation of Specimens of Fine Aggregate Matrix of Asphalt Mixtures (Level 3)	Completed 1/31/2013	6/30/2013	TAMU	Kassem	Draft submitted to FHWA Referenced in Reports A & B
AASHTO Method	Measuring intrinsic healing characteristics of asphalt binders	Completed 03/07/2013	9/30/2012	TAMU/ UT	Bhasin	Draft submitted to FHWA Referenced in Report B
AASHTO Method	Test Methods for Determining the Parameters of Material Models in PANDA (Pavement Analysis Using Nonlinear Damage Approach) (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	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	3/31/2014 from 9/30/2013	6/30/2014 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	Identification of Critical Conditions for HMA mixtures	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	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)	12/31/2013 from 9/30/2013	3/31/2014 from 12/31/2013	UWM	Hanz	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 6/30/2013	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	12/31/2013 from 9/30/2013	UWM	Hanz	Extended to address comments from ASTM
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	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.	12/30/2013	3/30/2014	VT	Wang	Draft data extension requested
AASHTO Method	Evaluate Healing using Continuum Damage Approach (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 (Level 3)	Completed 07/26/2013	10/31/2013	TAMU	Lytton/Luo	Appendix in Report W
AASHTO Method & Analysis Program	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	Method to determine surface roughness of aggregate and fines based on AFM	9/30/2013	4/30/2014	WRI	Grimes	Will be subject of Tech. Pub.
AASHTO Method	A method to determine ductile-brittle properties via AFM measurements	10/30/2013	2/28/2014	WRI	Grimes	Will be subject of Tech. Pub.
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.
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
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

Deliverable/ Product	Description	Draft Delivery Date	Final Delivery Date	ARC Partner	Staff Assignment	Notes
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	12/30/2013	3/31/2014	VT	Wang	Extension Requested Detailed in Report T
Software	PANDA Software (Pavement Analysis using a Nonlinear Damage Approach)	3/31/2014	6/20/2014	TAMU	Sun-Myung Kim	This software supports the PANDA constitutive models(UMAT) used in conjuction with Abaqus FE software. This includes the PUI and PPI software

REPORTS

REPORT A0: ARC TAMU COMPREHENSIVE SUMMARY REPORT

Status: This report is completed; however, the researchers are still working on securing the required permissions and providing separate files for 508 captions for the figures and equations. It is anticipated that this report will be submitted to FHWA for review by February 15, 2014. Due to the nature of this report, and the fact that in combines a significant review in one volume of all work elements performed under the ARC program at TAMU, this report underwent an thorough editorial review by the Communications Division of the Texas A&M Transportation Institute, TTI. This review is complete and the authors have responded to all editorial comments and are in the process of securing the required permissions and providing the 508 captions for figures and equations.

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:

- **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.

- **Enhancement of PPI**

During this quarter, ARC team continued to enhance the PANDA Parameter Identifier (PPI) package by implementing the procedure for identification of parameters associated with the hardening-relaxation constitutive relationship. Refinement and enhancement of PPI will be the focus of the current and the next quarter.

- **Further validation of PANDA**

During this quarter, PANDA was further validated against cyclic stress-controlled and strain-controlled laboratory tests on aged and unaged specimens. 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 and next quarter.

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

During this quarter, PANDA was used to conduct sensitivity 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. This work is still ongoing. Thorough investigation of the effect of layer properties on fatigue damage and rutting of pavements will be the focus of the current and next quarters.

- **Development of extrapolation techniques for performance predictions and auditing constitutive relationships of PANDA**

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 viscoelatic 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 evaluating the efficacy of simplification of the computational framework of 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.

Dr. Allen is also providing guidance in the methods for extrapolation to a larger, more realistic number of cyclic loads in both the damage and permanent deformation models within PANDA.

The focus of this quarter was on development of an extrapolation technique to predict rutting performance of pavements. The focus of the current and next quarter will also be on

development of extrapolation techniques to predict rutting and fatigue damage performance of pavements subjected to large number of loading cycles. Enhancement, refinement, and implementation of these extrapolation techniques will be the focus of future efforts.

We will focus our future efforts on the following subjects:

- Enhancement and refinement of PUI and PPI packages.
- Further validation of PANDA against ARC data, Waterways Experiment Station data, and Ohio test sections.
- Incorporation of realistic tire contact stresses in PANDA.
- Investigation of the effect of layer properties on performance of pavements.
- Enhancement, refinement, and implementation of extrapolation techniques for performance simulations.

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 scope of the plan of study but recent success in this area has provided the motivation to continue this work. The ARC report D, previously submitted will be augmented, or supplemented, by this work.

Main progress achieved during this quarter and focus of future work

Tensile testing on both binder samples AAD unaged and ARC BI 0002 unaged have been completed. AFM images taken before and after loading have been analyzed using image analysis techniques. Comparisons reveal that after 1% strain clear signs of crack initiation are displayed. After further loading (3% strain) cracks propagate further and coalesce into larger cracks. Experimental observations confirm that cracks/phase separation occurs around the bee/bee enclosure phases. Testing on both samples confirm the hypothesis of Krigons et al. that there exists a weak interstitial zone around the bee/bee casing phase that is primarily responsible for crack initiation under load. Geometrical features i.e. bee phase shape, percent area, roundness have been analyzed before and after loading is applied. The determination of zones within which damage is most likely to occur and an understanding of how to minimize the regions subject to damage is the goal of this work. Two factors are necessary in order to better understand the impact of these phases on the damage process: (1) the engineering properties of these phases specifically and relative to each other and (2) the fracture properties of the phases. We are working toward that end. Great progress has been made with regard to item (1) but it is not likely that item (2) will be completed before the end of ARC. However, we will provide a plan for moving in that direction.

AFM indentation tests have been completed on all samples that were tested in order to obtain visoelastic material properties (creep compliance) for finite element model material input parameters.

Using the images obtained during the tensile testing and the material properties obtained from the indentation experiments, a two dimensional finite element model is being developed. The purpose of this model is to analyze the stress distributions in the model and to examine the stress distribution in different phases when tensile strain is applied. The stresses in different regions will then be compared to the images obtained from tensile testing using the micro-loading frame to examine whether numerical analysis confirms experimental observations.

Currently tensile testing is being performed on both AAD, and BI0002 samples under RTFOT, and RTFOT+PAV aged conditions. The intent of these tests is to see how the experimental observations vary between different aging conditions for the same binder.

A presentation regarding this work has been prepared and given at the 93rd TRB annual meeting at the “Doctor Student Research in Asphalt Materials and Mixtures” workshop.

A journal publication regarding this work is already under progress and is intended to be completed by mid/late February. The application of this work will be presented in a separate

publication and will demonstrate its ability to analyze damage/micro-cracking in asphalt binder with respect to both unaged and aged binders.

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:

- Finalized sieving of the required amount of RAP and original aggregates.
- Finalized mixture design with 30% RAP with two dust proportions: 1.35 and 1.60.
- Started phase I of the DP work plan which includes studying the rutting resistance of lab-produced RAP mixtures with several dust-to-binder proportions (1.35 and 1.65). Based on the results from phase I, potential factors will be included in phase II which will investigate the effect of dust-to-binder on fatigue life and endurance limit of RAP HMA mixtures.
- Started compacting HMA beams for Phase II study.
- Completed two chapters of the final report out of eight. The difficulty in achieving mix designs with high dust proportions delayed the progress of the experimental design to study the effect of dust proportions on healing and endurance limit of high content RAP mixtures. 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 delivery date was revised accordingly in the Table of ARC deliverables.

The following list the work planned for next quarter:

- Finalize phase I of the DP work plan including testing 18 specimens using RLT.
- Conduct a calibration and verification study on the newly acquired beam fatigue equipment.
- Start Phase II of the study including testing beam fatigue specimens at several factors against the DP levels.
- Complete the writing of the final report.

REPORT H: CRITICALLY DESIGNED HMA MIXTURES

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

Status and Work Planned
The report has been completed and reviewed internally at UNR and will be submitted to FHWA for technical review and editing.

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. Report I-A: "STUDY OF PAVEMENT TEMPERATURE RATES IN HMA LAYERS," was revised to include section 508 captions. The following list describes the work items completed this quarter:

- The UTSST testing of the all field validation samples has been completed. The analysis of the results is underway.
- Evaluation of the Core materials is also underway. All of the binder aging, associated rheological measures, and Fourier Transform Infrared (FT-IR) testing have been completed.
- Continued the validation of asphalt binder aging model in free atmospheric condition and in the mixture.
- All laboratory testing has been completed relative to the thermal cracking resistant mixtures subtask. Analytical measurements remain to be completed in the coming quarter.
- The evolution of thermo-viscoelastic properties with aging was evaluated and has been submitted in a paper that has been accepted for presentation in the coming Transportation Research Board 93rd annual meeting.
- The outline of the E2d report on thermal cracking resistant mixtures is set, a good portion of the calculation and analysis has been completed, and writing is underway by both UNR and UWM.
- Development of the thermal cracking analysis package (TCAP) software is underway.

The following list the work planned for next quarter:

- Continue working on the subroutines for thermal cracking analysis package.
- Continue writing of the Report I.

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 55% complete.

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

- Continue work on 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
Behind schedule. The date is revised to reflect the delay in Report K.
The following list summarizes the work items completed or in progress this quarter.

- Create ARC FHWA test bed (FHWA meeting)
- Status of batch upload of data from Emad Hassan
- Timeout warning completed
- Improvements to the ListReportCount.aspx form
- Improvements to the data dictionary list
- Improvements to the role system
- Improvements to the property editor
- Database initialization feature
- Missing measurement data feature
- Status of final reports an documentation
- General code enhancements and code cleanup
- General user interfce improvements
- Work planned for next quarter
- Revisit the FileLinker form as subsystem, as necessary (no activity reported this quarter)

1. Significant Results ARC FHWA Test Bed: It was proposed at the Turner Fairbanks FHWA meeting that a test bed (separate ARC application and ARC database) be created so that selected FHWA staff could begin to experiment with the application's features. During a monthly meeting this quarter, it was decided not to continue with the ARC FHWA test bed at this time and allow FHWA staff to upload data to the production ARC database.

2. Status of Batch Upload: Discussed in previous reports, Texas A&M group has a significant volume of data to be uploaded to the ARC database and ARC file system. The following list describes the chronological anthology of this effort:

- A Microsoft Excel template and application prototype was developed so as to upload the files and perform the database updates using local physical media instead of the typical Internet-based file upload process used by the other ARC consortium members.
- The files submitted by this group contained a number of zip files organized such that those zip files formed an independent logical file structure that corresponded to one metadata entry in the corresponding Excel worksheet.
- The project guidelines suggested that .zip files were not generally acceptable and a data restructuring was necessary to change this file structure to both eliminate the .zip files and at the same time create a meaningful file organization.
- On 12/20/2013, Xue Luo from Texas A&M produced a first data inventory estimate of 37GB of uncompressed data. The development team and administration will provide the necessary storage space for all of this data.

- The development team at UNR will continue to work with Texas A&M to complete the data upload once the restructured files become available.

3. Timeout Warning Completed: Eric Weaver requested a timeout warning be added to the ARC application. The implementation of this timeout warning has been completed. The timeout is implemented using JavaScript code that executes on each page. The timeout warning interval and timeout period are stored in the application's web.config file and are stored as part of the user's session state. The session timeout is currently set to 30 minutes with a warning at 15 minutes. If the user clicks OK, the timeout period will be reset. Note that the timeout period is configurable by editing the application's web.config file.

4. Improvements to the ListReportCounts.aspx Form: The form named ListReportCounts.aspx was created last quarter in response to the request by Eric Weaver and others to determine the volume of support files uploaded to the ARC file system and the relative completion of the ARC project data archival. The initial implementation of this form allowed users to filter reports by approval status, material, work assignment, and date range. This quarter, the report was enhanced and the following filters were added. In addition, it is now possible to list the detail reports themselves instead of a summary. A feature will be added to export the results to Microsoft Excel for further manipulation.

- Flag reports with or without a description.
- Flag reports with or without a keyword.
- Flag reports with or without a metadata link. The system will also check that the actual file extension matches the file extension stored in the database.

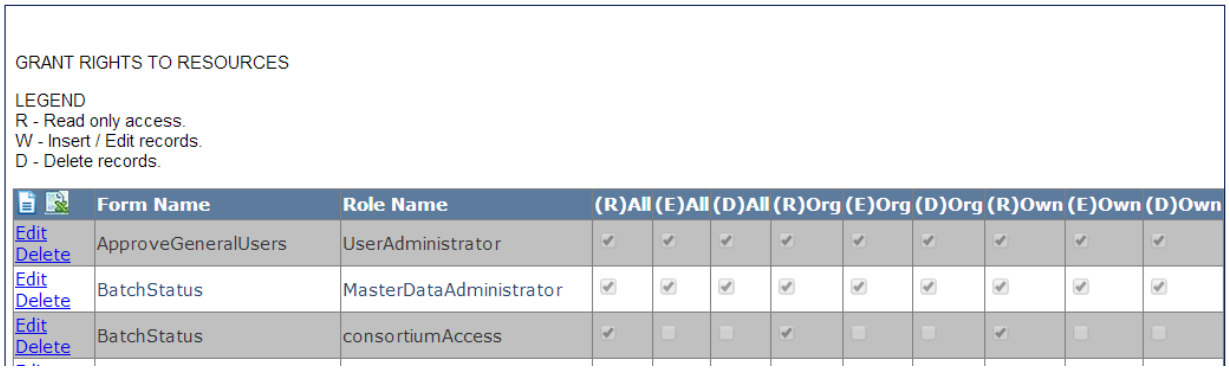
5. Improvements to the Data Dictionary List: The data dictionary list was implemented last quarter. As noted in last quarter's report, this data is obtained from metadata contained in the ARC database, rather than being created statically. The data dictionary generation code has been enhanced to list stored procedures in addition to the tables and views. The following information is produced by the stored procedure list. Just as the tables and views can be exported to Excel, so too can the list of stored procedures.

- The SPECIFIC_NAME field contains the name of the stored procedure. Note that procedure names beginning with "sp_" are part of the SQL Server system database procedures and not part of the ARC database itself.
- The PARAMETER_NAME field contains the name of the parameter passed to the procedure or returned by the procedure.
- The DATA_TYPE field contains the SQL Server data type of the parameter. Note that the ARC application maps these types into equivalent C# data types.
- For character (string) fields, the CHARACTER_MAXIMUM_LENGTH field contains the maximum length of the string. Note that a field size of VarChar -1 indicates that maximum field size should be used.
- The PARAMETER_MODE field depicts whether the parameter is used for input (IN), output (OUT), or both (INOUT).
- The IS_RESULT field depicts whether the field stores the procedure's result.
- The NUMERIC_PRECISION field applies to floating point fields and stores the SQL Server maximum numeric precision for the field.

6. Role System: Last quarter, the development team began updating system code, as necessary, to support enhancements to the role system. ***These changes should be transparent to the end users. While these changes are completed, there might be a few short outages (less than 1-2 minutes) to convert users from role to role.*** The changes and enhancements to the role and credential system are summarized in this section.

- Implementation of permission sets
- Creation of new roles
- Modification of forms and other resources to use these roles

In the original implementation of the role system, role names were hardcoded into the various forms and other database objects. Thus, it was not possible to add new roles or change the behavior of a role without modifying the underlying form code. The revised implementation solves this problem through the introduction of a ***permission set***. A permission set is used to grant rights to a resource. At this time, a resource corresponds to a physical ASP.NET form, but the system could be extended to make the resource concept more granular. The following figure shows the section of the ManageRoles form used to grant rights to resources:


GRANT RIGHTS TO RESOURCES

LEGEND
R - Read only access.
W - Insert / Edit records.
D - Delete records.

	Form Name	Role Name	(R)All	(E)All	(D)All	(R)Org	(E)Org	(D)Org	(R)Own	(E)Own	(D)Own
Edit Delete	ApproveGeneralUsers	UserAdministrator	☑	☑	☑	☑	☑	☑	☑	☑	☑
Edit Delete	BatchStatus	MasterDataAdministrator	☑	☑	☑	☑	☑	☑	☑	☑	☑
Edit Delete	BatchStatus	consortiumAccess	☑	☐	☐	☑	☐	☐	☑	☐	☐

Figure TT1D.1: Permission set editor

The following list describes the meaning of the three rows in the above figure:

- The first column allows the UserAdministrator to edit or delete a permission set.
- The final row of the grid (not shown in the figure), allows the UserAdministrator to create a new permission set.
- The second column contains the name of a resource. At this time, the resources correspond to ARC application form names.
- The third column contains the name of the role to which the permission set should be applied.
- The next three columns are used to grant read, edit/insert, and delete access to all users.
- The next three columns are used to grant read, edit/insert, and delete access to users belonging to the same organization.
- The final three columns are used to grant read, edit/insert, and delete access to individual users.

At the time of this writing, the following forms have been updated to use the revised role management system:

- AdminFunctions.aspx – Can only be run by the Administrator role.

- ApproveGeneralUsers.aspx – Can only be run by the MasterDataAdministrator role.
- ARCDeliverables.aspx – Can be edited by MasterDataAdministrator and read by ConsortiumAccess.
- BatchStatus.aspx – Can be edited by MasterDataAdministrator and read by ConsortiumAccess.
- DataDictionary.aspx – Can be executed by ConsortiumAccess and MasterDataAdministrator.
- FileMetaData.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- Keywords.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- ListRecordCounts.aspx – Can be executed by MasterDataAdministrator.
- ListReportCounts.aspx – Can be executed by ConsortiumAccess and MasterDataAdministrator.
- ListUserRoles.aspx – Can be executed by ConsortiumAccess.
- ListUsers.aspx – Can be executed by UserAdministrator.
- MaintainFolder.aspx – Can be executed by MasterDataAdministrator.
- ManageMyAccount.aspx – Can be executed by PublicAccess and ConsortiumAccess.
- ManageOrganizations.aspx – Can be read by ConsortiumAccess and edited by UserAdministrator.
- ManageRoles.aspx – Can be executed by UserAdministrator.
- ManageSources.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- ManageUsers.aspx – Can be executed by UserAdministrator.
- MaterialCategory.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- MaterialCharacteristics.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- MaterialReport.aspx – Can be executed by ConsortiumAccess.
- PropEntry.aspx – Can be edited by MasterDataAdministrator.
- PropGroup.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.
- PropReport.aspx – Can be executed by ConsortiumAccess.
- PropSortOrder.aspx – Can be edited by MasterDataAdministrator.
- StandardProcedures.aspx – Can be edited by MasterDataAdministrator.
- TaskManager.aspx – Can be edited by MasterDataAdministrator.
- UnitEditorForm.aspx – Can be edited by MasterDataAdministrator.
- ValidationSiteType.aspx – Can be read by ConsortiumAccess and edited by MasterDataAdministrator.

The forms in the following list need to be converted. This final conversion will be completed during the first quarter of 2014: BatchApproval.aspx, BatchViewer.aspx, Contacts.aspx, FieldSamples.aspx, FileApplyDefaultMetaData.aspx, FileDownloadR2.aspx, FileLinker.aspx, FileMove.aspx, FileUpload.aspx, ListReports.aspx, Materials.aspx,

MeasureApproveTestRun.aspx, MeasurEditTestRun.aspx, Measures.aspx, MeasureCreateTestRun.aspx, ValidationManager.aspx, VerifyReports.aspx.

In addition to changes to the role system, a few modifications have been made to the user system as follows:

- The search feature on the form named ManageUsers.aspx has been enhanced such that it is now possible to search for existing users by name in addition to e-mail address and login. If there are multiple users having the same last name, those matching users will be displayed in a grid.

The Delete User function on the form named Manage Users will now display a list of tables for which data is stored.

7. Improvements to the Property Editor: The Property Editor, designed for use by the MasterDataAdministrator, allows the user to add property groups to material types and to create new quantitative and qualitative properties. However, over time, the number of property groups applicable to selected material types has become quite lengthy. Thus, the resulting form's output can become very long and tedious to scroll. To solve this problem, a second step has been added to the form, allowing users to select specific quantitative and qualitative property groups from a predefined list. Only those property groups applicable to the selected material type will appear in the resulting editor.

8. Database Initialization Feature: As the development of the ARC application and database reaches the end of its current contract period, the development team is preparing the system for deployment with varying data configurations. These configurations are made possible by a sequence of T-SQL scripts that will initialize data as follows:

- One script will initialize such that all transactional data will be deleted but master data will not.
- Another script will initialize the system such that both master and transactional data will be deleted. This script will produce what the development team refers to as a **default configuration**.
- A final script will initialize the user system and role system.

At the end of this quarter, the preliminary scripts have been written. They will be finalized and tested next quarter.

9. Missing Measurement Data Feature: At the FHWA Turner Fairbanks meeting, the topic of missing measurement data was discussed. It was decided that a mechanism was needed to identify a measurement data point as missing. To that end, fields were added to the qualitative and quantitative measurement tables. The first field is flag to indicate that a data point is missing, and the second is a descriptive field designed to indicate why the data is missing. The following tables were modified to support the missing data feature:

- tblQNMeasure: Added fields fldIsMissing (bit) and fldMissingDescription varchar(255)
- tblQNMeasure: Added fields fldIsMissing (bit) and fldMissingDescription varchar(255)

The following views were modified:

- vAllMeasuresJoined: Added fields fldIsMissing and fldMissingDescription to view. (Used by spAllPropGroupsByAllFactors and others)

The following stored procedures were modified:

- spAllPropGroupsByAllFactors: Added field IsMissing to query.
- spAllMeasuresByAllFactors: Added field IsMissing to query. fldMissingDescription is selected too.
- spINSERTQLMeasure: Added field fldIsMissing and fldMissingDescription
- spINSERTQNMeasure: Added field fldIsMissing and fldMissingDescription.
- spINSERTQNMeasureAndDims: Added field fldIsMissing and fldMissingDescription.
- spINSERTQNMeasureMultiDim: Added field fldIsMissing and fldMissingDescription.
- spINSERTQLMeasureMultiDim: Added field fldIsMissing and fldMissingDescription.
- spUPDATEQLMeasure: Added field fldIsMissing and fldMissingDescription.
- spUPDATEQNMeasure: Added field fldIsMissing and fldMissingDescription.
- spUPDATEQNMeasureAndDims: Added field fldIsMissing and fldMissingDescription.
- spUPDATEQNMeasureMultiDim: Added field fldIsMissing and fldMissingDescription.
- spUPDATEQLMeasureMultiDim: Added field fldIsMissing and fldMissingDescription.

The following files were modified to add the fields named fldIsMissing and fldIsMissingDescription to the measurement system.

- App_Code/DBUtility.aspx.cs
- App_Code/FactorSelector.aspx.cs
- ucMultiDimMeasure.ascx.cs
- ucMeasureBulkEditor
- HighDimPropMeasureEditor.aspx.cs

At the time of this writing, the conversion is nearly complete and will be deployed to the production database during the first quarter of 2014.

10. Status of Final Reports and Documentation: Considerable effort has been put into the final report and other supporting documents as follows:

- The Help page named UserAdminManual.aspx contains an administration manual intended for use by the MasterDataAdministrator.
- The Help page named ConfigManual.aspx contains an installation and configuration manual.
- Finally, the relative completion of final Report K is discussed in this section.

The page named Tutorials.aspx contains links to tutorials designed for specific categories of users to perform specific tasks. The tutorial appearing in the form named UserAdminManual.aspx describes how perform all user management functions. This tutorial is intended for use by the individual(s) designated as the UserAdministrator. It addresses the following topics:

- It contains a conceptual discussion of the ARC user and role management systems implementation.

- It contains a conceptual discussion of how to manage users, manage roles, and permission sets.
- Administration of both public and consortium (trusted) users are discussed.
- There are specific steps to approve and reject public users, steps to create users and assign those users to roles, and steps to convert public users into consortium (trusted) users.
- The topic of permission sets is also discussed.

Note that while the tutorial is complete, figures need to be added to the tutorial. This task will be completed next quarter.

The tutorial appearing on the form named ConfigManual.aspx discusses the detailed steps needed to install and configure both the ARC application and the ARC database.

- The ARC database requires SQL Server. The steps to install the ARC database on an existing SQL server are discussed in this section. Note that the document does assume that an existing SQL Server exists. The installation process depicts the creation of the necessary user accounts and the process to import the ARC database template.
- IIS is intended to host the ARC application and connect with the ARC database. The second section this document describes how to configure IIS to host the ARC application. The topics of creating application pools, and the necessary worker processes are discussed.
- The final section describes how to install and configure the ARC application itself.

Note that this tutorial assumes that the administrator is familiar with Microsoft SQL Server, IIS administration, and has sufficient privileges to create the necessary objects.

Development is well-underway on the Final Report (Report K). The report is divided into three chapters.

- Chapter 1 contains a functional overview of the ARC database for internal users and master data administrators.
- Chapter 2 describes the master data and transactional data elements that make up the ARC database and ARC application. The content of this chapter would likely be relevant to those responsible for maintaining and enhancing the ARC application or database.
- Chapter 3 describes the implementation details of the ARC database and application along with how various technologies are employed. This chapter would be relevant to those responsible for installing, configuring, and tuning the ARC application and database.

At the time of this writing, development of the following appendices are underway:

- Appendix A contains a list and descriptions of the .aspx forms that comprise the ARC application. Custom HTTP handlers are also listed in this appendix.
- Appendix B contains a list and descriptions of the user controls that comprise the ARC application.

A draft of the final report will be completed February 2014 and made available for technical review by the FHWA.

11. General Code Enhancements and Code Cleanup: As the ARC application and database have evolved over the development period, some obsolete code remained resulting from changes in design and implementation. Much of this obsolete code has been removed.

- Development was started on a prototype that would record all database updates into a transactional logging subsystem. However, because of the complexity of the multidimensional measure system and the number of tables touched by a particular transaction, development of this subsystem was abandoned. The table tblChangeLog, and stored procedure spINSERTChangeLog were removed. In addition, the DBUtility library was updated to delete the related procedures and the entire XML region.
- A prototype user management system was created initially to manage the ARC user base. This system was not adequate and was enhanced to extend the ASP.NET membership and role providers. The obsolete table tblUser and stored procedures spInsertUser and spUpdateUser were removed from the data dictionary. The form named UserEntry.aspx was also removed.
- jQuery is being used by the application for various controls. And the development team continues use additional jQuery controls and AJAX to improve the application's visual appearance and performance. Initially, the jQuery libraries were downloaded and stored in the ARC application. All local jQuery libraries have been removed and the references updated to get current code from one of the common jQuery sites as follows:

```
<script type="text/javascript" src="http://code.jquery.com/jquery-1.9.1.js"></script>
<script type="text/javascript" src="http://code.jquery.com/ui/1.10.3/jquery-ui.js"></script>
```

  Standard jQuery style sheets are referenced similarly:

```
<link rel="stylesheet" href="http://code.jquery.com/ui/1.10.3/themes/smoothness/jquery-ui.css" />
```

- Obsolete files have been removed from the ClientBin folder. All jQuery libraries were removed. Obsolete files were removed from the Scripts folder.
- Removed the following obsolete forms and sitemap files for TestRunTest.aspx, TestucQnMeasureRecordEditor.aspx.

12. General User Interface Improvements: As planned last quarter and from ARC FHWA meeting, it was suggested that a redundancy check for material type names be created. For both material categories and material master categories, the name is checked to verify that it is not a duplicate. In addition, this same check is made to eliminate redundant property group names. The Unit Editor was originally implemented as a user control and included in the Property Editor to create units of measure for the ARC database. While supported for backward compatibility with the Property Editor, a new standalone form has been created allowing the MasterDataAdministrator to independently edit these units of measure.

The colors used in the system menu were changed to provide better contrast. Several changes were made to improve the organization of the cascading style sheets (CSS) used by the ARC application and redundancy between these CSS sheets.

- All application related cascading style sheets now appear in the folder CSS, which is a child of the main ARC folder.
- Unused styles were removed.
- Selected controls had their own internal style sheets. These were standardized and incorporated into the main application cascading style sheets.

The task manager form (TaskManager.aspx) was enhanced. The user interface to add and edit the program area, category, work element, and subtask was changed to use a FormView control instead of a DetailsView control so as to improve user interface consistency. In addition, a sanity check was added to make sure that both names and codes exist on an edit and update. Finally, a report was created that will list all of the work task hierarchy.

13. Work planned for Next Quarter:

- Complete figures in the system configuration manual (configManual.aspx).
- Complete update from the old role system to the new role system.
- Add a subsystem that will allow the system administrator to create announcements for general user consumption.
- Finalize system initialization scripts.
- Finalize DQA report draft.
- Complete final report K.
- 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.

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. Address editorial review comments from FHWA as needed.

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
Behind Schedule (Submission of Final Report).

Work Completed: Updated draft final report was submitted for review.

Work Planned: Technical review comments from FHWA are pending. Draft will be revised to address comments when they are received. Final version of report, Section 508 document, Image Descriptions, and Tech Brief will be submitted in one package.

Reason for Delay
Work on final materials is delayed pending receipt of peer review comments on updated version of draft final report.

Revised Delivery Dates
Draft Report: 10/31/11 (Submitted)
Final Report: 3/31/2014, (Revised from 10/31/13, completion pending receipt of review comments).

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
Behind Schedule (Submission of Draft Final Report)

Work Completed: Completed analysis of data and preparation of the draft final review. Report is under final internal review and will be submitted early in 2014Q1.

Work Planned: Submit draft final report and address any comments received from peer-reviewers.

Reason for Delay
Draft report is currently under internal review and will be submitted in 2014Q1.

Delivery Dates
Draft Report: 3/31/2014, (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
Behind Schedule

Work Completed: Submitted draft final report.

Work Planned: Address technical review comments. Submit revised final report with Section 508 document, Image Descriptions, and Tech Brief to FHWA.

Reasons for Delay
Comments from FHWA on draft final report pending. Extension requested to allow extra time for comments to be received and final documents to be submitted.

Delivery Dates
Draft Report: 9/30/2013 (Completed), extended from 6/30/2013
Final Report: 3/31/2014, (Revised from, 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: 50% of draft final report completed. In addition work related to selection of mixing temperatures based on quality of coating and compaction temperatures based on mastic viscosity has been compiled for inclusion in the draft final report.

Work Planned: Complete remainder of draft final report, incorporate input from UNR related to WMA mixture performance and the Manitoba field project, and complete internal review.

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

Delivery Dates
Draft Report: 3/31/2014 – extended from 9/30/2013, 3/31/2013, 12/31/2014
Final Report: 6/30/2014 – 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: Began compiling information for efforts related to CMA mix design and evaluation of fresh emulsion and residue properties. Literature review section of draft final report was completed. Additional chip seal field validations were surveyed in Wisconsin. Images of chip seal surface after approximately 2 months in-service were collected and MPD measurements using the sand patch method were conducted.

Work Planned: Finalize mixture design procedure and complete performance evaluation of CMA mixtures. In regards to field validation, coordinate with WRI, complete testing of emulsion residues from NCAT test track, and WI field sites will be revisited.

Delivery Dates
Draft Report: 3/31/2014, from 9/30/2013, 12/31/2013
Final Report: 6/30/2014, 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 can be delivered in non-508 format. A section 508 format report could be written if LaTeX notation format for equations provides sufficient clarity to visually impaired readers and if having only a small number of graphs can be deemed acceptable. The solution for describing complex organic chemistry molecules to visually impaired readers is unclear at this time.

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.

Compositions were identified in previous quarters. A peer-reviewed publication that disseminates new proposed compositions for AAA-1, AAK-1, and AAM-1 appeared on-line in the journal *Fuel* during a prior quarter and will appear in print in January 2014.

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

Slight delay during the past quarter.

Results from molecular simulations of model asphalts continued to be analyzed to obtain physical insights. A manuscript was accepted in the *Journal of Chemical Physics* that quantified the raw dynamics results. It will become available on-line and in print in January 2014. A manuscript that described complex modulus results obtained from molecular dynamics simulation results was submitted to the *Journal of Chemical Physics* during the quarter, and unfortunately it was rejected after it did not communicate the work sufficiently clearly for the reviewers. The manuscript will be revised early in the next quarter and will be resubmitted for

publication. These efforts have focused on the new AAA-1 model system, with results for other model asphalts set aside as the methods and understanding are refined.

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

Delay during the past quarter.

Work to simulate additional asphalt systems continues to proceed more slowly than expected. The main cause of the delay is the ongoing new teaching load assigned to the PI, which has slowed research progress significantly. Getting existing computer hardware operational and new computer hardware in place has also been impacted by the very large teaching load.

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, as described above. The inputs for these calculations are the molecule positions, velocities, and stress fluctuations that are calculated in the 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 will include direct molecular simulation outputs and some group contribution correlations.

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 will focus especially on interpreting the peer-reviewed publications in the chemistry literature into language and concepts that are most familiar to the asphalt pavement research community. The report will include detailed descriptions of the simulation data that will be included within the ARC database.

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

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

Included work elements/subtasks
Sub-subtask F3a-1.5. Molecular mechanics simulations of asphalt-aggregate interfaces (VT)
Sub-subtask F3a-1.6. Modeling of fatigue behavior at atomic scale (VT)
Sub-subtask F3a-1.7. Modeling of moisture damage (VT)
Sub-subtask F3a-1.8. *ab initio* Calculations of Asphalt Molecular Structures and Correlation to Experimental Physico-Chemical Properties of SHRP Asphalts (WRI-TUDelft)
Subtask F3a-2. Multiscale modeling based on phase field method and MD simulation (VT)
Sub-subtask F3a-2.1 Multiscale modeling of single mode cracking (VT)
Sub-subtask F3a-2.2 The generalized J – integral in multiscale modeling (VT)
Sub-subtask F3a-2.3 Multiscale modeling of Phase separation (VT)
Sub-subtask F3a-2.4 Potential multiscale applications (VT)
Subtask F3a-3. Phase-Field and Continuum Mechanical (Finite Element) Modeling of Asphalt Binder, 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 WE F3a:
The writing of Report T is in progress, but behind schedule with an anticipated draft completion date of April 15, 2014. Elements of Report S will be reflected in the present report regarding Subtask F3a-1.
Both reports S and T are delayed and require an extension to the end of the next quarter.

Status and Work Planned for Sub-subtasks F3a-1.5, 6 and 7:
On Schedule

Status and Work Planned for Sub-subtasks F3a-1.8:
Complete

Status and Work Planned for Subtask F3a-2:
On Schedule

At this moment, this research progress is on time according to the plan. Subtasks F3a 2.1-2.3 are completed. Work Element F3a-2.4 is ongoing with additional research planned for the next quarter.

Research on the single mode cracking by multiscale modeling combining phase field method and molecular dynamics simulation has been conducted. The bridging area for both approaches is in the crack tip. It is expected that the continuum Phase-field system will control the cracking process and MD simulation will dominate at the crack tip. The stress and strain from the phase field simulation will be used as the boundary condition in the MD simulation by LAMMPS ($P \rightarrow M$) and then the MD simulation returns the elastic energy into the two-way coupled system ($M \rightarrow P$).

If we want to expand the single mode cracking research to a general case, we need to figure out *J* – integral in the Multi-scale modeling. Since we have determined *J* – integral in Phase field system, the *J* - integral in MD simulation must also be obtained.

In the zero temperature equilibrium, the generalized Eshelby stress tensor is given as [Jones et al. 2011]

$$\boldsymbol{b} = F\mathbf{I} - (\boldsymbol{\nabla}\mathbf{u})^{\mathrm{T}}\boldsymbol{P} \tag{F3a-2.3.1}$$

where F is the total free energy density, $\mathbf{I}$ is the identity tensor, $\mathbf{u}$ is the displacement field and $\boldsymbol{P}$ is the first Piola-Kirchhoff stress. *J*-integral is then calculated as the boundary integral of $\boldsymbol{b}$**.** Note that, in the zero temperature equilibrium, any material is brittle and thus all the "usable" free energy will be transformed to the surface energy of two newly created surfaces.

In order to obtain the free energy density, the corresponding Hamiltonian needs to be figured out. Considering the classical harmonic oscillator [Sethna 2006], the harmonic oscillator of mass *m* and frequency ω has the total Hamiltonian

$$\mathcal{H}(p,q) = \frac{p^2}{2m} + m\omega^2 q^2/2 \tag{F3a-2.3.2}$$

and the corresponding partition function is (using $\hbar = \frac{h}{2\pi}$)

$$Z = \int_{-\infty}^{+\infty} dq \int_{-\infty}^{+\infty} dp \, \frac{1}{h} e^{-\beta\left(\frac{p^2}{2m} + m\omega^2 \frac{q^2}{2}\right)} = \frac{1}{\beta\hbar\omega} \tag{F3a-2.3.3}$$

Considering

$$F = -k_B T ln Z \tag{F3a-2.3.4}$$

we get

$$F = k_B T log(\hbar\omega/k_B T) \tag{F3a-2.3.5}$$

which is the expression for the free energy density in equation (F3a-2.3.1). The first Piola-Kirchhoff stress will be determined in the next quarter.

Status and Work Planned for Subtask F3a-3:
Complete

Status and Work Planned for Subtask F3a-4 and F3a-5:
On Schedule

References

Jones, R. E., J. A. Zimmerman, J. Oswald, and T. Belytschko, 2011, An atomistic J-integral at finite temperature based on Hardy estimates of continuum fields. *Journal of Physics: Condensed Matter*, Vol. 23, 015002.

Sethna, J. P., 2006, *Statistical Mechanics: Entropy, Order Parameters and Complexity*. Oxford University Press, USA.

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 approximately 80 percent complete.

The report will be completed next quarter. The revised delivery date for the draft report is March 15, 2014.

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 TT1d: Development of Materials Database

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
Behind Schedule

Work Completed:
Completed the extended test matrix using the mechanical and chemical compositions tests to develop an analysis methodology for assessing long term aging effects of aggregates on aging based on the filler characteristics. Work on draft report is currently underway.

Work Planned:
Submit draft final report in accordance to the delivery date and address any peer-review comments received.

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

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 completed next quarter. The revised delivery date for the draft practice is March 15, 2014.

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: Competed.

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
Behind Schedule. The date is revised to reflect the delay in the draft AASHTO practice.

This quarter effort mainly focused on RAP characterization and Mix design using the proposed seven step Mix design method. CIR materials from two different sources (i.e., Redrock and Alturus) and PASS R Emulsion from Western Emulsion were used for the validation of the proposed mix design.

The representative sample of RAP materials from each source were obtained by quartering the buckets of RAP. Two RAP gradations were chosen; a graded RAP which satisfies the medium gradation requirements of the Pacific Coast Conference on Asphalt Specification (PCCAS) and a non-graded RAP which is used as it is obtained from the millings but passing the 1 inch sieve. As a part of RAP evaluation, the asphalt content of the RAP materials was determined according to AASHTO T164. The RAP binder characterization of these materials are currently in progress.

The proposed 7-step mix design procedure was followed to perform the CIR mix designs.

- *Selection of suitable RAP gradation and emulsified asphalt:* CIR materials from two different sources (i.e. Redrock and Alturus) and PASS R Emulsion from Western emulsion were chosen. Two CIR mixes from Alturus (Graded RAP with 1.0% hydrated lime and Graded RAP with 0.5% cement) and one CIR mix from Redrock (Non-graded RAP with 1.0% hydrated lime) were identified.
- *Determination of mixing time:* RAP material was mixed with the required amount of water (1.0%-4.0%) for 1 minute, a pre-determined amount of lime or cement for 1 minute and then mixed with emulsion for 1 minute.
- *Determination of theoretical maximum specific gravity (Gmm):* The RAP material was mixed with required amount of water for 1 minute, a pre-determined amount of lime or cement for 1 minute and predetermined amount of emulsion is added to the mix and mixed for 1 minute. The mixed samples were cured at 60°C until they reach constant mass. Then the theoretical maximum specific gravities of the CIR mixes were determined according to AASHTO 209. The theoretical maximum specific gravity of CIR was calculated at one binder content first and the theoretical maximum specific gravities at other binder contents were calculated assuming the calculated constant effective specific gravity (Gse).
- *Determination of required no of gyrations to prepare compacted sample:* The required number of gyrations was selected to reach the target air void of 13 ± 1% and target height of 115 ± 5 mm.
- *Determination of curing time:* In the previous phase of this study, 24 hrs of curing at 140°F was found to be appropriate to reach the constant mass (less than 0.025% mass loss per hour). The same curing temperature and time were used in this experiment.

- *Determination of Optimum Emulsion Content (OEC) and Optimum Water Content (OEC):* The trial experimental matrix composed of 4 emulsion contents and 4 water contents (16 samples) was performed for one mix design. Whichever the best 2 combinations of emulsion content and water content out of 16 combinations meet the target air void of 13.0±1.0% and target specimen height of 115±5mm were selected for further experiment towards the mix design.

The following list describes the work planned for next quarter:

- Complete the mix design process for other two CIR mixes and TSR test for all three CIR mixes.
- Conduct performance related tests such as raveling test, cohesion test, dynamic modulus test, and flow number test for the various CIR mixes.
- Start writing 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: Study was designed to finalize mix design procedure.

Work Planned: Complete experimental design and use results to finalize mix design procedure.

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

Delivery Dates
Draft AASHTO Practice: 3/31/2014, from 9/30/2013
Final AASHTO Practice: 6/30/2014, from 3/31/2014

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: IDENTIFICATION OF CRITICAL CONDITIONS FOR HMA MIXTURES

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

Status and Work Planned
On schedule.

Responded to the Comments provided by the AASHTO Subcommittee on Materials (SOM) on the New Provisional Standard "Determining Asphalt Mixture Critical Conditions for Rutting Evaluation by Means of Dynamic Repeated Load Triaxial (RLT) Test"

DRAFT AASHTO METHOD: THERMAL STRESS RESTRAINED SPECIMEN TEST (TSRST)
(Formerly, 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 following list describes the on-going and completed work items:

- Responded to the Comments provided by the AASHTO Subcommittee on Materials (SOM) on the New Provisional Standard "Determining Thermal Cracking Properties of Asphalt Mixtures through Measurements of Thermally Induced Stress and Strain"
- Testing the standard aluminum specimens to calibrate the UTSST.
- 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 need it.
- Used the Viscoelastic Continuum Damage (VECD) along with the proposed modified TSRST measurements to evaluate the low temperature properties of the asphalt mixtures. Using the modified TSRST (i.e., UTSST), the damage characteristic curve (C vs. S) of the asphalt mixture was determined. The pseudo-strain was calculated from the undamaged relaxation modulus (interconverted from complex modulus) and the thermal strain (from the cooling rate in the TSRST and the temperature dependent thermal coefficient of contraction). When damage is not occurring, the relationship between the measured thermal stress and the calculated pseudo-strain should be linear. Consequently, any non-linearity in the relationship will be related to the damage growing under thermal loading.

DRAFT AASHTO METHOD/PRACTICE: DETERMINING ASPHALT BINDER BOND STRENGTH BY MEANS OF THE BINDER BOND STRENGTH TEST
(Formerly, Determining Asphalt Binder Bond Strength by Means of the Bitumen 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: Ruggedness testing and modifications to the AASHTO procedure were complete were presented to the FHWA Binder ETG in September 2013. Revisions were detailed and justified in the final version of Report M.

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. Additional testing to verify procedure was conducted.

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: 3/31/2014, from 6/30/2013, 3/31/2013, 9/30/2013, 12/31/2014
Final AASHTO Method: 3/31/2014 - 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 complete. Procedure was detailed in a TRB paper that was accepted for a poster session and publication.

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: Update regarding analysis procedure and test conditions were presented to the FHWA Binder ETG in the Sept. 2013 meeting.

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 last quarter.

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: Comments submitted by AASHTO SOM were addressed and sent to FHWA.

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
Behind Schedule.

Work Completed: Comments received from ASTM were addressed and submitted to equipment manufacturer for review. Decision was made to base Precision and Bias Statement on maximum eccentricity.

Work Planned: Complete analysis for precision and bias statement based on maximum eccentricity value. Data has already been collected.

Reasons for Delay
Approval of revised ASTM standard was not received until late in 2013Q4. Precision and Bias statement will be completed early in 2014Q1.

Delivery Dates
Draft ASTM Standard: Complete
Finalize ASTM Standard: Complete 12/31/2013
Complete Precision and Bias Statement P&B Statement: 3/31/2014 (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
Progress on this work element involves the development of a method to analyze AFM surface contour data to remove low-frequency (saw-cut) roughness so that the micro-scale (higher-frequency) roughness can be separated out. The method uses a Fourier transform to separate the frequency domains associated with the saw cut from the higher frequency associated with the micro-scale surface roughness. This technique should provide a simple method for the measurement of micro-scale roughness for an unpolished surface as typically left by a diamond saw.

Archival data (surface scans of selected aggregate types) that will be used for this subtask was retrieved and assembled this quarter. This work is currently on schedule to meet the revised completion date.

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
Force displacement curves have been collected and analyzed as a function of temperature and stress rate for two SHRP core asphalts. Both asphalts exhibit a clear step in an otherwise smooth change in fracture energy as the test temperature is increased. Work to date suggests that the dissipative component of the fracture energy drops significantly at temperatures well above those typically associated with the 'glass-transition', i.e., the dissipative function becomes negligible at the onset of the glass-transition.

Development of this test method will continue in the next quarter. Due to sharing of personnel and equipment between tasks, only minimal work was conducted on this subtask this quarter. This subtask is currently expected to meet the revised completion date.

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
Draft AASHTO Method has been completed

CHIP ADHERENCE STABILITY TEST APPARATUS

This new work element will generate a scaled-up adhesion test based upon the micro/nano-scale work described in previous reports. The new test method measures the adhesion of an aggregate chip as a function of both rate and temperature. The test provides a measure of fracture toughness as well as ultimate adhesive strength. The fracture toughness term incorporates the effects of embrittlement and should, therefore, provide a much better performance predictor than simple measures of ultimate adhesive strength. The new test is designed specifically to help assess and predict the performance, both short and long term, of various surface applied pavement preservation materials. Other possible applications are also being considered.

Status and Work Planned
A prototype chip adherence stability (CAS) test apparatus is nearly completed at the time of this writing. The test apparatus is ready for final assembly and is complete with the exception of two process controllers, delivery of which has been delayed several times by the supplier. We expect to receive the controllers and complete the assembly of this test apparatus early next quarter.

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

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

Status and Work Planned
Completed

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

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

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

MODELS AND SOFTWARE

MODEL: HMA THERMAL STRESSES IN PAVEMENT

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

Status and Work Planned
On Schedule.

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

- The validation of the aging model for the laboratory aging and field aging conditions are in progress. New approach has been proposed for determination of oxidative kinetic properties of asphalt binder using less experimental efforts.
- The work is in progress to incorporate damage evolution in analysis of thermal build up stress using the viscoelastic continuum damage (VECD) modeling.
- Work has been conducted to evaluate the effect of oxidative aging on the thermal coefficient properties of asphalt mixtures.
- The development of the thermal cracking analysis package (TCAP) is in progress. The research version of the software is scheduled to be released by the end of the next quarter.

The following list the work planned for next quarter:

- 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. No bugs were identified this past quarter with the version 2.1 of the software. Work continued on the new platform for next 3D-Move version (Ver. 3). Continued wrking on the Final Report and the 3D-Move documentation.

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.

OTHER RESEARCH ACTIVITIES

Subtask E2b-2: Compatibility of RAP and Virgin Binders

Work Planned Next Quarter

The viscosities of crossblends will be used to verify if the Pal-Rhodes model, that was developed from Einstein's colloid theory in terms of accommodating for more concentrated suspensions to account for asphalt flow property, can be employed to characterize the flow properties of recycled asphalt pavement (RAP) binder blends.

Status and Work Done This Quarter

To relate measures of compatibility to the D-EMT/Pal-Rhodes model, the asphaltene compatibility index (ACI= $\frac{Asphaltene_{Iso-Octane}}{Asphaltene_{n-heptane} + Asphaltene_{Iso-octane}} x10$) was further correlated to Heithaus compatibility parameters and is shown in Figure E-2b.2.1:

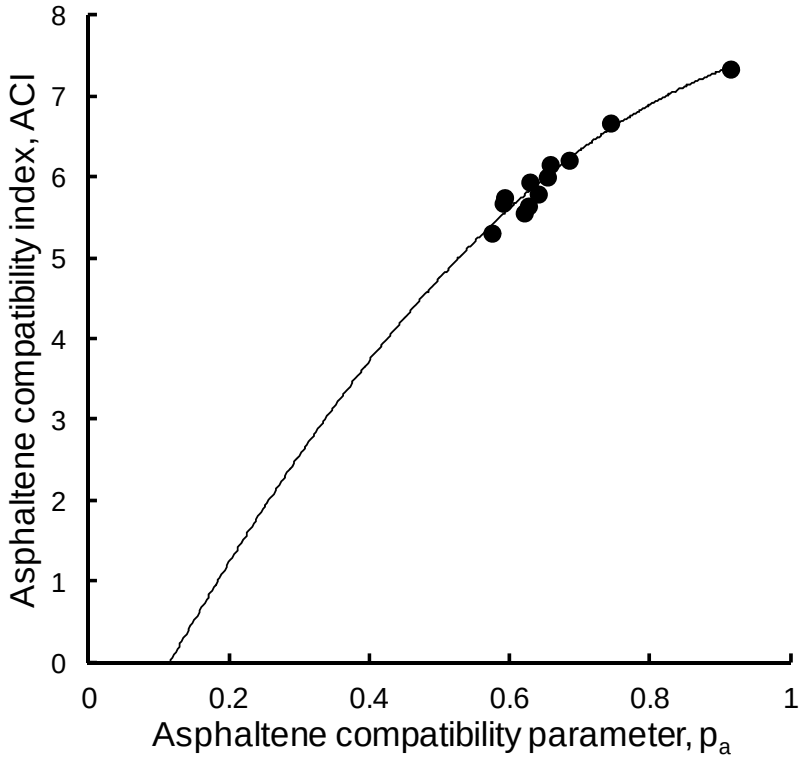


Figure E-2b.2.1. Plot of the asphaltene compatibility index versus the reversible asphaltene peptizability parameter for twelve SHRP asphalts.

Separately, the paper entitled "Aging Characteristics of RAP Binder Blends—What Types of RAP Binders Are Suitable for Multiple Recycling?" by Shin-Che Huang, Adam T. Pauli, R. Will Grimes, and Fred Turner has been accepted for presentation at the annual AAPT meeting, March 2014. The manuscript was also accepted for publication in both the Journal of the Association of Asphalt Paving Technologist and the Journal of Road Materials and Pavement design (RMPD). The revised manuscript has been submitted to both AAPT office and RMPD office for publication.

The viscosities of maltene fractions crossblends are being used to verify if the Pal-Rhodes model can be employed to characterize the flow properties of recycled asphalt pavement (RAP) binder blends at the present time.

Work Planned Next Quarter

A mixing rule, based on Pal-Rhodes model, for blending high RAP contents and virgin binder will be proposed and reported in the next quarter.

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

Work Done This Quarter
Mixture testing on the ATCA low temperature samples was completed. Furthermore, analysis of the large amount of data gathered over the last quarter continued and was completed this quarter. The information was added as a chapter to the draft final report and is under final review for submission.

Work Planned Next Quarter
Complete internal review and submit draft final report in 2014Q1. See Report N for additional details.

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.

Publications
Zhang, L.; Golalipour, A.; Tabatabaee, H.A.; Bahia, H.U.; "Prediction of Effect of Bio-Based and Refined Waste Oil Modifiers on Rheological Properties of Asphalt Binders," Accepted for Presentation at the Transportation Research Board Annual Meeting, 2014.

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

Emulsion testing framework was summarized in a TRB Symposium paper and continues to be used on emulsions for various applications. WI filed sites were revisited after two months in-service condition was photo-documented and mean profile depth measurements were taken using the sand patch method. WRI also continues validation efforts to sample emulsions, extract particulate matter, and measure performance properties (using 4 mm parallel plate) on four chip seal sections constructed nearly four years ago as part of the Federal Lands project.

For CMA mix design, procedures for coating evaluation and sample preparation detailed in a TRB paper were presented as a poster session. The paper was also accepted for full publication.

Work Planned Next Quarter

Revisit WI Chip Seal sites in spring, test NCAT emulsions and compare to initial field performance. Compile data collected by WRI. For CMA mix design, a small study will be executed to pilot the preliminary design procedure and assess the impacts of experimental factors on CMA performance. All work will be summarized and the draft final report will be delivered.

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: 3/31/2014, extended from 9/30/2013, 12/31/2103
Due Date for Final Report Submittal: 6/30/2014
Significant Problems, Issues and Potential Impact on Progress

None, on revised schedule.

Publications

Ling, C. Hanz, A.J., Bahia, H.U., "Developing Evaluation Method for Moisture Susceptibility of Cold Mix Asphalt." Accepted for presentation and publication at the 2014 TRB Meeting.

Work Element E3c: Laboratory Assessment of Mixture Long Term Aging

Work Done This Quarter

Completed the extended test matrix using the mechanical and chemical compositions tests to develop an analysis methodology for assessing long term aging effects of aggregates on aging based on the filler characteristics. Hydrated Lime and Dolomite filler were added to the matrix and correlations between rheological properties and chemical compositional data from GPC were derived based on the effect of filler characteristics on aging. Work on draft report is currently underway.

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.

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

Work Done This Quarter

NCAT completed monitoring of several active field sites.

WRI completed monitoring of the US 93 and SR 74Arizona validation sites in November 2013.

Work Planned Next Quarter

The NCAT team will continue testing the materials sampled from the field projects and working on reports for field testing and monitoring that have been completed.

The WRI team will also continue testing the materials sampled from the field projects and working on reports for field testing and monitoring that have been completed.

WRI is planning to monitor the Rochester, MN validation site in the 2nd quarter 2014.

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

Work Done This Quarter

The project teams at WRI and NCAT continued testing the materials sampled from the Arizona RAP project and other new field projects.

Work Planned

The WRI and NCAT teams will continue testing the materials sampled from the field projects and preparing reports for field work that has been completed.