Summary of ARC Journal Papers

March 1

2011

Tables of journal papers for the ARC Program Areas: Moisture Damage, Fatigue, Engineered Materials, Vehicle-Pavement Interaction, and Validation

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Contents

Pages

Table 1: Summary of Journal Papers for the Moisture Damage Program Area

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
M1a-3: Evaluate the moisture damage of asphalt mixtures (UWM)	Journal Paper	Measuring Asphalt-Aggregate Bond Strength Under Different Conditions	8/10	Complete	N/A
	Journal Paper	Measuring Effect of Moisture on Asphalt-Aggregate Bond with the Bitumen Bond Strength (BBS) Test	1/11	Complete	N/A
M1a-5: Propose a novel testing protocol (UWM)	Journal Paper	Evaluation of Bitumen Bond Strength Test (BBS) for Moisture Damage	3/11	N/A	N/A
M1b-1: Use of micro calorimeter to measure the total energy of adhesion	Journal paper	A method to use the micro calorimeter to measure total adhesion including the influence of chemical interactions and specific surface area.	9/30/09	Complete	N/A
M1b-3: Identify mechanisms of competition between water and organic molecules for aggregate surface	Journal paper	Journal paper on organic-aggregate interactions tying together the results of subtasks M1b-3 and M3a			
M1c: Quantifying Moisture Damage Using DMA	AASHTO procedure and journal papers	AASHTO procedure for preparing Fine Aggregate Matrix (FAM) specimens for the DMA testing	9/31/10	Complete	N/A
M2b-1: Measurement of diffusion of water through thin films of asphalt binders and FAM	Two journal papers	Mechanism and model for the diffusion of moisture through films of asphalt binder, methods to measure diffusivity in binders and mortars, and the influence of wet-dry cycles on the cumulative moisture induced damage.	12/21/09	Complete	N/A
M4a: Micro-mechanics Model (TAMU)	Journal papers	Numerical micromechanical model of moisture-induced damage in asphalt mixtures	9/30/10	Complete	N/A
M4a: Micromechanics Model Development (Moisture Damage) (UNL)	Two journal papers	Cohesive zone modeling with moisture damage of asphalt mixtures considering mixture microstructure: modeling methodology, constitutive theory, testing protocols, test data, model simulation/calibration/validation, and user-friendly manuals.	10/30/10 03/31/12	Complete No change	N/A
M4a: Lattice Micromechanics Model (NCSU)	Two journal papers	One paper on a method to include air voids in the virtual microstructure and the second paper on the description and verification of Multiscale Virtual Microstructure Lattice Model.	7/31/11 9/30/11	7/31/11 12/31/11	The experimental work is slightly delayed due to equipment issues.

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
M4a: Model to Bridge Continuum Damage and Fracture (NCSU)	Two journal papers	One paper on the experimental characterization of the fracture process zone using Digital Image Correlation and the second paper on the continuum damage to fracture process including validation with experimental data.	9/30/11 9/30/11	12/31/11 12/31/11	The experimental work is delayed due to the acquisition of the new equipment for the DIC.
M4c: Unified Continuum Model (TAMU)	Journal paper	Paper on formulating the moisture-damage model based on laws of thermodynamics	6/11	N/A	N/A
	Journal paper	Validation of the moisture-damage model against experiments on asphalt mixtures	10/11	N/A	N/A
	Journal paper	Effect of moisture damage on rutting and fatigue damage	01/12	N/A	N/A

Table 2: Summary of Journal Papers for the Fatigue Program Area

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
F1a: Cohesive and Adhesive Properties	Journal Paper	Paper on relationship between ideal and practical work of fracture for aggregate-asphalt systems	6/11	N/A	N/A
F1b-1: Nonlinear viscoelastic response under cyclic loading	Four journal papers	A constitutive model that accounts for the nonlinearity and three - dimensional stress state of the material including a method to obtain model constants for asphalt binders.	12/30/08 3/31/10 9/30/10 12/31/11	Complete Complete 3/31/11 No change	Development of the protocols required slightly more time than anticipated. A draft of the third paper is almost complete.
F1c-3: Develop a Transport Model of Binder Oxidation in Pavements	Presentation, Journal Paper	Contributions to a new thermal and oxygen transport model of binder oxidation in pavements	8/2009	Complete	N/A
	Two Journal Papers	Modeling pavement temperature for use in oxidation modeling	12/2010	Complete	N/A
	Presentation, Journal Paper	Contributions to Correlations of Oxygen Diffusivity in Asphalts and Mastics	12/2010	Complete	N/A
	Presentation, Journal Paper	A Fast-Rate, Constant-Rate reaction mechanism model	12/2011	N/A	N/A
	Journal paper	Incorporating air void size distribution into a pavement oxidation model	7/2011	N/A	N/A
	Journal paper	Modeling binder oxidation in pavements: Field Validation	3/2012	N/A	N/A
F1c-4:The Effects of Binder Aging on Mixture Viscoelastic, Fracture, and Permanent Deformation Properties	Journal paper	Relations between lab and/or field binder properties and their changes with oxidative aging and mixture fatigue properties	8/2011	N/A	N/A
F1c-5: Polymer Modified Asphalt Materials	Journal paper	Degradation kinetics of polymer modifiers in asphalt materials	3/2012	N/A	N/A
F1c: Aging (Unified Continuum Model for Aging)	Journal Paper	Document the aging model development and validation	4/11	N/A	N/A
	Journal Paper	Further validation of the aging model	11/11	N/A	N/A

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
F1d – 1,2,3,4,5a,5b,8: Healing	Six journal papers	A mathematical model for self-healing at the micron scale, partial validation of this model, measurement of properties related to this model, measurement of overall healing as a function of damage and rest period, and micro to nano scale evaluation of properties that influence fracture and self-healing	12/31/08 09/30/09 3/31/10 09/30/10 09/30/11 12/31/11	Complete Complete Complete Complete No change No change	
F1d-6: Evaluate relationship between healing and endurance limit of asphalt binders (UWM)	Journal Paper	White paper on the effect of stress relaxation on healing characterization by applying cyclic loading with rest periods to common mechanical analog models	7/09	Complete	N/A
	Journal Paper	Paper summarizing difficulties of using DSR for healing characterization of binders using cyclic loading with rest periods. Limitations with reaching target strain level after each rest period in reasonable time. Variability of using time sweep procedures with rest periods.	7/10	3/11	Successful implementation of healing procedure by means of cyclic loading with rest periods caused delays due to limitations of DSR
	Journal Paper	Healing characterization of binders by means of mechanical testing with rest periods.	8/11	N/A	N/A
F1d-7: Coordinate with Atomic Force Microscopic (AFM) Analysis	Journal paper	Paper describing the phase-segregation nature of asphalt at the micro-nano scale		Complete	N/A
F1d-8: Coordinate Form of Healing Parameter with Micromechanics and Continuum Damage Models (TAMU)	Journal Paper	Formulating the micro-damage healing model based on micromechanics arguments within the framework of continuum damage mechanics	4/11		
	Journal Paper	Further validation of the micro-damage healing model	10/11		
F2a-4: Collect Fatigue Test Data (UWM)	Journal Paper	Paper on the development of Elastic Recovery test on the DSR and the relation between elastic recovery and fatigue damage resistance of neat and modified binders.	1/09	Complete	N/A
	Journal Paper	Paper on mechanisms by which modifiers control fatigue under various conditions.	03/11	N/A	N/A

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
F2d: Structural Characterization of Micromechanical Properties in Bitumen using Atomic Force Microscopy	Journal Paper	Submit ASCE Journal paper describing results of measurement of viscoelastic properties of various phases of three SHRP binders	3/31/11	N/A	N/A
	Journal Paper	Submit journal paper describing how AFM characterization of viscoelastic properties can be used in micromechanical models	12/31/11	N/A	N/A
	Journal Paper	Submit journal paper describing how AFM characterization of asphalt phases can be used to classify performance potential of asphalt binders relative to fatigue, aging susceptibility, and moisture damage	12/31/11	N/A	N/A
F2e-3: Binder and Mixture Fatigue Testing (UWM)	Journal Paper	Practical Application of Viscoelastic Continuum Damage Theory to Asphalt Binder Fatigue Characterization	It was not included originally	7/09	Significant progress was made and team decided to submit two publications on the application of VECD to fatigue characterization
	Journal Paper	Modification and Validation of the Linear Amplitude Sweep Test for Binder Fatigue Specification	It was not included originally	1/10	
F2e-5: Interpretation and Modeling of Data (UWM)	Journal Paper	Characterizing Fatigue of Asphalt Binders Using Viscoelastic Continuum Damage Mechanics	7/08	Complete	N/A
	Journal Paper	Comparison of Bitumen Fatigue Testing Procedures Measured in Shear and Correlations with Four-Point Bending Mixture Fatigue	7/09	Complete	N/A
	Journal Paper	Effect of Oxidative Aging on Binder Fatigue Performance	8/10	Complete	N/A
F3a: Asphalt Microstructural Model	2 Journal papers	Paper describing phase separation in bitumen and its relationship to fatigue and self healing based on experiment and continuum mechanics modeling. (WRI-Delft). Paper describing self-ordering in bitumen at molecular level based on molecular mechanics simulations. (URI).	6/30/11	NA	N/A

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
F3b-1: Micromechanics Model Development (Fatigue)	Seven journal papers	Cohesive zone fracture modeling of asphalt mixtures considering inelasticity, nonlinearity, rate-dependent fracture, and mixture microstructure: modeling methodology, constitutive theory, testing protocols, test data, model simulation/calibration/validation, user element (UEL) codes in ABAQUS, and user-friendly manuals. Multiscale modeling of asphaltic mixtures and pavements: modeling methodology, constitutive theory, and parametric analyses of the model.	03/31/09 07/30/09 09/30/09 07/30/10 07/30/10 07/30/10 08/30/11	Complete Complete Complete Complete Complete Complete No change	N/A

Table 3: Summary of Journal Papers for the Engineered Materials Program Area

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
E1a- Characterization of asphalt mixtures using controlled-strain repeated direct tension test	Journal Paper	Journal paper prepared that describes the measurement and analysis method to characterize asphalt mixtures using controlled-strain repeated direct tension test	07/01/10	02/02/11	The analysis method was changed due to the new development work
E1a- Characterization of fatigue damage in asphalt mixtures using pseudo stain energy	Journal Paper	Journal paper prepared that describes the method to characterize and quantify the fatigue damage using pseudo strain energy	08/01/10	02/20/11	More tests are needed to obtain the essential material properties
E1a- Model fatigue crack growth in asphalt mixtures	Journal Paper	Journal paper prepared that describes the method to model the evolution of the damage density		03/20/11	
E1a- Determine the healing properties of asphalt mixtures using controlled-strain repeated direct tension test	Journal Paper	Journal paper prepared that describes the method to measure and model the healing rate of asphalt mixtures with fatigue damage		04/20/11	
E1a- Determine the healing properties of asphalt mixtures using tensile creep and recovery test	Journal Paper	Journal paper prepared that describes the method to efficiently measure and model the healing rate of asphalt mixtures with creep damage		05/20/11	
E1a- Influence of aging on the fatigue resistance and healing properties of asphalt mixtures	Journal Paper	Journal paper prepared to examine the effect of aging on the fatigue and healing properties of asphalt mixtures		09/01/11	
E1a- Nondestructive Characterization of Anisotropic Viscoelastic Properties of Undamaged Asphalt Mixtures under Compressive Loading	Journal Paper	A Paper written by TAMU researchers that state the testing protocols and analysis methods to obtain the comprehensive properties of the undamaged asphalt mixtures in compression.	Completed		
E1a- Microstructure-Based Inherent Anisotropy of Asphalt Mixtures	Journal Paper	A Paper that describes a characterization parameter and an easily done test for the inherent anisotropy	Completed		

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
E1a- Interpretation of Parameters in Microstructure-Based Viscoplastic Model of Asphalt Mixture	Journal Paper	A paper that provides the parameter inputs of the viscoplastic model within the PANDA program based on basic material properties		9/30/2011	
E1a- Viscoelastic and Viscoplastic Characterization of Asphalt Mixtures in Compression	Journal Paper	A paper that provides a fast technique to conduct the decomposition of the viscoelasticity and viscoplasticity and supplies the material parameter inputs for the PANDA program		6/30/2011	
E1a- Evaluation of the Stiffness Gradient in the Field aged asphalt samples	Journal Paper	The paper will describe the analysis methods for stiffness gradient prediction and finite element simulation model of test	07/31/2010	04/20/11	Testing more samples from different locations were needed
E1a- Fatigue damage characterizations of asphalt using the overlay tester	Journal Paper	The paper will use the strain energy concepts together with finite element modeling to find A and n parameters		05/20/11	
E1a- Model FAM Fatigue Crack Growth under Different Relative Humidity	Journal Paper	This paper will characterize the moisture damage of FAM conditioned under 5 different relative humidities		04/15/2011	
E1a- Characterize FAM Bond Energy under Different Relative Humidity	Journal Paper	This paper describes a new method to back calculate the bond energy of FAM by the means of fatigue cracking modeling		06/15/2011	
E1a- Characterize Permanent Deformation of FAM under Different Relative Humidity	Journal Paper	This paper will characterize the permanent deformation of FAM conditioned under 5 different relative humidities		03/31/2012	
E1a- Self-Consistent Micromechanics Model of Asphalt Mixtures	Journal Paper	This paper describes the inverse and forward self-consistent micromechanics models of asphalt mixtures.	Published (ASCE Journal of Materials in Civil Engineering)		
E1a- Crack Size Distribution in Asphalt Mixtures	Journal Paper	This paper presents the Weibull distribution models of crack size in asphalt mixtures at different numbers of load applications.	Accepted for Transporta-tion Research Record		

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
E1b1-3: Conduct Testing (UWM)	Journal Paper	The Relationship between Nonlinearity of Asphalt Binders and Asphalt Mixture Permanent Deformation	7/09	Complete	N/A
E1b1-4: Analysis & Interpretation (UWM)	Journal Paper	Effects of increased loading level and time on rutting resistance of modified asphalt binders and mixtures	7/08	Complete	N/A
	Journal Paper	Combined with E1b1-3 paper	7/09	Complete	N/A
	Journal Paper	Paper on the analysis and interpretation of results of tests run in accordance to test plan	10/10	3/11	Additional time was spent on mixture preparation, conducting DSR accuracy checks
E1b1-5: Standard Testing Procedure and Recommendation for Specifications (UWM)	Journal Paper	Paper on final conclusions and proposed procedures and specifications	9/11	N/A	N/A
E1b-2iii. Preliminary testing and correlation of results (UWM)	Journal Paper	The use of indentation test for characterization of asphalt binders.	7/10	4/11	Postponed due to significant delays in receiving the modified test setup from the machine shop.
E1b-2iv. Feasibility of using indentation tests for fracture and rheological properties (UWM)	Journal Paper	Report and paper on Finite element simulations of the indentation test and correlations with DSR results.	7/09	4/11	
E1c-1ii. Effects of Warm Mix Additives on Mixture Workability and Stability (UWM)	Journal Paper	Establishing a Framework for Analyzing Asphalt Pavement Sustainability	7/08	Complete	N/A
	Journal Paper	Measuring Effects of Warm-Mix Additives: Use of Newly Developed Asphalt Binder Lubricity Test for the Dynamic Shear Rheometer	7/10	Complete	N/A
E1c-1iii. Mixture Performance Testing (UWM)	Journal Paper	Impacts of WMA Production Temperatures on Binder Aging and Mixture Flow Number	7/09	Complete	N/A
E1c-2i: Review of Literature and Standards (UWM)	Journal Paper	Performance Grading of Bitumen Emulsions for Sprayed Seals	7/08	Complete	N/A

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
E1c-2v. Conduct Testing Plan (UWM)	Journal Paper	Rheological Behavior of Emulsion Residues Produced by Evaporative Recovery Method	7/09	Complete	N/A
	Journal Paper	Paper on the results and analysis of tests run in accordance to test plan (refer to E1c-2vi paper at 7/10)	7/10	Complete	N/A
E1c-2vi. Develop Performance Selection Guidelines (UWM)	Journal Paper	Correlating Rheological and Bond Properties of Emulsions to Aggregate Retention of Chip Seals	7/10	Complete	N/A
E1c-2ix. Develop CMA Performance Guidelines (UWM)	Journal Paper	Paper on performance of Cold Mix asphalt pavements	7/11	N/A	N/A
E2a-4: Write asphalt modification guideline/report on modifier impact over binder properties (UWM)	Journal Paper	Paper describing the effect of modification on elastic recovery and fatigue performance of asphalt binders	8/10	Complete	N/A
E2b-1: Develop a System to Evaluate the Properties of RAP Materials (UNR with UWM input)	Journal paper	Evaluation of Rheological Properties of Binders in Recycled Asphalt Pavement Without Extraction and Recovery (UWM input)	7/08	Complete	N/A
	Journal Paper	Evaluation of Rheological Properties of Binders in Recycled Asphalt Pavement Without Extraction and Recovery (UWM input)	7/09	Complete	N/A
	Journal paper	Summarizing results and findings of fracture testing of RAP binders.	07/11	N/A	N/A
E2b-1.b: Develop a System to Evaluate the Properties of the RAP Binder (UWM)	Journal Paper	Refer to E2b-1 paper (7/08)	1/09	Complete	N/A
	Journal Paper	Estimation of Reclaimed Asphalt Pavement Binder Low-Temperature Properties Without Extraction: Development of Testing Procedure	7/10	Complete	N/A
	Journal Paper	Paper on the results of fracture testing of RAP binders.	7/11	N/A	N/A
E2b-3: Develop a Mix Design Procedure	Journal paper	Summarizing results and findings of the laboratory mixing experiment.	10/11	N/A	N/A
E2c-3: Develop a Simple Test	Journal paper	Critical conditions of various types of HMA mixtures.	08/11	N/A	N/A
E2d-3: Identify an Evaluation and Testing System (UNR with UWM input)	Journal paper	Thermal cracking characterization of mixtures by means of the unified Tg-TSRST device. (UWM input)	07/11	N/A	N/A

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
E2d-4: Modeling and validation of the Developed System (UNR with UWM input)	Journal paper	Field validation of testing procedure and model using LTPP sections' performance. (UWM input)	07/11	N/A	N/A
E2d-5: Develop a Standard (UNR with UWM input)	Journal paper	Thermal cracking characterization of mixtures by means of the unified Tg-TSRST device. (UWM input)	07/11	N/A	N/A

Table 4: Summary of Journal Papers for the Vehicle-Pavement Interaction Program Area

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for Changes in Delivery Date
VP2a-4: Run parametric studies on tire-pavement noise and skid response (UWM)	Journal Paper	Paper on parametric studies on tire-pavement noise and skid response	7/09	Complete	N/A
	Journal Paper	Comparing Surface Characteristics of Laboratory and Field Asphalt Mixtures	4/10	Complete	N/A
VP2a-6: Model and correlate acoustic response of tested tire-pavement systems (UWM)	Journal Paper	Paper titled “Comparing Surface Characteristics of Laboratory and Field Asphalt Mixtures”	7/10	Complete	N/A
	Journal Paper	Paper describing Modeling and correlating acoustic response of tested tire-pavement systems	8/11	N/A	N/A

Table 5: Summary of Journal Papers for the Validation Program Area

Name of Deliverable	Type of Deliverable	Description of Deliverable	Original Delivery Date	Revised Delivery Date	Reason for changes in delivery date
V3a-3: Development of protocols for new binder tests and database for properties measured (UWM)	Journal Paper	Practical Application of Viscoelastic Continuum Damage Theory to Asphalt Binder Fatigue Characterization (BYET test)	7/09	Complete	N/A
V3a-4: Development of specification criteria for new tests based on field evaluation of construction and performance (UWM)	Journal Paper	Low Temperature Cracking Characterization of Asphalt Binders by Means of the Single-Edge Notch Bending (SENB) Test	1/11	Complete	N/A
	Journal Paper	Assessment of the Inter-Laboratory Variability of Superpave PG and PG+ tests	12/11	N/A	N/A
V3a-5: Interviews and surveys for soliciting feedback on binder tests and specifications (UWM)	Journal Paper	Importance of Elastic Recovery in the DSR for binder specification	10/10	Complete	N/A
V3b-3: Select LTPP Sites to Validate New Binder Testing Procedures (UWM)	Journal Paper	Modification and Validation of the Linear Amplitude Sweep Test for Binder Fatigue Specification	8/10	Complete	N/A
	Journal Paper	Validation of test procedures developed in thermal cracking and moisture damage work elements using LTPP binders.	It was not included originally	8/11	LTPP binders became available for validation of thermal cracking and moisture damage procedures