Research Project Work Plan

for

ADJUSTING ASPHALT MIXES FOR INCREASED DURABILITY AND IMPLEMENTATION OF A PERFORMANCE TESTER TO EVALUATE FATIGUE CRACKING OF ASPHALT CONCRETE

Submitted by

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for

Oregon Department of Transportation
Research Unit
555 13th St. NE, Ste 2
Salem, OR 97301-6867

July 2015

Research Project Work Plan
for
Adjusting Asphalt Mixes for Increased Durability and Implementation of a Performance Tester to Evaluate Fatigue Cracking of Asphalt Concrete

1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700
Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator (ODOT requests only one per institution or firm)

Erdem Coleri, Ph.D., Assistant Professor
School of Civil and Construction Engineering
Oregon State University
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Phone: (541) 737-0944, Email: erdem.coleri@oregonstate.edu

1.3 Technical Advisory Committee (TAC) Members

TBD

1.4 Friends of the Committee (if any)

TBD

1.5 Research Coordinator

Norris Shippen
Research Coordinator
Oregon Department of Transportation (ODOT), Research Unit
555 13th Street NE, Salem, OR 97301-4178
Phone: (503) 986-3538

1.6 Project Champion

TBD

2.0 Problem Statement

Asphalt concrete fatigue cracking has been accepted to be a major distress mode in Oregon. Oregon Department of Transportation (ODOT)'s Pavement Management system has shown that mixes placed in the last 20 years have had a tendency to develop premature cracking after 6 to 8 years of service life before reaching the structural design life of 15 years. The widespread nature of this distress would suggest that it is an issue with the way mix is designed and produced and not a specific project related problem. Thus, current test methods and design guidelines should be modified and improved to be able to develop more durable asphalt mixtures with longer service lives. In order to determine the most feasible test method and analysis protocol to be used in district and contractor laboratories in Oregon, accuracy, precision, time, cost, efficiency, and practicality of different cracking tests should be evaluated.

2.1 Background and Significance of Work

High surface tensile stresses for thin asphalt concrete layers (top-down), high near tire shear induced tension for thick structures (top-down), and high bending stresses at the bottom of the asphalt concrete layers (bottom-up) are accepted to be the major causes of cracking (Roque et al. 2010). Cracking of asphalt concrete pavements is considered to be a complex phenomenon since it is often a result of both structural factors and material characteristics (Underwood et al. 2012; Bonaquist 2013). Due to this complexity, implementation of practical cracking tests and analysis protocols for practicing engineers can be challenging. In order to understand and model cracking performance without conducting many experiments, a mechanistic-empirical design tool needs to be implemented. Because the major distress mode in Oregon is fatigue cracking, the current design method balancing rutting and cracking resistance needs to be improved. The impact of changing the composition of ODOT asphalt mixes on fatigue cracking performance needs to be determined by laboratory testing and mechanistic-empirical modeling.

3.0 Objectives of the Study

This research would have five major objectives: i) compare the results of direct tension fatigue (DT), indirect tensile (IDT), semi-circular bending (SCB), and beam fatigue tests using various energy and fatigue life parameters to determine how well they agree; ii) investigate the effectiveness of each test for identifying the impact of polymer modification, recycled asphalt content, compaction level, aggregate properties, and binder contents on mixture cracking performance; iii) investigate the effectiveness of each test in predicting in-situ cracking performance; iv) evaluate the tests for time, cost, efficiency, complexity, and practicality for use in district and contractor laboratories in Oregon; and v) investigate the effects of aggregate properties, volumetrics, binder content, air void content and binder grade on durability to provide recommendations to the Contractor Mix Design Guidelines.

3.1 Benefits

Implementation of an effective cracking test and an analysis protocol will allow ODOT engineers to evaluate long-term performance of different asphalt mixture types during the design stage. Using the implemented cracking test and analysis protocol, cracking performance of asphalt concrete pavements in Oregon can be improved. Improved cracking performance will lead to reduced life cycle costs and increased pavement condition ratings for the Oregon roadway network. Implemented cracking test will be used to investigate the effects of aggregate properties, volumetrics, binder content, air void content and binder grade on durability.

4.0 Implementation

This research will produce information and guidelines to implement a practical yet effective asphalt pavement cracking test and analysis protocol in Oregon. A comprehensive procedure and tools will be developed to more effectively predict cracking performance using the results of the implemented test. This research will also provide recommendations to the Contractor Mix Design Guidelines along with suggested changes to asphalt related specifications and test procedures.

5.0 Research Tasks

This section presents the tasks that will be undertaken to conduct the entire research study. The order in which the tasks will be conducted and their timing are shown in Section 6.0. Summary of tasks and outcomes are shown in Figure 1.

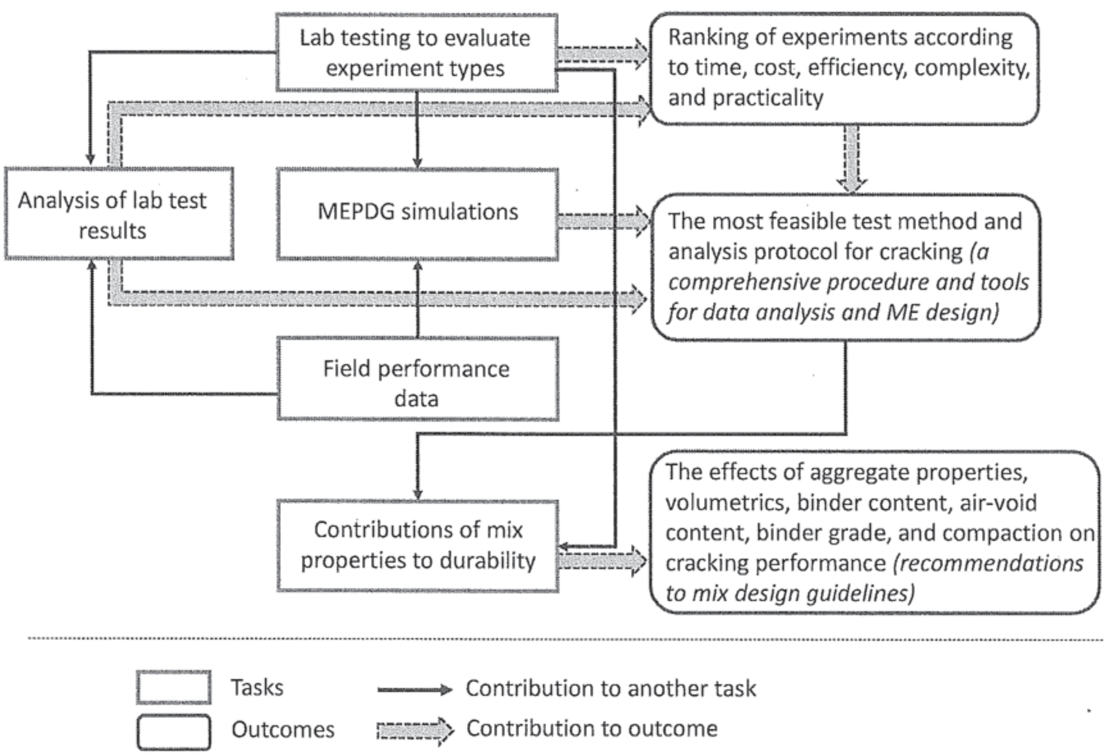

Figure 1. Summary of tasks and outcomes – General framework.

5.1 Expected tasks:

Task 1: TAC Meeting #1

Project kick off meeting.

Time Frame: September 2015
Responsible Party: PI, ODOT Research Coordinator, TAC
Deliverable: TAC meeting attendance, TAC meeting presentation, Meeting Minutes
TAC Action: Review project research problem statement, research question, the limits of the research, and the project schedule. Advise ODOT Research Coordinator regarding any critical issues with the project's scope or schedule. Advise PI's regarding related professional practices, standards, methods and context for the project.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents.

Task 2: Draft Literature Review and Draft Research Methodology

A literature review will be conducted to explore previous research on: i) factors affecting fatigue cracking (environment, traffic, drainage, construction, mixture properties, etc.); ii) cracking experiments and performance-based design methods; iii) cracking mechanisms (top-down and bottom up); and iv) best practices in mix design for pavement durability.

A detailed draft research methodology will be developed to identify and describe the required data, experiments, variables, and analysis techniques. A detailed experimental plan for lab testing and field sampling will be developed. Statistical analysis procedures that will be used for data processing will also be described.

Time Frame: 4 months (September 2015 – December 2015)
Responsible Party: PI
Cost: $9,517
Deliverable: Draft Literature Review and Draft Research Methodology Report Sections
TAC Action: Read Draft Literature Review and advise ODOT Research Coordinator regarding any gaps in the literature. Read Draft Research Methodology in preparation for TAC Meeting # 2.
ODOT Action or Decision: Review TAC advice, discuss with PI, and if necessary direct PI to make changes to project documents. Schedule TAC Meeting #2.

Task 3: TAC Meeting #2

Literature review and the proposed research methodology will be discussed with the TAC. Experimental plan and methodology will be revised according to the feedback from the TAC.

Time Frame: December 2015
Responsible Party: PI, ODOT Research Coordinator, TAC
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, meeting agenda

TAC Action: TAC review of Draft Research Methodology and Draft Literature Review. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. Advise ODOT Research Coordinator regarding project next steps.
ODOT Action or Decision: Review TAC advice. Assess project potential for successful completion. If necessary direct PI to make changes to project documents. Provide formal acceptance of Draft Research Methodology. Authorize PI to proceed.

Task 4: Data Collection- Laboratory Testing

Four asphalt mixtures, *two asphalt mixes with different RAP contents, a polymer modified mix, and an asphalt mix with no polymers or RAP*, will be prepared and tested with DT, IDT, SCB, and beam fatigue tests. Based on the test results, the effectiveness of each test for identifying the impact of polymer modification and RAP content on mixture cracking performance will be determined. Dynamic modulus tests will be conducted to evaluate the effects of asphalt mixture stiffness on cracking performance. Results of dynamic modulus tests will also be used for MEPDG model development. Flow number tests will also be conducted to investigate the effects of mixture type, RAP content, binder grade, polymer modification, and air void content on rutting resistance.

Draft experimental plan for Task 4 is given in Table 1. *The experimental plan given in Table 1 is subject to change according to feedback from the TAC.* Data will be collected, stored and delivered to ODOT in compliance with Institutional Review Board approvals and Federal requirements. The PI will be responsible for documentation of any departures from the Draft Research Methodology.

Time Frame: 10 months (November 2015 – August 2016)
Responsible Party: PI
Cost: $42,413
Deliverable Progress reports approximately every three months.
TAC Action: Review of progress reports and advise PI if necessary.
ODOT Action or Decision: Review

Table 1: Experimental plan for Task 4.

Test type	Mix Type	Temp.	Strain levels	Replicates	Total Tests
Beam fatigue	4 types[1]	20°C (1 temp.)	200 μstrain 400 μstrain (2 levels)	3	24
DT	4 types	20°C	1 level	2	8
SCB	4 types	20°C	1 level	6	24
IDT	4 types	20°C	1 level	6	24
Dynamic modulus	4 types	1 run[2]	N/A	2	8
Flow number	4 types	50°C	N/A	3	12

Notes: [1] Four mix types: Two asphalt mixes with different RAP contents, a polymer modified mix, and an asphalt mix with no polymers or RAP; [2] Each specimen will be tested at 0.1, 0.5, 1, 5, 10, and 25 Hz. loading frequencies and 4, 21, 38, and 55 °C temperatures.

Task 5: Analysis of Laboratory Test Results

Laboratory test results will be analyzed to develop several energy and fatigue life parameters, such as plateau value, cycles to failure, dissipated energy, fracture energy, secant stiffness, fracture toughness etc., to evaluate the fatigue cracking performance of different asphalt mixtures. The correlations between parameters from different tests will be determined. The effectiveness of these parameters in ranking field cracking performance of different asphalt mixture types will also be investigated. The impact of asphalt mixture stiffness on test results' bias and variability will also be determined. Based on the experience gained from DT, IDT, SCM, and beam fatigue testing, tests will be ranked according to testing time, cost, efficiency, complexity, and practicality.

Time Frame: 8 months (February 2016– September 2016)
Responsible Party: PI
Cost: $28,362
Deliverable: Progress reports approximately every three months.
TAC Action: Review and comment
ODOT Action or Decision: Review

Task 6: Field Performance Data

Historical pavement management system data and cracking data from previous ODOT research studies (Williams and Shaidur 2013) will be analyzed to develop a cracking database for different roadway sections in Oregon. Field cracking data will be used to evaluate the effectiveness of each test method and extract model parameters for in-situ cracking performance prediction. A list of projects that have performed well and ones that have cracked or rutted prematurely will also be compiled to compare the performance with the mixture properties during production.

Time Frame: 7 months (September 2015 – March 2016)
Responsible Party: PI
Cost: $11,818
Deliverable: Progress reports approximately every three months.
TAC Action: None
ODOT Action or Decision: Review

Task 7: Mechanistic-Empirical Pavement Design Guide (MEPDG) Simulations

Laboratory test results will be used to develop model coefficients for MEPDG cracking simulations. Developed models will be calibrated by using the cracking database developed under Task 6. Based on the results of the analyses, the effectiveness of each test method in predicting in-situ cracking performance will be determined.

Time Frame: 7 months (March 2016 – September 2016)
Responsible Party: PI
Cost: $18,181
Deliverable: Interim report describing the results of Tasks 4, 5, 6, and 7.
TAC Action: TAC meeting with the Principal Investigator to discuss results of Tasks 4, 5, 6, and 7, and provide comments and feedback on the deliverable and on future tasks.
ODOT Action or Decision: Review and advise

Task 8: Additional Data Collection - Contributions of Mixture Properties to Durability

Additional experiments will be conducted with the most effective cracking test selected in Task 7 to determine the effects of aggregate properties, volumetrics, binder content, air void content, compaction, and binder grade on durability. Experimental plan for Task 8 is given in Table 2. Test results will be combined with the results from Task 4. Statistical analysis and MEPDG simulations will be performed to identify the most critical mixture properties that affect asphalt mixture durability. In order to determine the impact of specimen preparation, compaction, and in-situ aging on cracking test results, field samples will be collected from sections constructed with the two asphalt mix types used for preparing lab samples (given in the last row in Table 2). *The experimental plan given in Table 2 is subject to change according to feedback from the TAC.*

Time Frame: 6 months (September 2016 – February 2017)
Responsible Party: PI
Cost: $47,829
Deliverable: Interim report describing the results of Task 8.
TAC Action: TAC meeting with the Principal Investigator to discuss results of this task, and provide comments and feedback on the deliverable.
ODOT Action or Decision: Review and advise

Table 2: Experimental plan for Task 8.

Test type	Mix Type	Comp.[3]	Temp.	Strain levels	Aggregate types	Binder content	Air void content	Repl.[7]	Total Tests
Selected cracking test[1]	2 mix types[2]	LMLC[4]	20°C (1 temp.)	1 level	2 types	2 binder contents	2 air-void contents	3	48
Dynamic modulus	2 mix types	LMLC	1 run[6]	N/A	2 types	2 binder contents	2 air-void contents	2	32
Flow number	2 mix types	LMLC	50°C	N/A	2 types	2 binder contents	2 air-void contents	3	48
Selected cracking test	2 mix types	FMFC[5]	20°C	1 level	1 type	1 binder content	1 air-void content	5	10

Notes: [1] Most effective cracking test selected in Task 7; [2] Two mix types: Two asphalt mixes with different performance grades; [3] Comp.=Compaction; [4] LMLC: Lab mixed lab compacted; [5] FMFC: Field mixed field compacted; [6] One specimen will be tested at 0.1, 0.5, 1, 5, 10, and 25 Hz. loading frequencies and 4, 21, 38, and 55 °C temperatures; [7] Repl.: Replicate.

Task 9: Draft Final Report

A draft final report will be written and submitted to ODOT for review.
Time Frame: 3 months (February 2017 – April 2017)
Responsible Party: PI
Cost: $5,703
Deliverable: Draft final report describing the results of the research study, selected cracking test method, a process (software) for converting the results of the selected cracking test to MEPDG model coefficients, a procedure to determine the long term cracking performance of ODOT pavement sections, recommendations to the Contractor Mix Design Guidelines.

TAC Action: TAC meeting with the Principal Investigator to discuss results of this task, and provide comments and feedback on the deliverable. TAC will provide feedback to the ODOT Research Coordinator.
ODOT Action or Decision: Review and counsel prior to TAC meeting

Task 10: Draft ODOT Research Note

A summary of the research project will be written. The summary will concisely document the research findings, value of the research to the agency, science and society, and any limitations on the use of the findings.

Time Frame: 3 months (February 2017 – April 2017)
Responsible Party: PI
Cost: $1,426
Deliverable: Draft ODOT Research Note using ODOT's report template
TAC Action: None
ODOT Action or Decision: Review and advise

Task 11: TAC Meeting #3.

This TAC meeting will include a review of the Draft Final Report, and Draft Research Note prior to the TAC meeting. The TAC will offer advice on the content and clarity of these work products. The TAC will also advise on post research implementation.

Time Frame: April 2017
Responsible Party: PI, assisted by the ODOT Research Coordinator, TAC
Deliverable: TAC meeting attendance, meeting presentation, Meeting Minutes
TAC Action: TAC review of Draft Final Report, and Draft Research Note. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. Advise ODOT Research Coordinator regarding any required final edits to the Draft Final Report, and Draft Research Note.
ODOT Action or Decision: Review TAC advice. If necessary direct PI to make changes to project documents.

Task 12: Final Report

Draft Final Report will be edited to incorporate revisions identified by the ODOT research Coordinator after the last TAC meeting. The report will include any proposed improvements to specifications, test procedure and recommendations for implementation.

Time Frame: 2 months (May 2017 – June 2017)
Responsible Party: PI
Cost: $3,802
Deliverable: Final Report
TAC Action: None
ODOT Action or Decision: Review. Provide formal acceptance of Final Report. Publish Final Report on ODOT's research website

__Task 13: Final Research Note__

Draft Research Note will be edited to incorporate revisions identified by the ODOT research Coordinator after the last TAC meeting.

Time Frame: 2 months (May 2017 – June 2017)
Responsible Party: PI
Cost: $950
Deliverable: Final Research Note
TAC Action: None
ODOT Action or Decision: Review. Provide formal acceptance of Research Note. . Publish Final Report on ODOT's research website

5.2 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting deliverables as professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.3 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Time Schedule

This section specifies the time line for the project, listing the task headings and showing monthly and/or quarterly time blocks in which each task will be accomplished. Also shown are interim and final deliverables.

Task	2015				2016												2017					
	FY 2016										FY 2017											
	Sep - Nov			Dec - Feb			Mar -May			Jun - Aug			Sep - Nov			Dec - Feb			Mar-May			Jun
2. Literature Review and Research Methodology (4 months) Deliverable: Interim report describing the results of Task 2.	■ †	■	■	■ † *																		
4. Laboratory testing (10 months) Deliverable: Progress reports approximately every three months.			■	■	■	■	■	■	■	■	■	■										
5. Analysis of lab test results (8 months) Deliverable: Progress reports approximately every three months.						■	■	■	■	■	■	■	■									
6. Field performance data (7 months) Deliverable: Progress reports approximately every three months.	■	■	■	■	■	■	■															
7. MEPDG simulations (7 months) Deliverable: Interim report describing the results of Tasks 4,5,6 and 7.							■	■	■	■	■	■	■ † *									
8. Contributions of mixture properties to durability (6 months) Deliverable: Interim report describing the results of Tasks 8.													■	■	■	■	■	■ † *				
9,12. Report (5 months) Deliverable: Final report describing the results of the research study.																		■	■	■ † R	■	■ F
10,13. Research Note (5 months) Deliverable: Final ODOT research note describing the results of the study.																		■	■	■ † N	■	■ O

*Deliverables; † = TAC meeting; R - Draft report submitted for ODOT review; N - Draft ODOT research note submitted for ODOT review; F - Revised report submitted to ODOT for publication; O - Revised ODOT research note submitted to ODOT for publication. End of contract.

7.0 Budget Estimate

An itemized budget for the project is included here, showing expenditures for each item by fiscal year and in total. A more detailed budget spreadsheet is also submitted with this work plan.

		FY--2016	FY--2017	Total
Personnel	PI	$ 0	$ 14,073	$ 14,073
	GRA (+tuition)	$ 38,125	$ 35,920	$ 74,045
Total Salaries		$ 38,125	$ 49,993	$ 88,118
Fringe Benefits	PI	$ 0	$ 7,459	$ 7,459
	GRA	$ 3,306	$ 3,603	$ 6,909
Total Fringe Benefits		$3,306	$ 11,061	$ 14,367
Total Personnel Costs		$ 41,431	$ 61,054	$ 102,485
Travel		$ 50	$ 150	$ 200
Operating expenses (detailed list attached)		$ 20,004	$ 19,050	$ 39,054
Total Direct Costs		**$ 61,485**	**$ 80,254**	**$ 141,740**
Total Indirect Costs		**$ 11,776**	**$ 16,484**	**$ 28,260**
Total Project Costs		**$ 73,262**	**$ 96,738**	**$ 170,000**

8.0 References

Bonaquist, R. (2013). *Impact of Mix Design on Asphalt Pavement Durability.* Transportation Research Circular – Enhancing the Durability of Asphalt Pavements. Number E-C186.

Roque, R., J. Zou, Y. R. Kim, C. M. Baek, S. Thirunavukkarasu, B. S. Underwood, and M. N. Guddati. (2010). *NCHRP Web-Only Document 162: Top-Down Cracking of Hot Mix Asphalt Layers: Models for Initiation and Propagation.* Final Report. NCHRP 1-42A. Transportation Research Board of the National Academies, Washington, D.C.

Underwood, B. S., C. Baek, and Y. R. Kim. (2012). *Simplified Viscoelastic Continuum Damage Model as Platform for Asphalt Concrete Fatigue Analysis.* In Transportation Research Record: Journal of the Transportation Research Board, No. 2296, Transportation Research Board of the National Academies, Washington, D.C., pp. 36–45.

Williams, R.C. and R. Shaidur. (2013). *Mechanistic-Empirical Pavement Design Guide Calibration for Pavement Rehabilitation.* Final Report. SPR 718. Oregon Department of Transportation, Research Section, Salem, OR.

OSU/State
Agreement No.30530

EXHIBIT A

ODOT WORK ORDER AUTHORIZATION

Agreement No. 30530 Work Order No. 16-07

Under the terms of the Oregon Department of Transportation (ODOT) and Oregon State University (UNIVERSITY) Agreement dated July 23, 2015, which is hereby incorporated by reference, the following Project work is authorized:

Project Name: Adjustng Asphalt Mixes for Increased Durability and Implementation of a performance Tester to Evaluate Fatigue Cracking of Asphalt Concrete

ODOT Work Order Coordinator: Norris Shippen

Total Authorized Amount of this Work Order $170,000 Expenditure Acct. No.: 17RF0785

Work Order Start Date: Upon Execution Work Order End Date: 6/30/2017

Effective Date: No Work shall occur until signed by all parties.	State Totals
A. Amount authorized for this Work Order	$ 170,000.00
B. Amount authorized on prior Work Orders	$ 871,000.00
C. Total Amount authorized for all Work Orders (A+B=C)	$ 1,041,000.00
D. Agreement Not-to-Exceed amount	$25,000,000.00
E. Amount remaining on Agreement (D-C=E)	$23,959,000.00

STATEMENT OF WORK is attached, and incorporated by this reference. *Please indicate which type of transportation research, policy analysis, or quality assurance services are to be undertaken by listing assumptions & expectations; roles and responsibilities; tasks; deliverable(s); deliverable due date(s); standards for work acceptance; and task breakdown, showing hours per task, estimated cost per task, and staff classifications and names assigned to each task, and summary of estimated cost per task. The work must be within the original scope of work in the Agreement.*

ACCEPTANCE OF TERMS AND ACTION APPROVED BY ODOT: I acknowledge and certify that the work in this work order authorization is within the scope of work of the original Agreement.

Name/Title Date

ACCEPTANCE OF TERMS BY UNIVERSITY

Name/Title Date

APPROVED AS TO LEGAL SUFFICIENCY: If work order exceeds $150,000 signature required

Asst. Attorney General Date

cc: UNIVERSITY ODOT's Work Order Coordinator
Construction Contracts Section, Support Services Branch for General Files *(original)*