Research Project Work Plan

for

BINDER-GRADE BUMPING AND HIGH BINDER CONTENT TO IMPROVE PERFORMANCE OF RAP-RAS MIXTURES

Submitted by

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for

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Research Unit
555 13th St. NE, Ste 2
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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
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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

General reduction in pavement program funding levels over the past decade and the possible consequent increase in pavement road roughness within the next couple years created a need for low cost yet effective alternative ways to rehabilitate, preserve and maintain roadway network in Oregon (ODOT, 2013). Recycling highway construction materials and minimizing the use of virgin materials can reduce the pavement life cycle costs, improve highway network condition, conserve natural resources, and protect the environment. Although the recycling of asphalt pavements is beneficial in most cases by reducing the need for virgin materials and construction costs, asphalt pavements with high recycled asphalt pavement (RAP) and recycled asphalt shingle (RAS) contents should be carefully designed to avoid premature cracking (West et al., 2013). The use of binder-grade bumping and high virgin binder content were determined to be effective in improving cracking performance (Al-Qadi et al., 2012; Bonaquist, 2007; West et al. 2009). Increased crack resistance allows the use of higher RAP/RAS contents. While these two strategies generally increase the cost of virgin binder used in the asphalt mixture, increased RAP/RAS content and improved RAP/RAS performance will reduce the overall life-cycle cost of recycled asphalt concrete material used in construction. Mechanistic-empirical (ME) pavement design methods and laboratory testing need to be combined with different modeling methods and life-cycle cost analysis (LCCA) to investigate the performance and cost benefits of using binder-grade bumping and high binder content in Oregon RAP/RAS mixes.

3.0 Objectives of the Study

This research would have five major objectives: i) identify the effects of binder-grade bumping and higher binder content on RAP/RAS performance; ii) determine the impact of these alternatives on increasing RAP/RAS contents; iii) evaluate the impact of higher RAP/RAS contents on asphalt mixture compaction; iv) evaluate the effect of blending on mixture performance; and v) investigate the impact of RAP/RAS content, virgin binder grade, and binder content on in-situ cracking performance.

3.1 Benefits

This research will quantify the performance benefits of using binder-grade bumping and increased binder content strategies in RAP/RAS mixture production in Oregon. The impact of virgin and recycled binder blending on cracking performance will also be investigated. The most effective strategies for different climate regions and traffic levels in Oregon will be determined by mechanistic-empirical procedures. Binder-grade bumping and high binder content strategies are expected to increase the RAP/RAS content in asphalt mixtures, reduce the life-cycle cost, improve the cracking performance, and encourage the widespread use of high RAP/RAS asphalt mixtures in Oregon.

4.0 Implementation

This research will produce information and guidelines for ODOT to implement in RAP/RAS mixture design methods. Software and interactive online maps will be developed to present the performance benefits of using grade bumping and high binder content strategies for

different climate regions and traffic levels in Oregon. Developed software and maps can be used to help decision making during the design stage. For a specific climate region and traffic level, the map and software will show the recommended RAP/RAS content, performance grade, and binder content.

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.

5.1 Expected tasks:

Task 1: TAC Meeting #1

Project kick off meeting.

Time Frame: October 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) blending of RAP and virgin binders; ii) characterizing and designing RAP/RAS mixtures; iii) in-situ performance of RAP/RAS mixtures with different performance grades and binder contents; iv) mechanical properties of RAP/RAS mixtures; and v) ME design procedures.

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 will be developed.

Time Frame: 3 months (October 2015 – December 2015)
Responsible Party: PI
Cost: $16,771
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 and Analysis

Asphalt mixtures with different RAP/RAS, binder-grade, and binder contents will be prepared and tested to determine the effects of binder-grade bumping and high binder content strategies on mixture stiffness and cracking performance. The possibility of increasing RAP/RAS contents and improving cracking resistance by using softer asphalt binders (such as PG 58-34) will also be investigated. Rutting resistance of these RAP/RAS mixtures with softer binders will also be measured by flow number tests. Four point bending beam (beam fatigue) and indirect tensile strength (IDT) tests will be conducted to determine the cracking performance of RAP/RAS mixtures. Dynamic modulus tests will also be conducted to investigate the effect of asphalt mixture stiffness on cracking performance.

Dynamic shear moduli of binders recovered from produced RAP/RAS mixtures will be determined by dynamic shear rheometer (DSR) testing. Produced mixtures containing RAP and RAS will be fabricated and tested in a simple performance tester to determine the mixtures' dynamic moduli over a range of temperatures and frequencies. Using the Hirsch model (or a micromechanical finite element model), with inputs of the mixture dynamic moduli, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA) from the compacted specimens, shear moduli of the effective binder in the specimen will be predicted. Predicted binder shear moduli will be compared to the extracted binder moduli to evaluate blending. Blending levels will be compared with measured mixture cracking performances to evaluate the impact of blending on mixture performance.

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: 13 months (December 2015 – December 2016)
Responsible Party: PI
Cost: $111,491
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	Binder grade	RAP content	Binder content	Temp.	Strain levels	Air-void content	Replicates	Total Tests
Beam fatigue	3 types	2 cont.	2 contents	20°C (1 temp.)	400 μstrain (1 level)	2 contents	3	72
IDT	3 types	2 cont.	2 contents	20°C	1 level	2 contents	3	72
Dynamic modulus	3 types	2 cont.	2 contents	1 run[1]	N/A	2 contents	2	48
Flow number	2 types	1 cont.	2 contents	50°C	N/A	1 contents	3	12

Notes: [1] 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: Mechanistic-Empirical Pavement Design Guide (MEPDG) Simulations

Coefficients for Mechanistic-Empirical Pavement Design Guide (MEPDG) cracking and stiffness models will be calculated by using laboratory test results (dynamic modulus and cracking) and regression methods. Developed model coefficients for asphalt mixtures with different RAP/RAS contents will be incorporated into MEPDG software to predict in-situ cracking performance of RAP/RAS mixtures for different climate regions, traffic levels, and structures in Oregon. Based on the predicted MEPDG cracking performance curves, in-situ cracking performance of asphalt mixtures with different RAP/RAS contents will be evaluated. The impact of binder-grade bumping, increased binder content, and blending on in-situ cracking performance will be quantified. Using the predicted MEPDG cracking performance curves and the cost for each RAP alternative, LCCA will be performed to determine the cost effectiveness of using binder-grade bumping and increased binder content strategies to increase RAP content in asphalt concrete mixtures.

Time Frame: 10 months (April 2016 – January 2017)
Responsible Party: PI
Cost: $29,191
Deliverable: Interim report describing the results of Tasks 4 and 5.
TAC Action: TAC meeting with the Principal Investigator to discuss results of Tasks 4 and 5, and provide comments and feedback on the deliverable and on future tasks.
ODOT Action or Decision: Review and advise

Task 6: Draft Final Report

A draft final report will be submitted to ODOT for review. Following this review, a final report will be developed, incorporating the ODOT Technical Advisory Committee comments, to document the findings of the research. The report will include any proposed improvements to specifications and recommendation for implementation.

Time Frame: 3 months (January 2017 – March 2017)
Responsible Party: PI
Cost: $6,022
Deliverable: Draft final report describing the results of the research study, information and guidelines for ODOT to implement in RAP/RAS mixture design methods, software and interactive online maps to help decision making during the design stage, a procedure to determine the long term cracking performance of ODOT pavement sections (MEPDG model coefficients for the ODOT materials library).
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 7: 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 (January 2017 – March 2017)
Responsible Party: PI
Cost: $1,506
Deliverable: Draft ODOT Research Note using ODOT's report template
TAC Action: None
ODOT Action or Decision: Review and advise

Task 8: 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: March 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 9: 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 (April 2017 – May 2017)
Responsible Party: PI
Cost: $4,015
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 10: 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 (April 2017 – May 2017)
Responsible Party: PI
Cost: $1,004
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					
		FY2016						FY2017											
	Oct-Dec			Jan-Mar			Apr -Jun			Jul - Sep			Oct - Dec			Jan - Mar			Ap-My	
2. Literature Review and Research Methodology (3 months) Deliverable: Interim report describing the results of Task 2.	†		† *																
4. Data collection and analysis (13 months) Deliverable: Progress reports approximately every three months.																			
5. MEPDG simulations (10 months) Deliverable: Interim report describing the results of Tasks 4 and 5.																† *			
6,9. Report (5 months) Deliverable: Final report describing the results of the research study.																		† R	F
7,10. 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 is also submitted with this work plan.

		FY--2016	FY--2017	Total
Personnel	PI	$ 9,728	$ 15,030	$ 24,759
	GRA	$ 21,934	$ 25,792	$ 47,725
Total Salaries		$ 31,662	$ 40,822	$ 72,484
Fringe Benefits	PI	$ 4,961	$ 7,966	$ 12,928
	GRA	$ 3,342	$ 3,902	$ 7,244
Total Fringe Benefits		$ 8,304	$ 11,868	$ 20,171
Tuition		$ 14,130	$ 14,766	$ 28,896
Total Personnel Costs		$ 54,096	$ 67,455	$ 121,551
Travel		$ 100	$ 100	$ 200
Operating expenses (detailed list attached)		$ 5,566	$ 13,566	$ 19,132
Total Direct Costs		**$ 59,762**	**$ 81,121**	**$ 140,883**
Total Indirect Costs		**$ 11,864**	**$ 17,252**	**$ 29,117**
Total Project Costs		**$ 71,626**	**$ 98,374**	**$ 170,000**

8.0 References

Al-Qadi, I., Q. Aurangzeb, S. Carpenter, W. Pine, and J. Trepanier. (2012). *Impact of High Rap Content on Structural and Performance Properties of Asphalt Mixtures.* Research Report FHWA-ICT-12-002. UIUC, Department of Civil and Environmental Engineering, Urbana, Ill.

Bonaquist, R. (2007). *Can I Run More RAP?* Hot Mix Asphalt Technology, Vol. 12, No. 5, National Asphalt Pavement Association.

Oregon Department of Transportation, Pavement Services Unit. (2013). 2012 Pavement Condition Report.

West, R., A. Kvasnak, N. Tran, B. Powell, and P. Turner. (2009). *Laboratory and Accelerated Field Performance Testing of Moderate and High RAP Content Mixes at the NCAT Test Track.* Presented at the 88th Annual Meeting of the Transportation Research Board, Washington, DC.

West, R., J.R. Willis, and M. Marasteanu. (2013). *Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content.* National Cooperative Highway Research Program Report No. 752. Transportation Research Board. Washington, D.C.