RESEARCH PROJECT WORK PLAN

2. PROJECT TEAM

1. Project Title:	Bio-material Maintenance Treatments
***MnDOT or LRRB Need Statement Number:**	Not applicable
***LRRB Knowledge Building Priority Number:**	***(if applicable)***
Total Project Budget:	$50,000 with Match Funding: $50,00
Total Project Duration:	12 months
Public Agency Champion (state, county, city, or township employee):	Michael C. Vrtis, Ph.D. MnDOT Research Project Engineer
Key Words (for cataloging):	Bio-materials, bio-rejuvenator, fog seals
Date Submitted:	August 9, 2019

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3. PROJECT ABSTRACT

As asphalt pavement oxidizes and ages, bio-materials can be used to restore flexibility to the asphalt pavement. Recent research at Iowa State University has developed bio-rejuvenators that do not have the negative impacts on elastic recovery as measured by the multiple-stress creep recovery test. The research team hypothesizes that these bio-materials can be formulated with asphalt emulsions to seal and soften weathered pavement. The bio-materials are derived from high oleic soybean oil (HOSO) and in the current global trade climate, there exists a need to develop new domestic markets for US agriculture products, especially soy-products. This study investigates further development of using HOSO-derived technologies for pavement applications and this study is presented with 1:1 matching funds from the United Soybean Board. Through this project, the research team will investigate formulations for a bio-based asphalt rejuvenating fog seal. The objective of this project is to investigate if a soy-based bio-rejuvenating asphalt emulsion can be formulated to achieve stiffness reduction in oxidized, aged asphalt surfaces. The penetration of bio-rejuvenating sealers into the aged-pavement is important for reducing

stiffness and restoring flexibility. This research will develop an asphalt emulsion with and without the HOSO bio-rejuvenator. The asphalt emulsion will act as the vehicle for the soybean-based rejuvenator. Particle size of the emulsion is an important factor for penetration of the bio-sealant. The material developed in this research will be tested at MnRoads on the shoulder of the pavement. Cores will be taken to study the effect of bio-rejuvenating seal on the asphalt. Minnesota DOT will perform friction testing on the control and test sections to determine impacted to pavement friction due to the application of the bio-sealant. The four main steps in this project are bio-sealant emulsion formulation, bio-sealant emulsion field application (pavement shoulders), investigation of stiffness reduction in the field, and studying the effect of the sealant on pavement friction.

4. INTRODUCTION

Aging pavement infrastructure and the deterioration of pavement surfaces over time remain an ongoing challenge in meeting roadway user expectations. A variety of bio-sealant products are available on the market and can be used to seal and, in some cases, rejuvenate the in-place asphalt. Several studies in Minnesota have investigated laboratory and field performance of available bio-based fog sealants. Rheological studies compared laboratory results with field cracking to enhance recommendations for laboratory testing procedures of bio-sealants (Ghosh et al. 2018). A comprehensive bio-fog sealant study performed by the University of Minnesota and MnDOT provides results from binder and mixture testing to study how bio sealants influence stiffness/rheological properties in mixtures and binders. This study showed that oil-based sealants provided greater softening affect than water-based. Results also showed that testing small beams from pavement field cores can be performed to provide strength and creep properties for control and treated pavement sections (Ghosh et al. 2016). MnDOT field studies have shown that the bio-based fog sealants provide waterproofing and some sections exhibited reduced thermal cracking but that all applications reduced pavement friction (Johnson 2018).

New soy-based bio-technologies developed at Iowa State University using high oleic soybean oil HOSO show promise in rejuvenating aged asphalts but the technology has not yet been developed into a bio-based rejuvenating asphalt emulsion fog seal. The unique feature of the rejuvenator is that multiple stress creep recovery tests are not negatively affected by the addition of the soy-based rejuvenator (Cochran et al. 2019). The study acts as a proof-of-concept for broadening the use of this technology to bio-rejuvenating fog seals. Iowa State University houses a comprehensive asphalt emulsion production laboratory that can be used to analyze and validate asphalt emulsion formulations. The Iowa State University research team includes expertise in asphalt emulsions, asphalt material formulation, asphalt materials testing, polymeric materials, bio-materials research and development for pavement applications. Dr. Ashley Buss has been developing and leading asphalt emulsion and pavement preservation research for over four years. Dr. Chris Williams has established himself as an international leader in bio-material development in asphalt pavement applications. Dr. Eric Cochran is internationally known for his work in bio-polymer chemistry, synthesis and developing new bio-materials for use in pavement applications. This study leverages past research and team's expertise to enhance bio-materials for pavement preservation applications.

5. OBJECTIVES AND BENEFITS

The objectives of this research are:

- Enhance pavement longevity by using bio-based materials to soften oxidized asphalt at the surface of the pavement and sealing up cracks in the surface to prevent water infiltration.
- Enhance development of soybean-derived bio-materials for pavement maintenance applications.

- Broaden the domestic market use for agriculture products in the US.
- Enhance sustainability of pavement materials through the use of bio-materials and reduce pavement life cycle cost through preservation treatments.

The benefits of this research are improved flexibility and preservation of roadways while developing new domestic markets for soybean products. Increased longevity of the roadway delays major rehabilitation and provides improved pavement condition in the interim. Preservation of pavements helps keep roads in better condition longer which leads to reduced pavement life cycle cost.

6. VARIABLES

The important variables to be measured in this study are:

- Particle size for the bio-asphalt emulsion will be measured in the Malvern Mastersizer housed in the Iowa State University Food Science Department. This measures the particle size and distribution of the emulsified asphalt
- Zeta potential of the bio-asphalt emulsion will provide a measurement of how the bio-material affects the emulsion stability. Zeta potential is measured using a Zetasizer house in the Iowa State University Chemical Instrumentation Facility.
- Stripping potential of the bio-asphalt emulsion will be measured on typical Minnesota aggregates using a boil test. The research team will visually evaluate the potential for the bio-asphalt emulsion to strip-away from the aggregates.
- Pavement stiffness is an important factor. Stiffness of small beams created from asphalt field cores will be measured in the BBR to determine if the bio-asphalt emulsion is penetrating into the aged-asphalt mixture.
- Pavement friction is an important factor. MnDOT will provide locked wheel skid friction testing on the experimental sections. The unit of measurement is a skid number.

7. QUESTIONS AND/OR HYPOTHESES

To date, Iowa State University research has shown that soy-based bio-materials work well in base asphalt formulations and can be used without negative impact to MSCR results. The overarching research questions for this project are:

- Can the bio-rejuvenated asphalts be formed into a stable slow-set emulsion for use in a rejuvenating fog-seal?
- How does particle size of a slow-set emulsion change when using a bio-modified asphalt compared to a control asphalt?
- How do the bio-materials affect the stability of the asphalt emulsion?
- Are differences in stiffness observed for a control emulsion versus a bio-modified experimental asphalt emulsion?
- What are the impacts to the pavement's surface friction?

8. RESEARCH METHODOLOGY

The proposed research provides a proof-of-concept opportunity for further development of soy-derived bio-production into asphalt materials. The research team will begin with a comprehensive literature review and develop potential emulsion formulations. Laboratory work will also begin at the start of the project to develop a slow-set, low viscosity asphalt emulsion formulation to use as a "control" emulsion for laboratory testing. Once the literature search is completed and the team will begin with formulations

of the bio-modified asphalt. The base-asphalts will be analyzed and tested with standard PG grading and a viscosity profile will be performed to determine optimum emulsion production temperatures. The asphalt emulsion testing will include particle size analysis, zeta-potential analysis, stability analysis, percent residue analysis, boil tests to analyze moisture sensitivity of the emulsion, and rotational viscosity testing to analyze emulsion's sensitivity to shear forces. The asphalt emulsion residue will be tested in the dynamic shear rheometer for final high temperature PG grade. The research team will use test methods developed by the University of Minnesota to test the stiffness of small beams of asphalt mixture in the bending beam rheometer to analyze the stiffness reduction of the "control" and "bio-modified" asphalt emulsion.

The laboratory testing builds on previous bio-modified asphalt-formulation research that shows these bio-materials do not negatively affect multiple stress creep recovery tests. After a suitable control and experimental benchmark formulations are identified in the laboratory, the research team will work with MnDOT/NRRA and a contractor and material supplier, hired by MnDOT/NRRA, to place field trails on oxidized, aged asphalt roadway shoulders. The research team will collect field samples and test field samples in the laboratory with tests similar to the testing plan used in the formulation-phase of the project. MnDOT/NRRA will provide one field core from a "no treatment", "control emulsion" and "bio-modified emulsion" section. The research team will measure the stiffness of three beams from each core and compare the results from the field section.

9. SCHEDULE AND TASKS

Task 1: Literature Review and Recommendations

Description: The research team will compile and summarize current research using bio-based pavement materials with a focus on pavement preservation and current test methods for analyzing bio-rejuvenating asphalt emulsions. Cost share will fund Post Doc and Professional and Scientific Staff (Austin Hohmann) salary.

- **Anticipated Start Date:** 02-01-2020
- **Scheduled Date to Submit Draft Deliverable:** 03-31-2020
- **Scheduled Date for Task Final Approval:** 04-30-2019
- **Duration:** 3 months including the review and comment period
- **Deliverable:** Literature review and Presentation to technical advisory panel

Task 2: Formulation for Bio-rejuvenating maintenance seals and Laboratory Testing

Description: The research team will investigate formulations for developing the bio-rejuvenating seal. A "control" emulsion slow-set, low viscosity formulation will be developed and tested. The team will build on past bio-modified asphalt formulations for further development into bio-modified asphalt emulsion formulations. The suite of testing includes rotational viscosity testing on the base asphalt(s) to determine the optimum milling temperature for the emulsion. Emulsion testing includes particle size analysis, zeta-potential analysis, stability analysis, percent residue analysis, boil tests to analyze moisture sensitivity of the emulsion, and rotational viscosity testing to analyze emulsion's sensitivity to shear forces. The asphalt emulsion residue will be tested in the dynamic shear rheometer for final high temperature PG grade. The cost share for this task will pay for laboratory fees and fund Post Doc and Professional and Scientific Staff (Austin Hohmann) salary.

- **Anticipated Start Date:** 02-01-2020

- **Scheduled Date to Submit Draft Deliverable:** 05-31-2020
- **Scheduled Date for Task Final Approval:** 06-30-2020
- **Duration:** 5 months
- **Deliverable:** Presentation of laboratory data and benchmark formulation for field testing.

Task 3: Field Trials

Description: MnDOT will take the lead in hiring a contractor to place the control fog-seal sections and bio-modified rejuvenating asphalt emulsion. The research team will work with MnDOT and the selected contractor to provide the benchmark formulation used in the laboratory for bio-rejuvenating maintenance seals for the experimental trial on MnRoads. The cost share for this task will fund Post Doc and Professional and Scientific Staff (Austin Hohmann) salary.

- **Anticipated Start Date:** 04-01-2020
- **Scheduled Date to Submit Draft Deliverable:** 08-31-2020
- **Scheduled Date for Task Final Approval:** 09-30-2020
- **Duration:** 6 months
- **Deliverable:** Presentation about the field trials, materials placed, and initial thoughts.

Task 4: Field Reports, Follow up Laboratory Testing, and Data Analysis

Description: The research team will be present at the time of the bio-material application and collect asphalt emulsion in the field for laboratory testing. The laboratory testing will follow the testing plan outlined in Task 2. The field testing will include lock-wheel skid trailer testing performed by the Minnesota DOT. The research team will conduct the data analysis to compare no-treatment, "control emulsion", and "bio-modified emulsion" sections. MnDOT/NRRA will collect one field core for each section for the research team to perform stiffness analysis in the bending beam rheometer. The cost share for this task will pay for laboratory fees and fund Post Doc and Professional and Scientific Staff (Austin Hohmann) salary.

- **Anticipated Start Date:** 06-01-2020
- **Scheduled Date to Submit Draft Deliverable:** 10-31-2020
- **Scheduled Date for Task Final Approval:** 11-31-2020
- **Duration:** 6 months
- **Deliverable:** A presentation discussing the test results from field-collected materials and friction testing.

Task 5: Draft Final Report

Description: A draft report will be prepared, following MnDOT publication guidelines, to document project activities, findings and recommendations. This report will need to be reviewed by the technical advisory panel. The research team will hold a technical advisory panel meeting to discuss the draft report and any recommended changes. Panel members may be consulted for clarification or discussion of comments. The cost share for this task will fund Post Doc and Professional and Scientific Staff (Austin Hohmann) salary.

Anticipated Start Date: 08-01-2020

- **Scheduled Date to Submit Draft Deliverable:** 11-30-2020
- **Scheduled Date for Task Final Approval:** 12-31-2020
- **Duration:** 3 months
- **Deliverable:** Draft Final Report

Task 6: Final Report
Description: The draft report will be updated by the Principal Investigator to incorporate technical advisory comments or suggestions. The final version of the report will be approved by the panel before this task is considered complete. There is no cost-share associated with this task.

- **Anticipated Start Date:** 12-01-2020
- **Scheduled Date to Submit Draft Deliverable:** 12-31-2020
- **Scheduled Date for Task Final Approval:** 01-31-2021
- **Duration:** 2 months
- **Deliverable:** Final Report

10. PROJECT SCHEDULE AND BUDGET DETAILS

Schedule with Budget and Cost-Share by Task

FY20 (7/1/19 – 6/30/20)						FY21 (7/1/20 – 6/30/21)							NRRA Project Budget	Cost-Share Budget	Budget By Task
Calendar Month	Feb.	M	A	M	J	J	A	S	O	N	D	J			
Task 1	X	X	X*										$4,000	$6,522	$10,522
Task 2	X	X	X	X	X*								$12,000	$10,870	$22,870
Task 3			X	X	X	X	X	X*					$12,000	$13,043	$25,043
Task 4					X	X	X	X	X	X*			$14,000	$13,043	$27,043
Task 5							X	X	X	X	X*		$6,000	$6,522	$12,522
Task 6											X	X*	$2,000	$0	$2,000

*****Technical Advisory Panel Review

Budget by Fiscal Year

Fiscal Year	NRRA Project Budget	Cost-Share Budget	FY Budget Totals
FY 2020	$22,000	$26,913.5	$45,913.5
FY 2021	$28,000	$23,086.5	$54,086.5
Total	**$50,000**	**$50,000**	**$100,000**

Project Budget in NRRA/MnDOT Format

Budget Line Items	Description	NRRA Budget Amount	Cost Share from USB	Total Project Funds
A. Salaries	**Total Salaries**	**$15,712**	**$34,655**	**$50,367**
Ashley Buss	67 hours at $59.33/hour	$ 3,975.50	-	$ 3,975.50
Chris Williams	67 hours at $89.00/hour	$ 5,963.50	-	$ 5,963.50
Eric Cochran	67 hours at $86.17/hour	$ 5,773.00	-	$ 5,773.00
Austin Hohmann	580 hours at $30.90	-	$17,922	$17,922.00
Post Doc	580 hours at $28.85	-	$16,733	$16,733.00
B. Fringe Benefits	**Total Fringe Benefits**	**$4,352**	**$11,723**	**$16,075**
Ashley Buss	27.7% Fringe	$1,101	-	$1,101
Chris Williams	27.7% Fringe	$1,652	-	$1,652
Eric Cochran	27.7% Fringe	$1,599	-	$1,599
Austin Hohmann	34.6% Fringe	-	$6201	$6201
Post Doc	33.0% Fringe	-	$5,522	$5,522
C. Non-Salary	Total Non-Salary	-	-	-
D. Equipment:		-	-	-
E. Supplies:	Field Supplies and Consumables for Laboratory Testing	$5,518	-	$5,518
F. Research Travel:		$5,098	-	$5,098
G. Out of State Conference Travel:		-	-	-
H. Other: (describe)	Publishing Costs: $2000 Laboratory Fees: $3,622	$2000	$3,622	$5,622
I. Subcontractors*		$0	-	$0
J. Total Direct Cost		$32,680	$50,000	$82,680
K. Indirect Costs	Indirect Cost Rate:	$17,320	$0	$17,320
Project Total Cost		$50,000	$50,000	$100,000

RESEARCH PROJECT WORK PLAN

			Funds Requested	Cost-Shared Matching Funds	Total Project Funds
	Hourly	# hours			
Key Personnel	Rate	# hours	**$15,712**	**$17,922**	**$33,634**
Faculty					
Ashley Buss	$59.33	67.0	$3,975		$3,975
Chris Williams	$89.00	67.0	$5,963		$5,963
Eric Cochran	$86.17	67.0	$5,773		
P&S					
Austin Hohmann	$30.90	580.0	$0	$17,922	$17,922
Other Personnel	Rate	# hours	**$0**	**$16,733**	**$16,733**
Post Doc	$28.85	580.0	$0	$16,733	$16,733
Subtotal: Salaries and Wages			**$15,712**	**$34,655**	**$50,367**
Fringe Benefits	Rate		**$4,352**	**$11,723**	**$16,075**
Ashley Buss	27.7%		$1,101		$1,101
Chris Williams	27.7%		$1,652		$1,652
Eric Cochran	27.7%		$1,599		
P&S					
Austin Hohmann	34.6%		$0	$6,201	$6,201
Post Doc	33.0%		$0	$5,522	$5,522
Subtotal: Salaries, Wages, and Benefits			**$20,064**	**$46,378**	**$66,442**
Travel			**$5,098**		**$5,098**
1. Domestic Travel					
Other Direct Costs			**$7,518**	**$3,622**	**$11,140**
Materials and Supplies			$5,518		$5,518
Services			$2,000		$2,000
Pubs Group	**$ 2,000.00**			$3,622	$3,622
Subtotal: Total Direct Costs (TDC)			**$32,680**	**$50,000**	**$82,680**
Subtotal: Modified Total Direct Costs			**$32,680**	**$50,000**	**$82,680**
[MTDC = TDC - Tuition - Equipment - Participant Support Cost]					
Indirect Costs			**$17,320**	**$0**	**$17,320**
IDC on MTDC 53%	IDC = MTDC * Indirect Rate		$17,320		$17,320
Total Direct + Indirect Costs			**$50,000**	**$50,000**	**$100,000**

NOTES:

1. ISU employees are salaried. This estimate is based on the FY2020 base rates. Annual increases (July 1) and/or midyear promotions or rate changes may affect the level of effort possible under this budget.

2. Fringe rates for FY2020 are as follows: Faculty - 27.7%; P&S - 34.6%; Postdocs-33%; Merit - 43.5%; Research Assistants - 5.9%; non student hourly - 17%; registered students hourly - 0.6%.

3. ISU charges indirect on all direct costs shown above except equipment items over $5000, sponsor paid tuition, and each subcontract's cost over $25,000. Indirect rate is determined by a negotiated agreement between Iowa State University and the Department of Health and Human Services. ISU's policies that pertain to research or intellectual property can be found at http://www.vpresearch.iastate.edu/policy/. Basic institutional information can be found at http://www.ospa.iastate.edu/proposal/institutional.html.

4. Iowa State University charges salaries to sponsored projects on a percentage of effort basis. This documentation method is based on monthly faculty and staff personnel appointments and verified by semi-annual effort reports. The hourly rates used are estimates derived by dividing a month's base salary by 174, using the rates in effect for FY2020. Annual increases (July 1) and/or midyear promotions or rate changes may affect the level of effort possible under any budget.

Budget Justification

The funding includes salaries/benefits for researchers, travel for Minnesota for field application and meetings. The budget includes laboratory fees, supplies, and publishing services. The travel budget will cover the costs of vehicle rentals, fuel, meals, and accommodations occurring during field visits. The supplies budget includes costs for laboratory disposable supplies needed for emulsion production.

11. PARTNERSHIPS

Match funding in the amount of $50,000 for the proposal is provided and approved by the United Soybean Board (USB) https://www.unitedsoybean.org/. The United Soybean Board is funded through the soybean checkoff. The USB invests in projects that increase demand for soybeans with a focus on meal, oil, and sustainability.

12. REFERENCES

Cochran, E.W., N. Hernandez, A. Hohmann, R.C. Williams, M. Forrester, J. H. Podolsky, P. Ledtje, and C. Chen. Biosolvents Useful For Improved Asphalt Products Utilizing Recycled Asphalt Pavement or Other Brittle Asphalt Binders Such as Vacuum Tower Bottoms. ISURF Provisional Patent Application. In Review.

Ghosh, D., M. Turos, M. Marasteanu. Evaluation of Bio-Fog Sealants for Pavement Preservation. Report Number: MN/RC 2016-20. June 2016. Available at: http://www.dot.state.mn.us/research/TS/2016/201620.pdf

Ghosh, D., M. Turos, M. Marasteanu. Rheological Characterization of Asphalt Binders Treated with Bio Sealants for Pavement Preservation. *Canadian Journal of Civil Engineering.* Vol. 45(5). DOI: 10.1139/cjce-2017-0058

Johnson, E. Nontraditional Fog Seal for Asphalt Pavement: Performance on Shoulder Sections in Minnesota. Report Number MN/RC 2018-18. Available at: http://www.dot.state.mn.us/research/reports/2018/201818.pdf