Proposal for 2019 Call for Innovation

AN INNOVATIVE PRACTICAL APPROACH TO ASSESSING BITUMEN COMPATIBILITY AS A MEANS OF MATERIAL SPECIFICATION

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1. Title: An Innovative Practical Approach to Assessing Bitumen Compatibility as A Means of Material Specification

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3. Abstract

A major challenge in current asphalt pavement material selection, specification and mix design processes is the lack of knowledge in determining compatibility between virgin binders and binders in recycled materials as well as those between binders (new and recycled) and rejuvenators. This lack of a characterization process to evaluate compatibility is a significant issue in the currently adopted U.S. practice for asphalt specification and purchase, whereby multiple sources of binders are often blended and most agencies allow for use of recycled asphalt pavements in the mixtures. The consequence of this is manifested in the form of inferior pavement performance and longevity, lack of guidance to agencies in adopting higher amounts of asphalt recycling, as well as selection of appropriate binders and rejuvenators.

The innovations from the proposed study will be realized in terms of novel applications of material characterization methods (most of which have not been evaluated for the proposed purpose) as well as recommendations to material selection and specification processes. Furthermore, the outcomes of the proposed study will allow NRRA agencies (and others) to improve existing materials by correctly being able to identify compatibility and therefore select the right materials and additives to use. This would then lead to higher performance and overall greater sustainability for pavement materials. Both analytical and mechanical testing methods as well as advanced analyses will be evaluated to develop a practical and readily implementable protocol for binder compatibility evaluation. Possible examples of a practical binder compatibility characterization method based on preliminary research may include: a rheological index parameter measured using existing binder testing equipment or use of binder elemental analysis using tools such as X-ray fluorescence spectroscopy (XRF).

This project will extensively leverage existing and recently completed MnROAD, NRRA, and national studies; for example, it will utilize materials in on-going MnROAD trials. The project will include an application specific optimization tool for binder formulation; at present, such tool is considered severely impractical. There is need for this high-risk high-reward innovative research that can fill the current knowledge gap and provide a practical tool that can be readily implemented. The application of this work would not be limited to hot-mix asphalt pavements. A similar knowledge gap exists for preservation treatments, specifically for spray applied rejuvenators, whereby chemical compatibility between the existing pavement and the rejuvenator is usually unknown. Similarly, for cold recycling applications, the compatibility between the emulsion or foamed asphalt and RAP is not evaluated due to lack of a characterization method. Another potential application would be in specification of tack coat materials (especially for bonded pavement construction), whereby the asphalt emulsion properties are only controlled in terms of emulsion's physical properties and emulsifier ionic characteristics. While the project will focus on utilizing all available tools in the analytical and mechanical characterization processes, the emphasis of this project will be to develop a simple and easy to implement tool kit. The simplicity of the test protocol will be a primary factor in the development process. The researchers will also develop educational materials as part of this project (such as, implementation manuals and recorded webinars) to aid in implementation of the research outcomes. The proposed research will bring an academic and industry member of NRRA together with complementary strengths in areas of analytical chemistry characterizations and performance testing and modelling. Both proposers will make over 25% cost share contributions to the proposed study, leading to over 59% matching funds to those provided by NRRA.

4. Introduction

"Rejuvenation vs. Softening" has become a common discussion point among asphalt material researchers and practitioners in recent years. Many accept that something beyond decrease of modulus should be expected from a "true" rejuvenator, with "compatibilization" often cited as the main differentiating mechanism. While guidance and recommendations regarding rejuvenator dosages have been developed through previous research efforts, none of these focus on a finger-print evaluation of asphalt binders that could determine suitability with respect to asphalt recycling and/or use of specific additives (primarily rejuvenating agents of concern).

Continuum rheological parameters such as ΔTc (defined as the difference in critical temperature for the creep stiffness (S) and relaxation rate (m value) passing values from bending beam rheometer (BBR) test); indices from Black space plots (Black space is two dimensional representation of dynamic modulus and phase angle of viscoelastic materials at various temperatures and frequencies), and mastercurve shape parameters have often been employed for assessing binder compatibilities. On the other hand, molecular fractional ratio analysis (such as, SARA: Saturates, Aromatics, Resins and Asphaltenes) have been used to determine chemical index parameters such as "colloidal instability Index" for bitumen compatibility. It should be noted that both rheological and chemical indices have been demonstrated only as empirical circumstantial evidence of compatibilities. Solid evidential support through direct measures of asphaltene association, compatibilization, and sol/gel morphology continues to be elusive.

As stakeholders work through the process of creating new specifications for complex binders and rejuvenators, reliable and non-circumstantial measures of bitumen compatibility are becoming an increasingly evident gap in the current state of knowledge and practice. At present, there is a major knowledge gap with regard to practical and implementable tools available for determining compatibility between asphalt binders and rejuvenating agents. A number of previous studies have clearly shown that depending on compatibility between new virgin binder and aged binder from RAP, the aging profiles and the performance trajectories of asphalt mixtures vary tremendously. Furthermore, current tentatively accepted limits for existing indirect compatibility tests are based on limited historical datasets, such as the ΔTc limit of -5°C which is ultimately based on correlations with ductility 5 cm at 15°C for asphalt that block cracked in Ohio and Pennsylvania (Figure 1), yet is being considered for many different regions and diverse binder sources today (Kendhal, 1977; Anderson, et. al., 2011). Figure 2 shows data by the proposers, showing potential limitations when trying to relate ΔTc to analytical measures of binder compatibility.

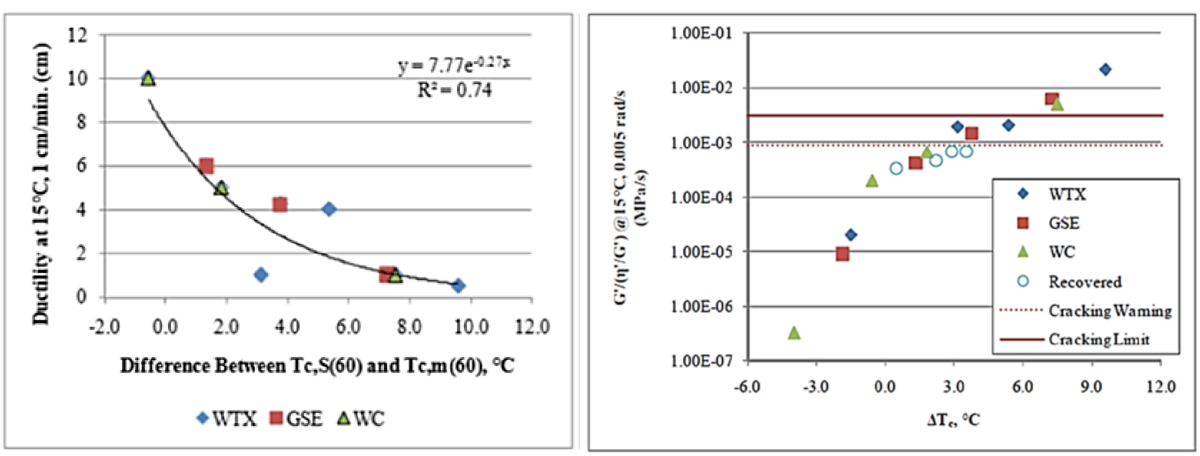

Figure 1: Relationship between ΔTc, "Glover Parameter", and Ductility

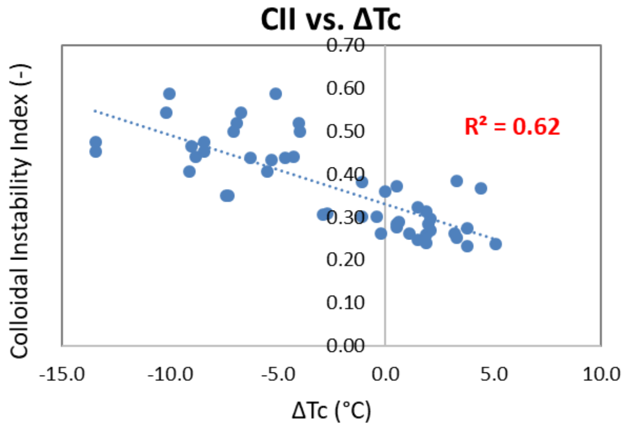

Figure 2. Proof of concept data by the proposers, showing the loose relationship between colloidal instability index, and ΔTc. The relationship highlights the potential inadequacy of either ΔTc or CII as measures of binder compatibility, as bitumen with equal CII can have ΔTc that varies by 5-10°C, and bitumen with equal ΔTc can have CII varying by more than ±50% of the average CII.

As the causal mechanisms of compatibility are postulated to intermolecular interactions and associations, it becomes critical to be able to evaluate such behavior in the natural state of asphalt. Use of solvents can affect and modify the molecular association, therefore confounding results of compatibility analysis carried out using analytical methods that study asphalt in solution. Thermal analysis methods investigating the evolution of the glass transition behavior with oxidative and physical aging have shown promise as a means of investigating binder compatibility in the past (Kriz, et. al., 2008), as shown in Figure 3. Figure 3(II) shows data collected by the proposers as proof of concept, showing the clear difference in transition behavior for an incompatible (AC #2 with multiple transitions) and a compatible bitumen (AC #1 with a single transition), as well as the impact of subsequent aging. Such methods can potentially be refined and extended to look at complex binders at various levels of aging, modification, or rejuvenation, and therefore are an important part of the analytical stage of the present proposal.

While the direct innovation of the proposed research is not in the form of a new material system or construction process, it will be a novel characterization and acceptance process that will have the potential to tremendously alter material selections and pavement designs, and pave the way for implementation of blind-to-source specifications that have the ability to accommodate new technologies in the future.

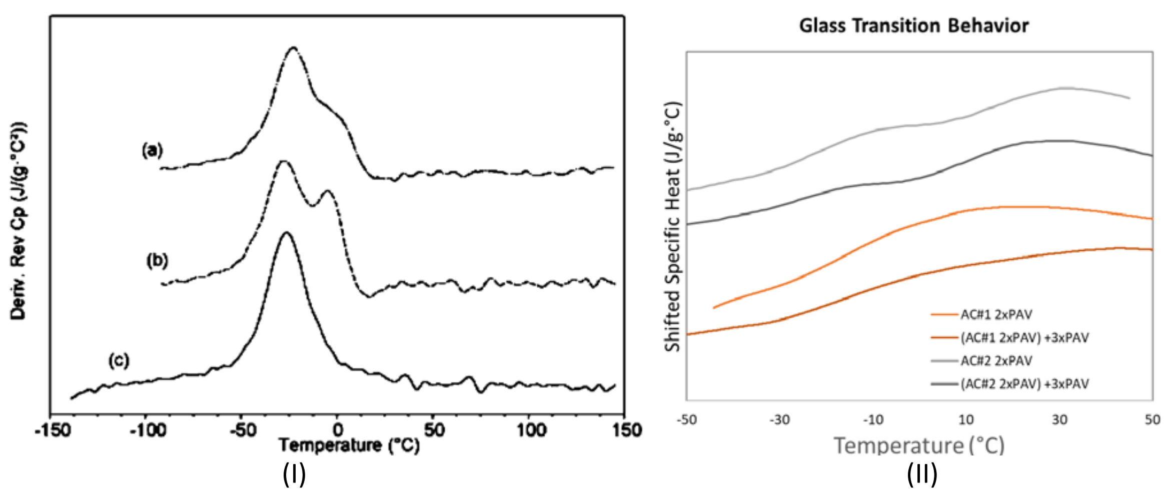

Figure 3: Use of DSC Thermal Analysis to three asphalt binders of different levels of compatibility: (I) (a) and (b) show incompatibility in the amorphous phase (Kriz, et. al., 2008); (II) Impact of aging on a compatible (AC#1) and incompatible (AC#2) bitumen, measured by the proposers (Cargill)

5. Objectives

The primary objectives of the proposed innovation study are:

- Development of a practical and implementable characterization system to determine compatibility between virgin asphalt binder and recycled asphalt pavement (RAP) as well as that between virgin asphalt binder, recycled asphalt pavement and rejuvenating agents;
- Build a methodology for adopting the compatibility characterization system to select appropriate asphalt binder sources with respect to available RAP and/or rejuvenation agents;
- Define threshold values and criteria for the selected compatibility criteria based on direct measures of compatibility in a diverse sample set; and,
- Provide guidance to agencies on implementation of the binder and rejuvenator compatibility based material selection methodology.

The proposed innovation will develop new processes for material characterization which will lead to innovations in adopting and implementing better performing material systems for use in flexible pavements. The innovative methodology developed in this study will have applications beyond hot-mixed asphalt; the same characterization system will also be applicable to selection of appropriate binder bases (for emulsions) for preventive maintenance treatments as well as for spray on rejuvenator applications for pavement preservation.

6. Variables

The key variables that will be assessed in the proposed study are as follows:

A. Compatibilities of asphalt binders, as impacted by crude source, aging history, and rejuvenation. The compatibility will be directly assessed analytically at various conditioning levels using a combination of thermal analysis (e.g. DSC: differential scanning calorimetry, pressure DSC, TGA: thermo-gravimetric analysis) and chemical analysis (e.g. FTIR: Fourier transform infrared, GPC: gel permeation chromatography, ICP: inductively coupled plasma elemental analysis, Iatroscan/SARA fractionation).
B. Impact of these compatibilities on performance of asphalt mixtures (including aging susceptibility), and existing field performance. These will be assessed directly for a field section in terms of prevalent distresses and their amounts as well as in terms of service life analyses. The lab performance evaluation of asphalt mixtures will be conducted through use of currently specified performance tests (such as, disk-shaped compact tension, complex modulus, semi-circular bend and direct tension cyclic fatigue tests).
C. The compatibility will also be indirectly assessed using rheological measures. A major component of the study will involve critical assessment of currently identified parameters (e.g. ΔTc, Glover-Rowe, cross-over parameters) for proper predictive ability compared to the directly measured compatibility properties (as described in A) with the object of determining, or if need be, developing, the most practical indirect measure that provides the appropriate level of predictive accuracy.

7. Research Question and Hypothesis

Research Question: At present, there is a lack of practical characterization method that can be readily adopted and used in construction specifications to ensure compatibilities between virgin binder and RAP as well as between virgin binder, RAP and rejuvenators. Is there a practical methodology for compatibility analysis of bituminous compounds and if so, what are properties and their thresholds to screen out incompatible materials?

Hypothesis: It is possible to determine the bitumen's state of compatibility regardless of conditioning, source and formulation using practical and implementable test methods, verified with clear analytical support. This method would create a clear bridge between bitumen analytical testing, binder rheology, and mixture and field performance at various levels of aging and rejuvenation.

8. Methodology

8.1 Overview

The research activities for the proposed study will be undertaken in four main thrusts:

1. Material Selection: This thrust will focus on additional review of published literature on the topic as well as on developing a detailed testing plan that will be executed in subsequent stages. During review of literature, compatibility evaluation systems outside of the asphalt materials domain will also be explored, specifically in fields of organic chemistry and polymer science. In this stage, the materials for field and laboratory evaluation will also be identified. Specific focus will be on identification of known incompatible and known compatible materials, these will serve as control cases in evaluation of different analytical and performance based assessment methods. Note that subsequent thrusts will be conducted in parallel in order to maximize the time and effort, as well as to cross-inform new findings from various tasks and make necessary adjustments.
2. Analytical Compatibility Assessment: This research thrust will utilize analytical instrumentation for evaluation of the known incompatible, known compatible and intermediate material systems. All testing will be conducted on asphalt binders (virgin and recycled) as well as asphalt binders and rejuvenators.
3. Binder Performance Assessment: Asphalt binder performance assessment using traditional (such as, standard binder grading tests) as well as recently developed techniques (such as, linear amplitude sweep and rheological indices) will be conducted. This is critical in assessing factors such as impacts of aging on binder blends (virgin and recycled as well as virgin, recycled and rejuvenator) which cannot be done using data coming only from field sections (due to each section only representing one age and substantial costs of installing new sections for each material combination). While field core samples will be sliced to obtain samples representing different levels of aging (due to presence of aging gradient), there will still be question of limited control over the extent of aging. As primary concern with use of recycled asphalt as well as primary application of rejuvenation is typically geared towards cracking performance, major emphasis will be on cracking related performance parameters.
4. Mixture Performance Assessment: Similar to the binder performance assessment, this research thrust will conduct asphalt mixture performance assessment at various aging levels to expand the data set that will be evaluated using analytical techniques as well as through binder performance assessment beyond the materials represented through pavement test sections. Even with use of slicing techniques to obtain materials with different levels of aging from field cores, most of mix performance tests are unable to utilize sliced specimens with small thicknesses (typically 0.25 inch), thus necessitating lab age conditioning. As with binder performance assessment, the main emphasis will be on cracking performance parameters, however, rutting indices from complex modulus will be evaluated to ensure that final project recommendations do not lead to rutting prone outcomes.

8.2 Research Activities

<u>8.2.1 Collection of Data</u>

Samples Considered: A set of clear reference binders will be selected to represent a “compatible”, “incompatible”, and “in-between” bitumen, as conventionally understood. The selection would preferably be made from material utilized in field sections to enable future field verification. These include:

a. MnROAD 45%RAP+Rejuvenator and 25% control sections constructed in Sep 2018, using a base binder with a relatively good ΔTc.
b. Wisconsin NCHRP 09-58 Test sections including 31% RAP + rejuvenator, 31% + soft asphalt, and a control section.
c. NCAT 45%RAP + Rejuvenator and 30% RAP control sections constructed in Aug 2018. This project uses a base binder with a relatively poor ΔTc (-6.5) after 20hrs of PAV.

Set of assessment and verification samples with criteria shown in Table 1 will be considered. The material will be subjected to different levels of oxidative and physical aging. Recently completed research at UNH has validated loose mixture aging protocols that were recently developed through the NCHRP 09-54 project. These protocols will be utilized to simulate various levels of aging in addition to the aging conditions represented by the material procured directly from field sections.

Table 1: Proposed material selection criteria.

Sample #	Description
1	"Compatible" good quality bitumen to establish upper extreme of performance
2	"Incompatible" poor quality bitumen to establish lower extreme of performance
3	"In-between" medium quality bitumen, to complete trend established by above extremes
4 to 8	Up to 5 verification materials will be selected from the aforementioned field projects.

Analytical Assessment Stage: The following test methods will be considered for the direct analytical assessment of bitumen compatibility. The full list will be conducted on the three main binder and binder/rejuvenator blends. The main blends are those listed as sample # 1, 2 and 3 in Table 2. The most discriminating test methods established from this phase will be utilized for the verification samples.

Table 2: Analytical assessment methods, measured results and their significance.

Test Method	Results	Significance
Differential Scanning Calorimeter (DSC)	Tg, Phase Miscibility	Results will be used to establish the existence of immiscible binder fractions, and impact of conditioning and rejuvenation on compatibility
Size Exclusion Chromatography	Molecular Size Distribution	Establish uniformity of molecular size distribution, and transition of polydispersity with conditioning and rejuvenation
Pressure DSC	Oxidation Induction Time	Establish impact of various fraction, conditioning, and/or rejuvenation on the oxidation potential.
Thermo-gravimetric Analysis (TGA)	Volatilization spectra	Complimentary method of assessment of various fractions within the bitumen in terms of volatility.
Iatroscan	SARA fractionation	Establish chemical fractions of various bitumen, calculate the Colloidal Instability Index
Inductively Coupled Plasma Analysis (or X-ray fluorescence)	Elemental Analysis	Determine the presence of certain elements to help fingerprint various bitumen sources considered.

Binder Assessment Stage: The binder lab evaluation methods listed in Table 3 will be considered for performance assessment. This is a preliminary list and will be refined through Task 1. Labs at both primary and subcontractor facilities are equipped to conduct a wide range of binder testing. Binder performance assessment will be on the same materials as those assessed in the analytical stage. Properties obtained from binder performance assessment will be compared against established threshold values from previous and on-going studies.

Table 3: Binder performance assessment methods, measured results and their significance.

Test Method	Results	Significance
Dynamic shear rheometer testing (4 mm, 8 mm and 25 mm)	Superpave PG parameters, linear viscoelastic characterization, rheological indices (such as, Glover-Rowe parameter and ΔTc), and aging index parameters	The current asphalt binder specification limits as well as recently developed and validated binder rheological performance properties will provide an initial baseline comparison with analytical measurements as well as provide initial thresholds to assess binder and binder/rejuvenator compatibilities.
Linear amplitude sweep (LAS) testing	Binder damage characteristic curve, fatigue performance indices	Fatigue performance of asphalt binder blends at various aging levels will be determined. LAS testing protocol determines continuum damage based fatigue performance indicators by conducting cyclic tests are increasing strain magnitudes on binder samples. It is significant to expand the limited performance dataset obtained from pavement sections.
Multiple stress creep recovery (MSCR) testing	Recoverable and non-recoverable portion of binder creep compliance as a rutting performance parameter	To ensure that the compatibility methodology does not result in binder blends that are susceptible to rutting, it is important that rutting performance is assessed. The MSCR properties go above and beyond those derived from linear viscoelastic characterization.

Mixture Assessment Stage: Mixture performance assessment is critical in this study due to the presence of RAP in the mixtures, which makes it challenging to conduct only binder performance assessment where new and recycled binder as well as rejuvenators fully blend during the recovery process. Due to this challenge, it is essential that mixture performance evaluations are also conducted to support the expansion of the dataset used in analytical method assessments as well as to determine performance at varying aging levels (in addition to field aging experienced by pavement sections). An initial list of mixture performance tests that will be employed in the proposed study is shown in Table 4, as with other tasks, on the basis of literature review and in consultation with the project technical advisory panel, this list will be updated as necessary.

Table 4: Mixture performance assessment methods, measured results and their significance.

Test Method	Results	Significance
Complex (dynamic) modulus	Linear viscoelastic (LVE) characterization, mix rheological indices (such as, mix Glover-Rowe parameter and mastercurve shape factors), and aging index parameters	Similar to binder testing, full LVE characterization will allow to look at rheological cracking and rutting performance indices for mixtures to expand the field performance data-sets. These properties are also crucial if any type of performance modelling is to be undertaken (either as part of this study or in future).
Direct tension cyclic fatigue	Mixture damage characteristic curve, fatigue performance indices	On the baseline samples at various lab aging levels, this test will determine fatigue cracking performance. The outcomes of this test are also input to FHWA's FlexPAVE performance prediction system.
Fracture and cracking tests (such as DCT, SCB and CTIndex)	Cracking performance parameters	In addition to full LVE and fatigue cracking performance testing, various cracking lab performance tests, that are currently being adopted by several NRRA partners, will also be included. Often times these have simpler testing procedures and these can serve as quicker proofing tests for validating the findings from binder analytical and performance assessment tasks.

Note: Significant binder and mixture data has already been collected by Cargill for these sections. This data will be available as in-kind cost sharing for this project, and will allow the research team to build on an existing dataset, significantly decreasing the testing resources required for the present proposal. Similarly, through involvement in the NCHRP 09-58 study, researchers already have access to substantial data on the test mixtures placed in Wisconsin.

<u>8.2.2 Data Analysis</u>

- The compatibility of the bitumen samples will be directly assessed analytically at various conditioning levels using a combination of thermal and chemical analysis. This measure will be used as the basis of assessment and validation of the practical non-analytical compatibility measures.
- Performance testing with and without aging will be performed on the selected material to establish the relevance of the assessed and developed compatibility parameters, and ensuring that compatibility predictions carry through from analytical through binder rheology, to mixture performance. The establishment of a coherent relationship between these three phases is recognized as a major shortcoming in current indirect measures of compatibility.
- The correspondence of the verification material with available field sections will allow for establishment of acceptance limits and criteria, ensuring connection to field performance both within the project timeline, and create the potential for continued correspondence studies in the future.

<u>8.2.3 Communication of Results</u>

Researchers will provide quarterly progress reports to the project technical advisory panel (TAP) detailing activities on each project task as well as plans for the upcoming quarter. At the initiation of the project, a kick-off meeting with held with the TAP to receive their feedback on the overall work-plan and specifically on the material selection. Near the end of Task 1, another meeting with the TAP will be held where final material selection lists as well as proposed testing plan will be presented. Feedback from this meeting will lead to the finalized testing plan as well as list of considered materials. At end of this task, a report will be submitted with a detailed literature review, material selection (and sampling details, if applicable) and testing plan to be executed in subsequent tasks. For each technical task of the project a task report will be submitted detailing the activities of that task as well as key results and findings. At the mid-point of the assessment tasks (analytical, binder performance and mixture performance), another project TAP meeting will be held to update the project panel on the findings to date. If possible, researchers would also like to provide annual updates at the NRRA Conference and Workshop in May of each year. The final deliverables for this study will include examples with annotations to demonstrate the use of the proposed characterization methodology as well as accompanying information on specifications and costs of equipment required to adopt the project outcomes. To train agency personnel on use of the project outcomes, a web based tutorial will be developed by researchers and disseminated through NRRA webinar series. Any other pertinent tools (such as, automated calculation spreadsheets) that might be necessary for an agency to implement project results will also be provided as part of the deliverable tasks.

9. Schedule

The proposed study will span over a course of 24 months. Specific project tasks and their schedule are shown in Table 5. This schedule is developed to ensure that all project milestones and deliverables can be realistically achieved. The project will initiate with a review of literature (preliminary bibliography on topic is already collected and provided in this proposal) and simultaneous selection of study materials as well as development of the testing plan. The next task will undertake sampling of materials (majority is already available at subcontractor facility, additional will be in form of field cores) as well as their distribution between primary and subcontractor facilities. Task 2 will also include material processing activities (such as, lab aging and extraction/recovery of binder). Tasks 3 and 4 will be underway in parallel with subcontractor leading activities in Task 3. Both Tasks 3 and 4 will focus on evaluation of asphalt binders (blends of virgin and recycled with and without rejuvenators). Task 5 will undertake mixture performance assessment. There will be substantial overlap between Tasks 3, 4 and 5 to allow for cross-feeding of information and developments and their corresponding impacts on outcomes. Task 5 will span slightly longer to ensure that validation testing on the basis of Task 3 and 4 findings can be accommodated. Tasks 5 and 6 will develop and refine project deliverables. Details on these deliverables was discussed earlier in this proposal.

Table 5: Project Schedule

FY20 (7/1/19 – 6/30/20)												
Month of Contract					**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Calendar Month	J	A	S	O	N	D	J	F	M	A	M	J
Task 1: Lit. Review, Material Selection & Testing Plan					X	X	X	X	X			
Task 2: Material Sampling & Specimen Preparation										X	X	X
Task 3: Analytical Assessment												
Task 4: Binder Performance Assessment												
Task 5: Mixture Performance Assessment												
Task 6: Draft Deliverables												
Task 7: Final Deliverables												

FY21 (7/1/20 – 6/30/21)												
Month of Contract	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Calendar Month	J	A	S	O	N	D	J	F	M	A	M	J
Task 1: Lit. Review, Material Selection & Testing Plan												
Task 2: Material Sampling & Specimen Preparation	X											
Task 3: Analytical Assessment	X	X	X	X	X	X	X	X				
Task 4: Binder Performance Assessment	X	X	X	X	X	X	X	X				
Task 5: Mixture Performance Assessment			X	X	X	X	X	X	X			
Task 6: Draft Deliverables										X	X	X
Task 7: Final Deliverables												

FY22 (7/1/21 – 6/30/22)												
Month of Contract	**21**	**22**	**23**	**24**								
Calendar Month	J	A	S	O	N	D	J	F	M	A	M	J
Task 1: Lit. Review, Material Selection & Testing Plan												
Task 2: Material Sampling & Specimen Preparation												
Task 3: Analytical Assessment												
Task 4: Binder Performance Assessment												
Task 5: Mixture Performance Assessment												
Task 6: Draft Deliverables	X											
Task 7: Final Deliverables		X	X	X								

10. Budget

BUDGET BY LINE ITEM	Description and Justification	Budget
Salaries		**$72,444**
Eshan V. Dave, PI (Assoc. Professor)	Principal investigator for the study. 0.5 months of effort is budgeted for each year.	$11,720
Jo E. Sias, Co-PI (Professor)	Co-principal investigator for the study. 0.25 months of effort is budgeted for each year.	$6,980
Graduate Research Assistant	Ph.D. student will be responsible for analysis; collecting data, laboratory characterization & report development under supervision of project PI & Co-PI. Time & effort for 2 semesters (one in each year) & 2 summer periods.	$38,358
Fringe Benefits	8.0% partial fringe rate for summer appointments	**$2,879**
Non-Salary		
Equipment:	No equipment will be procured.	$0
Supplies:	Supplies for lab testing and shipping of materials.	$1,000
Travel:	Travel for project TAP meetings.	$500
Other	Tuition and fees for graduate student	$18,279
Subcontractors	Cargill Bioindustrial	$80,000
Total Direct Costs		$160,216
Indirect Costs	Indirect Cost Rate: 50.5%	$43,903
<u>TOTAL NRRA COST</u>		**$204,119**
Cost Share		
UNH Cost Share (27% of NRRA share)		$56,040 (27%)
Cargill Bioindustrial Cost Share (32% of NRRA share)		$65,600 (32%)
<u>TOTAL PROJECT BUDGET (including 59% cost share with respect to total budget)</u>		**$325,759**

Justifications for the primary project applicant (UNH) is shown in the table above. Funds are budgeted for project subcontractor (Cargill Bioindustrial). Subcontractor will be responsible for analytical evaluation of binder blends as well as for supplying various testing mixtures, binders and rejuvenating agents according to the project work-plan. For subcontract, 1.5 month of time is budgeted for Dr. Hassan Tabatabaee and 2 months are budgeted for a laboratory chemist as well as $2,500 funds are budgeted for supplies to support material processing and laboratory testing.

This project substantially leverages NRRA funds at a level of 59% cost-share. Cost share from UNH includes one month of Dr. Dave and Dr. Sias' time each. Cost share from Cargill Bioindustrial will be in form of Dr. Tabatabaee's time and validation material binder and mixture performance testing results, provided for the study. It should also be noted that while this innovative project will employ a very wide spectrum of equipment and analyses, no cost for those are borne upon project. Also, both primary contractor and subcontractor already have access substantial data on the topic through previous research studies, all of this will be available to the proposed project at no cost.

11. Partnerships

(1) University of New Hampshire (primary proposer)
Authors: Eshan V. Dave and Jo E. Sias
(2) Cargill Bioindiustrial (subcontractor)
Author: Hassan Tabatabaee

A letter of support for the proposed research is also included from H.G. Meigs LLC (which is a company that supplies asphalt materials to multiple NRRA member agencies).

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13. Appendixes

CVs of all authors are attached

ESHAN V. DAVE

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PROFESSIONAL PREPARATION

- Sardar Patel University Civil Engineering 2001 B.Eng.
- University of Illinois at Urbana-Champaign Civil Engineering 2003 M.S.
- University of Illinois at Urbana-Champaign Civil Engineering 2009 Ph.D.
- University of Illinois at Urbana-Champaign Civil Engineering 2009-10 Post. Doc.

APPOINTMENTS

- Associate Professor, Univ of New Hampshire, Dept of Civil & Env. Engineering (2018-present)
- Assistant Professor, Univ of New Hampshire, Dept of Civil & Env. Engineering (2015-2018)
- Associate Professor, Univ of Minnesota Duluth, Dept of Civil Engineering (2014-2015)
- Assistant Professor, Univ of Minnesota Duluth, Dept of Civil Engineering (2010-2014)

SELECT AWARDS

- Outstanding Assistant Professor Award, 2018
- CTS Faculty Fellow, 2013-14
- AAPT Scholarship Award, 2007
- Runner-up for AAPT Walter J. Emmons Best Paper Award, 2005

RECENT PUBLICATIONS RELATED TO THE PROPOSED PROJECT

- Oshone M., J.E. Sias, E. V. Dave, A. Epps Martin, F. Kaseer, and R. Rahbar-Rastegar (2019). “Exploring Master Curve Parameters to Distinguish between Mix Variables.” Journal of Road Materials and Pavement Design. Published online 05 July 2019.
- Cannone Falchetto A., L. Porot, C. Riccardi, M. Hugener, G. Tebaldi, E.V. Dave (2019). “Effects of Rejuvenator on Reclaimed Asphalt Binder: An Exploratory Study of the RILEM TC 264-RAP Task Group 3,” RILEM Bookseries, Vol 20, pp. 195-200, Springer.
- Rahbar-Rastegar, R., R. Zhang, J. E. Sias, and E. V. Dave. (2019) “Evaluation of Laboratory Aging Procedures on Cracking Performance of Asphalt Mixtures.” Journal of Road Materials and Pavement Design. Published online 04 July 2019.
- Zhang, R., J.E. Sias, E.V. Dave, and R. Rahbar-Rastegar (2019). “Impact of Aging on the Viscoelastic Properties and Cracking Behavior of Asphalt Mixtures,” Transportation Research Record: Journal of Transportation Research Board. Vol 2673, Issue 6.
- Oshone, M., E.V. Dave, J.S. Daniel, and G.M. Rowe (2018). “Assessment of Various Approaches to Determining Binder Bending Beam Rheometer Low Temperature Specification Parameters from Dynamic Shear Rheometer Test,” Journal of Association of Asphalt Paving Technologists, 87, pp. 345-374.

SYNERGISTIC ACTIVITIES

- Recent research: Incorporating Impact of Aging on Cracking Performance of Mixtures during Design, *New Hampshire Department of Transportation;* Deputy chair for RILEM Technical Committee on Asphalt Pavement Recycling (TC264) and participant in inter-laboratory study on rejuvenators for asphalt recycling.
- Professional Leadership: Transportation Research Board: Chair of Subcommittee AFK50(1) Subcommittee on Advanced Models to Understand the Behavior and Performance of Asphalt Mixtures (2017-present), Member of AFK50 (2010-present), Chair of Int. Soc. for Asphalt Pavements (ISAP) Committee on Pavement Field Evaluation and member of the ISAP Board of Directors, Member of Expert Task Group for Long Term Pavement Performance Program.

JO ELLEN SIAS

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PROFESSIONAL PREPARATION

- University of New Hampshire Civil Engineering 1994 B.S.
- North Carolina State University Civil Engineering 1996 M.S.
- North Carolina State University Civil Engineering 2001 Ph.D.

APPOINTMENTS

- Professor, Univ of New Hampshire, Dept of Civil Engineering (2013-present)
- Director, UNH Center for Infrastructure Resilience to Climate (2015-present)
- Associate Professor, Univ of New Hampshire, Dept of Civil Engineering (2007-2013)
- Assistant Professor, Univ of New Hampshire, Dept of Civil Engineering (2001-2007)

SELECT AWARDS

- UNH Carpenter Professorship, 2019-2022
- US-UK Fulbright Fellow, 2015-16
- Transportation Research Board K.B. Woods Award, 2014
- Runner-up for AAPT Walter J. Emmons Best Paper Award, 2003, 2016, 2017
- National Science Foundation CAREER Award, 2005

RECENT PUBLICATIONS RELATED TO THE PROPOSED PROJECT

- Oshone M., J.E. Sias, E. V. Dave, A. Epps Martin, F. Kaseer, and R. Rahbar-Rastegar (2019). “Exploring Master Curve Parameters to Distinguish between Mix Variables.” Journal of Road Materials and Pavement Design. Published online 05 July 2019.
- Rahbar-Rastegar, R., R. Zhang, J. E. Sias, and E. V. Dave. (2019) “Evaluation of Laboratory Aging Procedures on Cracking Performance of Asphalt Mixtures.” Journal of Road Materials and Pavement Design. Published online 04 July 2019.
- Zhang, R., J.E. Sias, E.V. Dave, and R. Rahbar-Rastegar (2019). “Impact of Aging on the Viscoelastic Properties and Cracking Behavior of Asphalt Mixtures,” Transportation Research Record: Journal of Transportation Research Board. Vol 2673, Issue 6.
- Ogbo, C., F. Kaseer, M. Oshone, J. E. Sias and A. Epps Martin. (2019) “Mixture-based Rheological Evaluation Tool for Cracking in Asphalt Pavements.” Journal of Road Materials and Pavement Design. Published online 21 March 2019.
- Oshone, M., E.V. Dave, J.S. Daniel, and G.M. Rowe (2018). “Assessment of Various Approaches to Determining Binder Bending Beam Rheometer Low Temperature Specification Parameters from Dynamic Shear Rheometer Test,” Journal of Association of Asphalt Paving Technologists, 87, pp. 345-374.

SYNERGISTIC ACTIVITIES

- Recent research: Incorporating Impact of Aging on Cracking Performance of Mixtures during Design, *New Hampshire Department of Transportation;* Member of NCHRP 9-58 research team: The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios
- Professional Leadership: Transportation Research Board: Chair of Committee AFK50 Characteristics of Bituminous Paving Mixtures to Meet Structural Requirements (2008-14), Member of AFK50 (2001-present), member of Committee AFK30 Nonbituminous Components of Bit. Paving Mixtures (2004-present), Director at Large, Association of Asphalt Paving Technologists Board of Directors (2014, 2018-present), Member of FHWA Asphalt Mixtures & Construction Expert Task Group, Associate Editor, International Journal of Road Materials and Pavement Design (2013-present).

HASSAN A. TABATABAEE

13400 15th Ave N, Suite B, Plymouth, MN 55441   PH: (763) 203-2258

PROFESSIONAL PREPARATION

- Sharif University of Technology Civil Engineering 2007 B.S.
- Sharif University of Technology Civil Engineering 2009 M.S.
- University of Wisconsin Madison Civil Engineering 2012 Ph.D.

APPOINTMENTS

- Global Technical Manager - Asphalt Solutions, Cargill (2017-present)
- Senior Scientist, Industrial Specialties, Cargill (2014-2017)
- Research Associate, Univ of Wisconsin Madison, Modified Asphalt Research Center (2012-2014)

SELECT AWARDS

- The Achiever's Circle Innovation Award, 2018
- Cargill Shining Star Award, 2015
- Awarded Five Patents on Bitumen Chemical Modification, 2018-2019

RECENT PUBLICATIONS RELATED TO THE PROPOSED PROJECT

- Tabatabaee, H.A. and Kurth, T.L., "Analytical Investigation of the impact of a novel bio-based recycling agent on the colloidal stability of aged bitumen," Journal of Road Materials and Pavement Design, 2017.
- Tabatabaee, H.A. and Kurth, T.L., "Critical Comparison Of Asphalt Recycling Agents From Bio-based and Petroleum Sources," Proceedings of the 22° Encandro de Asfalto, 2016, Rio de Janeiro, Brazil.
- Tabatabaee, H.A. and T.L. Kurth. "Rejuvenation vs. Softening: Reversal of the Impact of Aging on Asphalt Thermo-Rheological and Damage Resistance Properties." Proceedings of the International Society of Asphalt Pavements, Jackson, USA, July 2016.
- Lei, Z., A. Golalipour, H.A. Tabatabaee, H.U. Bahia. "Prediction of Effect of Bio-Based and Refined Waste Oil Modifiers on Rheological Properties of Asphalt Binders." Annual Meeting of the Transportation Research Board. Washington D.C., 2014.
- Tabatabaee, H.A., R. Velasquez, H.U. Bahia. "Predicting Low Temperature Physical Hardening in Asphalt Binders." Journal of Construction and Building Materials 34 (2012): 162-169.
- Bahia, H.U., H.A. Tabatabaee, R. Velasquez. "Importance of Bitumen Physical Hardening for Thermal Stress Buildup and Relaxation in Asphalt." The 5th Eurasphalt & Eurobitume Congress. Istanbul, Turkey, 2012.
- Tabatabaee, H.T., R. Velasquez, H.U. Bahia. "Modeling Thermal Stress and strain in Asphalt Mixtures undergoing Glass Transition and Physical Hardening." Transportation Research Record (National Academies of Science), 2012.

SYNERGISTIC ACTIVITIES

- Professional Leadership: Chair, ASTM D4552 Task Force on Rejuvenator Specification; Chair, Emulsion Task Force on Rejuvenation; Member, Transportation Research Board Subcommittee on Asphalt Binders (AFK20); Member, Asphalt Institute Foundation Research Committee; Member, RILEM TC on Recycled Materials; Member, American Society of Civil Engineers; Member, American Chemistry Society; Member, American Society of Testing Materials.

August 8, 2019

Dr. Hassan Tabatabaee
Cargill Bioindustrial
13400 15th Avenue North
Plymouth, MN 55441

RE: Letter of support for NRRA Innovation Proposal "An Innovative Practical Approach to Assessing Bitumen Compatibility as a means of Material Specification"

Dear Hassan,

I have read and reviewed your team's proposal to the NRRA regarding the assessment of bitumen compatibility for material specification. As a technical manager for an asphalt supply terminal please accept this letter as a representation of our support for your proposed research efforts.

We have experienced firsthand the role that asphalt binder composition plays in the performance of constructed pavements. As your proposal points out, our current specification system (AASHTO M320/M332) does not address binder compatibility. In addition, the increased use of recycled materials (RAP and RAS) in new asphalt mixtures further highlights the need to better understand the chemical mechanisms that govern performance in asphalt binder.

I wish you luck during the proposal review process. If there is anything I can assist you with in the meantime or after the project is awarded, please do not hesitate to reach out.

Sincerely,

Dan Swiertz, PE
Director of Mix Design Laboratories
Bitumix Solutions, a Div. of H.G. Meigs, LLC
1220 Superior St.
Portage, WI 53901