Proposal for 2019 Call for Innovation

Cold Asphalt Recycling Technologies using Rejuvenating Asphalt Emulsion: Impact; Implementation; Specification

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1. Title: Cold Asphalt Recycling Technologies using Rejuvenating Asphalt Emulsion: Impact; Implementation; Specification

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3. Abstract

The CIR/CCPR processes have traditionally relied on commodity asphalt emulsion products (CSS-1, CSS-1h, etc.) or foamed asphalt as the stabilizing additive, either with or without the addition of cementitious materials. More recently so-called "engineered" asphalt emulsions have become common in some areas of the Country. Advancements in the use of asphalt Recycling Additives (RAs) in the hot mix asphalt and pavement preservation arenas have demonstrated the efficacy of RAs in increasing pavement or treatment performance relative to control materials. In particular, research into the use of RAs in high recycle content asphalt mixtures is demonstrating that through the proper selection and dosage, these mixtures can perform similarly or even better than control mixtures.

In the current proposal it is hypothesized that the use of RAs in asphalt emulsion stabilized CIR and/or CCPR process can provide performance benefits relative to commonly used ("Control") stabilization options. Performance benefits will be quantified using a suite of binder and mixture performance test methods in the laboratory. The research will also explore development of practical evaluation guidelines, test methods, or tools to select an appropriate RA for a given recycling project (i.e., key performance properties that need to be measured to ensure performance); determination of the dosage of RAs to be considered during the mix design phase; and importantly: Are the performance benefits of using RAs during cold recycling operations justified in terms of the potentially added mix design and raw material effort/costs?

A detailed plan and proposal for construction of innovative rejuvenated CIR test sections at MnROAD or other locations as determined by NRRA members will also be developed as part of this study. Although the construction of the test sections is outside the scope of the current proposal, the research team and partners have declared their interest in participating in such a project if it were to be pursued by NRRA.

The proposed project is anticipated to last 18 months at a cost of $141,442. The proposers will also provide 35% of cost share at the value of $49,504. No equipment will be purchased using NRRA funds. The majority of the NRRA costs will go towards salary compensation for the primary investigators and laboratory technicians and a small portion will be used for travel and operational supplies.

4. Introduction

America's roadway infrastructure is currently rated at a "D" level (A (best) through F (worst) scale) by the American Society of Civil Engineers (ASCE), with an estimated backlog in capital needs for road repair of $420 billion. The ASCE further recommends "support[ing] research and development into innovative new materials, technologies, and processes to modernize and extend the life of infrastructure…" as a means to help reduce the funding backlog and raise the infrastructure grade. Although certainly not “new” technologies, cold-recycling processes such as Cold in Place Recycling (CIR) and Cold-Central Plant Recycling (CCPR) offer opportunities for innovation that support this recommendation.

The CIR/CCPR processes have traditionally relied on commodity asphalt emulsion products (CSS-1, CSS-1h, etc.) or foamed asphalt as the stabilizing additive, either with or without the addition of cementitious materials. More recently so-called “engineered” asphalt emulsions have become common in some areas of the Country; these products are produced by careful selection of the base asphalt properties and/or emulsifier packages to match the unique needs of recycling processes. The benefit of engineered emulsion, in the experience of the authors, is the ability to control the curing rate of the emulsion product as opposed to standard emulsion products which may produce inconsistent results even throughout the course of a single project.

Recent advancements in the use of asphalt Recycling Additives (RAs) in the hot mix asphalt and pavement preservation arenas have demonstrated the efficacy of RAs in increasing pavement or treatment performance relative to control materials. In particular, research into the use of RAs in high recycle content asphalt mixtures is demonstrating that through the proper selection and dosage, these mixtures can perform similarly or even better than control mixtures. This concept has been explored by several researchers using the framework of “Balanced Mixture Design”, in which performance properties of the mixture are “balanced” across several modes of failure (e.g., rutting is balanced against cracking resistance) (Epps Martin, et. al, 2017).

The analogous nature of high recycle content mixtures and cold recycling processes such as CIR/CCPR suggests that the use of RAs in these processes might demonstrate particular utility in balancing mixture performance. Progress has been made in identifying key mixture and process-related variables that dictate performance in CIR/CCPR through recent National (NCHRP 09-51, NCHRP 09-62) and State-level research efforts, such as recent work by Braun Intertec for LRRB (Wegman and Sabouri, 2016). Leveraging the knowledge gained in these key projects with that gained from recent research into RAs and balanced mix design is the basis for this project.

For example, it is hypothesized by the authors that using traditional asphalt emulsion and/or foaming processes, the amount of recycled binder that is made available to contribute to performance is minimal (i.e., the RAP binder behaves as “Black Rock”); through the use of RAs the RAP binder may blend more thoroughly with the stabilizing material, thereby making the process more efficient and perhaps more performance-effective. Research conducted by the authors in developing a 100% RAP paving mixture suggests that the use of RAs applied directly to the RAP material may support this hypothesis. Figure 1 shows the effect of adding an RA directly on RAP material (no virgin asphalt binder used) at a specified dosage; as the percentage of RA increases, the peak load decreases but the cracking index (resistance to cracking) increases. The RA is evidently softening the RAP binder to a degree that allows the residual asphalt plus the RA component to blend and create a cohesive matrix. A “balance” between cracking and stability (peak load) must be achieved. Note that this work was done for hot mix, and the mechanism observed for cold mixing applications may be different.

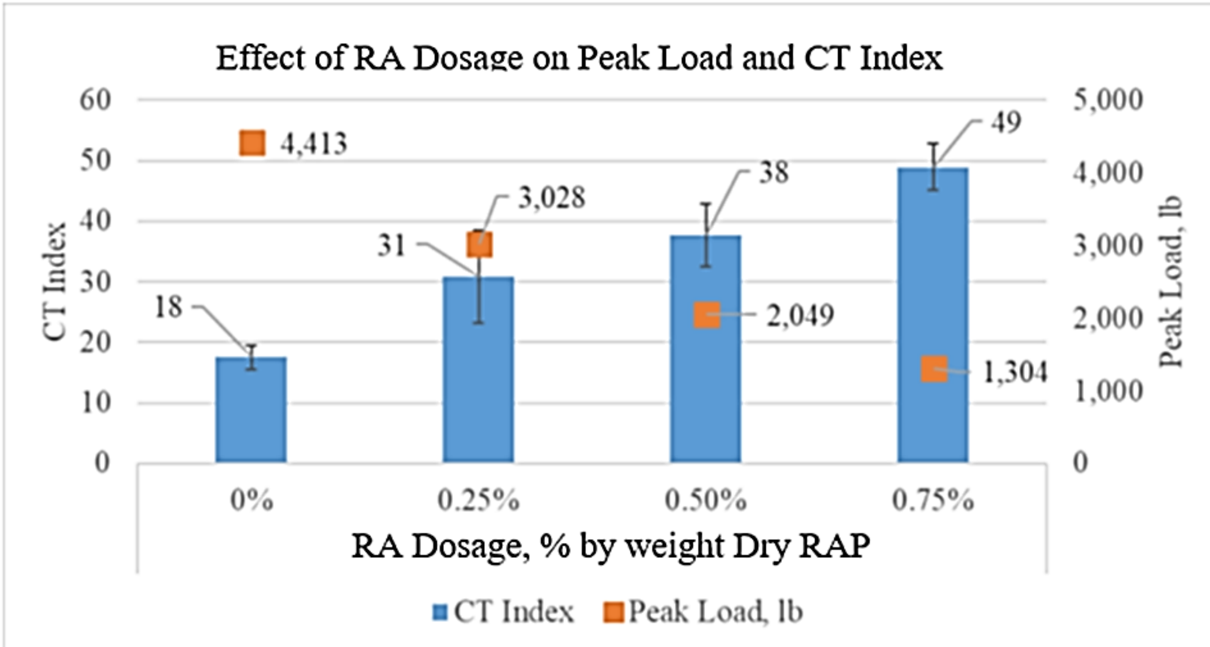

Figure 1. Effect of RA dosage on 100% RAP material for hot mix asphalt (data by proposers).

This research will evaluate the use of RAs in cold recycled mixtures as it pertains to mixture performance through laboratory study of the recycled asphalt binder and the corresponding mixtures. In particular, this research will evaluate the use of asphalt emulsion technology containing RAs either with or without the addition of other additives (Portland Cement, lime, etc.). The product of the proposed research will be an evaluation tool that will offer the NRRA a rapid path to practical implementation of these technologies on a trial basis (a test strip or similar).

5. Objectives

The objectives of this study are:

- Evaluate the efficacy of rejuvenating asphalt emulsions in the CIR and/or CCPR process in terms of potential performance benefits relative to existing stabilization options (e.g., foamed asphalt, engineered emulsion) using concepts of balanced mixture design;
- Provide preliminary usage and design guidelines for the use of rejuvenating asphalt emulsion in CIR and/or CCPR processes;
- Develop a “roadmap” for rapid implementation of a test section utilizing rejuvenating asphalt emulsion stabilization.

The proposed research study will result in a better understanding of the key RA and recycled asphalt properties that influence performance. The unique composition and experience of the proposed research team with RAs and cold recycling processes will aid in successfully completing the proposed objectives. Appendix I provides a list of the proposers’ relevant qualifications, experience and synergies with regards to achievement of the objectives of this study.

6. Variables

Key variables identified by the research team that will require careful consideration are:

- **Selection and dosage of RA:**

  According to NAPA, RAs have been classified based on starting material source into five basic categories, which are described below in Table 1 (NCAT, 2014) It should be noted that although this categorization is convenient, it does not account for the differences in performance that may be achieved using various products in the same category based on physical and chemical properties, chemical modifications, and production process.

Table 1: Types of Recycling Additives for Asphalt (NCAT, 2014)

CATEGORY	DESCRIPTION
Paraffinic Oils	Refined used lubricating oils
Aromatic Extracts	Refined crude oil products with polar aromatic oil components
Nathenic Oils	Engineered hydrocarbons for asphalt modification
Triglycerides & Fatty Acids	Derived from vegetable oils *Has other key chemical elements in addition to triglycerides and fatty acids.
Tall Oils	Paper Industry byproducts Same chemical family as liquid antistrip agents and emulsifiers

Although many types of RAs exist, their basic mechanism for performance should be consistent. The layering of asphaltene particles as a result of binder aging must be interrupted to get effective results from RAP and use of an RA should reduce the overall viscosity through a decrease in the effective particle size of the asphaltenes by peptizing the asphaltenes. “Rejuvenation” does not mean reversing the oxidation; rather it means a return of the viscoelastic properties of the binder (Holmes, 2016).

Significant progress has been made as a result of NCHRP 09-58 with regard to dosage selection guidelines for RAs. It is expected that the results from that landmark study will be used as a starting point during this study. One of the general outcomes of this study will be dosage selection recommendations/guidelines.

- **Incorporation of RAs in asphalt emulsion:**
  Two general methodologies for incorporating RAs into asphalt emulsion have been identified by the research team. The first is production of a “standard” grade asphalt emulsion but using the RA either as an additive to the base asphalt used in the emulsion or as a post-added additive to a finished emulsion product. The second is the emulsification of the RA itself analogous to some of the “rejuvenating fog seal” products available on the market. Both methods have benefits and disadvantages, and this study will need to initially consider both processes for cold recycling applications.

- **RAP properties (source):**
  The residual properties of the RAP used in the cold recycling process will change between (and perhaps within) regions as a result of climate differences, in-service time, mix design practices/materials, and other factors (Swiertz et. al, 2019). Therefore, if the rejuvenated RAP binder is expected to contribute significantly to performance, an understanding of the RAP binder properties is required. For this study it is expected that this variable will be addressed through the selection of RAP from either (a) known sources that differ from one another, or (b) significantly different climatic regions.

- **Use of other performance additives:**
  It is common practice in the cold recycling industry to use mixture additives to aid in initial strength gain, moisture resistance, or other performance factors. Commonly these are cementitious materials such as Portland Cement, fly ash, and lime. Although these materials have proven history of performance, they may affect the cracking susceptibility of cold recycled mixtures negatively, particularly in high amounts relative to the bituminous stabilizing component (ARRA, 2015). As such, a “balance” must be achieved between early strength gain, stability, moisture resistance, and cracking resistance.

It is anticipated that these factors will be addressed in the laboratory experimental design, outlined in Section 8 of this proposal.

7. Questions and/or Hypotheses

Research Hypothesis: The use of RAs in asphalt emulsion stabilized CIR and/or CCPR process can provide performance benefits relative to commonly used (“Control”) stabilization options. Performance benefits will be quantified using a suite of binder and mixture performance test methods in the laboratory.

Research Questions: Key research questions that this research will address are:

- What practical evaluation guidelines, test methods, or tools exist to select an appropriate RA for a given recycling project (i.e., what are the key performance properties that need to be measured to ensure performance)?
- How should dosage of RAs be considered during the mix design phase?

- Are the performance benefits of using RAs during cold recycling operations justified in terms of the potentially added mix design and raw material effort/costs?

8. Methodology

8.1 Overview

The research will consist of three major stages consisting of:

1. Literature review, material selection, and finalization of test plan
2. Material rheological and analytical characterization, for determination of the fundamental impact of rejuvenators on the CIR material, and determination of proper design dosages.
3. CIR Mix Design, performance testing, and comparison to conventional and innovative controls

The results of these tasks will be used for creation of a protocol and roadmap for implementation of rejuvenation in CIR, for use in both future projects and possible implementation in material specifications. This is described in detail in the following sections.

8.2 Research Activities

<u>Collection of Data</u>

Task 1: Literature Review and Material Selection: In the first stage RAP, rejuvenator, and bitumen materials will be selected from relevant sources of use within NRRA states. Furthermore, a thorough review of literature will be carried out, the results of which will be a synthesis of prior and ongoing research including but not limited to the NCHRP 09-58 and MnDOT studies on CIR/CCPR. Based on the literature review the test plan will be refined and finalized at the end of this task. The following tables provide an overview of the proposed materials:

Table 2: Proposed material selection criteria.

Sample Type	Description
RAP	Two RAP sources will be selected, preferably from two different PG regions and from two planned CIR projects.
Base Binder	A typical midwestern base binder will be used as the basis of the rejuvenating emulsion
Rejuvenator	One bio-based and one petroleum-based rejuvenator
Controls	A CSS-1H, Foamed bitumen, and/or a CIR engineered emulsion

Task 2: Material Collection, Preparation, and Characterization: In this task the material will be collected, prepared (2a), and analyzed using analytical and rheological measures (2b) to determine critical properties of potential importance to final product performance. The following tables provides an overview of the proposed characterization tests to be conducted on the base asphalt, selected RAs, and RAP binder (which will be extracted and recovered from the selected RAP sources):

Table 2: Bitumen and Rejuvenator 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
Dynamic Shear Rheometer	Mastercurve, PG	Determination of the performance grade, rheological performance, and mastercurves of the binder with aging and rejuvenation
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

Task 3: CIR Mix Design and Performance: In the next stage existing CIR mix designs from NRRA states will be leveraged as control materials. Performance testing will then be carried out to identify impact of rejuvenation on the performance and properties of the CIR mix in support of validating or disproving the hypothesis. The following design variables will be considered by the research team. It should be noted that the study will not use the following levels in a full factorial design, but instead utilize the findings of Task 1 to create a smart and efficient partial factorial design based on these parameters.

Table 3: Example CIR Mix Design Matrix.

Variable	Level 1	Level 2	Level 3	Level 4	Level 5
RAP Source	PG 58-28 Region	PG 64-22 Region			
Base Binder	PG58-28				
Cement	No Cement	Added Cement			
Rejuvenator	None	Bio-based	Petro-based		
Liquid Type	Rejuvenating Emulsion	CSS-1H	Engineered Emulsion	Foamed Asphalt	Only Rejuvenator

Note that all asphalt emulsion materials used in this study will be produced in the research team's laboratory using a controlled source of base asphalt, emulsification, and additive package. The experience of the research team in production of CIR and CCPR emulsions will aid in this endeavor.

Since the overarching objective of this research is to attempt to demonstrate the performance benefits of using a rejuvenating asphalt emulsion for CIR/CCPR, it is anticipated that the mixture performance testing selected will be sourced from both existing CIR design procedure (MnDOT, for example) as well as the Hot Mix Asphalt industry. It is envisioned that two general distresses will be targeted during this study: high temperature deformation resistance (rutting) and cracking. Deformation tests are used principally to place an effective maximum limit of asphalt binder in a mixture while the cracking tests ensure adequate quantity and quality of asphalt binder in the mixture.

Table 4 summarizes two high temperature test methods recommended for evaluation. The HWT device is relatively costly, but is fairly common in consulting, large contractor, and Agency labs. The test suffers, however, from high variability and relatively long testing time (Azari, 2014; Schram, 2013). This makes the test a poor choice for QC practices and verification and dispute resolution samples must also account for variability of the test method. The Marshall Stability test is currently used in CIR/CCPR specification by some Agencies (MnDOT, for example), and generally requires minimal additional equipment since the load frame used is the same as used for the TSR test. Final selection will be based upon Task 1and NRRA feedback.

Table 4: Recommended Deformation Resistance Test Methods for Evaluation.

Consideration	Hamburg Wheel Tracking Test	Marshall Stability
Standardization	AASHTO T324	ASTM D1559
Current Usage	Up to 39 DOTs use test for HMA characterization	Common in cold mix industry; used worldwide
Performance Limits in Literature (Y/N)	Yes	Yes
Precision and Bias Available (Y/N)	N; Estimates from NCHRP 10-87 (*6*); Iowa DOT (*7*)	Yes
Moisture resistance (Y/N)	Yes	No, a moisture conditioned subset must be fabricated
Equipment	Separate device; at least four manufacturers	Same device as TSR load frame
Sample Preparation Effort	High Additional sample required; samples must be cut	Low
Testing Time	High	Low

Table 5 summarizes two cracking test methods recommended for evaluation. NCHRP Project 09-57 identified no fewer than 10 candidate cracking test methods for consideration ranging in complexity, cost, and current use (NCHRP, 2016). The two methods in Table 5 is based on the researchers' current understanding of the literature, experience with these methods, cost, availability of accepted limits, standardization. The SCB-IFIT (AASHTO TP 124) has gained popularity as a cracking resistance test in Hot Mix Asphalt and has been used effectively to evaluate CIR/CCPR materials. An indirect tension test using some of the same concepts in data analysis as the SCB-IFIT has been developed, called the IDEAL-CT. Both procedures produce a "cracking index", but other parameters from the test can also be analyzed (Zhou, et. al, 2017). The primary advantage of the IDEAL-CT is the ease of use: reduced sample preparation not only saves time but also limits technician influence on the results.

Table 5: Recommended Cracking Resistance Test Methods for Evaluation.

Consideration	SCB-IFIT	IDEAL-CT
Standardization	AASHTO TP124	ASTM D8225
Current Usage	Up to 21 DOTs according to TRB survey and many research studies.	Unknown, recommended to at least 1 DOT; used extensively in research
Performance Limits in Literature (Y/N)	Yes	No, but recommendations have been made.
Precision and Bias Available (Y/N)	No, but estimates exist from published literature.	Yes, Conducted as part of ASTM Standardization
Equipment	Several manufacturers as well as retrofitting Marshall Load Frame available; 1-2 saws required	Use Marshall load frame; no saw required
Sample Preparation Effort	High Samples must be cut to "half-moon" and notched	Low Samples do NOT need to be cut
Testing Time	Low	Low

A low temperature cracking test is notably not included in this initial selection of test methods for this proposal to minimize budget as this research project is intended to show proof of concept and is by no means exhaustive. Additional funding is earmarked should the review panel recommend a low temperature test; if not, the budget monies will be used to test additional combination, aging times, etc. Since binder characterization will be completed during Task 2, the research team recommends maintaining proper specification of low temperature binder PG (e.g. -28 or -34 in Northern regions) and/or including another binder parameter such as ΔTc to provide reliability against thermal cracking.

Mixture aging conditions will be considered and finalized during the literature review process. It is hypothesized that at least two levels of aging will be considered since the blending of RAP binder with virgin binder and RAs is a diffusion process and relies on both time and temperature. Therefore, the actual benefit of utilizing an RA may not be fully realized until after a mixture has aged considerably. Data generated by the research team supports this hypothesis (Figure 2). Recall the data presented in Figure 1; the same mixture dosed at 0.5% RA by weight RAP was exposed to varying levels of long term oven aging (LTOA) (up to eight days). The results show that for this mixture eight days of aging produces a mixture with a cracking index the same as the "un-rejuvenated" mixture after short term oven aging (STOA).

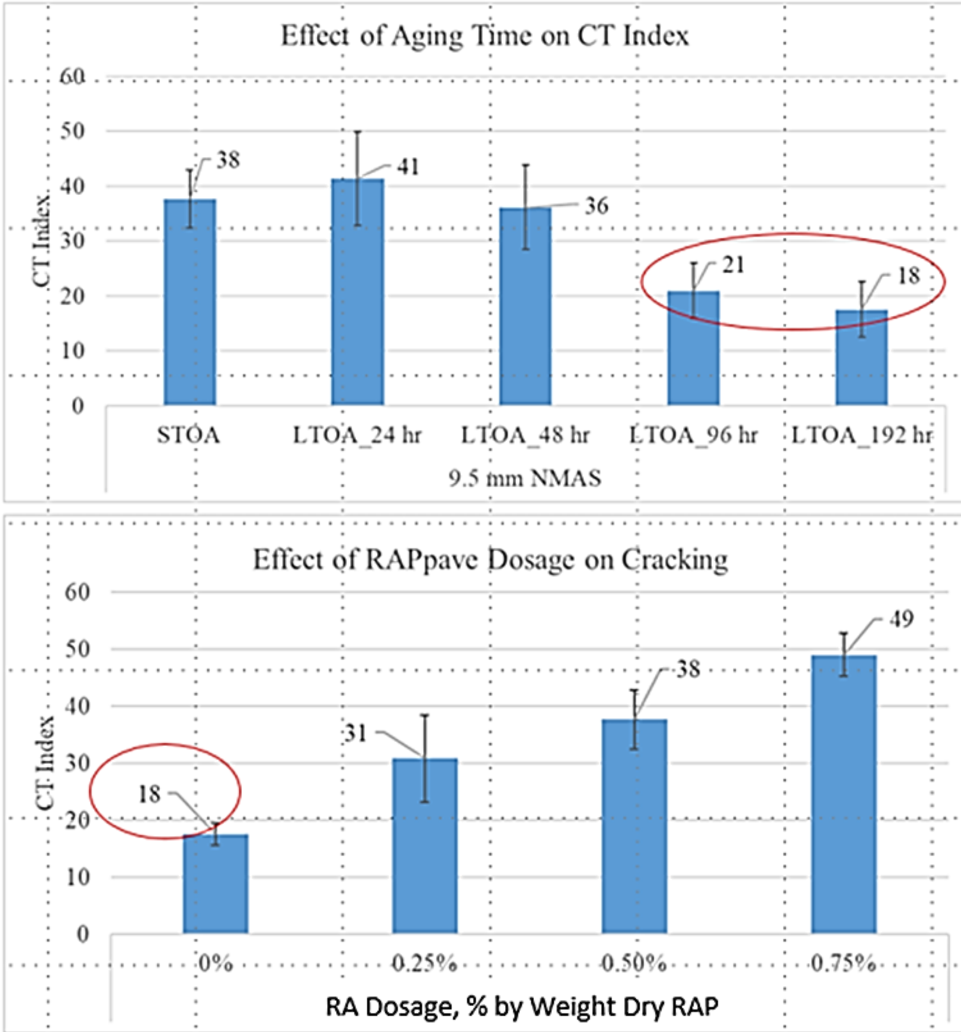

Figure 2. Effect of aging on mixture containing an RA (data by proposers).

<u>Data Analysis</u>

The Task 2 analytical and characterization testing will be used to determine the impact of rejuvenation of the studies binders and RAP sources. Based on the results a dosing methodology will be developed and use to determine the dosage for each rejuvenator type and mix design for use in Task 3.

The mix designs made in accordance to the variables determined in Table 3 will be tested and analyzed using the proposed performance tests. The extended performance characterization will be used to compare the rejuvenated CIR to various types of conventional CIR, and a special innovative control in the form of a 100% rejuvenator + RAP CIR that does not incorporate additional bitumen. Results will analyzed in the context of impact of rejuvenation on CIR durability and expected performance life compared to conventional alternatives.

Task 4 & 5: Draft and Final Deliverables and Communication of Results

The final deliverables of the project are anticipated to include the following:

- Final Report, documenting findings, conclusions, and detailed results. This will include a proposed method for design and incorporation of rejuvenators in CIR, along with documentation of expected impact. This can include suggested items that may be incorporated into specifications to address such technology.
- Presentation summarizing the research and findings.
- A detailed plan and proposal for construction of innovative rejuvenated CIR test sections at MnROAD or other locations as determined by NRRA members. Although the construction of the test sections is outside the scope of the current proposal, the research team and partners have declared their interest in participating in such a project if it were to be pursued by NRRA.

The research team will provide the Technical Advisory Panel with regular updates and solicitate input in accordance to the following schedule:

1. Kick-off meeting at the initiation of the project to align on initial work plan.
2. Quarterly updates in the form of 5 power point slides.
3. Alignment meeting at the end of Task 1 to present and finalize work plan for Tasks 2 through 5.
4. Draft Report provided to the TAP for review and solicitation of final input and recommendations (Task 4).
5. Final Report and Presentation, incorporating TAP input (Task 5).
6. Presentation of findings to NRRA and/or MAPA events, if possible.

9. Schedule

The testing and analysis efforts will be divided between Cargill as the principal investigator Bitumix Solutions as a subcontractor. The proposed project schedule is shown below; the project is anticipated to last 18 months. Cargill will primarily focus on binder and RA material characterization, analytical testing, and will lead report drafting. Bitumix Solutions will primarily focus on mix design and performance testing tasks. Both entities will jointly work on analysis, interpretation, and preparation of deliverables.

Table 5: Proposed Project Schedule

	BY 2019			BY 2020								
Month of Contract					**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Calendar Month	O	N	D	J	F	M	A	M	J	J	A	S
Task 1: Lit. Review, Material Selection & Testing Plan					X	X	X	X				
Task 2a: Material Sampling & Preparation							X	X	X			
Task 2b: Material Characterization								X	X	X	X	X
Task 3a: CIR Mix Design								X	X	X		
Task 3b: Mixture Performance Assessment											X	X
Task 4: Draft Deliverables												
Task 5: Final Deliverables												
	BY 2020			**BY 2021**								
Month of Contract	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Calendar Month	O	N	D	J	F	M	A	M	J	A	S	O
Task 1: Lit. Review, Material Selection & Testing Plan												
Task 2a: Material Sampling & Preparation												
Task 2b: Material Characterization	X	X	X	X	X							
Task 3a: CIR Mix Design												
Task 3b: Mixture Performance Assessment	X	X	X	X	X							
Task 4: Draft Deliverables					X	X	X					
Task 5: Final Deliverables								X	X	X		
BY: Budget Year												

10. Budget

BUDGET BY LINE ITEM	Description and Justification	Budget
Salaries + Fringes		**$73,763.54**
Hassan Tabatabaee, PI	Principal investigator for the study.	$30,959.54
Laboratory Technician	Technician will be responsible for analysis; collecting data, laboratory characterization under supervision of project PI.	$42,804.00
Non-Salary		
Equipment:	No equipment will be procured.	$0
Supplies:	Supplies for lab testing and shipping of materials.	$2,000
Travel:	Travel for project TAP meetings.	$500
Other	External Testing Services (Dependent on selected performance tests)	$5,000
Subcontractors	Bitumix Solutions	$60,176,67
<u>TOTAL NRRA COST</u>		**$141,440.21**
Estimated Cost Share		
Cargill Cost Share (Estimated 19% of NRRA share)		$27,065.59 (19%)
Bitumix Solutions Cost Share (Estimated 15% of NRRA share)		$21,594.69 (15%)
<u>TOTAL PROJECT BUDGET (inc. approx 35% cost share by billable cost)</u>		**$190,100.49**

No equipment will be purchased using NRRA funds, although some of the cost-sharing monies indicated for may be used to purchase equipment, depending on the final test methods selected. The majority of the NRRA costs will go towards salary compensation for the primary investigators and laboratory technicians.
Cost share is estimated in the form of researcher and technician time, mix design resources, and possible procurement of testing equipment.

11. Partnerships

1. Cargill Industrial, Primary proposer
    a. Author: Hassan Tabatabaee
2. Bitumix Solution, Sub-contractor
    a. Author: Dan Swiertz

12. References

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13. Appendixes

Appendix I: Strengths of This Proposal

Appendix II: Author one-page CVs

Appendix I: Strengths of this Proposal

The strengths of this proposal include the expertise and experiences of research team directly related to proposed project:

- Cargill is a worldwide leader in the production of recycling additives for the asphalt industry and has the knowledge and infrastructure in place to effectively engineer, support, and modify these materials as performance dictates on a chemical level. The working relationship between Cargill and industry (including the subcontractor) has afforded a high degree of practical and readily implementable knowledge on these processes.
- Bitumix Solutions as a division of H.G. Meigs LLC has extensive experience in manufacturing and supporting asphalt emulsion materials designed for cold-recycling projects, including materials currently performing on MnROAD. Field experience working with major midwestern contractors on cold recycling projects has given Bitumix Solutions a practical perspective on these technologies. Being a member of the cold recycling materials industry also affords the opportunity to accurately analyze cost-effectiveness of proposed treatment. The Bitumix Solutions laboratory is AASHTO accredited and is also a certified testing laboratory in the State of Wisconsin. The laboratory is staffed by a Professional Engineer as well as certified highway technicians.
- The peer-reviewed accomplishments of the research team on the subject matter demonstrate a high level of working technical knowledge of the cold recycling process.

Appendix II: Author One-Page CV

HASSAN A. TABATABAEE

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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.

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PROFESSIONAL PREPARATION

- University of Wisconsin Madison Civil Engineering 2009 B.S.
- University of Wisconsin Madison Civil Engineering 2010 M.S.
- Wisconsin DOT Highway Technician, No. 105379; AGG-TEC-1, -ATTS, HMA-IPT, -TPC, -MD
- Asphalt Institute: Asphalt Mix Design Certification
- Professional Engineer (P.E.), State of Wisconsin License No. 44383-6

APPOINTMENTS

- Director of Mix Design Laboratories, Bitumix Solutions, a Div. of H.G. Meigs, LLC (2013-Present)
- Researcher, University of Wisconsin Madison (2014-Present)
- Research Engineer, University of Wisconsin Madison (2011-2013)

SELECT AWARDS

- Gene Skok Award, Outstanding Paper by a Young Author (Transportation Research Board, 2015)
- Elaine Thompson Award for Best Written Paper (Canadian Technical Asphalt Association, 2011)

RECENT PUBLICATIONS RELATED TO THE PROPOSED PROJECT

- Wisconsin Highway Research Program 0092-17-04 Field Aging and Oil Modification Study, 2018.
- Transportation Pooled Fund TPF5-302 Modified Binder (PG+) Specifications and Quality Control Criteria, 2018
- Wisconsin Highway Research Program 0092-15-04 Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications for WisDOT, 2016.
- Swiertz, D. "Method for Determination of Optimum Emulsion Content for Emulsion-Stabilized Full-Depth Reclamation with Field Study" Presented at the Transportation Research Board Meeting, 2015.
- Swiertz, D., Johannes, P., Tashman, L., Bahia, H. Analysis of Laboratory Coating and Compaction Procedures for Cold Mix Asphalt. In *Journal of the Association of Asphalt Paving Technologists (AAPT),* Vol. 81, 2012, pp. 81-107.
- Swiertz, D., Mahmoud, E., Bahia, H. Estimating the Effect of RAP and RAS on Fresh Binder Low Temperature Properties without Extraction and Recovery. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2208, Washington, D.C., 2011, pp. 48-55.

SYNERGISTIC ACTIVITIES

- Asphalt Emulsion Manufacturers Association (AEMA), Younger Members Committee; Asphalt Recycling and Reclamation Association Member; Transportation Research Board peer reviewer for 3 committees.