TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Minnesota Department of Transportation

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *(i.e, SPR-2(XXX), SPR-3(XXX) or TPF-5(XXX)* TPF-5(341) http://www.pooledfund.org/Details/Study/590	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – April 30) ☒Quarter 2 (May 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
An Innovative Practical Approach to Assessing Bitumen Compatibility as an End Means of Material Specification

Name of Project Manager(s):	**Phone Number:**	**E-Mail**
PI: Eshan V. Dave / PC: Deborah Sinclair / TL: Benjamin Worel	603-862-5268	eshan.dave@unh.edu
Lead Agency Project ID: MnDOT Contract 1036816	**Other Project ID (i.e., contract #):** UNH Grant 14G305	**Project Start Date:** 05/15/2020
Original Project End Date: 04/30/2022	**Current Project End Date:** 04/30/2022	**Number of Extensions:** 0

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$204,119	0.00	3%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
0.00	0.00	2%

Project Description:

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).

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):
General: One project TAP meeting was held, and one project update presentation was made by research team during this quarter. A project kick-off meeting was held on June 1st, 2020 (minutes of the meeting and presentation are attached with this quarterly report). During this meeting, the material sampling plan and testing plan were specifically discussed by the research team and the project TAP. Second, a project update was made during the during NRRA's Flexible Team Web-based Workshop on June 3rd, 2020.

Specific progress for various study tasks is provided below.

Task 1 Initial Memorandum on Expected Research Benefits and Potential Implementation Steps: During the proposal phase and the development of the work plan, key benefits were selected to clearly define the benefits the state agencies will receive from the results and conclusions of this research. The research team is currently developing the task 1 deliverable to provide an initial assessment of overall research benefits, a proposed methodology, as well as the potential implementation steps. A draft of the Task 1 deliverable will be submitted to the project TAP for review by end of July 2020.

Task 2 State of the Art Review, Material Selection and Testing Plan: The research team is conducting a thorough literature review regarding the available tools and techniques to assess compatibility of asphalt binders with respect to virgin and recycled asphalt sources as well as rejuvenators. In addition, the research team is currently working on finalizing the material sampling and testing plans based on the discussions and feedback from the TAP during the project kick-off meeting. The amount of material for different material groups (core group and validation group) that is needed for various performance and analytical tests included in this project have been determined by the research team. These material needs are being distributed to various contacts that are helping with coordination of material sampling efforts. A draft of the Task 2 deliverable will be submitted by end of July 2020 for review by project TAP.

Task 3 Material Sampling and Specimen Preparation: No progress to report.

Task 4 Analytical Assessment: No progress to report.

Task 5 Binder Performance Assessment: No progress to report.

Task 6 Mixture Performance Assessment: No progress to report.

Task 7 Final Memorandum on Research Benefits and Implementation Steps: No progress to report.

Task 8 Draft Final Report: No progress to report.

Task 9 Editorial Review and Publication of Final Report: No progress to report.

Anticipated work next quarter:
Key activities that will be undertaken in the upcoming quarter are the following:

Task-1&2: The research team will submit the initial memo and summary of literature review by the end of July 2020 to the TAP for their review.

Task-3: Task 3 is anticipated to start at the beginning of July for executing the material sampling plan that is developed in Task-2 of this study. Various material processing activities will be undertaken in this task as well; these will include binder extraction and recovery from mixtures, mixture long term lab aging, and preparation of mixture test specimens for use in Task 6 will also be undertaken.

In addition, a project update meeting will be conducted in late July or early August 2020. The research team will present the finalized list of selected materials and corresponding project sites. A detailed testing plan on the selected materials will be presented to the TAP for their feedback.

Significant Results:
Significant results from this quarter are listed below:

1.Literature review: the research team is currently conducting a thorough literature review. The review focuses on literature both in the asphalt materials domain as well as those available in fields of organic chemistry and polymer science.

2.Material sampling plan:

a) The A-C three core materials have been preliminarily identified based on the discussions between the research team and the project TAP. These binders are the reference binders to represent the “compatible” and “incompatible” bitumens (for core materials A and B), as conventionally understood, and have been utilized in field sections to enable future field verification. Table 1 below shows the detailed information for these binders. Two of the validation materials have been also identified and are shown in Table 1. The research team is still working on finalizing the other three validation materials (several potential candidate materials are being evaluated including materials representing US 8 test sections that were part of WHRP study and materials from NCHRP 09-58 project)

Table 1 Information for Core and Validation Materials (preliminarily selected)

Material Group	Material	Base Binders	Binder Sources	Expected Binder Compatibility (Virgin and Recycled)	Corresponding Field Section/Pavement Built
Core	A	PG 58-28	Minnesota	Compatible	MnROAD/NRRA
	B	PG 64-22	Alabama	Incompatible	NCAT, Alabama
	C	PG 64-22	Missouri	Unknown	Missouri (District: SE)
Validation	D	PG 46-34	Missouri		Missouri (St. Louis Area)
	E	PG 58-28	Illinois		Illinois (Chicago region)
	F	TBD	TBD		TBD
	G	TBD	TBD		TBD
	H	TBD	TBD		TBD

TBD: To be determined.

b) In light of discussions with the TAP, research team decided to not include asphalt binder modifiers (such as polymer modification) for the A-C three core materials. Instead, modifiers will be considered to increase the material base evaluated in this project for the verification materials. The A-C core materials will be primarily used to evaluate the

compatibility and incompatibility between the binders (different sources), RAP (sources and dosages) and the rejuvenator additives (sources and dosages).

c) The research team was able to locate significant quantities of aggregate and RAP from core materials A and B. Thus, as per the TAP's recommendation, all core and validation mixtures will be prepared using these same sources of aggregates and RAP. The research team will also conduct limited mixture performance tests and binder tests from as produced mixtures for the selected materials. In addition to binder and plant-produced mixtures, raw materials (aggregate, binder, RAP, additives) for each material type will also be sampled in case these materials are needed during the course of the project.

d) The research team is currently working with NRRA members to finalize the list of validation materials.

e) Based on the preliminary testing plan proposed in the project, the table below shows the estimated the amount of materials needed for the two material groups.

Table 2 Estimated Amount of Material Needed for Each Group (A-H)

Materials	Amount of Mixture Needed (lbs)	Amount of Raw Material Needed (lbs)			
		Binder	RAP/RAS	Aggregate	Rejuvanator
Core (A/B/C)	875.0	60.0	435.0	875.0	3.0
Validation (D/E/F/G/H)	550.0	40.0	275.0	550.0	2.0

3. Material testing plan

a) Based on the feedback from the TAP, the suggested binder analytical methods and the binder/mixture performance tests will be conducted on the three core materials. The tests/methods that show promise in identifying the compatibility/incompatibility of the core materials will be used for the validation materials to further evaluate their effectiveness. The research team will keep the same aggregate source and gradation but vary the binder sources (A-C binders) when designing the mixtures for the fractional factorial design that will be used with the core materials in this study.

b) The material testing plan will be finalized based on the final material sampling plan, results of literature review and further discussions with the TAP.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).
Nothing to report at this time.

Potential Implementation:
Nothing to report at this time.

National Road Research Alliance (NRRA)

An Innovative Practical Approach to Assessing Bitumen Compatibility as a Means of Material Specification

Project Webpage: https://www.dot.state.mn.us/mnroad/nrra/structure-teams/flexible/assessing-bitumen-compatibility.html

Minutes of Project Kick-off Meeting 06/01/2020

Attendees: Andrew Cascione, Ben Worel, Brian Hill, Dan Oesch, Erik Lyngdal, Eshan Dave, Hassan Tabatabaee, Jo Sias, Kiran Mohanraj, Richard Willis, Runhua Zhang

1. Welcome & Introductions
2. Project Kick-off presentation
    a) Eshan Dave went through the presentation to briefly discuss the project objectives, overall research approach and project tasks etc.
    b) Discussion took place around the following areas
    i. Testing Plan for the study materials
        1. The suggested binder analytical methods and the binder/mixture performance tests will be conducted on the A-C three core materials. The tests/methods that show the promising to identify the compatibility/incompatibility of the core materials will be applied on the D-H verification materials to further evaluate their effectiveness.
        2. For the fractional factorial design that will be applied on the core materials in this study, suggested to keep the aggregate source and gradation same, but varying the binder sources (A-C binders) when designing the mixtures.
    ii. Sampling Plan
        1. For the A-C three core materials, decided to not include the modifiers, but for the verification materials, modifiers will be considered to increase the material base evaluated in this project. The A-C core materials will be primarily used to evaluate the compatibility and incompatibility between the binders (different sources), RAP (sources and dosages) and the rejuvenator additives (sources and dosages).
        2. For the raw materials (aggregate, binder, RAP, additives) that will be sampled, research team will use them to design and blend the mixtures as close as possible to the mixtures placed in the track/test sections.

3. For binder C, there are four potential candidates. Research team will select one as the finalized C material. Other three will be considered as the verification materials.

c) Current project status: Research team is working on: Task 1 the initial memo on expected research benefits and Task 2 state of art review. Research team will submit the initial memo and summary of literature review by end of July to TAP for their review.

3. Action Items

a) Brian Hill will work with IDOT to see if it is possible to collect the PG 58-28 (with low ΔTc value) binder for group C material; Eric Lyngdal will try to determine if materials are available from WHRP US Highway 8 test sections; Daniel Oesch from MoDOT will be able to provide the PG 46-34 high recycling mixes with rejuvenator for this study.

b) UNH team will look at the potential materials left from the NCHRP 09-58 project for this study.

c) Research team needs to provide the estimated amount of materials needed for the performance and analytical tests in this project.

d) Research team needs to come up with a finalized testing plan.

NRRA Innovation Project: An Innovative Practical Approach to Assessing Bitumen Compatibility as a Means of Material Specification

Eshan V. Dave, Jo E. Sias, Runhua Zhang
University of New Hampshire
Hassan Tabatabaee
Cargill Bioindustrial

Project Kick-off Meeting 06/01/2020

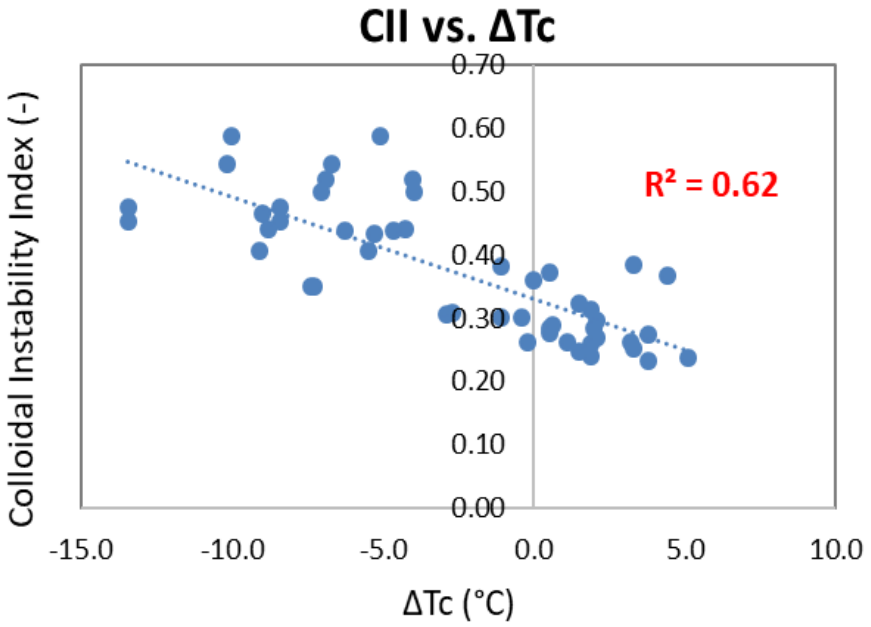
University of New Hampshire

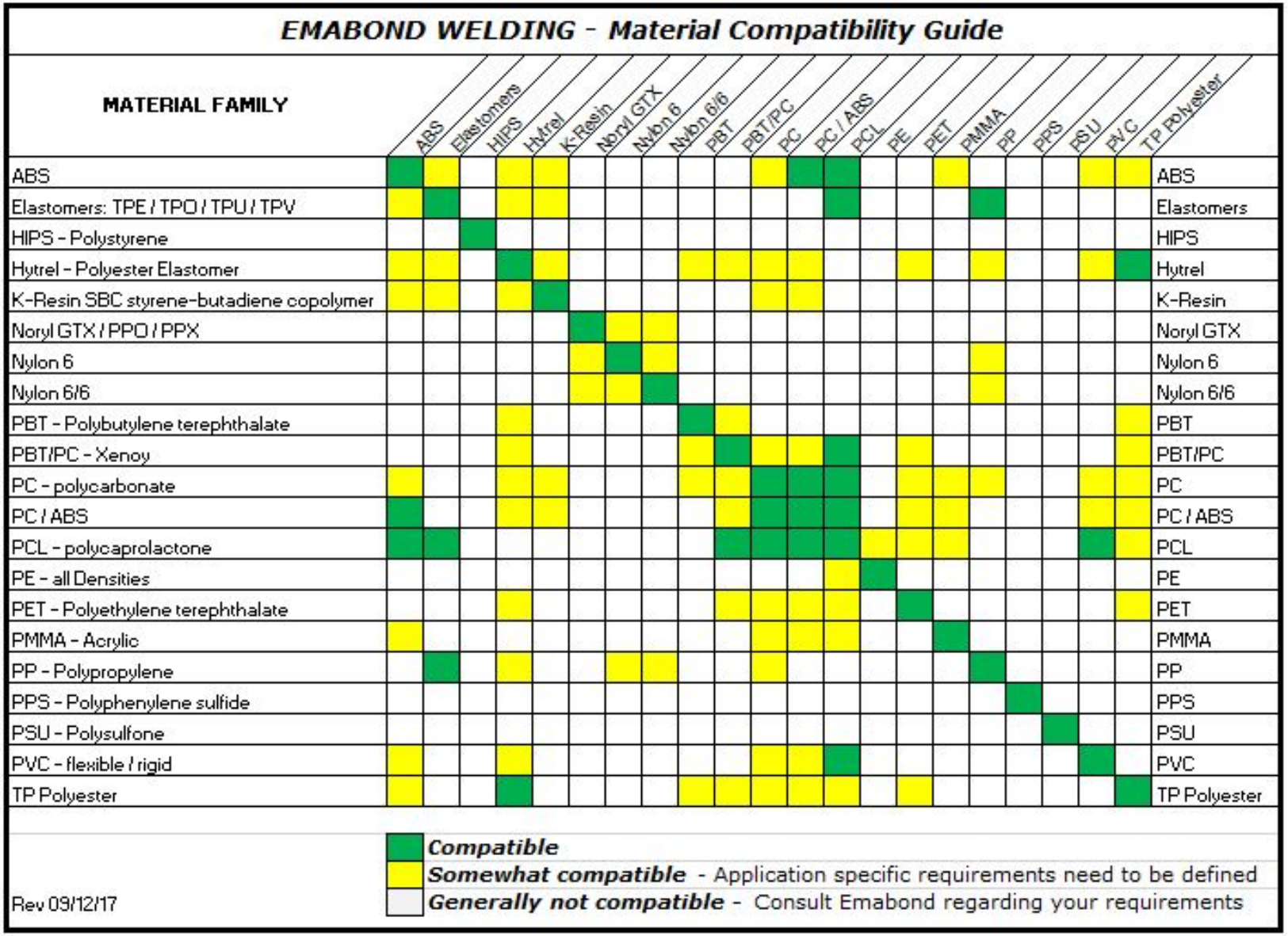
NRRA National Road Research Alliance

Cargill Helping the world thrive

Goal and Challenges

- Goal: Determining compatibility between virgin binders, binders from recycled materials and rejuvenators
- Challenge: Incompatibility and lack of reliability between continuum rheological parameters and chemical index parameters
- Also, most rheo. indices are based on limited datasets with limits based on correlations
  - Ductility to develop ΔT_c thresholds



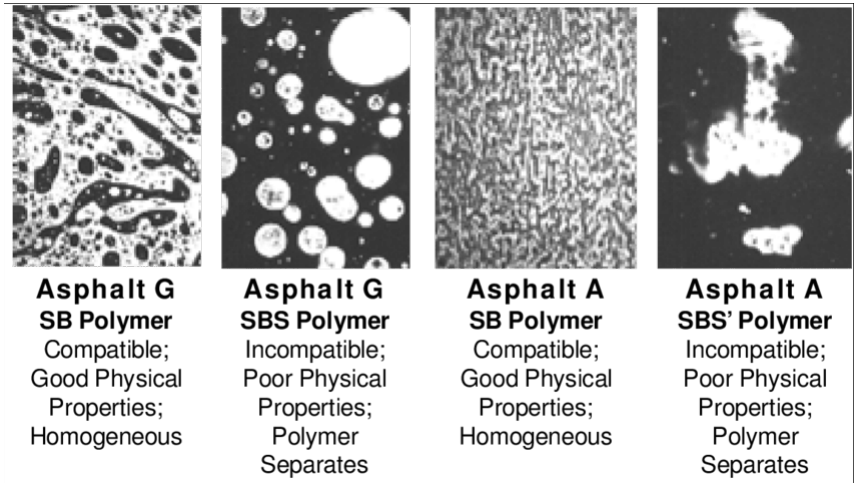

EMABOND WELDING - Material Compatibility Guide
MATERIAL FAMILY
ABS
Elastomers
HIPS
Hytrel
K-Resin
Noryl GTX
Nylon 6
Nylon 6/6
PBT
PBT/PC
PC
PC / ABS
PCL
PE
PET
PMMA
PP
PPS
PSU
PVC
TP Polyester
ABS
Elastomers: TPE / TPO / TPU / TPV
HIPS - Polystyrene
Hytrel - Polyester Elastomer
K-Resin SBC styrene-butadiene copolymer
Noryl GTX / PPO / PPX
Nylon 6
Nylon 6/6
PBT - Polybutylene terephthalate
PBT/PC - Xenoy
PC - polycarbonate
PC / ABS
PCL - polycaprolactone
PE - all Densities
PET - Polyethylene terephthalate
PMMA - Acrylic
PP - Polypropylene
PPS - Polyphenylene sulfide
PSU - Polysulfone
PVC - flexible / rigid
TP Polyester
Compatible
Somewhat compatible - Application specific requirements need to be defined
Generally not compatible - Consult Emabond regarding your requirements
Rev 09/12/17

Study Objectives

- Explore practical and implementable compatibility characterization system:
  - Combination of various asphalt sources (virgin binders, recycled asphalt binders)
  - Combination of asphalt binders (virgin, recycled) with rejuvenating agents
- Build a methodology for adopting the compatibility characterization system
- Define threshold values and criteria for the selected compatibility measures
- Provide guidance to agencies on implementation of the compatibility-based material selection methodology

Potential Sources of Binder Incompatibility

- Binder source itself (blending of binder sources to make targeted virgin binder)
- Virgin and recycled binders
  - RAP, RAS
- Binder (virgin, recycled) and mix additives
  - Added at terminal
  - Added at plant
  - Modifiers: SBS, PPA, EVA, waxes etc.
  - Rejuvenators: Aromatic extracts, paraffinic oils, tall oils, organic/vegetable oils, etc.



King et al. (2020), Federal Lands Highway Study

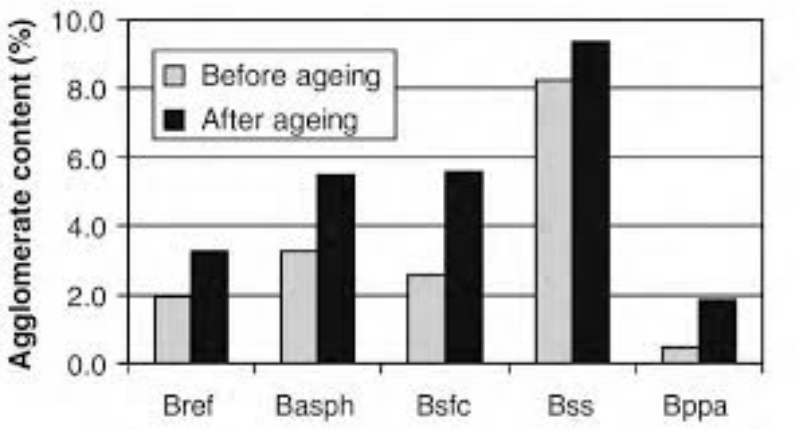


Planche (2014), Shell Sol-Gel Model and Aging

Research Approach

- Literature review and material selection:
  - Compatibility evaluation systems (specifically those from outside asphalt materials domain)
  - Identification of binders/materials with known incompatibilities and compatibilities
- Analytical compatibility assessment:
  - DSC, TGA, SARA, elemental analysis etc.
- Binder performance assessment
  - LVE, LAS, MSCR
- Mixture performance assessment
  - Performance tests and modelling
- Recommendation development

Project Tasks

1. Initial Memorandum on Research Benefits
2. Literature Review, Material Selection and Testing Plan
3. Material Sampling and Specimen Preparation
4. Analytical Assessment
5. Binder Performance Assessment
6. Mixture Performance Assessment
7. Final Memorandum on Research Benefits and Implementation Steps
8. Compile Report, Technical Advisory Panel Review, and Revisions
9. Editorial Review and Publication of Final Report

Project Schedule

Month of Contract					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Calendar Month	2020												2021												2022			
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Task 1: Initial Memo on Expected Research Benefits					X	X	X	R	R																			
Task 2: State of the Art Review, Material Selection, Testing Plans					X	X	X	R	R																			
Task 3: Material Sampling, Specimen Preparation							X	X	X	X	R	R																
Task 4: Analytical Assessment											X	X	X	X	X	X	X	X	R	R								
Task 5: Binder Performance Assessment											X	X	X	X	X	X	X	X	R	R								
Task 6: Mix Performance Assessment															X	X	X	X	X	X	R	R						
Task 7: Final Memo on Expected Research Benefits																							X	X	R	R		
Task 8: Draft Deliverables																					X	X	X	X	R	R		
Task 9: Final Publishable Report and Implementation Guide																											X	X

X : Project Activity

R : Review/Revision Period

Task 2: Literature Review and Material Selection

- State of the Art Review
- Selected Study Materials:

Sample ID	Description
A	“Compatible” bitumen to establish upper extreme of performance
B	“Incompatible” bitumen to establish lower extreme of performance
C	“In-between” bitumen, to complete trend between extremes
D to H	Up to 5 verification materials from field projects

- Material sampling plan
- Finalized testing plan (analytical as well as binder and mixture performance assessment)
  - Fractional factorial design will be used

Material Selection: A- C

- Binders A, B and C (preliminary list for discussion):
  - Materials with field performance (and lab testing) availability:

Material	Base Binders	Binder Sources	Rheological Quality	Corresponding Field Section Built
A	PG 58-28	Minnesota	Good Binder (Positive ΔTc)	MnROAD/NRRA
B	PG 64-22	Alabama	Poor Binder (low ΔTc)	NCAT
C (alt-1)	PG 58-28	Illinois	Poor Binder (low ΔTc)	ICT/IDOT
C (alt-2)	PG 58-28	Minnesota	Unknown	NRRA Rejuvenator Test Section (Emily MN)
C (alt-3)	PG 58-28	Wisconsin	Unknown	WHRP US Highway 8 Test Sections
C (alt-4)	California, Iowa, Michigan, Missouri, North Dakota…?			

Material Selection: D- H

- Verification materials (preliminary list for discussion):
  - Samples with field performance and/or extensive laboratory testing available:

Project	Location	Description
NHDOT Aging Project	New Hampshire	11 mixtures, range of binders, RAP amounts and modifiers, varying aging levels
WRI – Mathy (CR112)	Minnesota	Five binder sources and test sections
Ontario Test Sections	Ontario	Pavement cracking and durability test sections
NCAT-MnROAD Cracking Experiment	MnROAD and NCAT	Test sections as part of NCAT-MnROAD pooled fund study
NCHRP 09-58 Sources	All over US (specific binder from IN, TX and WI might be of interest)	Extensively tested for effect of rejuvenating agents and aging
Others?		

TAP Feedback / Recommendations?

Task 3: Material Sampling and Specimen Preparation

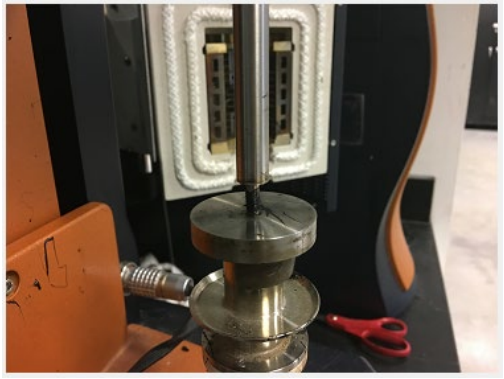
- Work with NRRA agencies to sample materials (where needed)
- Binder, mixture, aggregate, RAP, rejuvenator sampling
- Binder extraction and recoveries, preparation of blends
- Mixture lab aging and performance test specimen preparation
  - Loose mix aging using NCHRP 09-54 protocol
  - 95˚C multi-day aging (duration depending on location and depth)
  - 2-3 aging levels are planned

Task-4 Analytical Assessment

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.

Task-5 Binder Performance Assessment

- 4, 8 and 25 mm DSR testing
  - Superpave PG parameters, LVE charac. & rheological indices (G-R, R-value, ΔT_C)
  - Provides baseline comparisons & basis for initial thresholds of analytical measures

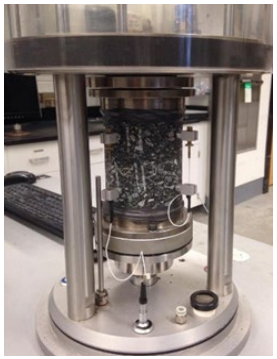


- Linear Amplitude Sweep (LAS)
  - Fatigue performance measure
  - Conducted as different aging levels
  - Allows to expand limited pavement performance data from field sections
- Multiple Stress Creep Recovery (MSCR)
  - To ensure that compatibility methods do not result in rutting prone recommendations
  - J_{nr} parameter has shown potential for modifier selection

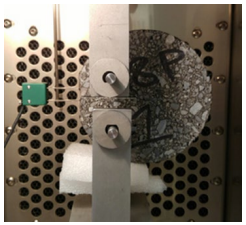
Task 6: Mixture Performance Assessment

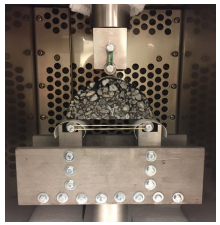
- Performance Testing and Modeling
  - *Linear Viscoelastic Characterization: Complex Modulus (AASHTO T 342)*
    - *Rheological cracking and rutting indices*
    - *Necessary inputs for performance modelling*

  - *Direct tension cyclic fatigue (AASHTO TP 107)*
    - *Fatigue cracking performance (D^R, S_{app})*
    - *Performance prediction using FHWA's FlexPAVE system*



  - *Fracture and Cracking Performance Index Tests*
    - *CT-Index*
    - *Disk-shaped Compact Tension*
    - *Illinois Flexibility Index*
    - *IlliTC Thermal Cracking Performance Prediction*



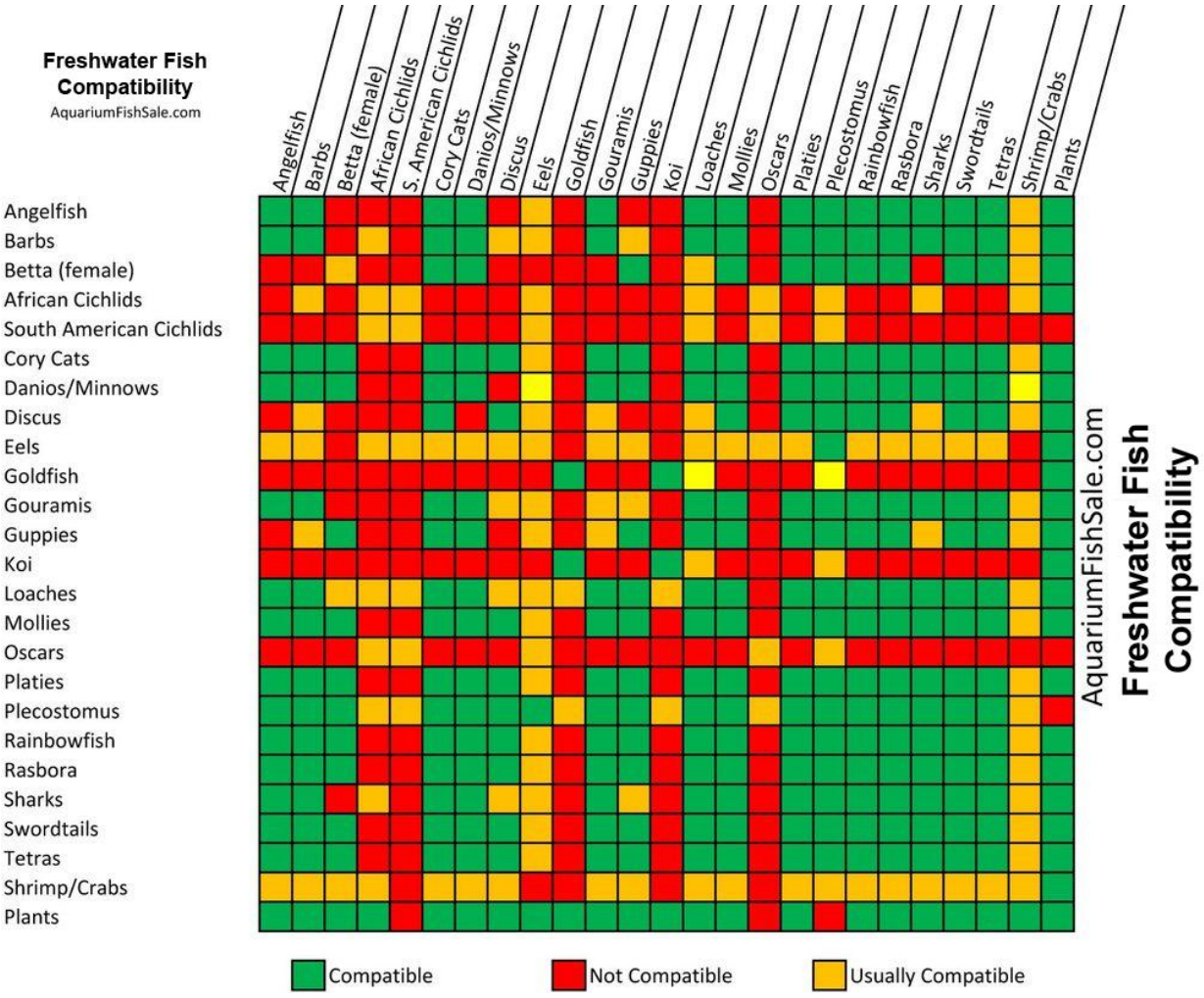


Task 8 & 9: Compilation, Review and Publication of Final Report

- Draft final report following MnDOT publication guidelines
- Review by Technical Advisory Panel (TAP)
- Develop and deliver close-out presentation
- Develop and deliver webinar and implementation guide
- Revisions to incorporate TAP review comments
- Incorporate editorial review
- Final publishable report

Thank you for your attention!

- Questions and Comments?



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