Q1 NRRA TAP Meeting

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

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Q1 Update Meeting, 10/28/2020

Meeting Setup and Agenda

TAP members:

- Terry Beaudry, MNDOT (TL)
- Ben Worel, MNDOT
- Jerry Geib, MNDOT
- Mark Gawedzinski, Illinois DOT
- Pouya Teymourpour, WisDOT
- Dan Schellhammer, Midstate Co.
- Dan Staebell
- Jo Sias, UNH
- Andy Cascione, FHR
- Guy Sisler, Husky Energy
- Mohammad Sabouri, Braun Intertec
- Dan Wegman, Braun Intertec
- Kiran Mohanraj, Transtec Group
- Daniel Oesch, MODOT
- Curt Dunn, NDDOT
- Kevin Kliethermes, FHWA

Agenda:

1. Brief review of project objectives and approach
2. Review of Draft Task 1 Report (sent out Oct 6)
   - Literature Review
   - Test Plan
3. Material collection (Task 2a Update)
4. Next Steps

Project 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., 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.

- **Key practical questions need to be addressed:**
  - What performance properties need to be measured to ensure performance?
  - How can the dosage of RAs to be determined 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?

Project Tasks

- Task 1: Literature Review and Material Selection
- Task 2: Material Collection, Preparation, and Characterization
- Task 3: CIR/CCPR Mix Design and Performance
- Task 4 & 5: Draft and Final Deliverables and Communication of Results

Month of Contract					1	2	3	4	5	6	7	8
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												

Month of Contract	9	10	11	12	13	14	15	16	17	18	19	20
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		

Task 1: Lit. Review, Material selection and work plan

- Task 1 DRAFT Final Report sent electronically October 6th for feedback
  - GOAL: Provide and justify a work plan to complete the remainder of project
  - Will serve as chapter in final report

- Report Sections:
  - Chapter 1: Project Overview, Objectives of report
  - Chapter 2: Review of RA’s in Asphalt
  - Chapter 3: Review of Performance Testing and Curing of CR processes
  - Chapter 4: Proposed Work Plan

Summary of "Chapter 2" Findings on use of RAs

- No universally accepted method to classify RAs yet.

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

Test	ASTM Test Method	RA 0		RA 1		RA 5		RA 25		RA 75		RA 250		RA 500	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Viscosity • 60 °C [140 °F], mm²/s	D2170	10	49	50	175	176	900	901	4500	4501	12500	12501	37500	37501	60000
Flash Point, COC, °C [°F]	D92	219 [425]	...	219 [425]	...	219 [425]	...	219 [425]	...	219 [425]	...	219 [425]	...	219 [425]	...
Saturates, wt. %[A]	D2007	...	30	...	30	...	30	...	30	...	30	...	30	...	30
Tests on Residue from RTFO 163 °C [325 °F]	D2872														
Viscosity Ratio[B]	*	...	3	...	3	...	3	...	3	...	3	...	3	...	3
Wt Change, ±, %	*	...	4	...	4	...	4	...	3	...	3	...	3	...	3
Specific Gravity at 25 °C [77 °F]	D70 or D1298	0.900	1.100	0.900	1.100	0.900	1.100	0.900	1.100	0.900	1.100	0.900	1.100	0.900	1.100

[A] The suitability of D2007 for measurement of saturates content and determination of compatibility of non-petroleum-based recycling agents has not been established. Additional testing may be required for assessment of the compatibility of non-petroleum-based recycling agents.

[B]
$$ViscosityRatio = \frac{Viscosity\ of\ Residue\ from\ RTFO\ Test\ at\ 60°C\ [140°F]}{Original\ Viscosity\ at\ 60°C\ [140°F]}$$

- Two broad categories: bio-based (e.g. vegetable-based or tall oil-based) and non (e.g., petroleum) bio-based
  - **Choose 1 from each category with demonstrated commercial history in asphalt emulsion.**
- Efficacy of individual RA depends on rheological properties of recycled asphalt, **justifying the need to include more than one distinct RAP source for this project (more later)**

Summary of "Chapter 2" Findings

- Dosage Selection
  - Hot Mix Asphalt Industry: Often empirical
    - NCHRP 09-58: Select dosage to restore High Temperature Continuous Grade to a target
      - This removes subjectivity to dosage selection
  - Recycling Industry:
    - NCHRP Synthesis 421: Pacific Coast Specification – "restore aged asphalt to current specification" – usually Pen
    - ARRA Manual: Viscosity approach, verify with mix testing
    - HIR Industry: Final recycled mix properties such as resilient modulus or stability, rather than binder properties, to determine the final mix selection
      - Diffusion phenomena important – e.g., effects of temperature or "curing" need to be considered

→ **RA dosage in the project test plan** will be selected based on the rheological properties of the extracted and recovered binder, but generally following guidance proposed in NCHRP 09-58, e.g., **to meet a rheological target**; we will also test oil-alone

→ However, ultimately efforts will be made to simplify dosing methods to be implementable and proportional to overall typical level of CIR/CCPR design method complexity

Summary of “Chapter 3” Findings

Chapter 3 broken into 2 parts: Review of Current State of Practice and Review of Literature

- Synthesis of Existing CR Design Methods and Specs
  - 15 total “entities” reviewed, incl. all NRRA members, 4 additional Agencies, ARRA, AASHTO, and 1 private contractor (Wirtgen)
    - **13** include mixture testing provisions
- Reviewed relevant published literature: NCHRP, MnDOT, TRB, ASCE…etc.

Goal: Identify which methods of sample production, testing and curing are most prevalent in industry

Table 3. Summary of Required Mix Design Tests and Curing Conditions for Select Agencies, Associations, and Design Documents

	Entity	Required Testing	Curing Conditions
NRRA Agencies	California[1]	- Asphalt content of RAP and Ratio of Residue to Cement - 4" Marshall Stability and Retained Stability after moisture conditioning - RAP Coating Test - Raveling Test	- Stability: 140 F to constant weight, but between 16-48 hours (note: a reduction in retained stability percentage is allowed for higher levels of dry stability - Raveling: ASTM D7196 at 50 F
	Illinois[1]	- 4" or 6" Marshall Stability and Retained Stability after moisture conditioning - Raveling Test	Not specified
	Iowa	- No mix design; specified additive rate (0.30 gallons/SY/in)	NA
	Michigan[1]	- Modified Proctor for Optimum Moisture Content - 4" or 6" Marshall Stability and Retained Stability after moisture conditioning - Raveling Test	Not specified
	Minnesota[1]	- Washed (after ignition) gradation, sand eq., and FAA of RAP - 4" Marshall Stability and Retained Stability after moisture conditioning - IDT for Thermal Cracking - Raveling Test	- Stability: 140 F to constant weight, no less than 16 hours; bring to ambient between 12-24 hours - IDT: 60 C for no less than 48 hours, no more than 72 hours - Raveling: Ambient lab temp (65-75 F) for 4 hours

Summary of “Chapter 3” Findings

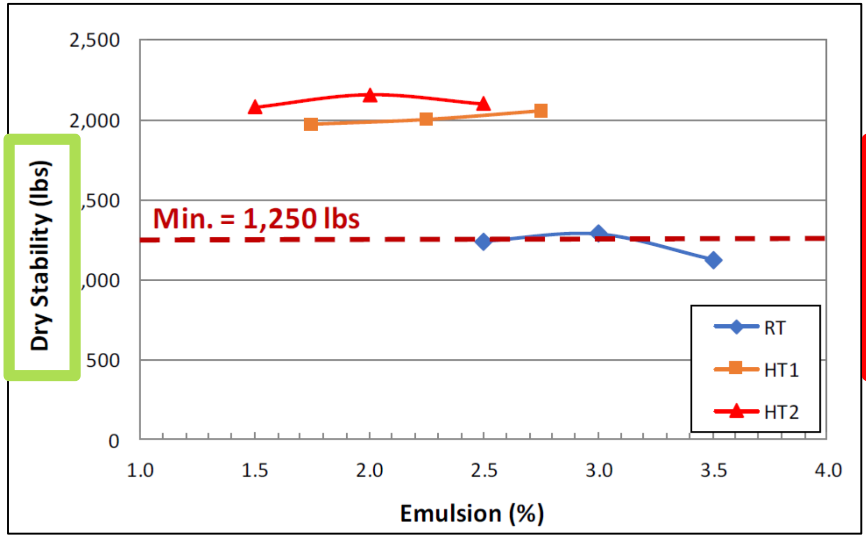
Sample Testing: We are proposing 1 curing test, 1 stability (rutting) test, and 1 cracking test to facilitate a “Balanced Mix Design” approach

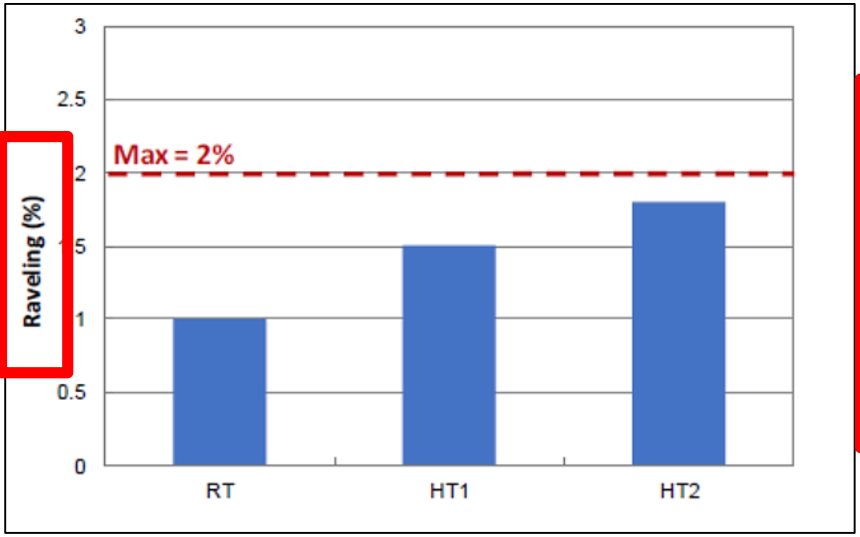
- 11 of 13 entities that include mixture testing specify a form of **Raveling Test, ASTM D7196**
  - Used to measure curing and usually controls minimum stabilizer content
- 10 of 13 specify **Marshall Stability**
  - Usually specified on fully cured specimens
  - Usually includes a moisture subset
  - There is a large database to support the use of this test
- 6 of 13 specify T322 IDT for Thermal Cracking
  - Some use as “Report Only”
- 5 of 13 specify **IDT at 25 C**
  - Usually a minimum strength (psi) AND a minimum conditioned ratio (moisture damage)
- Fewer than 3 specify: **rheology**, HWT, DcT, APA, Unconfined Compression, SCB….and more!
- Literature sources found (in addition to what is listed): **IDEAL-CT**, Triaxial, FIVE, Cantabro…

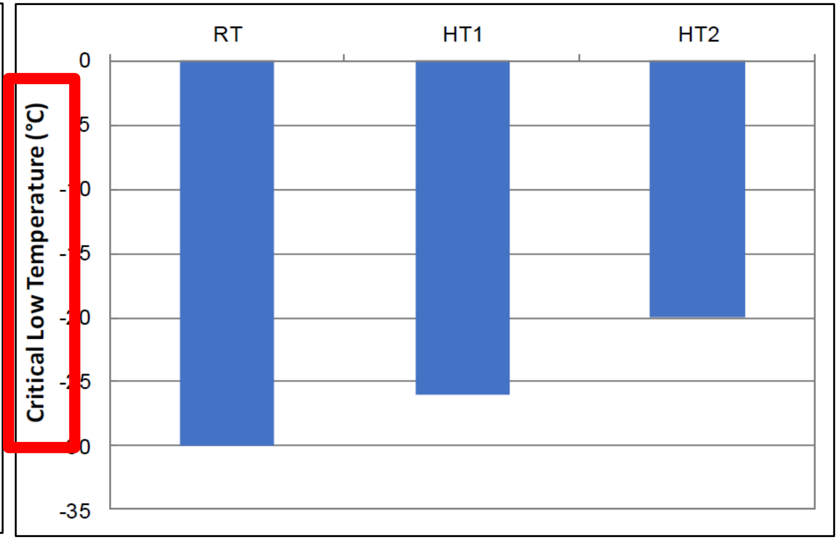
Summary of “Chapter 3” Findings

Sample Curing: Generally we found we can divide curing into 2 groups among tests: “Fully Cured” (fully emulsion-cured) and “Partially Cured” (partially emulsion-cured)

- When specified, Marshall Stability, IDT @ 25 used “Fully Cured” specimens
  - ***Most typically*: Cure at 60 C (140 F) to a constant mass, but between 16 and 48 hours, then allow to cool between 12 and 24 hours prior to testing**
- When specified, Raveling used “Partially Cured” specimens
  - ***Most typically*: Cure at 10 C (50 F) to a constant time (4 hours); sometimes 50% RH specified**
- NCHRP 09-62 Draft Final: raveling-based properties were chosen to quantify time to opening
- At least one recent study investigated role of mixing temperature (Wegman) and found significant effect:







Chapter 4: Work Plan Conceptualization

- Balance practicality with "Proof of Concept"
  - Tests that have:
    - Widespread use in recycling industry (Marshall, Raveling)
    - Demonstrated efficacy in quantifying RA impacts (IDEAL-CT/IDT)
    - Can be used in a Balanced Mix Design Concept
- "Emulsion-Curing" vs. "RA Curing" concept
  - Test at Full- and Partial- curing (both partial RA- and Emulsion-curing).
  - Full Emulsion-curing determined as achieving constant mass
  - Full RA-curing determined as achieving constant cracking performance (test criteria TBD)
  - Factors:
    - Vary mixing temperature (LT = Lab or Low Temperature, HT = High Temperature = ~110 F)
    - Vary curing temperature (ST = Standard = 50 F, HT = High Temperature = ~110 F)

Chapter 4: Work Plan

Initial Material Characterization (Task 2a-b)

Rheological and Chemical Characterization of Recycled Binder

Material Procurement and Emulsion Production

Emulsion Design and RA Dosage

Mix Design and Parameter Selection (Task 3a)

- *Determine emulsion and RA curing conditions (time/Temp)*
- *Define full- and partial-cured levels*
- *Confirm mix designs*

Tests:
Marshall Stability
IDT/IDEAL-CT
Raveling

Validate Mix Designs

Verify test measure for RA-curing

Define criteria for full and partial RA-curing and partial E-curing

Evaluate optimal RA addition method

Main Testing Plan (Task 3b)

Determine impact of parameters:

- *Mixing Temperature*
- *Curing Level*
- *Rejuvenator Type/Dose*
- *Emulsion Content*

Tests:
IDT/IDEAL-CT
Raveling

Carry out partial factorial test matrix

Define parameter trends and interactions

Analysis and Deliverables (Task 4-5)

Analyze for feasibility, pros/cons, implementation process
Propose practical recommendation and guidance

Determine potential for optimization (e.g. RA vs. emulsion %)

Provide framework guidance for potential RA-CIR Design Method

Develop a test plan for potential field trial and implementation

Test Tables

Task 2b – Material Characterization

Material Tested	Test Types	Factors	Outcome	Estimated Test # - May vary
RAP, Binder, RAs	Extraction, PG/Rheology, Analytical	RAP type, RA Dosage	RA Dosages and Emulsion Design	2 x 3 (extracted RAP + RA Tests) 2 x 3 (Bind + RA Emulsion Tests)

Task 3a – Mix Design and Parameters (~28 mix levels)

Material Tested	Test Types	Factors	Outcome	Estimated Test # - May vary
Selected CIR Mixes	Marshall Stability	Mixing Temperatures RA order of addition	Define mixing conditions	2 x 3 x 2 x 1 (Temps x RA type x RA order x 1 (full) cure) – x0.5 Partial
Selected CIR Mixes	Marshall Stability, Raveling	Curing Time/Temperature	Define curing conditions and partial RA-cure criteria/levels	2 x 2 x 3 (Temps x RA type x 3 cure times)
All CIR Mixes	Marshall Stability, Raveling	RAP type, Emulsion dosage	CIR mix Designs	2 x 2 (RAP x E% - Same for all RA levels for now)

Task 3b – Performance Testing Matrix (~132 mix levels)

Material Tested	Test Types	Factors	Outcome	Estimated Test # - May vary
All CIR Mixes	Marshall Stability, IDT/IDEAL-CT, Raveling Binder extraction + PG/analytical on select mixes (cost share)	Mixing + curing Temperatures, cure level, RA, dose, E%, RA order of addition	Define parameter trends and interactions in terms of impact on performance	22* x 2 x 2 x 3 (CIR mixes x mix temps x cure temp x cure level) x 0.5 (partial factorial) *22 = 2 RAP x 2 E% (controls) + 2 RAP x 2 RA types x 2 RA% x 2 E%

Task 2a Update: Material Selection and Collection

- RAP from two projects were selected from NRRA States.
- Bitumen used for emulsion base from typical source in MN
- 2 stabilizer (EE, oil, etc) dosages per combination (i.e. run “two-point” analysis); based on mix design
- Two RAs (one petroleum-based and one bio-based)
  - Selected RAs have history of regular use in emulsions, no need for an emulsion feasibility study
  - Plan is to NOT use oil commercial name or branding in report.
  - Objective of study is NOT comparison or ranking of different rejuvenators

Variable	Level	Description
RAP Source	2	Minnesota RAP (CIR Project) Illinois RAP (CCPR Project)
Stabilizing Additive	1	Engineered Asphalt Emulsion
Recycling Additive	4	None – Engineered Emulsion only Bio-Based – Rejuvenating Emulsion-1 Petro-Based – Rejuvenating Emulsion-2 Bio-Oil (No additional asphalt residue)
Active Filler	1	None*

*If inclusion of cement is considered potentially advantageous to correcting performance for a given combination, a sub-study will be initiated.

Project Schedule and Next Steps

- Project to be carried out over 18 months (started July 2020).
  - Q1 Meeting held Oct 28, 2020: Task 1 Report

Month of Contract					**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
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												
Month of Contract	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
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		

  - Q2 Meeting proposed for Jan 2021:
    - Report on Task 2a (Material collection) and 3a (CIR Mix Designs)
    - Updated on Task 2b (Material Characterization)

Other considerations for future work?

- The research team has received interest from the industry for the following:
  - Expanding RAs considered
  - Other CIR technologies (i.e. foaming)
  - Field trials of proposed rejuvenated CIR mixes
- These are interesting, but out of scope of current budgeted “proof of concept” research plan.
- The research team proposes that these scope expansions can be considered as part of a “Phase 2” proposal.
  - Towards the end of Task 3 of the current research plan the research team will have a clearer idea on the design framework for a rejuvenated CIR/CCPR. This is scheduled to be during Spring of 2021.
  - If the TAP is supportive of this idea, the researchers can prepare a proposal for a Phase 2 study that will focus on:
    - Verification of Phase 1 design framework with different RAs
    - Construction of field trial sections with participation of interested industry partners.
- Decision point on this is probably during the Q3 TAP meeting, when some Task 3 results are available (~ March-April 2021)

Thank you for your attention!

Questions and Feedback?

Chapter 4: Workplan - Initial Material Characterization

- The following initial characterization testing will be performed on the extracted and neat binders with and without RAs to create a fundamental baseline understanding of the material.
- Results are not expected to be directly correlated to mix design and performance parameters measured in this study but may help provide context for interpretation of performance results.

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
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

Research Approach

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/CCPR material, and determination of proper design dosages.
3. CIR/CCPR 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 and/or CCPR

Test Plan: Cracking and Deformation Tests

- Team is considering 2 cracking and 2 rutting resistance test methods for use in this project based on experience and current understanding of literature.
- **Final selection** of tests to be used will be based upon Task 1 findings and **TAP feedback**.

Recommended Cracking Resistance Tests

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

Recommended Deformation Resistance Tests

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

Test Plan: Aging and Curing Considerations

- Aging conditions will be considered and finalized during the literature review process.
  - Hypothesized that at least 2 levels of aging will be considered.
- Asphalt emulsions used in this study will be produced in the research team's laboratory using a controlled source of base asphalt, emulsification, and additive package.
- Discussion Point: A low temperature cracking test is not included in the initial selection of test methods for this proposal.
  - Recommend maintaining proper specification of low temperature binder PG (e.g. -28 or -34 in Northern regions) and/or including another binder parameter such as m-value or ΔTc to provide reliability against thermal cracking:

Results from:
Transportation Pooled Fund: TPF-5(352), WO 6 - 0092-19-13: Long-Term Performance of Asphalt Concrete Mixed with RAP and RAS – Draft Final Report – May 2020