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

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

• Task 1 DRAFT Final Report sent electronically October 6\textsuperscript{th} 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.

- 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
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
### Task 2b – Material Characterization

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

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

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

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

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

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

*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

  - 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.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Results</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Differential Scanning Calorimeter (DSC)</td>
<td>Tg, Phase Miscibility</td>
<td>Results will be used to establish the existence of immiscible binder fractions, and impact of conditioning and rejuvenation</td>
</tr>
<tr>
<td>Size Exclusion Chromatography</td>
<td>Molecular Size Distribution</td>
<td>Establish uniformity of molecular size distribution, and transition of polydispersity with conditioning and rejuvenation</td>
</tr>
<tr>
<td>Pressure DSC</td>
<td>Oxidation Induction Time</td>
<td>Establish impact of various fraction, conditioning, and/or rejuvenation on the oxidation potential.</td>
</tr>
<tr>
<td>Thermo-gravimetric Analysis (TGA)</td>
<td>Volatilization spectra</td>
<td>Complimentary method of assessment of various fractions within the bitumen in terms of volatility.</td>
</tr>
<tr>
<td>Iatroscan</td>
<td>SARA fractionation</td>
<td>Establish chemical fractions of various bitumen, calculate the Colloidal Instability Index</td>
</tr>
</tbody>
</table>
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**.

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### Recommended Cracking Resistance Tests

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<thead>
<tr>
<th>Consideration</th>
<th>SCB-IFIT</th>
<th>IDEAL-CT</th>
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<tbody>
<tr>
<td>Standardization</td>
<td>AASHTO TP124</td>
<td>ASTM D8225</td>
</tr>
<tr>
<td>Current Usage</td>
<td>Up to 21 DOTs according to TRB survey and many research studies.</td>
<td>Unknown, recommended to at least 1 DOT; used extensively in research</td>
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<tr>
<td>Performance Limits in Literature (Y/N)</td>
<td>Yes</td>
<td>No, but recommendations have been made.</td>
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<tr>
<td>Precision and Bias Available (Y/N)</td>
<td>No, but estimates exist from published literature.</td>
<td>Yes, Conducted as part of ASTM Standardization</td>
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<tr>
<td>Equipment</td>
<td>Several manufacturers as well as retrofitting Marshall Load Frame available; 1-2 saws required</td>
<td>Use Marshall load frame; no saw required</td>
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<tr>
<td>Sample Preparation Effort</td>
<td>High</td>
<td>Low</td>
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<tr>
<td>Testing Time</td>
<td>Low</td>
<td>Low</td>
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### Recommended Deformation Resistance Tests

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