REJUVENATED COLD RECYCLED MIXES

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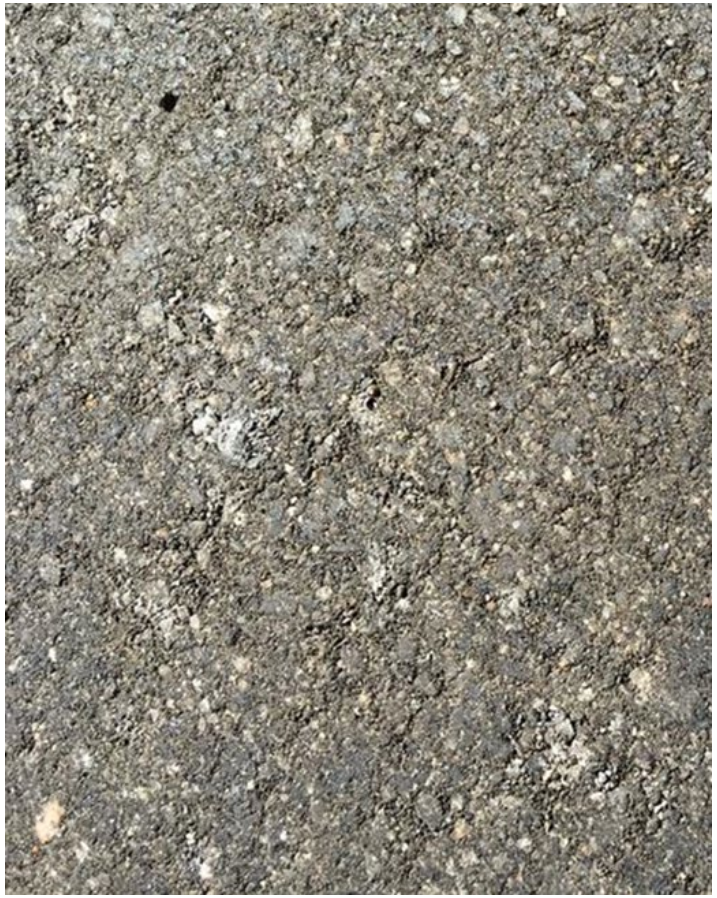
Cold Recycling 101

- A method of reconstructing the pavement base using 100% (or close to 100%) recycled material
  - Milled or stockpiled RAP
- Allows for tighter control of product compared to other similar processes
- Produced at *ambient* temperatures

So what materials are used?

- RAP
- Corrective aggregate
  - Sometimes used to achieve gradation target
- Water [what?!]
- Small percentage of Active filler
  - Lime, cement, fly ash, etc. sometimes used
- Recycling agent
  - foamed or emulsified asphalt
- *This is a hybrid material*



How is CCPR like HMA?

- It provides a flexible base material (viscoelastic)
- Contains asphalt binder
  - RAP binder
  - Foam and/or emulsified asphalt binder known as a “recycling agent”
- Can be placed using conventional paving equipment
- Use the Indirect Tensile Test or Marshall Stability Test

How is CCPR *not* like HMA?

- Add water to achieve an optimum moisture content
- An active filler is often added to help with strength, stiffness (i.e. lime, cement, etc.)
- Recommended to focus on density, not air voids, in design and construction
  - Variability of the RAP can lead to faulty air void estimates
- Allow the material to “cure” before placing an overlay
  - New rapid field test to identify whether its ready

Mix Design Process

1. Check *black rock* gradation
2. Establish optimum moisture content
3. Evaluate recycling agent properties
4. Mix at minimum 3 binder contents (2-2.5% foam)
5. Compact to 30 gyrations
6. Cure in forced draft oven
7. Run Indirect Tensile Test (foam) or Marshall Stability (emulsion)

Rejuvenation… can we do it?

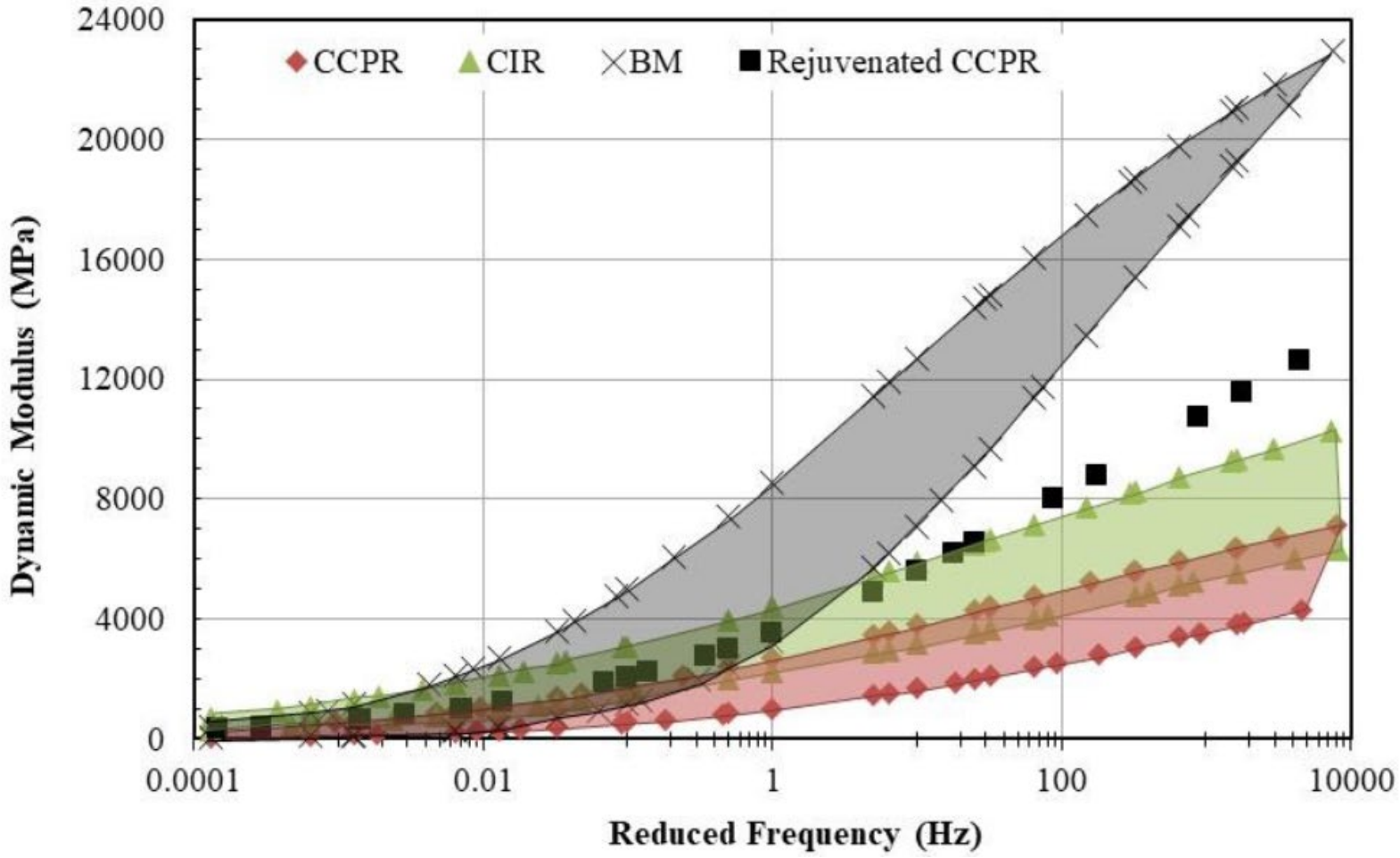
- The question has surfaced multiple times: Can we rejuvenate cold recycled mixes?
- Some work has been done in this area, but little has been published…

A little history…

- Rejuvenated mix produced by a contractor in Kansas City
  - Foamed binder + rejuvenator
  - 65% coarse RAP + 35% fine RAP
  - 1% foam, 50-50 blend of PG 64-22 and bio-based rejuvenator
- Mix placed in the contractor's yard
  - CCPR = two 3-inch lifts
  - HMA overlay = 2-inches
- Cores were sent to VTRC for testing

A little history…

- Among other tests, Dynamic Modulus test was conducted
- Compared to NCHRP 09-51 E* data for CCPR, CIR, and base mix HMA
- Rejuvenated CCPR was *somewhere in between…*



So, what now?

- This mix isn't CCPR… and it's not a typical asphalt mixture either… so what is it?
  - Rejuvenated Cold Recycled Mix (RCR)

Feeling an urge to investigate… Ben and Buzz devised a plan!

2021 NCAT Offramp Study

- Six sections were constructed on the offramp at NCAT
  - 4 in of asphalt
  - 4 in of foamed CCPR
  - 4 in of engineered emulsion CCPR
  - 4 in of CCPR with R1 rejuvenator
  - 4 in of CCPR with R2 rejuvenator
  - 4 in of CCPR with emulsion + R3 rejuvenator

Mix Design

- Used the same RAP for all designs that was used for production
  - RAP was processed, all < ¾ inch
- Foamed mixtures tested with ITS (45 psi minimum)

Mix Design Challenges

- Attempted to hold rejuvenated mixes to the same IDT standard as foam control mix…
  - Couldn’t hit this target with the first rejuvenator tested
- Tried Marshall Stability testing and was able to achieve target for design (1250 lb_f min)
  - Success!
- Some mixes leaked fluid in the gyratory and had to be recompacted at reduced fluid contents (water was removed)
  - Result of rejuvenator activating binder and densifying the mix

Mix Design

- RAP lab optimum moisture content ~4.5-5%
- Hydroscopic M.C. in field ranged from 4-5% during construction

Section	Recycling Agent	Rejuvenator	Active Filler	Add Water
Foam	2% PG 67-22	NA	1% Cement	2%
Engineered Emulsion	3%	NA	NA	NA
R1	NA	4.2%	NA	NA
R2	NA	0.9% by wt of RAP + Moisture	NA	NA
R3	3.5% emulsion	7% by wt of emulsion	NA	NA
CONTROL	Hot Mix Asphalt			

Mix Design Finding

- Three designs performed by NCAT
  - Foam; R2; Emulsion + R3
- Bulk dry density increased when rejuvenator was added
  - RAP gradation, etc. was the same
  - Activation binder is assumed to be the cause

Density	Foam	R2	Emulsion + R3
Bulk Dry Density (pcf)	126.6	134.4	130.9

Two Plant Options

Wirtgen KMA 240i

Two Plant Options

Pugmill Systems Portable Pugmill

Construction

- Compacted until refusal for density; Checked with nuclear gauge.

Foam

Engineered Emulsion

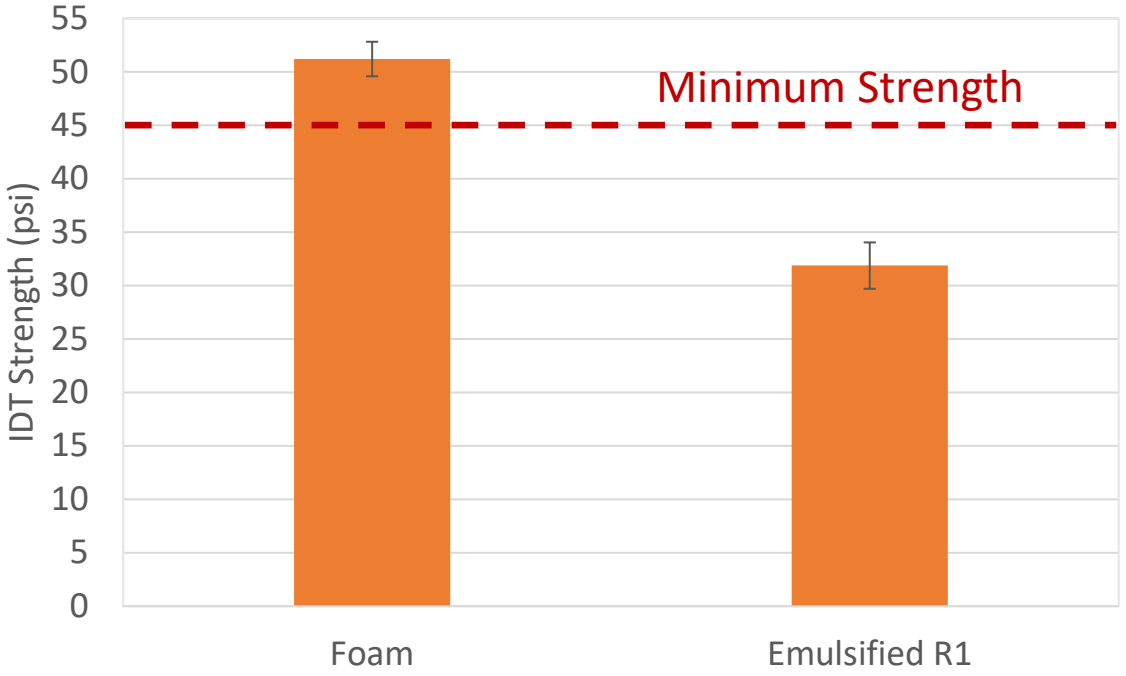
Emulsified R1

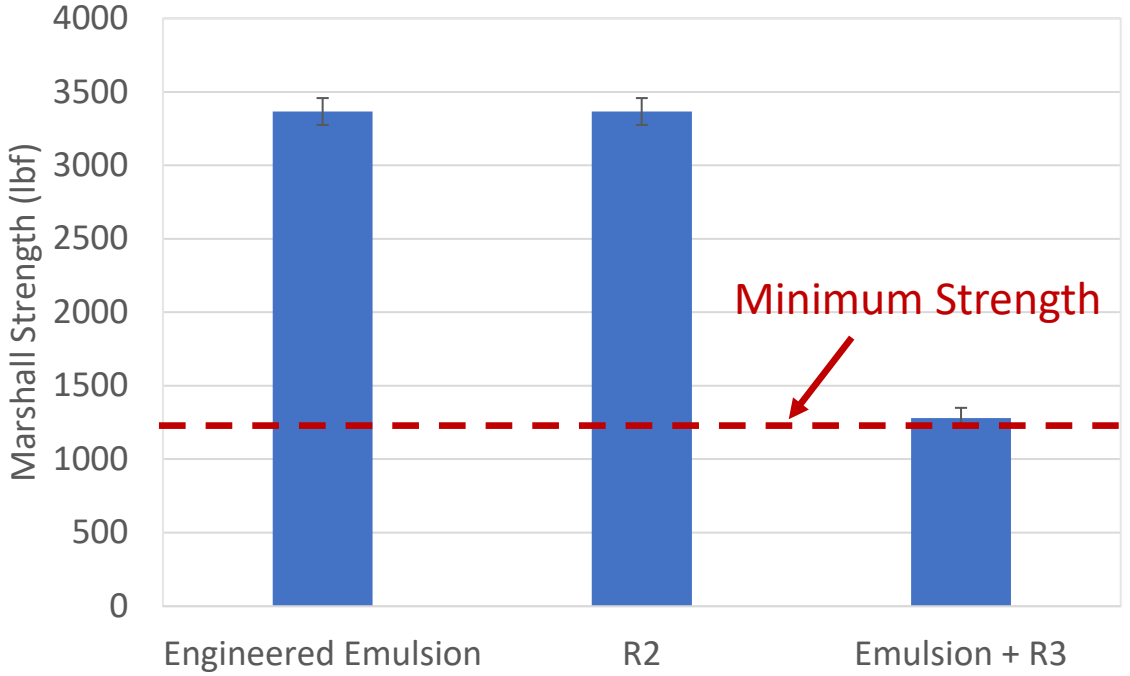
R2

Emulsion + R3

Plant Produced, Lab Compacted Results

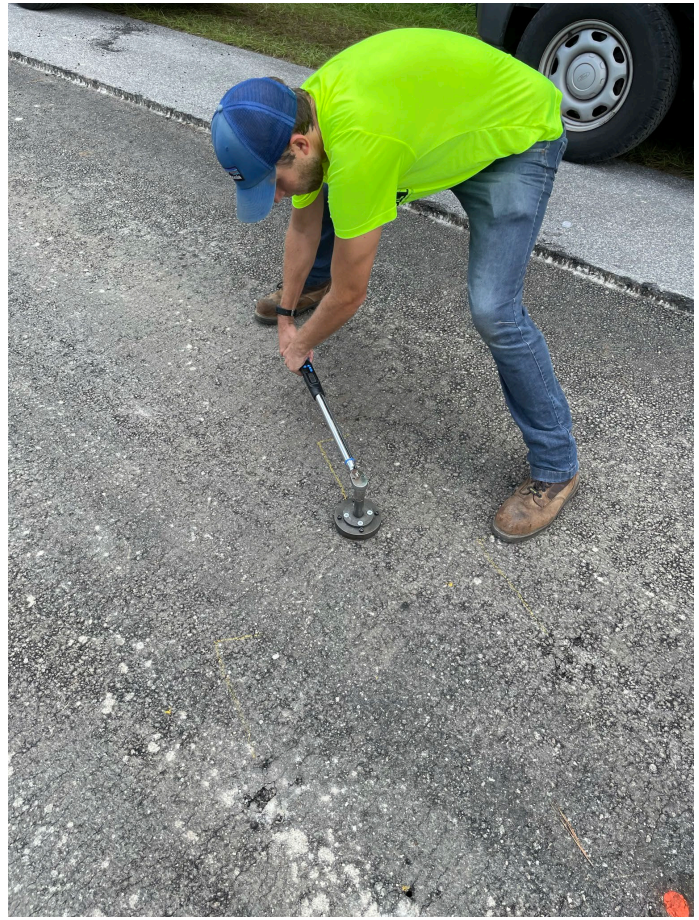
- One product didn't pass lab compacted results
  - Function of test? Mixing? Passed pre-construction tests.





NCHRP 09-62 Testing

- Tests to help identify when mix can be opened to traffic and/or overlay
  - Uses a DCP + Torque wrench
  - Short Pin = Raveling
  - Long Pin = Shear
- All mixes passed these tests
  - Note: Multiple replicates were not run on all mixes due to time constraints + not loading immediately



What's next?

- Extensive laboratory characterization
  - CT_{index} for cracking
  - High Temperature-IDT for rutting
  - Dynamic modulus for stiffness
  - Repeated Load Permanent Deformation for rutting
  - Cyclic fatigue for fatigue performance
- All materials were collected on site for laboratory mixing

Field Performance

- Monitoring of the site weekly using pathways van
- Falling weight deflectometer measurements 3x per month
- Density cores are taken quarterly
- Friction trailer testing monthly

Potential long-term benefits/applications?

- Moving toward the ability to make 100% RAP pavements that perform more like a typical asphalt mixture;
  - Lowers greenhouse gas emissions and energy consumption.
  - Enhances the resilience of the infrastructure.
- Option for lower volume roads
  - Higher density – can we use this as a surface? Surface treatment?
  - Often thin structure, so a 2 to 5-inch CIR or CCPR with an overlay may not be possible

Thank you!

Please reach out with questions!

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