Overview of CR Mix Designs – Current & Future Directions

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CR Mix Designs

- **From: Typical Emulsion Contents**

  (No Mix Design)
- **To: Surface Area Methods**
- **To: Task Force 38**

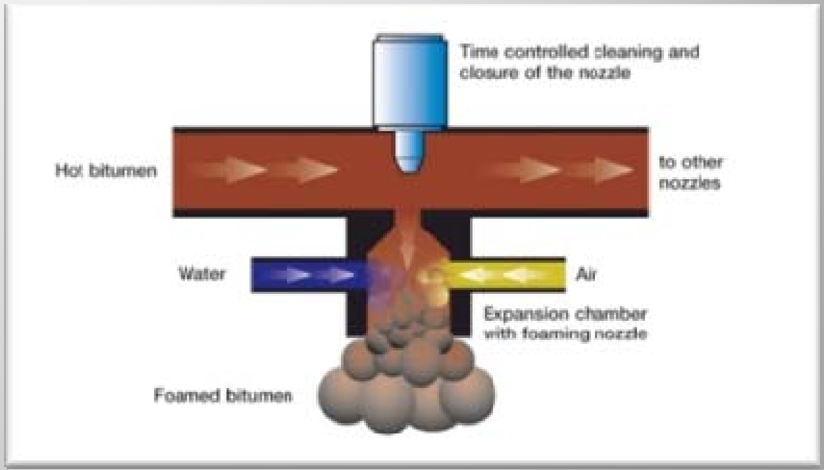
  (50-75 Blow Marshall)
- **To: Road Science & Predecessor's**
  - **CR (CIR, CCPR)**
  - **FDR**

Mix Design Methods

- Procedures can be found as Supplemental Specifications on many DOT web sites
  - Kansas, Montana, Missouri, Utah
- Simplified Procedures have been adopted by many
  - ARRA
  - CFLHD
  - PCCAS
  - Some DOTs

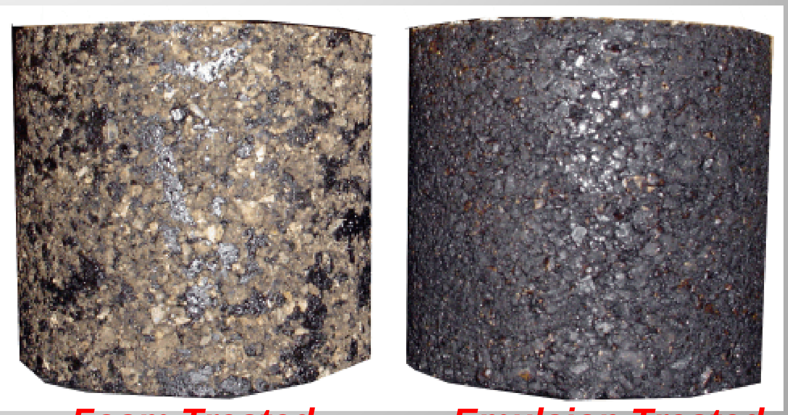
Foam Mix Designs

- **Developed by Wirtgen/Loudon International**
- **Developed for FDR**
- **Applicable to CR**
  - **Basically same procedure/requirements for CR & FDR**
- **Appendix 1, *Wirtgen Cold Recycling Technology***



Foam vs. Emulsion

- **Foam is a Binding Technology**
- **Emulsions are a Coating Technology**



Foam Treated *Emulsion Treated*

- **For Binding Technology to Work, most Literature Recommends:**
  - **5-20% Fines (-No. 200)**
  - **100% RAP < 5% Fines (-No. 200)**
  - **Active filler (1% cement)**

Basic CR Emulsion Procedure

1. **Obtain cores from pavement.**
2. **Remove portion of core to be recycled and crush to create RAP.**

3. **Determine binder content and recovered aggregate gradation of select cores.**
4. **Determine RAP Gradation and batch samples to desired gradation.**

Basic CR Emulsion Procedure

5. Select type and grade of asphalt emulsion and any additives.
6. Mix samples at different emulsion contents and compact.
7. Cure samples.
8. Test trial mixtures:
   a) Basic mix properties,
   b) Final cure mix properties,
   c) Moisture sensitivity.
   d) Other tests
9. Establish Job Mix Formula.

Basic FDR Procedure

(Foam or Emulsion)

1. **Obtain cores and aggregate base from pavement**
2. **Crush cores to create RAP.**

3. **Determine binder content and recovered aggregate gradation of select cores.**
4. **Determine gradation of aggregate base.**

Basic Procedure

5. Blend RAP and aggregate base to selected percentages from job.
6. Determine SE & PI of blend.
7. Select type and grade of stabilizing agent and any additives
8. Perform Modified Proctor (AASHTO T 180 Method D)and determine optimum moisture content and maximum dry density of blended material

Basic Procedure

9. Mix samples at different stabilizing agent contents, perform initial cure and compact.
10. Initial Cure Testing
11. Final cure samples
12. Test trial mixtures:
    a) Mix properties
    b) Indirect Tensile Strength
    c) Moisture sensitivity
13. Establish Job Mix Formula

Comparisons

Parameter	Emulsion CR	Emulsion FDR	Foam CR & FDR
Opt. Moisture	1.5-3.0%	T 180 or 3%	T 180
Cure before compaction	None	30 min @ 40 C	None
Compaction	30 gyrations SGC 75-Blow Marshall	30 gyrations SGC 75-Blow Marshall	75-Blow Marshall Modified T 180 - 4 layers, 55 blows
Curing After Compaction	Constant mass @ 60 C, 16-48 hrs.	Constant mass @ 60 C, 16-48 hrs.	72 hrs. @ 40 C
Bulk Gravity	T 166	T 166	Volumetrically
Rice Gravity	T 209	T 209	T 209
Air Voids	Required (% Sat.)	Required (% Sat.)	Not required

Comparisons – Marshall Stability

Parameter		Emulsion CR	Emulsion FDR	Foam CR & FDR
Dry Stability		Min 1250 lbs. @ 40 C	N/A	N/A
Wet Stability			N/A	N/A
	Vacuum Sat.	55-75%	N/A	N/A
	Soak	23 hrs. @ 25 C, 1 hr. @ 40 C	N/A	N/A
Stability Ratio		Min. 0.70	N/A	N/A

Comparisons – Indirect Tensile Strength

Parameter	Emulsion CR	Emulsion FDR	Foam CR & FDR
Dry ITS	Min. 45 psi @ 25 C	Min. 40 - 45 psi @ 25 C	Min 225 kPa (32.6 psi) @ 25 C
Wet ITS	N/A	Min. 20 - 25 psi @ 25 C	Min. 100 kPa (14.5 psi) @ 25 C
Conditioning			
Vacuum Sat.	55-75%	55-75% or > 55%	N/A
Water Soak	24 hrs. @ 25 C	24 hrs. @ 25 C	24 hrs. @ 25 C
TSR	Min. 0.70	N/A	If < 0.60 requires active filler

Additional Tests

- Raveling ASTM D7196
- High Temperature Validation
- Thermal Cracking AASHTO T 322
- Recovered Binder Tests
- Other Tests
  - Hamburg or APA Rut Test
  - Fracture Energy Test
  - Air Void Requirements
  - Field Tests

Raveling Test - ASTM D 7196
(CR Emulsion Only)

- Evaluates curing / breaking time to prevent raveling
- Tested at Optimum EAC
- Cure @ 50 F at 50% relative humidity for 4 hours
- Abrade samples for 15 min
- What % Loss (2-7%)

High Temperature Validation
(CR Emulsion Only)

- **At high temperatures (> 85ºF) CR mixtures can compact to higher density**
- **Often require less recycling agent for optimum performance**
- **Procedures to validate effect of reducing recycling agent content 0.25 – 0.50% on strength, retained strength and raveling at high temperatures**

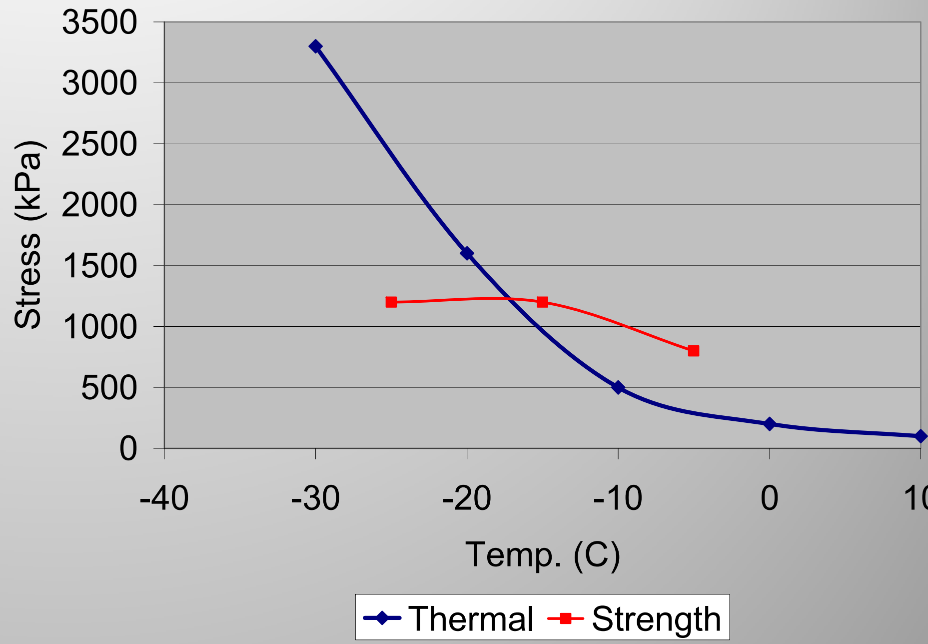
High Temperature Validation

- Test for Marshall stability/tensile strength and raveling on samples mixed 0.50% less RA than optimum
- Mix and compact at 104ºF (40ºC)
- Cure and test Marshall stability/tensile strength and retained strength using normal parameters
- Test for raveling after 4-hour cure at 77ºF and 50% relative humidity

Evaluation of Existing Binder

- Presence of unusually soft or high asphalt content existing binders can affect recycling agent selection and CR pavement performance.
- If their presence is expected can test recovered binder
  - AASHTO T 319
  - AASHTO T 164 and T 170
- Recovered pen > about 30 you have an active binder

Low Temperature Validation (AASHTO T 322)



- Crack initiation temperature must be less than expected low pavement temp. CR mix
- Select base asphalt of recycling agent to meet AASHTO M 320 low temperature requirement for project location.

Proposed Tests

- Hamburg Rut Test AASHTO T 324
- Asphalt Pavement Analyzer AASHTO T 340
- Fracture Test (Semi-Circular Bend Test) AASHTO TP 105
- Air Void Requirements
- Field Curing/Stability Tests

Hamburg or APA Rut Test

- CDOT has experimented with Hamburg
- What temperature?
- What threshold value?
- What effects on performance if I pass?
- Need to calibrated to actual performance

Fracture Energy Tests

- ►Semi-Circular Bend Test
- ►AASHTO TP105
- ►Measures fracture energy
- ►Related to cracking?
- ►Might help prevent brittle mixtures with use of additives
- ►Has potential

Thanks Instrotek

Air Void Requirements

- What air void content do you want?
- How do I control it?
- Where and how do we measure it?
- What effect does VTM have on CR and FDR performance?

Air Void Requirements

- **With HMA I Control Air Voids by:**
  - **VMA**
    - **Gradation of Aggregate**
    - **Compactive effort**
  - **Asphalt content**
- **I want 3-5% VTM in field after traffic so I design for 4% in the Lab**
- **What & where do you want VTM with CR & FDR and when?**

RAP Gradation

- **Gradation affects VMA**
- **Most Mix designs use 1 to 3 standard gradations**
- **How well do these match what we actually produce?**
- **These gradation bands were based on full CIR trains, not single unit trains**
- **Gradation can easily be verified**

Compactive Effort

- ► **SGC Compaction**
  - **Ndes = 30 gyrations**
  - **Based on 6 sites over 16 years ago** (TRR 1819 vol. 2)
  - **remove 1 site Ndes increased 10 gyrations**
  - **Do better job now – need to validate**
- ► **75- Blow Marshall**
  - **How good is this?**

Gmm: AASHTO T 209

- Dry-Back procedure (sec. 11) is required to account for uncoated particles.
- How accurate is this, especially with foam?

Gmm: ASTM D 6857 (Optional)

- **Does the CoreLok procedure work any better?**
- **Other methods?**

G_{mb}: AASHTO T 166 or T 331

- Due high air voids, water absorption of AASHTO T 166 will exceed 2.0%. Use AASHTO T 331? Most procedures do not.
- Foam uses volumetric

- How well do lab voids compare to field voids?
- Performance appears to not be a function of void content but how much my voids change in the field.

Verification of Field Mix Properties

- Sample age and temperature can have pronounced affect on measured mix properties
- Sealing uncompacted samples in containers does not appreciably help
- Must specify maximum compaction delay and sample temperature
- Usually requires compaction on-site

Results QA Testing CIR

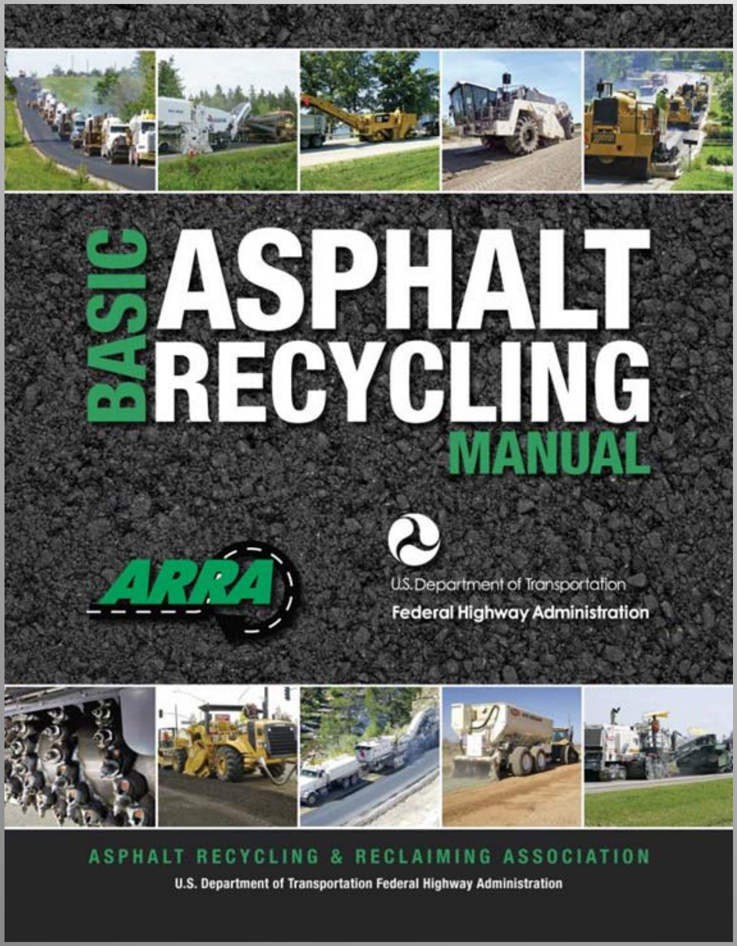
Test	No Delay	Delay
Lab Molded Voids	13.3%	20.6%
Dry Tensile Strength	74.5 psi	72.1 psi
Wet Tensile Strength	55.9 psi	64.9 psi
TSR	0.75	0.90
E* 20 C, 1 Hz	456,000 psi	355,000 psi

NCHRP Fiscal Year 2017

- **Project 09-62, Problem # D-13**
- ***Quality Assurance and Specifications for In-Place Recycled Pavements Constructed Using Asphalt-Based Recycling Agents***
- **3-year, $1 M, Last step for approval**
- **Could be a big help in moving technology forward**

Basic Asphalt Recycling Manual

2^{nd} Edition



- Chapters on:
  - Preconstruction Activities (project selection)
  - Mix Design
  - Construction
  - QA Sampling & Testing
- For CP, HIR, CR & FDR

ARRA Guidelines

- **100 Series - Recommended Construction Guidelines**
- **200 Series - Recommended Mix Design Guidelines**
- **300 Series - Recommended Quality Control Sampling and Testing Guidelines**
- **400 Series – Recommended Project Selection Guidelines**

Status of ARRA Guidelines

Series	Cold Planing		Cold Recycling	
	Milling	Micro Milling	CIR	CCPR
100 Series Construction	Final Review	Final Review	Complete	Complete
200 Series Mix Design	N/A	N/A	Complete*	
300 Series QC	N/A	N/A	Complete	
400 Series Project Selection	N/A	N/A	Under Development	

Status of ARRA Guidelines

Series	Full Depth Reclamation (FDR)		
	Bituminous	Cementitious	Lime
100 Series Construction	Complete	Complete	Complete
200 Series Mix Design	Under Development	Complete	
300 Series QC	Under Development		
400 Series Project Selection	Under Development		

Thank You www.ARRA.org

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