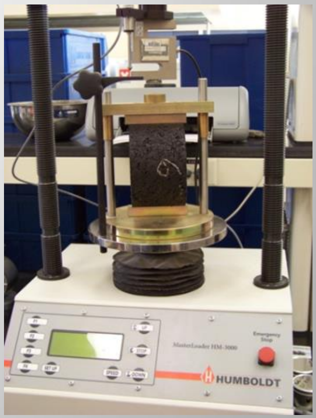
Mix Design for Cold in-Place Recycling (CIR) and Full Depth Reclamation (FDR)

Outline

- Purpose of mix design
- Sampling
- Mix design tests and emulsions
  - CIR
  - FDR
- Summary and conclusions

Purpose of Mix Design

- Determine emulsion content – provide guidance on low and high contents for construction
  - Impact on project cost
- Determine emulsion properties to meet mix and job requirements
- Look for problem materials and ways to correct for them



Sampling

- Ideally, sample locations are determined by construction and maintenance records or in-place testing (FWD, GPR)
- Samples should represent the width and length of the project to provide an overall “picture” of layer thickness values

Sampling

- Cores may identify thin areas that are insufficient for CIR or where new material could be added
- Other testing, such as DCP, can be performed at the time of coring to evaluate the aggregate base and subgrade for strength and train support

Sampling

- Overall quantity depends on specification and job requirements

- Bottom line – The mix design must plan on variability in materials and thicknesses

Mix design – material preparation and evaluation

- Saw-cut material that will not be used
  - Will pre-milling occur?
  - Cut bottom portion for CIR work
- Look for signs of stripping, fabric, delamination, etc.
  - Don’t leave stripped layers in place

Mix design – material preparation and evaluation

- Excessive thickness of chip seals or cold mix may give lower strength
  - High binder content
- Round aggregates may give lower strength
- Consider lime (CIR) or cement (FDR) for stripping / high fines
  - New aggregate or RAP for strength or thickness

Mix design – material preparation and evaluation

- Samples taken for extraction and gradation
- Core grinder to required gradation target(s)
  - Before grinding, look for material differences!
- Aggregate for FDR – washed gradation
- Aggregate / RAP batched to correct ratio
- Recovery of asphalt
  - Penetration and PG grading

Mix design – emulsion

- Formulated to meet mixture requirements
- Base asphalt properties, emulsifier type, and emulsifier amount

KDOT - Asphalt Emulsion (CSS)(SPECIAL)		
Test	**Minimum**	**Maximum**
Residue from distillation, % ASTM D2441	64.0	66.0
Oil distillate by distillation, % ASTM D2441		0.5
Sieve Test, % ASTM D2441		0.1
Penetration (TBD), 25oC, dmm ASTM D5	-25%	+25%

Mix design tests – CIR

CIR	Purpose
• Grinder / crusher	➢ Simulate milling
• Mixer	➢ Simulate mixing
• Raveling test	➢ Adequate setting
• Marshall stability	➢ Long-term strength
• Retained strength	➢ Long-term performance
• Thermal crack	➢ Non-load cracking

Mix design – material preparation and evaluation

- Most samples are usually 100 mm in diameter
  - Raveling and IDT for thermal cracking are 150 mm in diameter
- About 1000 grams each
- Normally 3 emulsion contents
- Maximum specific gravity – 2 samples, mixed at highest emulsion content. Dryback procedure.

Mix design tests – CIR

Notes:

- The tests are based on a procedure known as an “engineered” design
- Tests and specs can vary agency to agency
- There are others tests and methods that have worked well (gradation or volumetric based), such as in NY

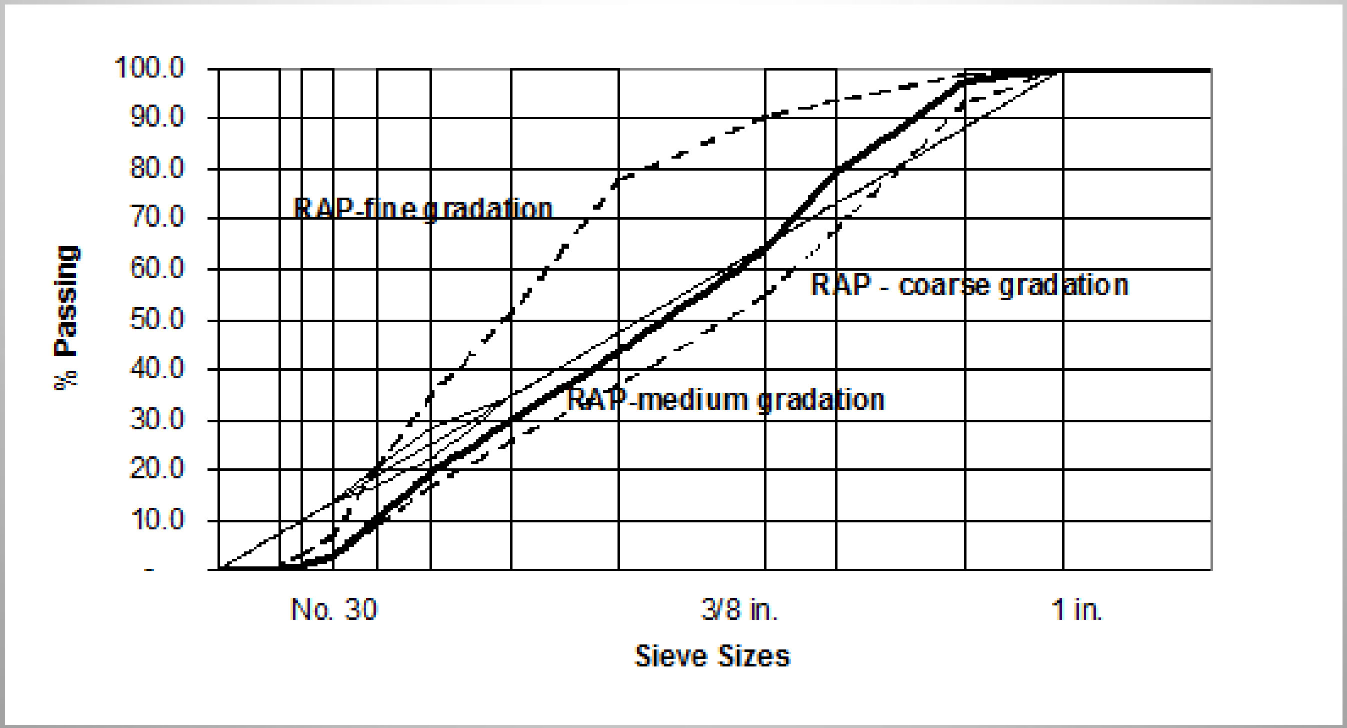
Mix design – grinder or crusher to simulate milling

- Miniature lab milling machine or jaw crusher to simulate expected field gradations
- Will need to experiment with crusher settings to determine how to obtain target gradations

or

Mix design – target gradations

- CIR targets are similar to below curve
- Usually two target gradations per mix design



Mix design – mixing

- Use a mechanical mixer to better simulate mixing that occurs in field equipment
- Modified bucket mixer

Mix design – mixing

- Percentages are on a dry weight basis of RAP
- Mix water thoroughly
  - Usually 2 to 3 percent (does not act like an aggregate – can't determine Proctor properties)
- If lime is used, use hydrated lime, mixed with water at 35% solids
- Add emulsion and mix thoroughly
- 60 seconds of mix time for water or emulsion

Mix design – compaction and curing

- Superpave gyratory compactor
  - 30 gyrations for 100 mm specimens
  - Some specs state 20 gyrations for raveling test specs
- Cure at 60° C from 16 to 48 hours (except raveling) after compaction – usually 48h

Mix design – raveling test (ASTM D 7196)

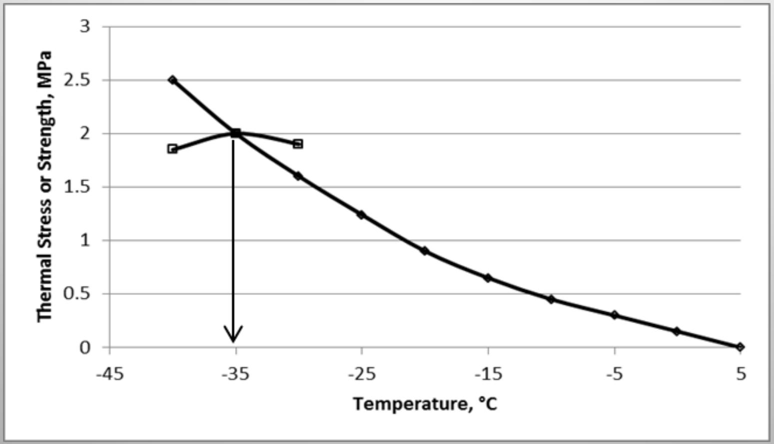
- Indicator of emulsion breaking and setting properties
- Usually after 4 hours of curing at 50F and 50% humidity
  - California considering three temperatures
- Criteria – 2% maximum (some states 7%) after 15 minutes
  - Weigh before and after

Mix design – Marshall stability and retained stability

- 1,250 pounds Marshall stability at 40C
- 70% retained stability
  - 55 to 75% vacuum saturation (a few seconds), 23 hour soak at 25C, 1 hour soak at 40C
  - Retained strength - key performance indicator
- Some agencies use TSR

Mix design – Thermal cracking (AASHTO T-322)

- LTPPBind software – 98% reliability for closest weather station at top of CIR (overlay depth must be known)
- Not an issue for some climates
- At design emulsion content
- Three temperatures
- Two specimens are cut from one tall specimen
- Two to three samples per temperature
- Two tests on each sample – creep compliance followed by tensile strength



CIR

Mix design – summary

Test	**Result**
Gradation	Report
Asphalt content	Report
Air voids	Report – Typically 9 to 14%
Raveling test	2% maximum
Marshall stability at 40C	1,250 lbs min.
Retained stability	70% minimum
IDT thermal cracking	LTPPBind for weather station
Emulsion	In order to meet mix and project requirements

Mix design – typical emulsion rates

Typical emulsion quantities for CIR

- 1.5 to 3.5% or higher for engineered emulsion - CSS-1/1h (special)
- Depends on how “active” the asphalt in the RAP is

Mix design – FDR

FDR

- Grinder
- High shear mixer
- Cohesion test
- ITS
- Retained strength
- Modulus
- Thermal crack

Purpose

- Simulate milling
- Simulate mixing
- Early strength
- Long-term strength
- Long-term perf.
- Structural
- Non-load cracking

Mix design tests – FDR

Notes:

- The tests are based on a procedure known as an “engineered” design
- Tests and specs can vary agency to agency
- There are others tests and methods that have worked well (gradation or volumetric based)

Mix design – grinder or crusher to simulate milling

or

- Miniature lab milling machine or jaw crusher to simulate expected field gradations
- Target gradation (only one)

Mix design – preparation of materials

- Blend RAP and aggregate base to expected ratios
- Perform Modified Proctor for OMC – Method C, 6 inch mold

- Water for mixing:
  - 60 to 75% of OMC if SE ≤ 30
  - 45 to 65% of OMC if SE > 30 (blend of RAP and aggregate)
  - Lower end of range for western / arid climates

Mix design – material preparation and evaluation

- Samples with emulsion are usually 150 mm in diameter
- About 2700 grams each
- Normally 4 emulsion contents
- Maximum specific gravity – 2 samples, mixed at highest emulsion content. Dryback procedure.
  - Cannot use aluminum pressure vessel if it contains cement

Mix design – mixing for FDR

- Use a high shear mixer to better simulate mixing that occurs in field equipment

Mix design – mixing

- Percentages are on a dry weight basis of material
- Mix water thoroughly
  - Based on OMC
  - Can back down water for increasing emulsion as long as within required range
- If a dry additive is needed, cement (Type 1) is used. Type C fly ash is also possible.
  - Mixed into RAP / aggregate blend before water
  - Range of 1% to 1.5% (usually 1%)
- Add emulsion and mix thoroughly
- 60 seconds of mix time for water or emulsion

Mix design – curing before compaction

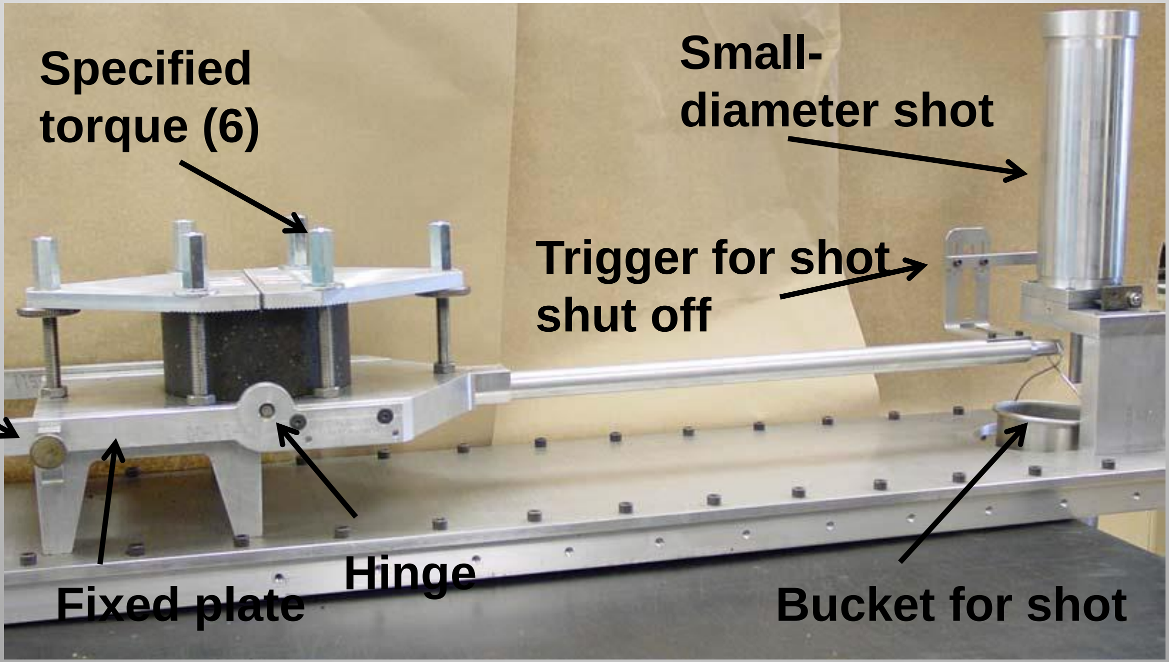
- Loose specimens cured individually in plastic containers of 4 to 7 inches (100 to 180 mm) height and 6 inches (150 mm) diameter
- Specimens cured at 40° C for 30 (± 3) minutes. No further mixing or aeration shall occur during this time

Mix design – compaction and curing

- Superpave gyratory compactor
  - 30 gyrations
  - 10 second hold after 30 gyrations
- Cure at 40° C for 72 hours (except cohesiometer) after compaction

Mix design – cohesiometer for FDR

- Indicator of emulsion breaking and setting properties
- Cured 60 minutes at 25C
- Two tests per specimen

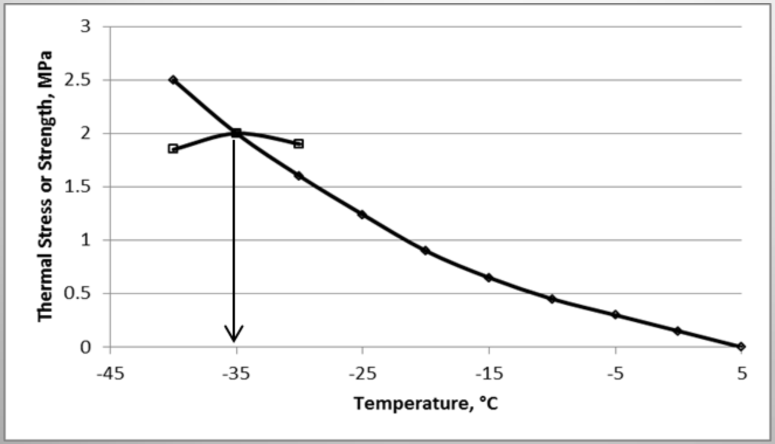


Mix design – indirect tensile strength and retained strength for FDR

- 40 psi ITS at 25C
- 25 psi retained strength after vacuum saturation and moisture conditioning
  - Key performance indicator

Mix design – Thermal cracking (AASHTO T-322)

- **Modulus <u>before</u> IDT at 25C**
- LTPPBind software – 98% reliability for closest weather station at top of CIR (overlay depth must be known)
- Not an issue for some climates
- At design emulsion content
- Three temperatures; two specimens are cut from one tall specimen; two to three samples per temperature
- Two tests on each sample – creep compliance followed by tensile strength



FDR

Mix design – summary

Test	**Result**
Gradations	Report for all materials
Asphalt content of RAP	Report
Air voids	Report – Typically 9 to 14%
Cohesiometer test	150 or 175 min. (depends on fines)
ITS at 25C	40 psi minimum
Retained ITS	25 psi minimum
Resilient Modulus at 25C	150,000 psi minimum
IDT thermal cracking	LTPPBind for weather station
Emulsion	In order to meet mix and project requirements

Mix design – typical emulsion rates

Typical emulsion quantities for FDR

- 2.0 to 5.5% or higher for engineered emulsion - CSS-1/1h (special)
- Depends on amount of aggregate base and quantity / quality of fines

Mix design – summary

- HMA industry tests have been adapted for CIR and FDR mix designs (except raveling or cohesion)
- CIR or FDR acts like a slightly lower modulus HMA material

Questions?