Mix Design Issues for In-Place Recycling Products

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Outline

- Need for mix design
- Overview of procedures
- Key points of different procedures
- Issues and gaps

Processes Covered

- Cold In-Place Recycling
  - Foamed asphalt
  - Emulsified asphalt

- Full Depth Reclamation (FDR)
  - Emulsified asphalt
  - Foamed asphalt
  - Cement, fly ash Class C, CKD

- Hot In-Place Recycling
  - Rejuvenators

Need for Mix Design

- Determine if material will work for the process
  - Strength, durability, resistance to moisture-induced damage
- Accurately determining stabilizer properties and content to meet mix and job requirements for a successful project
- Determine if other additives are needed

Need for Mix Design

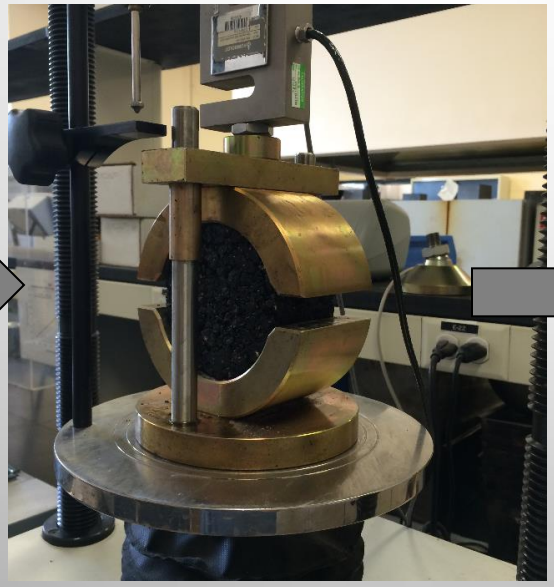
- Determine water content range
- Provide guidelines if stabilizer content or water content needs adjusted during construction
- Look for problem materials and ways to correct for them, if possible

Mix Design – Hot or Cold?

- Hot mix – Proportioned blend of two to five materials / knowledge of what's there / adjust with minor material changes
- In-place recycling mixes – Road variations, construction variables / plan ahead to adjust

Mix Design – Material Evaluation

- Material evaluation
  - Testing the materials before design is critical
- Core report / sampling
  - The lab should receive the coring / sampling report



Sampling

- Proper and representative sampling is important!
- The mix design is irrelevant if sampling and project selection are not performed properly

Material Evaluation and Preparation

	CIR	FDR	HIR
Cores			
Density, thickness	X	X	X
Asphalt content and PG or pen	X	X	X
Blending chart with new binder			?
Extracted aggregate gradation / quality	X	X	X
Need for corrective aggregate or mix?	X		X
Remove portion not to be recycled	X	X	X
Crushing method	ambient	ambient	heated
Base Material			
Gradation / quality		X	
Sand equivalent and plasticity index		X	
Proctor		X	

Material Selection - FDR

Material	Quality of fines	Quantity of P200	Other
Foamed asphalt	PI < 10	5 to 20%	
Emulsified asphalt	PI < 6 or SE > 30	< 20%	
Cement or Class C fly ash	PI < 20		SO_4 < 3000 ppm

Other criteria should also be considered in material selection – structural contribution, construction conditions

Considerations in Material Evaluation

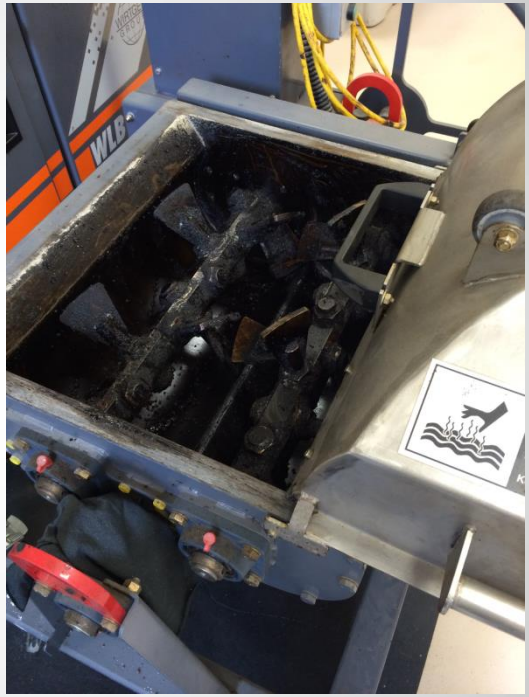
Problem	Possible solution
Excessive built-up surface treatments or cold mix	Add new crushed aggregate, potentially low new binder content
Excessive rounded aggregate or no coarse aggregate	Add new crushed aggregate
Excessive binder	Add stone or low new recycling agent
Rubber mixes	
Variable mixes	Multiple designs – consult agency and contractor Must be practical for job size
Fabric	If within recycled layer, ensure contractor has a plan to deal with it
Delaminated or stripped layer	Ensure its in recycled layer, will be removed, or far below recycled layer

Crushing

CIR or FDR
Cores are cut down to a manageable size and crushed to a target grading

Alternative laboratory milling machine

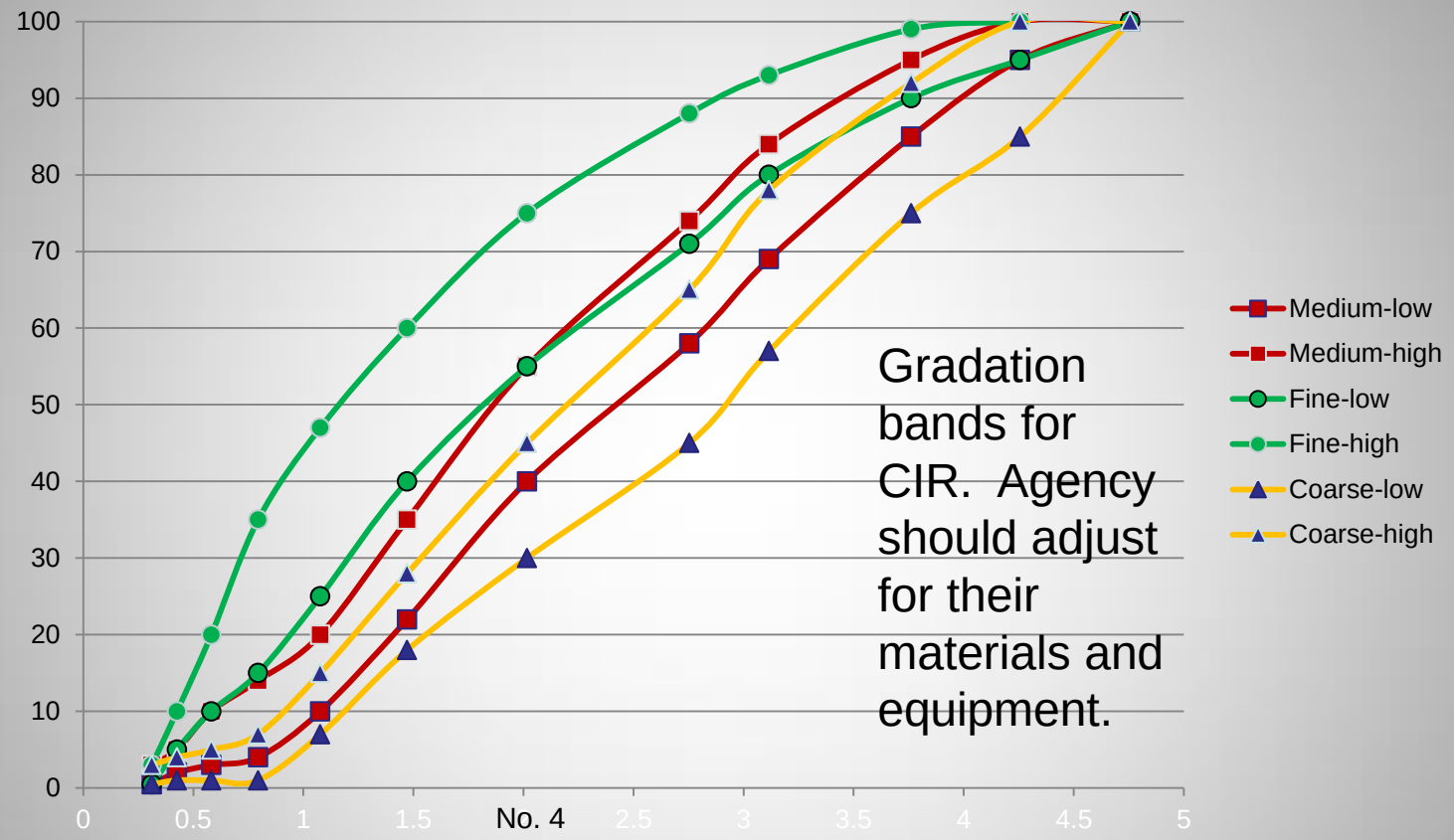
Crushing



HIR

Heat cores and then break by hand or break up in lab heated heavy-duty pugmill

Crushing



CIR

Materials is crushed to a target grading (preferred), or the material is batched.

FDR

Material is crushed to minus 1 or 1.5-inch (mold size). Blend in correction proportion with base.

Mixing

Emulsified asphalt

CIR
Ambient or elevated (100F) temperature. Low-energy bucket mixer.

FDR
Ambient temperature. High-energy mixer better simulates the mixing from a reclaimer.

HIR
Mix about 230F. Same type of mixer as HMA

Mixing – Foamed asphalt

- Expansion ratio and half life is determined prior to mixing for foamed asphalt
  - Various water contents and asphalt temperatures
- Use the source asphalt
- Larger batches are made with the foaming unit and mixer
- Batches broken into sample size after mixed

Mix design tests – CIR

Property	Test(s)	Purpose
Note: emulsified asphalt CIR typically produces two designs from two different gradation bands, resulting in two contents		
Compaction	Superpave Gyratory - 30 Marshall compaction - 75	Simulate compacted density + traffic
Mold size	100 mm or 4-inch common 150 mm if desired	Test dependent
Curing	2 days at 60C or 3 days at 40C	Water loss for ultimate strength
Early Strength (measurement of curing)	Same as strength – X cure Raveling – 4-hr curing	Strength for same-day traffic for emulsified asphalt

Mix design tests – CIR

Property	Test(s)	Criteria or purpose
Strength (only one is needed)	Marshall stability @ 40C Indirect tensile @ 25C Hveem @ 25C – CDOT Hamburg @ 50C - TxDOT	1,250 pounds min. 45 psi min. 5000 passes min.
Conditioned strength	Same test as dry	70% or greater of dry strength (emulsified) or 35 psi (foam)
Conditioning	55 - 75% saturation + soak 24-hour soak	Wetter climates Dry or wet climates
Other	Resilient modulus Thermal cracking IDT	Structural coefficient Low-temp cracking
Recycling agent content selection	Minimum content to meet all criteria	

CIR mix design – mixing

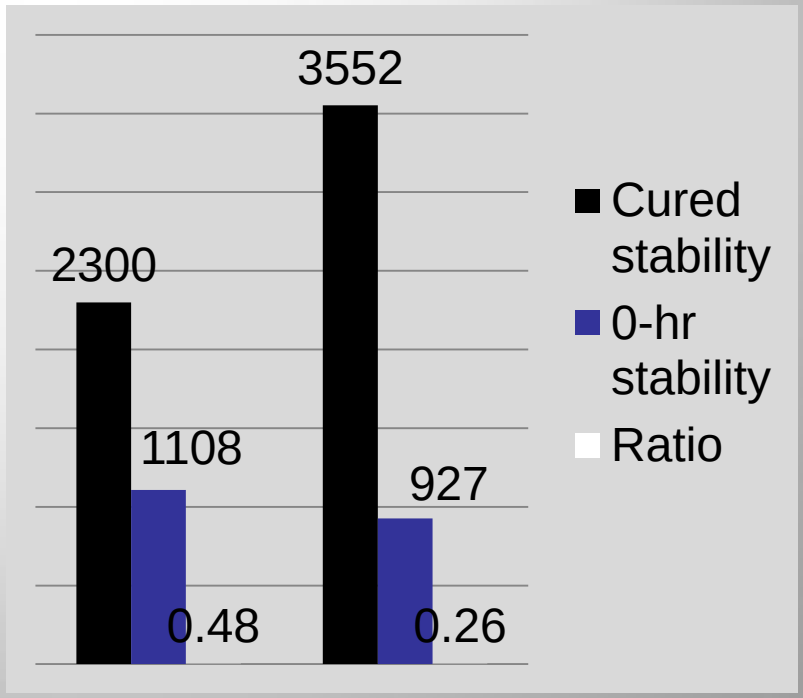
- Water is mixed first for 60 seconds
- If lime slurry is used, target 1 to 1.5% lime solids by weight of RAP. Use hydrated lime solution (35% lime)
- If cement is used, dry mix with material first before water
- After water, lime slurry, or cement mixed, mix recycling agent for 60 seconds

CIR mix design – compaction

- 100 mm or 150 mm mold for SGC
- 30 gyrations (20 for raveling)
- Slotted mold to relieve water is not needed if water and recycling agent contents are chosen properly

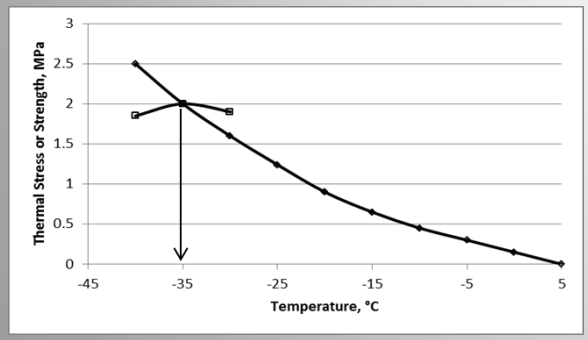
Mix design – early curing test

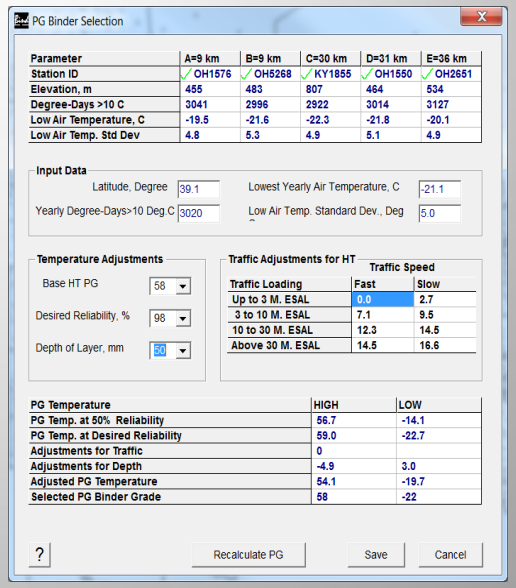
- Indicator of emulsified asphalt breaking and setting properties (cohesion measurement) – traffic effects
- Raveling (ASTM procedure) or early strength test (concept)
- Worst case curing - 4 hr at 10C and 50% RH (early / late season)
- Summer season curing – Mix RAP at 40C, cure 4 hr at 25C and 50% RH



Mix design – thermal cracking

- AASHTO T-322
  - Critical cracking temperature
  - Extra materials and time
  - Not needed for every project
- Alternative
  - Base asphalt specified from climate grade
  - Put upper limit on cement if used
    - Foam 1% max.
    - Emul. res. AC:C – 3:1 max.





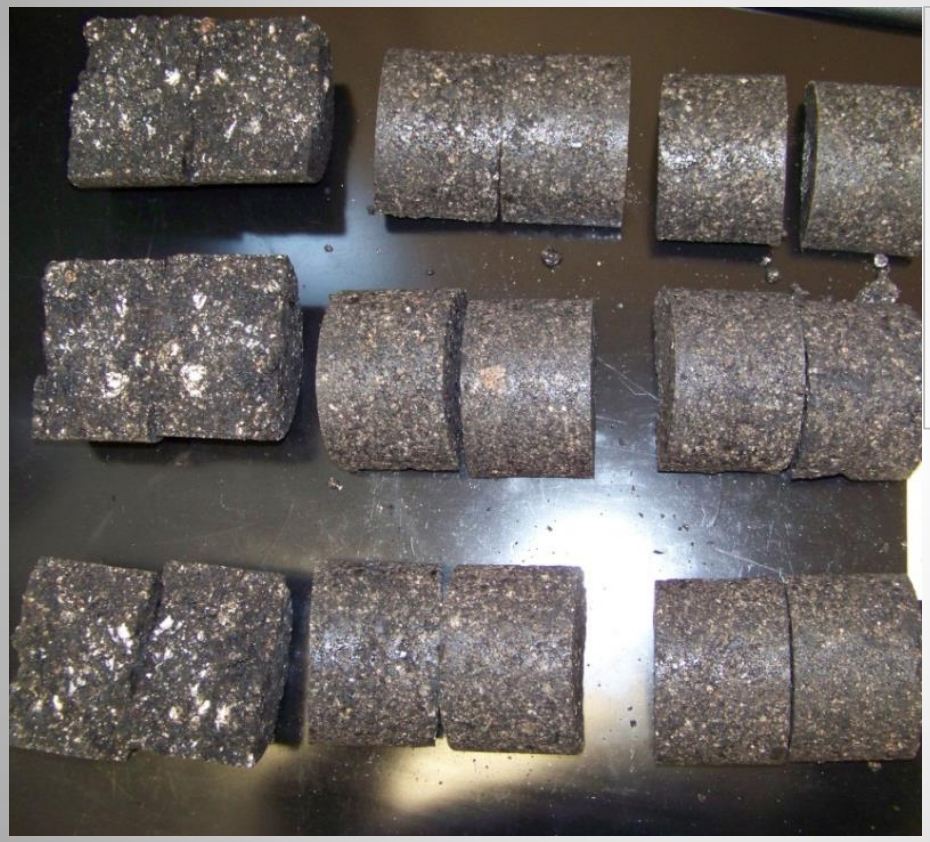
CIR Mix design – typical rates

- Water – 1.5 to 3%
- Foamed asphalt – 2 to 2.5%
- Emulsified asphalt – 1 to 3.5%

At least 3 contents

  - Engineered emulsified asphalt
  - Cationic medium or slow set
  - High float medium-set anionic
- Lime, if needed – 1 to 1.5%
- Cement, if needed – 0.25 to 1%
  - Ratio of AC emul. residue : cement (3:1max.)
  - 1% max. cement (foam)
- Add stone, if needed – About 20%, if needed

CIR lab specimens



Medium-gradation emulsified asphalt samples (with 1.5% lime solids)

3.25% top
2.75% middle
2.25% bottom

Note: Lime or cement gives the specimens a lighter color. Compare to the picture on the right with no dry additive.

Mix design tests – Bituminous FDR
(including combination with chemical)

Property	Test(s)	Purpose or criteria
Optimum water of combined materials for mixing water – no stabilizing agent	Modified Proctor	50 to 75% of OMC – emulsified 90% of OMC - foam
Compaction	Superpave Gyratory - 30 Marshall compaction - 75	Simulate compacted density + traffic
Mold size	4-inch Marshall 150 mm SGC	Test dependent
Curing	3 days at 40C or 2 days at 60C	Water loss for ultimate strength

Mix design tests – Bituminous FDR
(including combination with chemical)

Property	**Test(s)**	**Criteria or purpose**
Strength	Indirect tensile @ 25C	40 psi min.
Conditioned strength	Same as dry	Minimum absolute (25 or 35 psi)
Conditioning	55 - 75% saturation + soak 24-hour soak	Wetter climates Foam / Dry or wet climates
Other	Resilient modulus Thermal cracking IDT	Structural coefficient Low-temp cracking
Emulsion content selection	Minimum content to meet all criteria	

Mix design tests – Chemical FDR

Property	Test(s)	Purpose
Compaction	Moisture-density with median cement content	Simulate compacted density
Mold size	4-inch diameter, 4.6-inch tall	
Curing	Moist cure for 7 days	
Strength	Unconfined compressive strength (UCS) – 200 to 500 psi	7-day strength
Wet-dry and freeze-thaw conditioned strength	Conditioning + UCS	Durability

FDR mix design – blending and determination of OMC

- Blend RAP and underlying layer to expected ratios
- Perform modified Proctor (bituminous) or standard Proctor for chemical

- Water for mixing:
  - 50 to 75% of OMC for emulsified asphalt
  - 90% of OMC for foamed asphalt
  - OMC for cement

FDR mix design – mixing

- Use a high shear or pugmill mixer to better simulate mixing that occurs in field equipment
- Same general guidelines as CIR mixing

FDR mix design – compaction

- Bituminous
- 100 mm or 150 mm mold for SGC
- 30 gyrations
- Slotted mold to relieve water is generally not a big concern if water and recycling agent contents are chosen properly

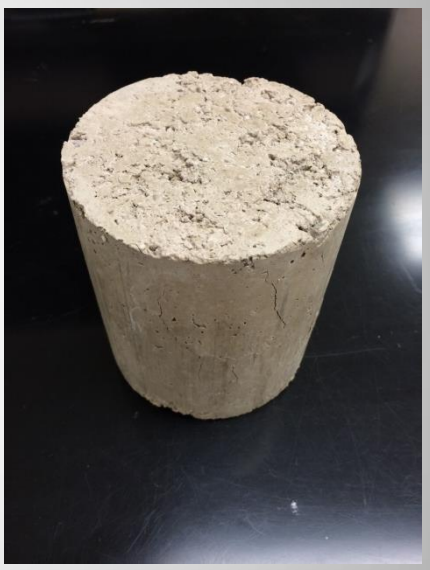
FDR Mix design – typical rates

- Water – Varies
- Foamed asphalt – 2.5 to 3%
- Emulsified asphalt – 3 to 5%

3-4 contents

  - Engineered emulsified asphalt
  - Cationic medium or slow set
  - Cement as an additive, if needed – 1 to 1.5%
- Cement – 3 to 6 %
  - Class C fly ash, kiln dusts may be different
- Add stone, if needed

Various FDR lab specimens



Mix design tests – HIR

Property	Test(s)	Purpose
Determine binder or rejuvenator type and quantity	Physical properties of recovered aged binder plus varying rejuvenator quantities	Determine effect and optimum quantity
or		
Determine effects on mixture properties	Physical tests on blends of rejuvenator and aged mixture	Determine effect and optimum quantity
Surface recycling	Other than rejuvenator, no other material is added	
Remixing	Rejuvenator with new aggregate or mixture	
Repaving	Surface recycling or remixing with integral overlay	

Comprehensive mix design testing – HIR

Property	Test(s)	Criteria or purpose
Aggregate properties in existing	Gradation, shape, angularity	Meet current agency criteria?
New aggregate (usually new HMA)	Gradation, shape, angularity	To bring recycled mix to agency criteria
Mixing	250 to 265F (120 to 130˚ C)	Thoroughly blend rejuvenator, admixture, and RAP
Curing	At compaction temperature 30 – 60 minutes	Allow the rejuvenator to diffuse in blend
Compaction	Gyratory, Marshall, or Hveem methods	
Mixture tests	Volumetrics, common HMA tests, APA	
1% rejuvenating agent or less		

Mix design – summary

- HMA industry tests have been adapted for CIR, FDR, and HIR mix designs
- Aggregate / soils tests are used in part of FDR procedures
- Bituminous CIR or FDR acts like a slightly lower modulus HMA material
- Chemical FDR acts like a less stiff concrete
- HIR acts similar to HMA

Mix Design Procedures

- ARRA
- Emulsion Task Force
  - In-Place Recycling Subcommittee
- Wirtgen design manuals
- Portland Cement Association
- American Coal Ash Association

Issues and gaps

- Consideration of construction temperature for bituminous FDR and CIR designs
- Pavement design guidelines
  - Current NCHRP study
- Quality assurance, inspection, and acceptance guidelines

Summarizing thoughts

- Art or science?
- No universal mix design procedures. Is this an issue?
- Pre-bid or post-bid design?
- Bidding quantities

Thank You!

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