Mix Designs for FDR, CIR, and HIR

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Outline

- Purpose and other considerations for mix designs
- FDR
- CIR
- HIR
- Summary



Purpose of a Mix Design

- Increase the probability of a successful project
- Additive type determination and check compatibility
- Determine additive quantities and other requirements such as water
- Is add-rock or a secondary material required?
- Provide QC targets

Other considerations

- Provide guidance on or be involved with sample collection
- Will the road be widened?
- Are multiple designs required for the project?
- Determine if pavement design parameters are achieved (i.e. structural coefficients)

Other considerations

- Dealing with fabric
- Is there a stripped layer?
- Saw-cut to depth and remove non-recycled layers
- Correctly proportion materials

Full Depth Reclamation

Suggested Additives for Full Depth Reclamation – Blend of existing bituminous and base / soil

Material Type	Well-graded gravel	Poorly graded gravel	Silty gravel	Clayey gravel	Well-graded sand*	Poorly graded sand	Silty sand	Clayey sand	Silt, Silt with sand	Lean clay	Organic silt / organic lean clay	Elastic silt	Fat clay, fat clay with sand
USCS	GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	OL	MH	CH
AASHTO	A-1-a	A-1-a	A-1-b	A-1-b or A-2-6	A-1-b	A-3 or A-1-b	A-2-4 or A-2-5	A-2-6 or A-2-7	A-4 or A-5	A-6	A-4	A-5 or A-7-5	A-7-6
Emulsion FDR / GBS Best if SE > 30 and P200 < 20 (100% base to 100% RAP)													
Foamed asphalt P200 5 to 20% and follow max. density grad.													
Portland cement PI<10													
Lime PI>10 and P200<25 or PI 10-30 and and P200>25, SO_4 in clay < 3000 ppm													

FDR Additive Contents - typical

- Asphalt emulsion (2% to 6%)
- Foamed asphalt (1% to 3%) + cement
- Portland cement (3% to 6%)
- Fly ash (8% to 14%)
- Lime (2% to 6%)

FDR Mix Design Methods

- Asphalt emulsion – Industry-adopted and agency-specific (i.e. PennDOT) mix designs
- Foamed asphalt – Foamed Bitumen Mix Design Procedure Using the Wirtgen WLB 10
- Portland cement – PCA EB052, Soil-Cement Laboratory Handbook
- Fly ash – American Coal Ash Association
- Lime – National Lime Association

FDR Tests

Common Tests

- Moisture density relationships
- Gradation analysis, liquid limit, plastic limit

Bituminous

- High shear mixer
- Superpave gyratory compactor or Marshall
- Strength (indirect tensile, Marshall)
- Moisture-conditioned strength
- Short-term strength
- Modulus for pavement design
- Thermal cracking

Chemical

- Unconfined compressive strength
- Wet-dry and freeze-thaw durability tests

Adjustments for FDR performance

Applies more to bituminous

- Strength
  - Add rock, add small amount of cement or lime, lower binder content
- Moisture-conditioned strength
  - Add small amount of cement or lime, higher binder content
- Setting characteristics (short-term strength)
  - Solventless emulsion, add small amount of cement
- Modulus (structural coefficient)
  - Same as strength
- Thermal cracking
  - Softer or more binder

Cold in-place recycling

CIR Mix Design Methods

- Industry-adopted or state specific (i.e. PennDOT) procedures

CIR Mix Design

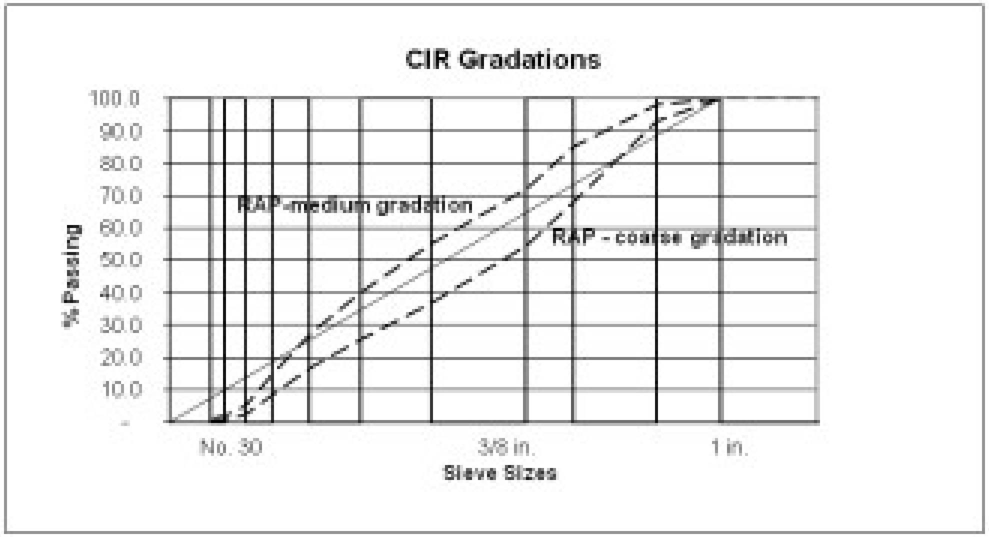
- Mix design
  - RAP crushed to defined gradations
  - Emulsion formulated
    - ***Climate & project needs***
    - ***Controlled break, cohesion, coating/adhesion***
  - Superpave Gyratory Compactor (SGC) or Marshall compaction at field moisture content
- Performance-related tests

Milling & Crushing, Screening & Sizing

Lab

Lab RAP Analysis

- Lab
  - Field cores crushed to 2 gradation bands
  - A design for both gradations



- Field
  - Field gradation depends upon multitude of factors: milling, weather, etc.
  - Gradation compared to lab tested band
  - Emulsion rate based on applicable gradation

Density Compaction Effort

Superpave Gyratory Compactor

Lab

Performance-Related Tests

- Raveling
- Strength – Marshall stability, indirect tension test, or APA
- Moisture susceptibility
- Thermal cracking

Raveling Test

Engineered CIR Specimen
(AZ project)
1% loss after 15 minutes

Conventional CIR Specimen
(MN project)
11% loss after 10 minutes

Adjustments for CIR performance

- Strength
  - Add rock, add small amount of lime
- Moisture-conditioned strength
  - Add small amount of lime, higher emulsion content
- Setting characteristics (short-term raveling test)
  - Solventless emulsion, change emulsion formulation
- Thermal cracking
  - Softer or more binder

Hot in-place recycling

- Surface recycling
- Repaving
- Remixing

HIR Additives

- Rejuvenating agent – blending charts for type and amount
- Asphalt emulsion with rejuvenating agent and polymer
- New aggregate or HMA

HIR Mix Design Methods / Tests

- Mix design effort ranges from as little as additive selection only to as much as a full mixture analysis
- Industry-adopted or other procedures
- Thicker -> Mix design more important
  - Marshall and SGC compaction
  - Volumetrics, Marshall strength, indirect tensile strength, APA, resilient modulus, thermal cracking

Adjustments for HIR performance

- Adjustment of additive / formulation
- Adjustment of other added materials

AASHTO Structural Coefficients

Treatment	Coefficient
Aggregate base	<0.10 to 0.14
Cement treated base / soil cement	0.14 to 0.23
Bituminous FDR	0.20 to 0.25
Emulsion CIR	0.28 to 0.33
HIR	0.40
HMA	0.40 to 0.44

Coefficients dependent on original material quality and local experience

Summary – Mix Designs for FDR, CIR, and HIR

- Increase the probability of success
- Determine additive type and check compatibility
- Determine primary additive quantities and the need for secondary additives (i.e. new aggregate)
- Determine if modulus or strength is achieved to meet pavement design requirements
  - Consider dynamic modulus - MEPDG

Questions?

Thank you!

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