Comparisons of Emulsion, Foamed, and Cement Stabilized Bases

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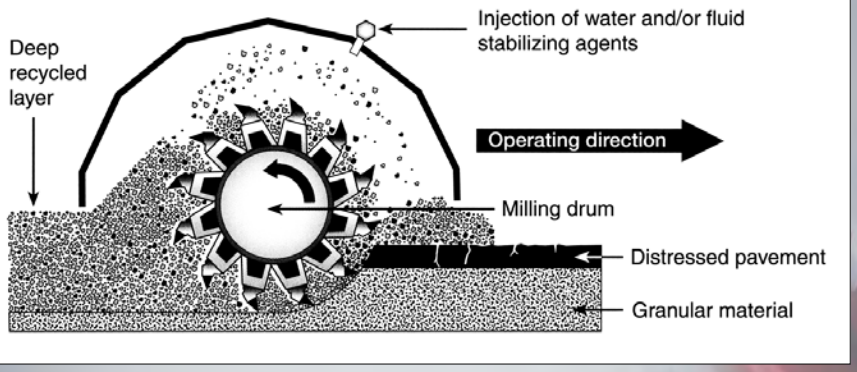
FDR Definition

Full Depth Reclamation (FDR) is a pavement rehabilitation technique in which the full flexible pavement section and a predetermined portion of the underlying materials are uniformly pulverized and blended together to produce a homogeneous stabilized base course.

- Emulsified Asphalt Treated Base
- Foamed Asphalt Stabilized Base
- Cement Stabilized Base


Injection of water and/or fluid stabilizing agents
Deep recycled layer
Operating direction
Milling drum
Distressed pavement
Granular material

Primary stabilizing methods

- Pulverization only
- Mechanical stabilization
- Bituminous stabilization
- Chemical stabilization

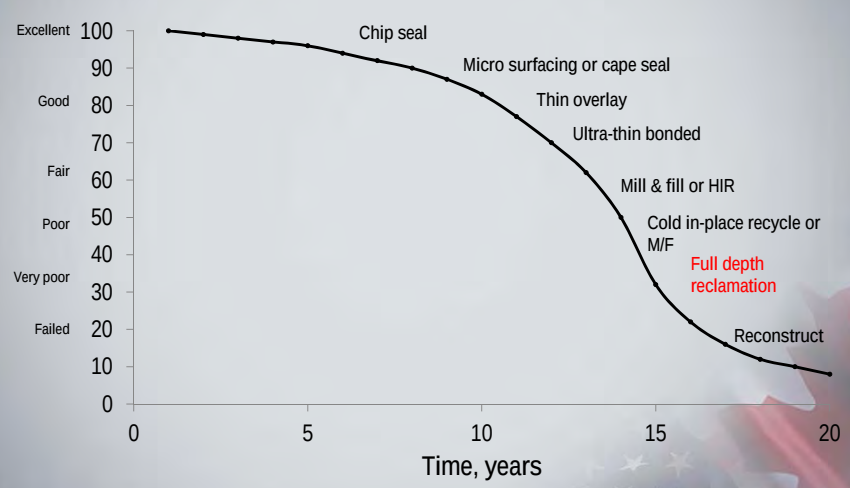
Overview of FDR Processes

	Pulverization	Mechanical
Thickness, inches	4 to 12	4 to 12
Stabilizer content, %	0	0
Additive type & content	None	0 to 20+% rock
Stabilizer Types	N/A	N/A
Alternative process	Reconstruction	
Typical surface	Surface treatment or O/L	

Overview of FDR Processes

	Emulsified Asphalt	Foamed Asphalt	Cement
Thickness, inches	4 to 8	4 to 10	8 to 15
Stabilizer content, %	2 to 5 (60 to 65% res.)	1 to 3	3 to 6
Additive type & content	0 to 1.5% cement 0 to 20% rock	1 to 1.5% cement 0 to 20% rock	0 to 20% rock
Stabilizer Types	CSS-1, HFMS-2, engineered emulsion, polymer versions	PG grades (non-polymer modified)	Portland cement
Alternative process	Reconstruction		
Typical surface	Surface treatment or O/L		

Generalized Performance Curve



Project Selection

From Table 6, NCHRP Synthesis 421 and ARRA

	CIR	FDR
Alligator Cracking	G	G
Bleeding, Flushing	F	G
Block Cracking	G	G
Bumps	F	G
Edge Cracking	F	G
Friction Improvement	G	G
Longitudinal Cracks	G	G
Oxidation	G	G
Patches	G	G
Polishing	G	G
Potholes	G	G
Raveling	G	G
Rutting	G	G
Reflective Cracking	G	G
Shoulder Dropoff	P	P
Shoving	G	G
Slippage	G	G
Transverse Cracks	G	G
Moisture Damage	G	G
Ride Quality /minor profile corrections	F	G

Project Selection

Pavements with functional or structural distresses. Major pavement distresses and / or structural upgrades for current or future traffic. Treats the bituminous layer and base and possibly the subgrade (cement).

- Parking lots
- Low volume roads
- City streets and medium volume roads
- Shoulders
- Interstate highways
- Airports

Project Selection

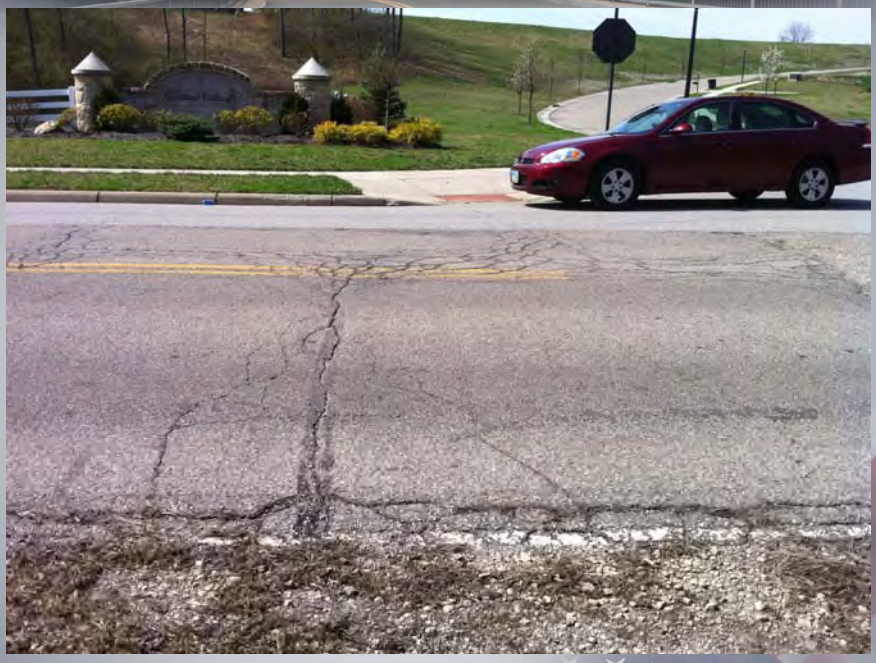
Asphalt pavement with good drainage with side ditches or an internal drainage structure

Asphalt pavement over aggregate base or stabilized base

Could be an existing gravel road with adequate thickness of base material over the subgrade

Very worn asphalt pavement with medium to high severity cracks going through entire asphalt layer

Asphalt pavement with signs of rutting, fatigue cracking, or patches due to structural distress not related to the subgrade



Material Selection

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 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													

Bituminous FDR Mix Design

- No. 200 on the RAP/aggregate blend typically < 20% for optimum performance
- Cleanliness of fines: PI < 6 or SE > 30
- Use small quantity of cement if P200 is high or SE is low
  - Usually 1 to 1.5%

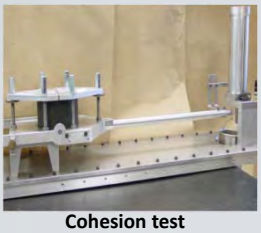
Bituminous FDR Tests

Test	Purpose
Grinder	Simulate milling
Extraction	AC content and gradation
High shear mixer	Simulate mixing
Superpave gyratory compaction or Marshall	Simulate long-term density
Early strength test (Marshall or cohesiometer)	Early strength (chemistry)
ITS	Long-term strength
Retained strength	Key performance indicator (chemistry)
Modulus	Structural
Thermal cracking	Non-load cracking

Bituminous FDR Mix Design

- Mix in high-shear mixer
- Superpave gyratory compactor (or Marshall hammer)
  - 30 gyrations for 150 mm specimens (or 75 blows per side)
- Cure at 40°C from 72 hours

Bituminous FDR Mix Design



Cohesion test

Marshall stability

Indirect tensile strength

IDT thermal cracking

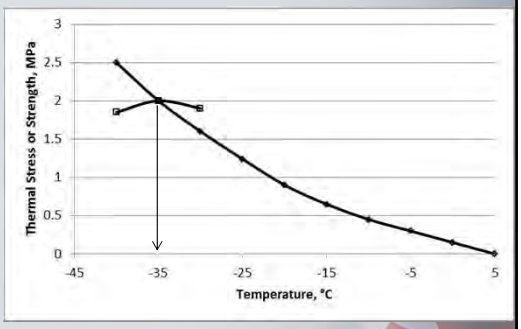
Thermal Crack Testing

Bituminous FDR mixtures can be designed to have good cold-temperature performance

Predicted low temperature of pavement in Anchorage area:

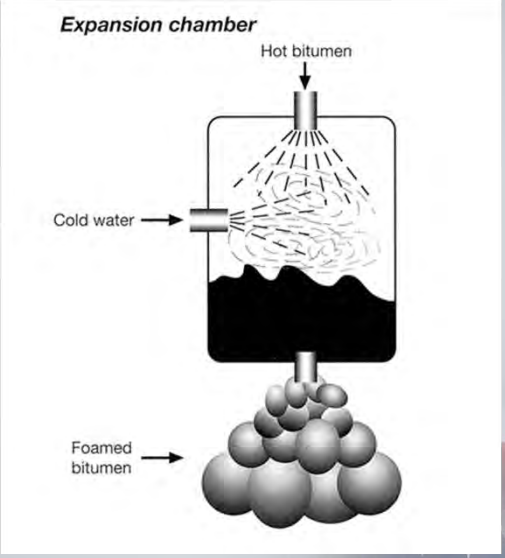
- -30° C at surface
- -27° C at 3 inches depth

AASHTO T-322



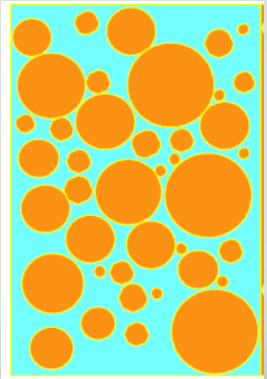
Foamed Asphalt

- Binding technology

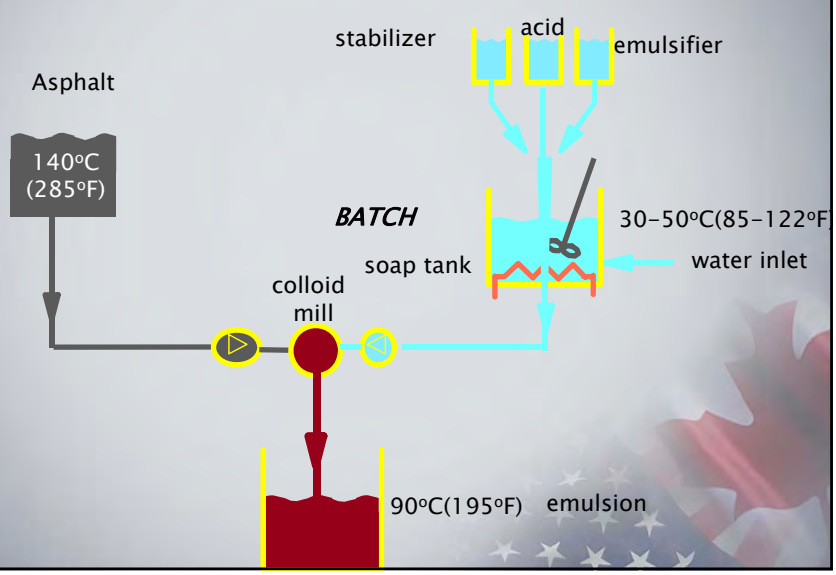


Emulsified Asphalt

- An emulsion is a dispersion of small droplets of one liquid in another liquid
- Binding and coating technology

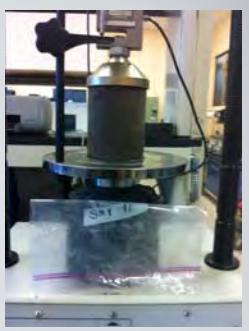


Emulsified Asphalt Production



Cement FDR Mix Design

Modified Proctor Compaction



Unconfined compressive strength

Tube suction test

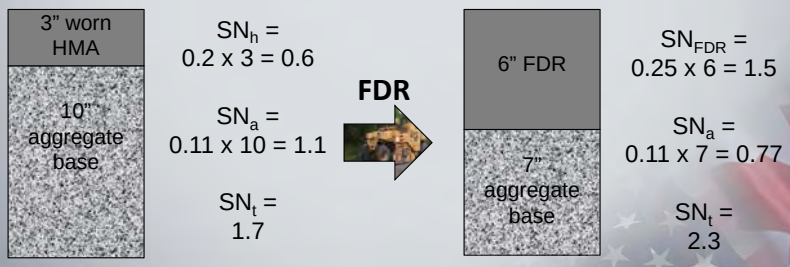
Pavement Design

- FDR
  - Cement: 0.14 to 0.20 (0.15 typical)
  - Engineered emulsion: 0.20 to 0.28 (0.25 typical)
  - Mechanical: Treat as aggregate base
- Aggregate base
  - 0.08 to 0.12 (0.11 typical)
- Note: 1993 pavement design guide to be replaced by MEPDG methodology

Pavement Design

Strength is built into a pavement structure with FDR

- Corrects pavement defects
- Increases structural capacity



Pavement Design

Strength is built down into a pavement structure with FDR

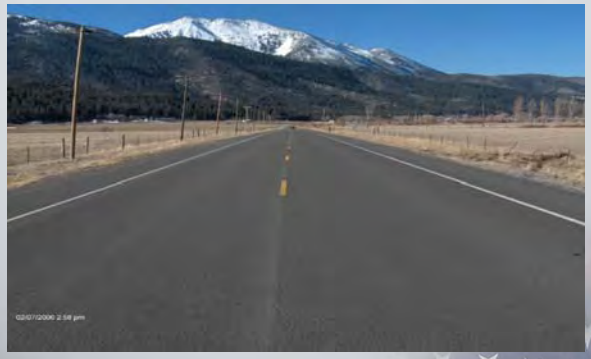
- Corrects pavement defects
- Increases structural capacity

Pavement Design - MEPDG

- Default modulus value assigned FDR in the present form of the MEPDG is not realistic
  - MEPDG considers FDR as unbound material. Dynamic modulus testing showed otherwise
- Emulsion FDR characterized as less-aged asphalt concrete
- NCHRP 09-51

Surface Courses

- HMA binder and wearing courses
- Surface treatments – micro surfacing or chip seal, etc.
- Dense-graded cold mixes



Surface Courses

The recycled layer must be covered by at least a bituminous treatment (i.e. micro surfacing or chip seal). If chip seal, double chip seal is best. The specific treatment needed will depend on pavement design and ride expectations

Bonding of the surface course is critical for life expectations and performance of recycled layer. More difficult to bond over cement FDR.

FDR Construction - bituminous

Road before pulverization

Pulverization and water addition
(shaping if needed)

FDR Construction - bituminous

Cement addition (if needed)

Emulsion addition

FDR Construction - bituminous

Padfoot rolling until walkout

Shave padfoot marks and final grading

FDR Construction - bituminous

Final compaction (often in combo with pneumatic)

Completed FDR

Moisture content in the recycled mix must be low enough before recycled layer is covered (50% of OMC for FDR)

FDR Construction - cement

Cement spreading after pre-pulverization

Reclaim with water addition

FDR Construction - cement

Padfoot compaction

Grading followed by finish rolling – keep moist for curing

FDR Quality Control

- Depth
- Top size
- Water content
- Stabilizer content
- Additive content
- Mix testing
- Grade and cross slope control
- Compaction
- Time to overlay

AK Foamed Asphalt Stabilized Base Specification

- 500 lb base, 200 lb pavement, 10 gal, 1 sack PC
- OMC, ITS, gradations
- On site foamed asphalt tech for 10 days / 5 yrs exp.
- Measure density on road; ITS by sublot; have field lab
- Heavy rollers – 30T padfoot, 25 T pneumatic
- In place moisture < OMC. If rain, then >2% over OMC
- ITS > 85% of design for payment; otherwise more HMA
- Field density > 98% of control strip

AK Emulsified Asphalt Treated Base Specification

- Section 308 Asphalt Base Course
- When item 308(2) is in bid schedule, add emul. AC
- CSS-1 (sec. 702)
- Add emulsion through metered mixing equipment
- Control strip - >98% density for rest of project
- No mix / lab requirements

Engineered Emulsions

- Asphalt emulsions designed for cold in-place recycling (CIR) and full depth reclamation (FDR) on a job-to-job basis using newer emulsifier chemistry
- Not just an emulsified asphalt specification
- Meet specific mixture requirements also
- Ensures compatibility with the reclaimed asphalt pavement (RAP) and aggregate, considers the climate when choosing the grade of asphalt and considers environmental conditions at the time of the project

Foamed Asphalt	Emulsified Asphalt	Cement
Established mix designs	Safe to handle	Handle more material types
Less moisture in system	Transport long distances	Go deeper than bituminous
	Does not need to be hot	Established mix designs
	Established mix designs	
Keep hot	Avoid freezing	More brittle
Ensure AC foams	Cures slower in shade	Bonding difficult – thin lifts
		Dust during construction

ARRA Life Guidelines

FDR

- Normally 25 to 35% cost savings compared to reconstruction. Up to 50% if surface treatment.
- 7 to 10 years with surface treatment
- Up to 20 years with HMA overlay

Questions?

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