Performance of Concrete Overlays over Full Depth Reclamation (FDR)

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National Road Research Alliance

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Typical Road Cross Section

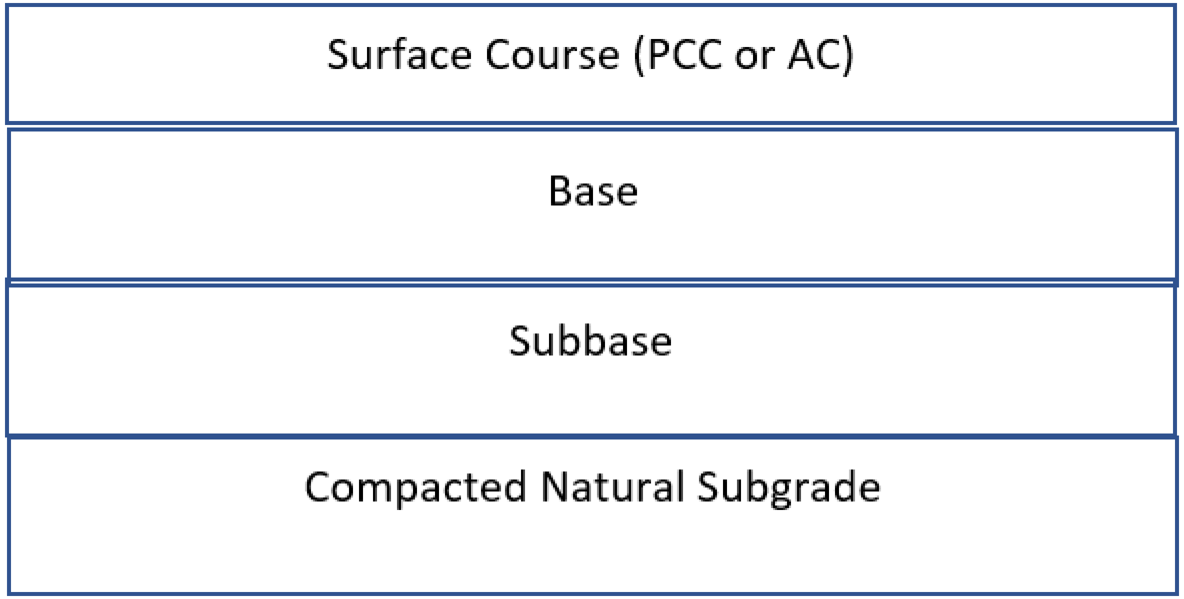


Figure 1. Typical Pavement Structure

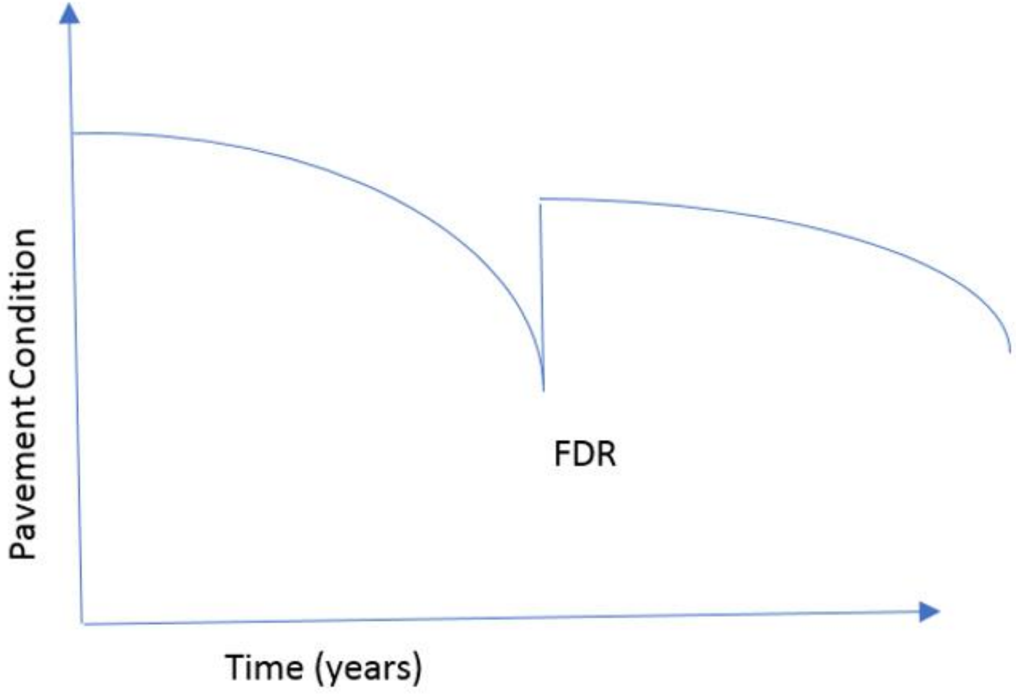


Figure 2. Pavement Service Condition and rehabilitation

Rehabilitation Strategies

Table 1. Comparison of different strategies for rehabilitation of pavement

	Reclamation	Structural Overlay	Removal and Replacement
Fast Construction	Yes	Yes	No
Traffic disruption lower	Yes	Yes	No
Minimal material hauling	Yes	Yes	No
Conserve resource	Yes	Yes	No
Maintain existing elevation	Yes	No	Yes
Low cost	Yes	Yes	No

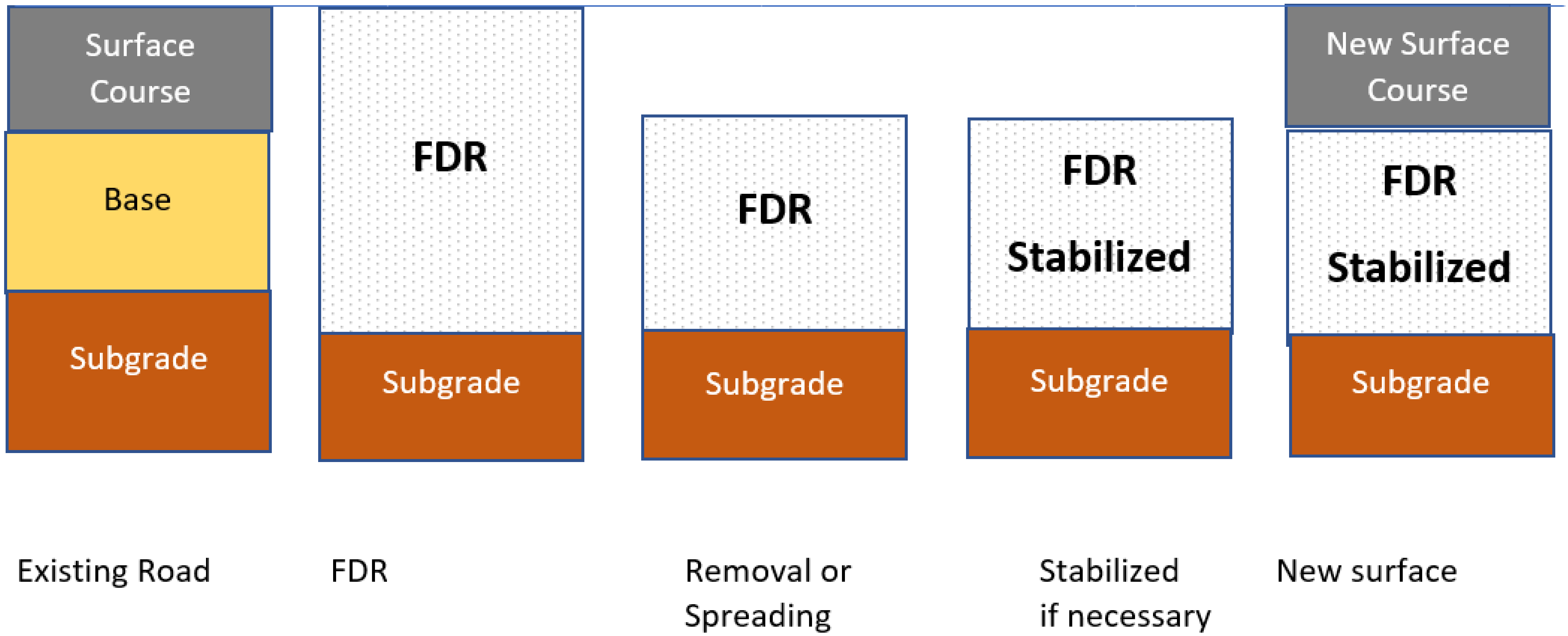
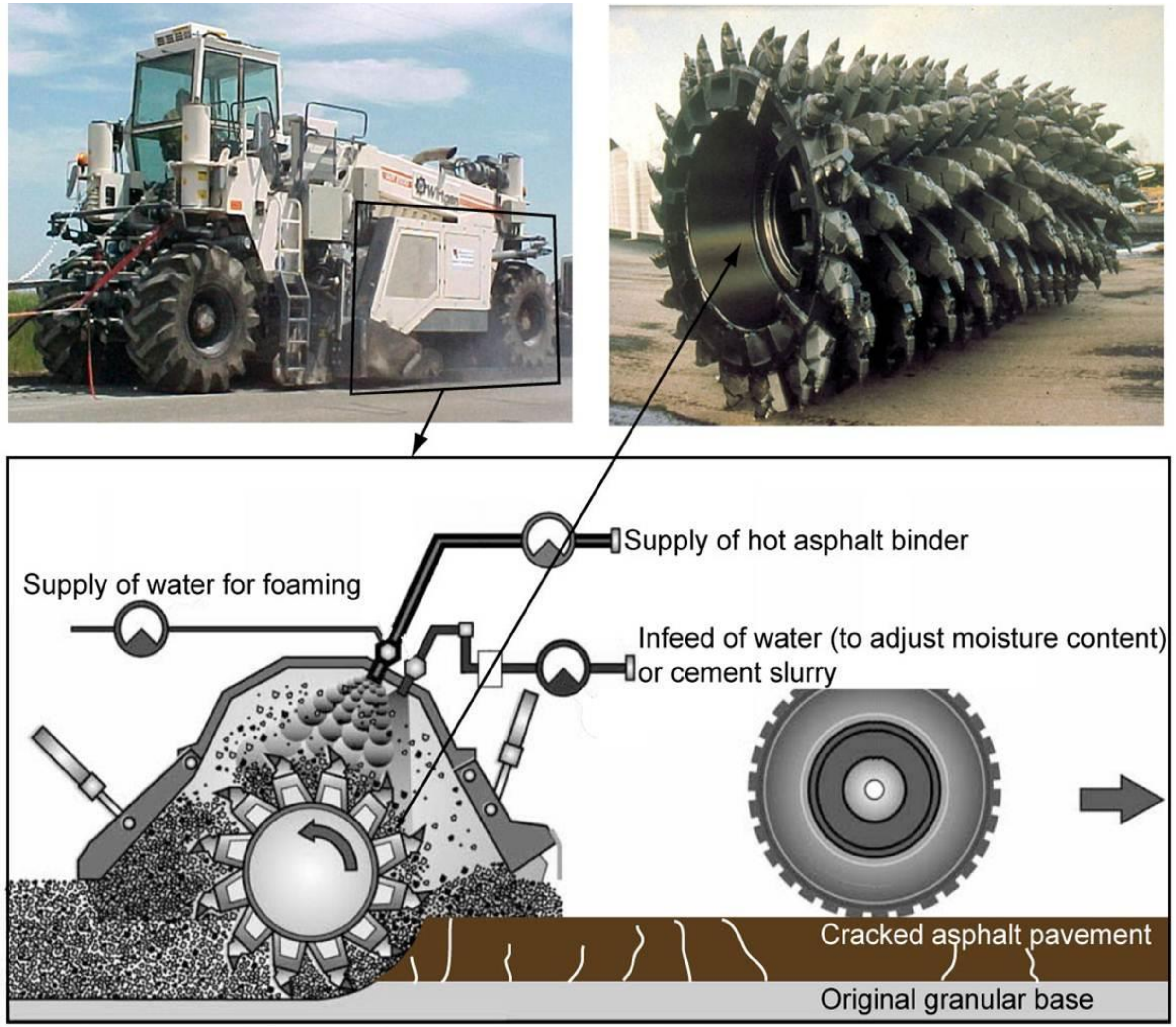
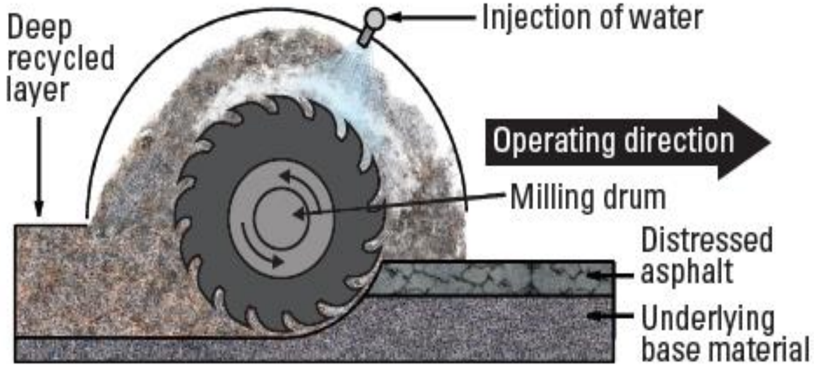


Figure 3. FDR Construction Process


Supply of hot asphalt binder
Supply of water for foaming
Infeed of water (to adjust moisture content)
or cement slurry
Cracked asphalt pavement
Original granular base


Deep
recycled
layer
Injection of water
Operating direction
Milling drum
Distressed
asphalt
Underlying
base material

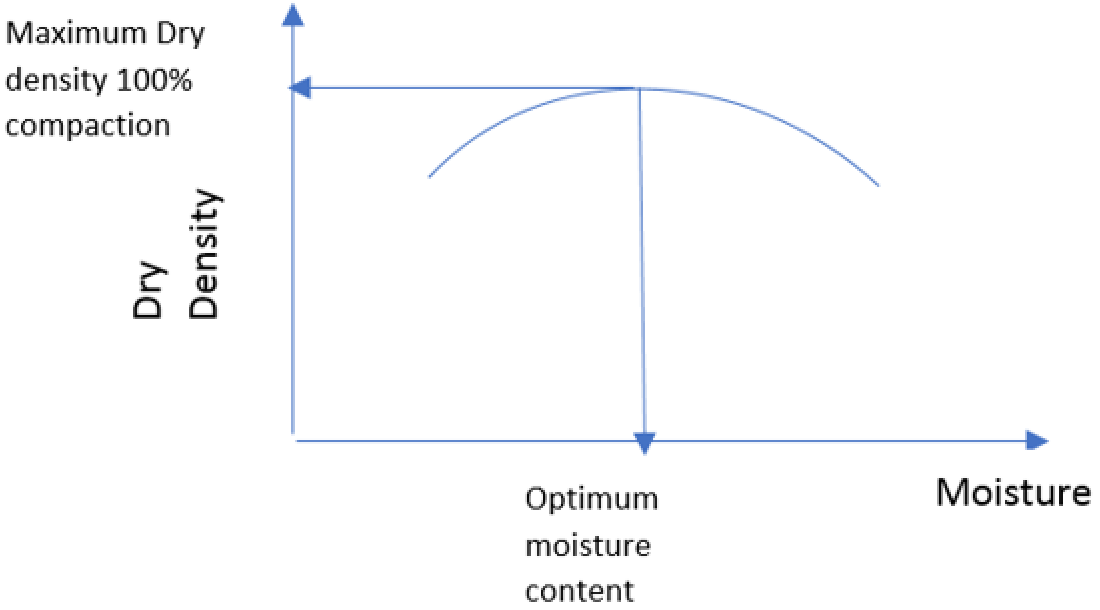


Figure 7. Finding optimum moisture content for maximum dry dens

Figure 6. Final compaction of FDR with tamping roller and smooth wheeled vibrating roller [[4]]

Full Depth Reclamation

- Cost effective
- Increased structural capacity
- Increased durability
- Road geometry can be changed
- Shorter construction schedule
- Early opening to traffic
- Reduced impacts on community during construction
- Reduced environmental impact

Concrete overlays

- Low need for maintenance
- High durability
- Long service life

FDR Types

- Mechanical stabilization (addition of aggregate)
- Chemical stabilization (addition of cement or other stabilization additive)
  - Portland Cement
  - Lime
  - Class C or Class F Fly ash
  - Lime kiln dust
  - Calcium chloride
  - Magnesium chloride
- Bituminous stabilization

Table 4. Weather Limitations [[5]]

Type of Additive	Climatic Limitation for Construction
Lime, Fly Ash or Lime-Fly Ash	Do not perform work when reclaimed material could be frozen. Air temperature in the shade should be no less than 4ºC (39ºF) and rising. Complete stabilization at least one month before the first hard freeze. Two weeks minimum of warm to hot weather is desirable after completing the stabilization work.
Cement or Cement Fly-Ash	Do not perform work when reclaimed material could be frozen. Air temperature in shade should be no less than 4ºC (39ºF) and rising. Complete stabilization should be at least one month before the first hard freeze.
Asphalt Emulsion	Do not perform work when reclaimed material could be frozen. Air temperature in the shade should be no less than 15ºC (59ºF) and rising. Asphalt emulsion stabilization should not be performed if foggy or when other high humidity conditions (humidity >80%). Warm to hot dry weather is preferred for all types of asphalt stabilization involving cold mixtures because of improved binder dispersion and curing.
Calcium Chloride	Do not perform work when reclaimed material could be frozen. Air temperature in shade should be no less than 4ºC (39ºF) and rising. Complete stabilization should be at least one month before the first hard freeze.

Table 2. Correlation of stabilization additive as a function of soil type, percent passing No. 200 sieve and plastic index [[5]]

Percent Passing No.200	Plastic Index	Stabilizer	Soil Type												
			Granular Material								Silt-Clay Material				
											LL<50			LL≥50	
			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
			GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	OL	MH	CH
			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
<25	<6	Bituminous	■	■	■	■	■								
	<10	Cement	■	■	■	■	■	■	■	■					
	>10	Lime								■					
≥	10	Cement				■			■	■	■				
	10-30	Lime								■		■		■	■
	>30	Lime+cement								■		■		■	■

Comparison of Cement Stabilizations

Soil-Cement Type	Cement-Modified Soil (CMS)	Cement-Stabilized Subgrade (CSS)	Cement-Treated Base (CTB)	Full-Depth Reclamation (FDR)
Purpose	• Promotes soil drying • Provides a significant improvement to the working platform • Provides a permanent soil modification (does not leach)	• Provides all the benefits of CMS plus the following: - Potentially allows for a reduction in pavement thickness or increased pavement life - Increases the bearing capacity for building slabs, footings, and other structural elements	• Provides a strong, frost-resistant base layer for asphalt or concrete pavements	• Provides a strong, frost-resistant base layer for asphalt or concrete pavements
Materials	• Primarily fine-grained soils • 2%–4% cement	• Primarily fine-grained soils • 3%–6% cement	• Primarily coarse-grained manufactured materials • 3%–6% cement	• Pulverized asphalt blended with existing pavement base, subbase, and/or subgrade • 3%–6% cement
Material Properties	• Reduced moisture susceptibility	• 100–300 psi (0.7–2.1 MPa) seven-day compressive strength	• 300–600 psi (2.1–4.1 MPa) seven-day compressive strength	• 300–600 psi (2.1–4.1 MPa) seven-day compressive strength
Construction Practices	• Minimum 95% of maximum density • Mixed in place	• Minimum 95% of maximum density • Mixed in place	• Minimum 95%–98% of maximum density • Mixed in place or at a plant	• Minimum 95%–98% of maximum density • Typically mixed in place

Quality Control of FDR During Construction

- Sieve Analysis (ASTM D 422 C136)
- Atterberg limits (ASTM D4318):.
- Moisture Density (ASTM D558):
- Compressive Strength (ASTM D1633)

Performance analysis of pavements (FDR + Concrete Overlay)

- FDR performance
- Concrete Overlay performance

FDR Performance

- Compressive strength (if stabilized and cored)
- Thickness (if cored)
- DCP Value (core hole or shoulder)
- Ground Penetrating Radar
- Sample from shoulder for gradation

Concrete Overlay Performance

- Compressive Strength & Thickness measurement(if cored)
- Joint layout and faulting Crack mapping (visual) and width measurement (D cracking, fatigue cracking, crack reflection etc.)
- Falling Weight Deflectometer
- Ground Penetrating Radar

Coring

Compressive strength FDR (if stabilized) and pavement

Each core will be measured to the nearest ¼-in. Cores will be cut with a 4 or 6-in. diameter bit,

After coring pavement, DCP (Dynamic Cone Penetrometer) test will be applied on FDR and subgrade layer.

3 cores will be taken for strength measurement. 2-3 cores will be taken from cracked areas. The crack propagation to FDR layer will be investigated.

Thickness of the concrete pavement will be measured at three different sides of the core and average will be taken.

2. Thickness measurement

The thickness measurement will be done visually after coring. (If the core is intact from the core , if not from dredged material from the core hole.) If high PH stabilizers are used phenolphthalein will be used to identify the depth.

3. GPR(Ground Penetrating Radar)

GPR analysis will provide the following information about the pavement:

1. Road surface depressions
2. Voids or anomalies
3. Pavement and subgrade thicknesses

4. Concrete Pavement Distress Assessments

Surface Defects

Surface delamination

Material related cracks: (visually)

Transverse and Diagonal Cracking

Longitudinal Cracking

Corner Cracking

Faulting

Joint Curling and Warping

Blowups

Subgrades and Base Support Conditions

5. Falling Weight Deflectometer

Table 8. Recommended FWD Loading for PCC Pavements[[18]

Height Designation	Target Load (kN (lbf))	No. of PCC Drops
Seating[b]	N/A	3
1[c]	26.7 (6,000)	N/A
2	40.0 (9,000)	4
3	53.4 (12,000)	4
4	71.2 (16,000)	4

Table 9. Sensor Locations for PCC Pavements[[18]]

Deflection Sensor	Seven Sensors (PCC) (mm (inches))
D1	0
D2	−305 (−12)
D3	305 (12)
D4	457 (18)
D5	610 (24)
D6	914 (36)
D7	1,524 (60)
D8	N/A
D9	N/A

Table 10. Summary of testing for PCC Pavements [[18]]

Testing Component	PCC Pavements Recommendation
Sensor configuration, mm (inches)	0, 203, 305, 457, 610, 914, 1,219, 1,524, −305 (0, 8, 12, 18, 24, 36, 48, 60, −12)
Load level, kN (lbf)	Seating, 40.0 and 53.4 (9,000 and 12,000)
Number of drops	One for seating, 9,000- and 12,000-lbf (40- to 15.2-kN) load levels
Testing locations	• Testing in outer traffic lane on multiple lane facilities • Possible directionally staggered testing on two-lane facilities • Midlane, outer wheelpath, and transverse joint
Testing increments, general	12 to 15 tests per uniform pavement section, at 30.5- to 152.4-m (100- to 500-ft) intervals
Testing increments, project level	25- to 50-ft (7.62- to 15.24-m) intervals
Temperature measurements, air and surface	Measure at each test location

Table 11. Summary of tests

Testing	Units (estimate)
Compressive & Density Testing	30 specimens 3 concrete 3 FDR if bounded
GPR	5hours per site 5 different sites
FWD	5hours per site 5 different sites
Crack and fault mapping	5 different sites

Candidate Projects (not stabilized)

Minnesota (all unbound FDR + concrete overlay)

Wabasha CSAH 2 & 25 (2015)

- Average FDR Thickness 12inch
- Concrete Pavement thickness 7.5inch 5miles, 8 inch for 0.6 miles
- Doweled joints
- 3.6 miles on CSAH 25 and 2 miles CSAH 2

Rice CSAH 46 (2016)-(2020 October) Still under construction

- 8 inch?

Fillmore CSAH 1 (2018)

The Freeborn County Road 46(2008)

- 5.9 miles
- 7.5 inch concrete pavement
- Dowels on the wheel paths
- Joints spaced 15feet

Candidate Projects (Fly Ash Stabilized)

Wisconsin

- STH 100(Fly ash FDR + Concrete Overlay)

o 12 inch Fly ash stabilized (previous pavement 8 inch concrete + 6 inch base)

o 6 inch concrete pavement

Candidate Projects (Cement Stabilized)

Wyoming

- City of Sheridan, 2003, (Cement stabilization + Concrete overlay 3.5inch)

Candidate Projects (Cement Stabilized + RCC)

- **Texas**
- TxDOT San Angelo District, Leakey, TX (October 2016)
- US83 – 8” RCC and 8” FDR with cement
- RR377 – 7.5” RCC and 8” FDR with cement stabilization
- City of Haslet, TX (August- September 2018)
- Brentwood Lane, Cedar Lane, Second Place, First Place, Odessa Drive, Schreiber Drive, Berry Drive\
Cement stabilization + Concrete overlays 6inch

Candidate Projects (Cement FDR + RCC)

- California Roseville
- RCC 5.5 inch – 600psi
- Truck per day 20, design year 20
- Subgrade 2800psi Modulus
- Cement stabilized layer 8 inch , 360.000psi Modulus

Candidate Projects (ECB + Concrete Pavement)

Lyon County US 75 MP 151.98 to 153.07 1977 – resurfaced 2008.

Taylor County IA 2 MP 56.84 to 70.00 1978 – resurfaced various sections in 2006 -2010 & 2012

ECB 4 inch (Recycled concrete used as aggregate)

Concrete pavement thickness 10inch