Recycling Pavement– It is in the INDOT Pavement Design Toolbox

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Presentation Agenda

- INDOT Pavement Design History and Future with Pavement Recycling
- Pavement Recycling Options
- General Criteria for Good Project Candidates for Pavement Recycling
- Pavement Recycling Design Inputs and Issues
- INDOT Project Case Studies: What Went Well and Some Lessons Learned

Cold Pavement Recycling Processes

		
Full Depth Reclamation (FDR) Typical Depth: 5 - 12 inches Stabilizer: Emulsified/ Foamed Asphalt or Portland Cement	Cold In-place Recycle (CIR) Typical Depth: 3 – 5 inches Stabilizer: Emulsified/ Foamed Asphalt	Cold Central Plant Recycle (CCPR) Typical Depth: 3 - 6 inches Stabilizer: Emulsified/ Foamed Asphalt
Agency Usage: - Alternative to Reconstruction	Agency Usage: - Alternative to Deep Mill and Fill or Partial Depth Patching	Agency Usage: - Structural Base Layer - Alternative to Deep Mill and Fill

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INDOT Recycling Projects

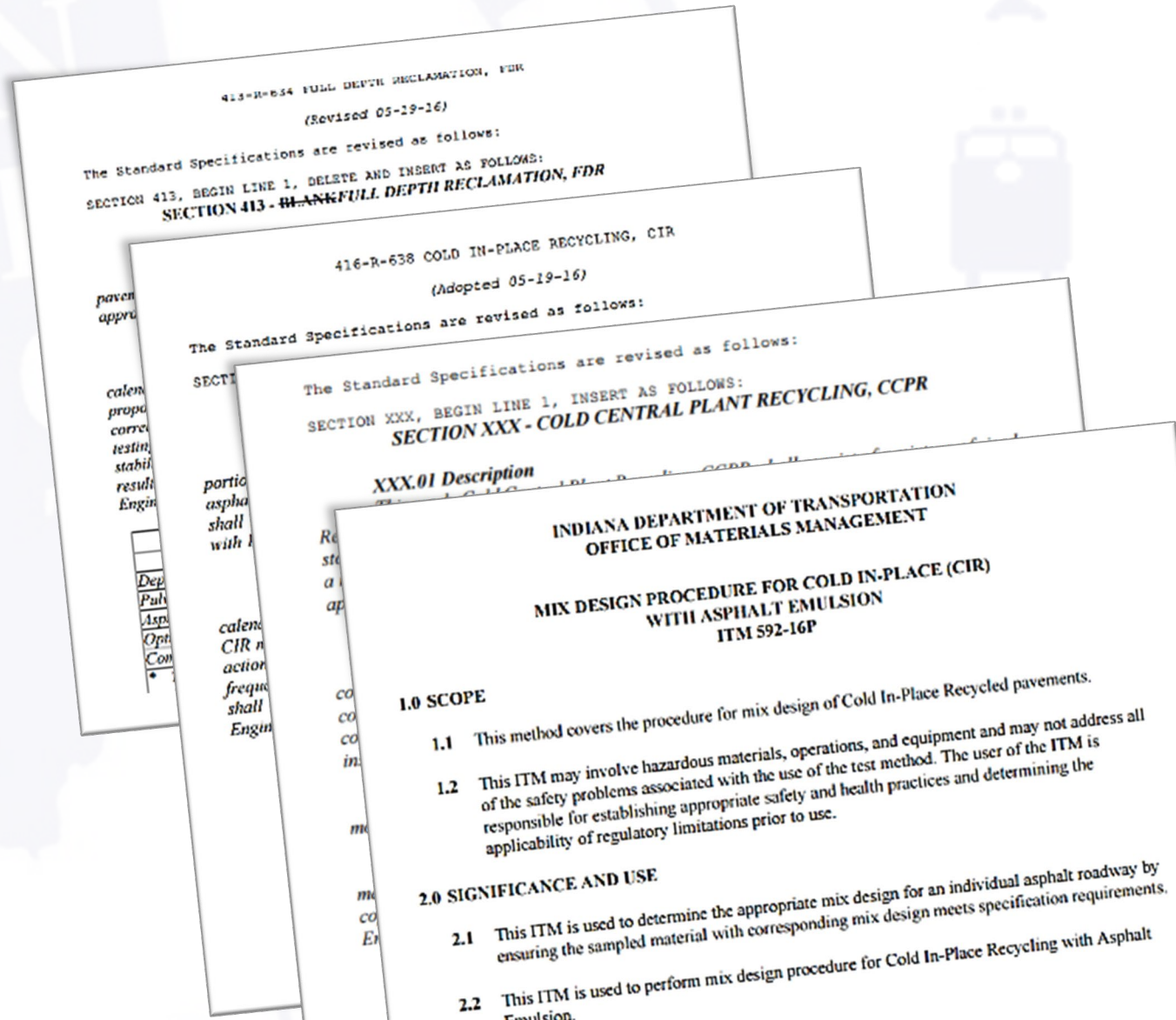
FDR	CIR	CCPR
 20+	 15	 5
Completed Projects: SR 38 SR 227 SR 26* SR 26 SR 236 SR 38* SR 1 SR 18 I-74 Shoulders SR 28 SR 59 SR 129 SR 65 SR 236* SR 244 SR 327 SR 101 SR 14 SR 1 SR 55*	**Completed Projects:** US 40 SR 32 US 421 US 30 SR 234 SR 14 US 35 SR 149 SR 38 SR 5 SR 26 SR 39* SR 3* SR 4 US 231*	**Completed Projects:** SR 101 US 421 SR 236* SR 55* SR 38*

Why Recycle?

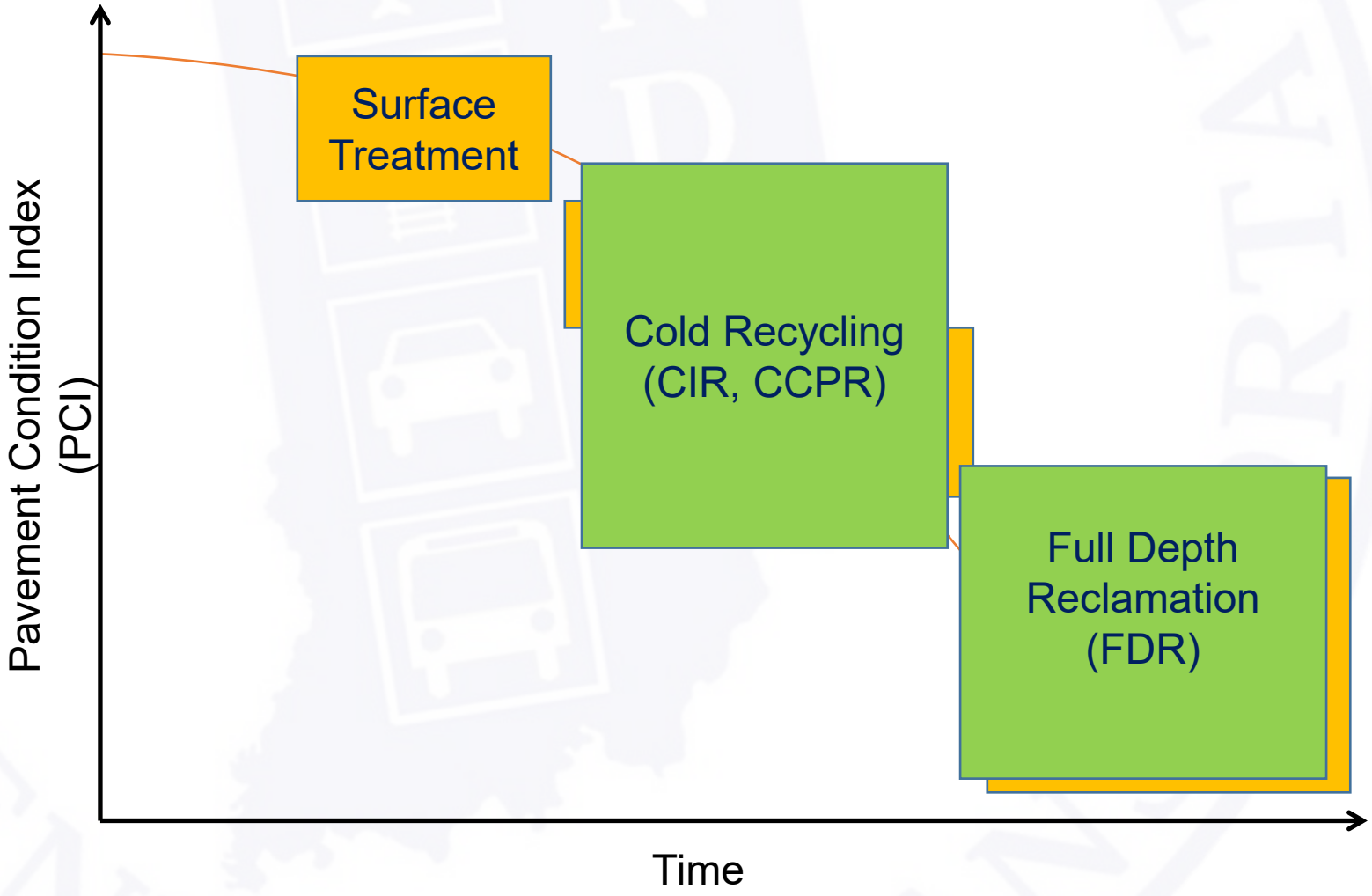
- Provides additional rehabilitation techniques for existing roadways
- Reuse and conservation of nonrenewable natural resources
- Reduce landfilling or stock-piling material
- Reduced trucking and energy conservation
- Cost savings realized by agencies

Specification Development

- Information Gathering
  - ARRA Guidelines
  - DOT Specifications
  - Working with existing industry
- Standard Specifications
  - SECTION 307 – CEMENT STABILIZED FULL DEPTH RECLAMATION, FDR
  - SECTION 308 – ASPHALT EMULSION STABILIZED FULL DEPTH RECLAMATION, FDR
  - SECTION 416 - COLD IN-PLACE RECYCLING, CIR
  - SECTION 417 - COLD CENTRAL PLANT RECYCLING, CCPR
- Iterations
  - Separating Cement and Emulsion FDR Specs
  - Just In Time Training
  - Quality Control
- Mix Designs
  - Creation of Indiana Test Method (ITM)



Treatment Selection with Recycling

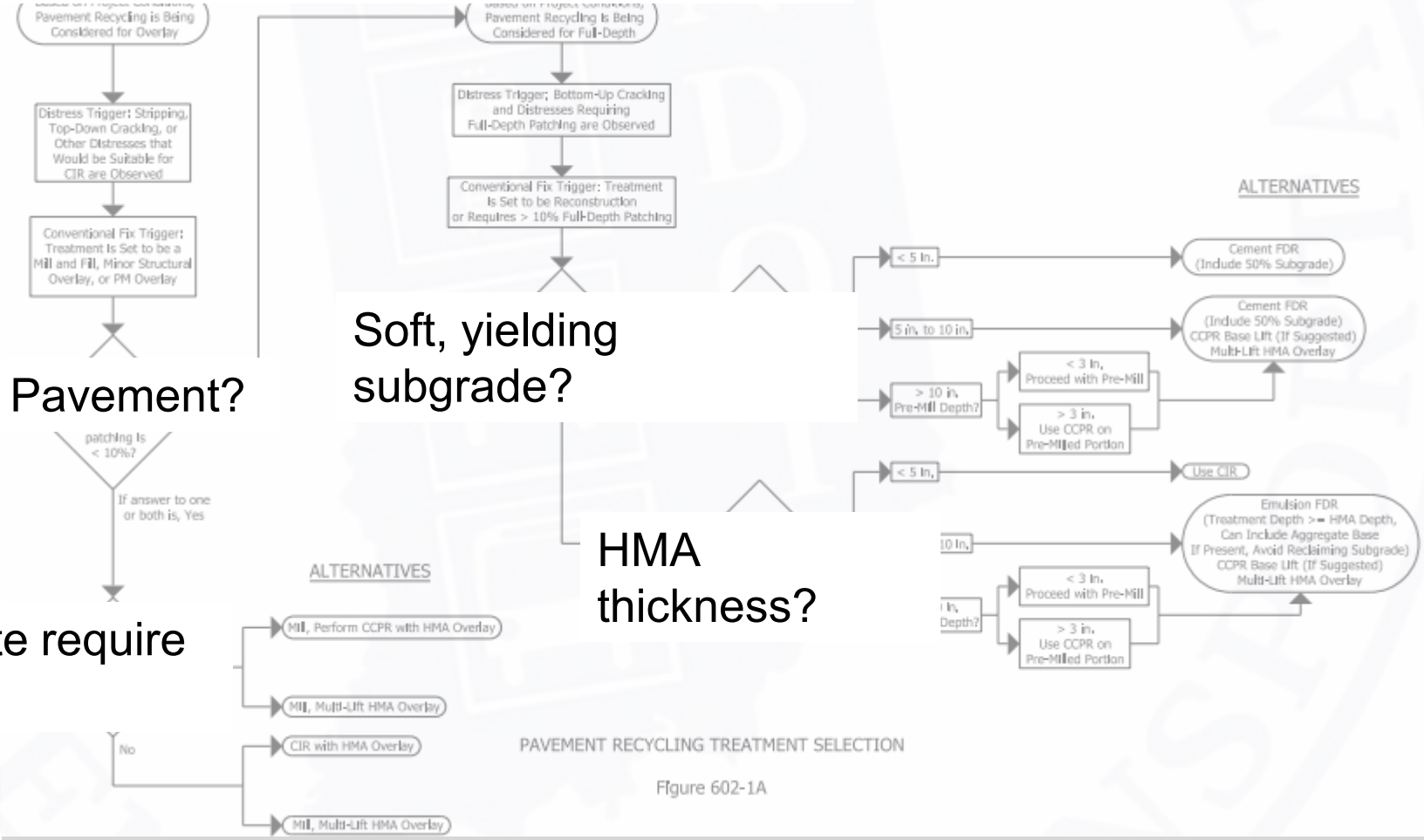


Project Scoping Decisions

Top-down cracking, Surface distresses

VS.

Full Depth cracking and subgrade-related distresses



Composite Pavement?

Soft, yielding subgrade?

HMA thickness?

Does concrete require attention?

INDOT Design Manual Chapter 602: Project Categories and Pavement Types

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When should FDR be considered

- Pavement at end-of-life cycle
- Alternative to roadway reconstruction
- When planned full depth patching is 10% or greater of the existing pavement area
- Widening to improve pavement edge support (2 to 3 ft on each side of roadway)
- Asphalt roadways only – FDR can’t be used on composite (HMA over PCCP) pavements

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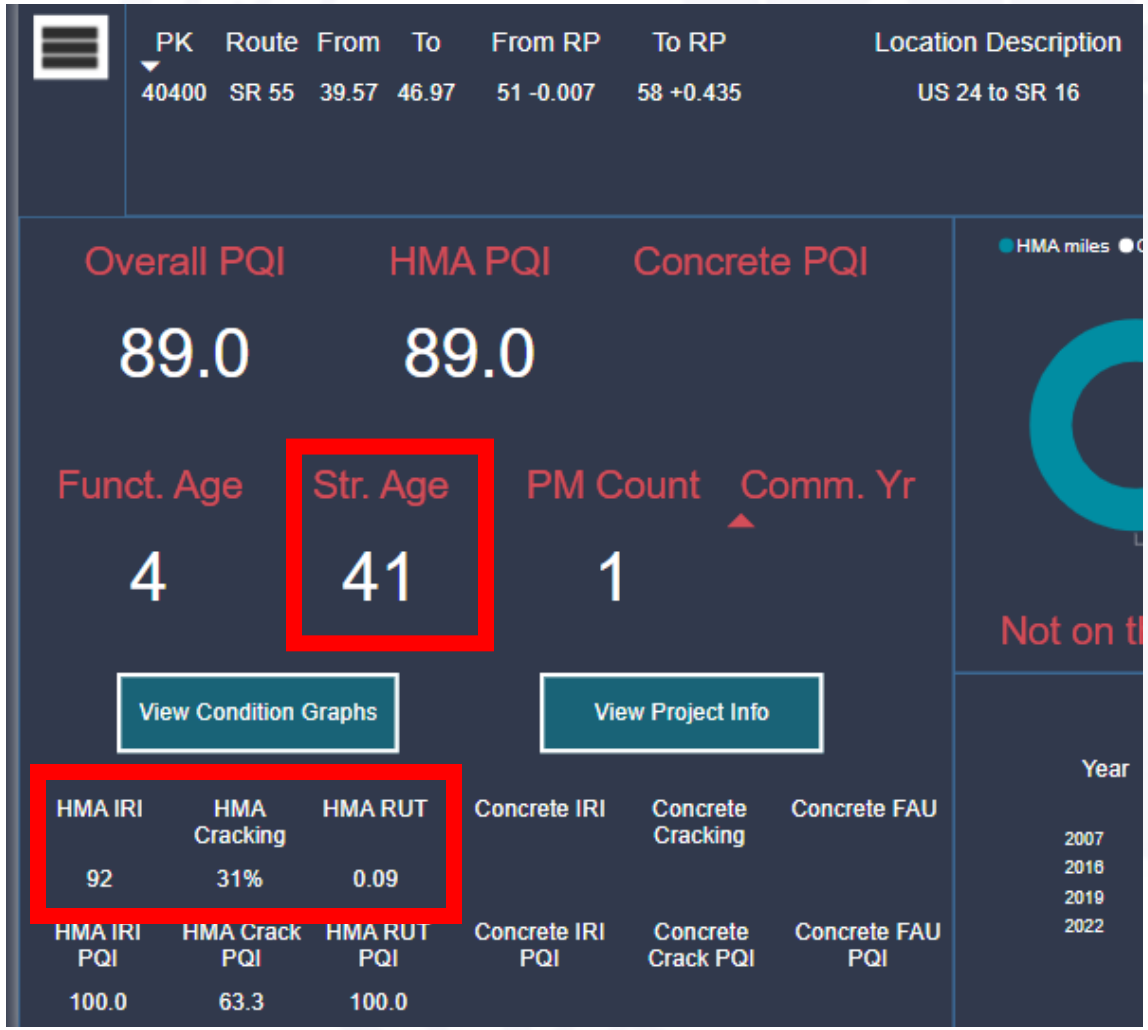
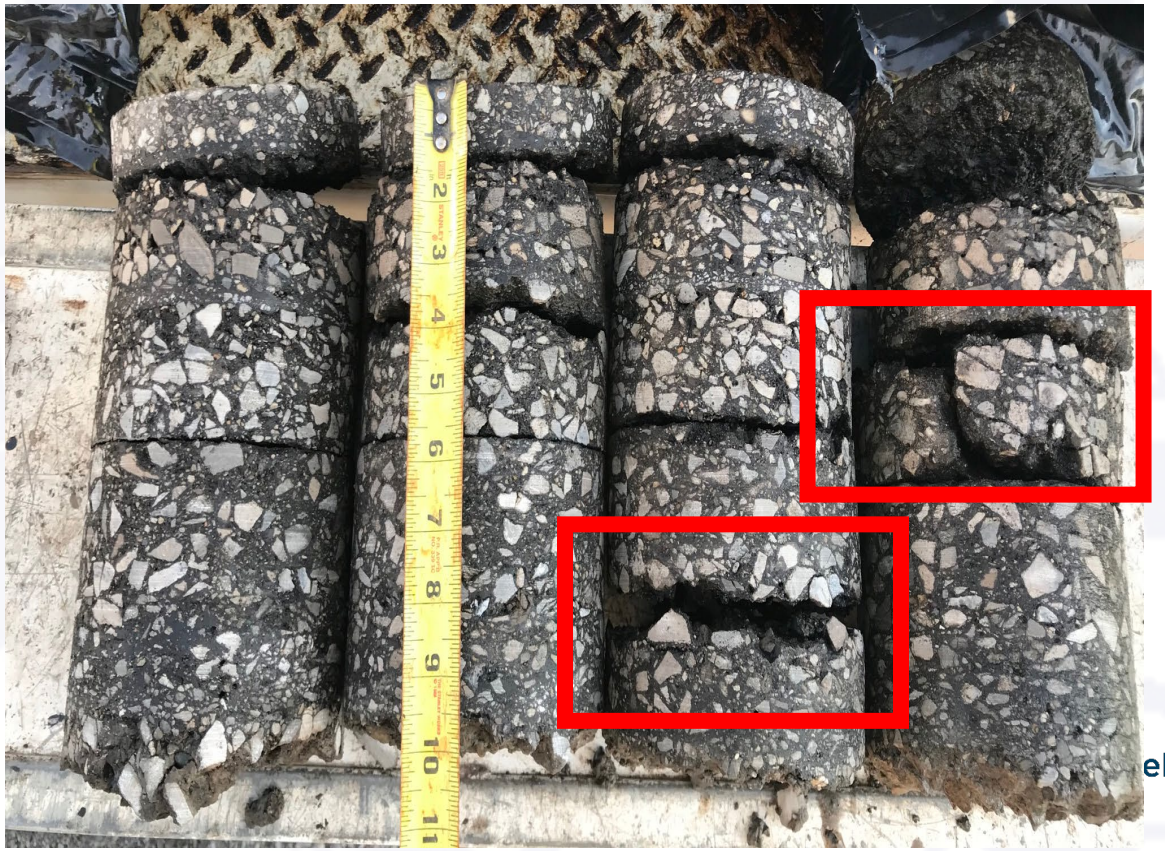
Tools to determine if FDR is the right treatment

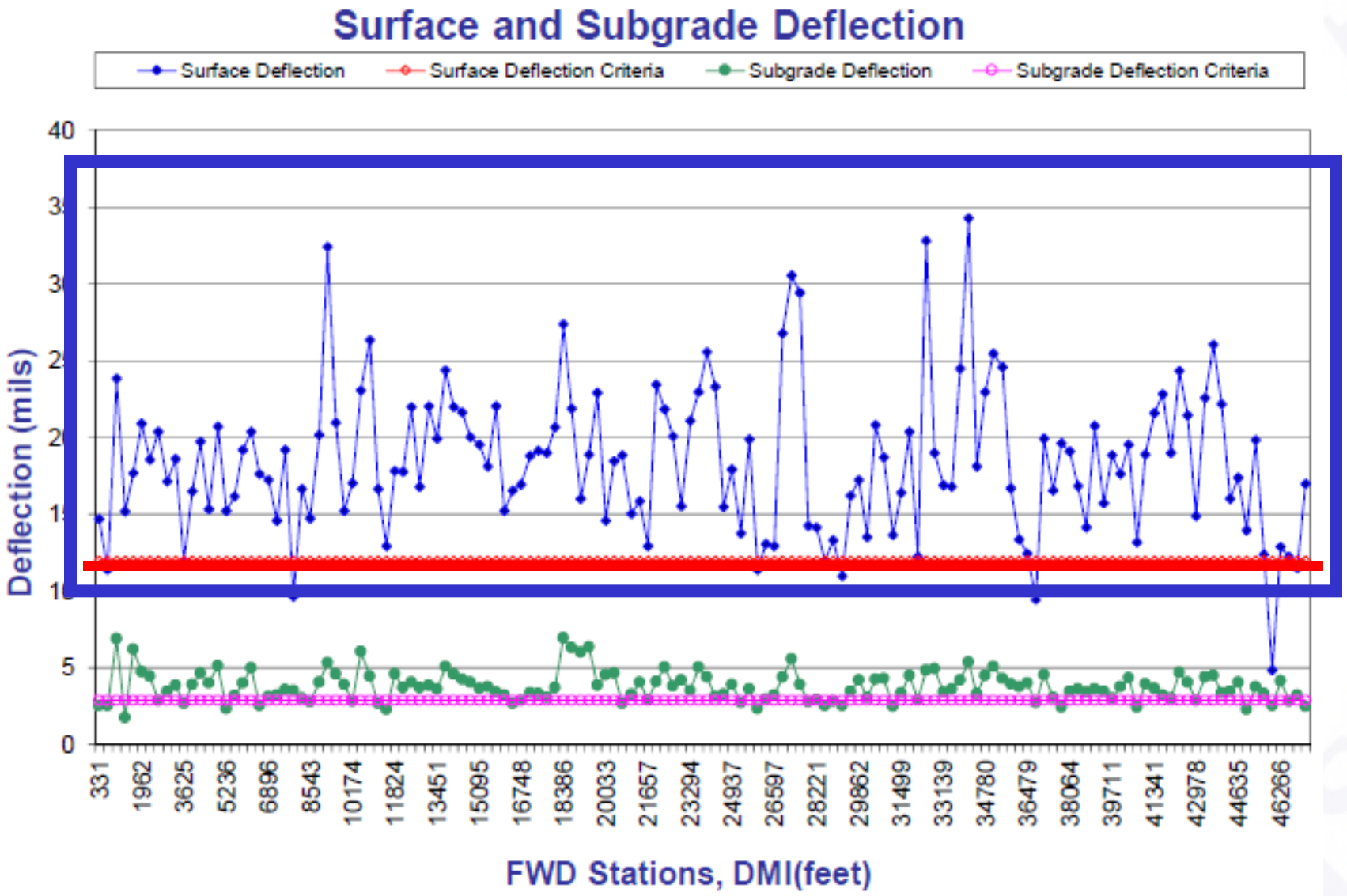
- Pavement Condition Data (provided by INDOT Asset Management)



- Pavement Cores (provided by INDOT Geotech) – Look for Distress below 4 inches from the surface



Tools to determine if FDR is the right treatment



- Falling Weight Deflectometer (provided by INDOT Asset Management/ Research)
- Blue dots represent the deflection at the surface
- Red line represents the maximum deflection for sufficient structural capacity for the roadway classification

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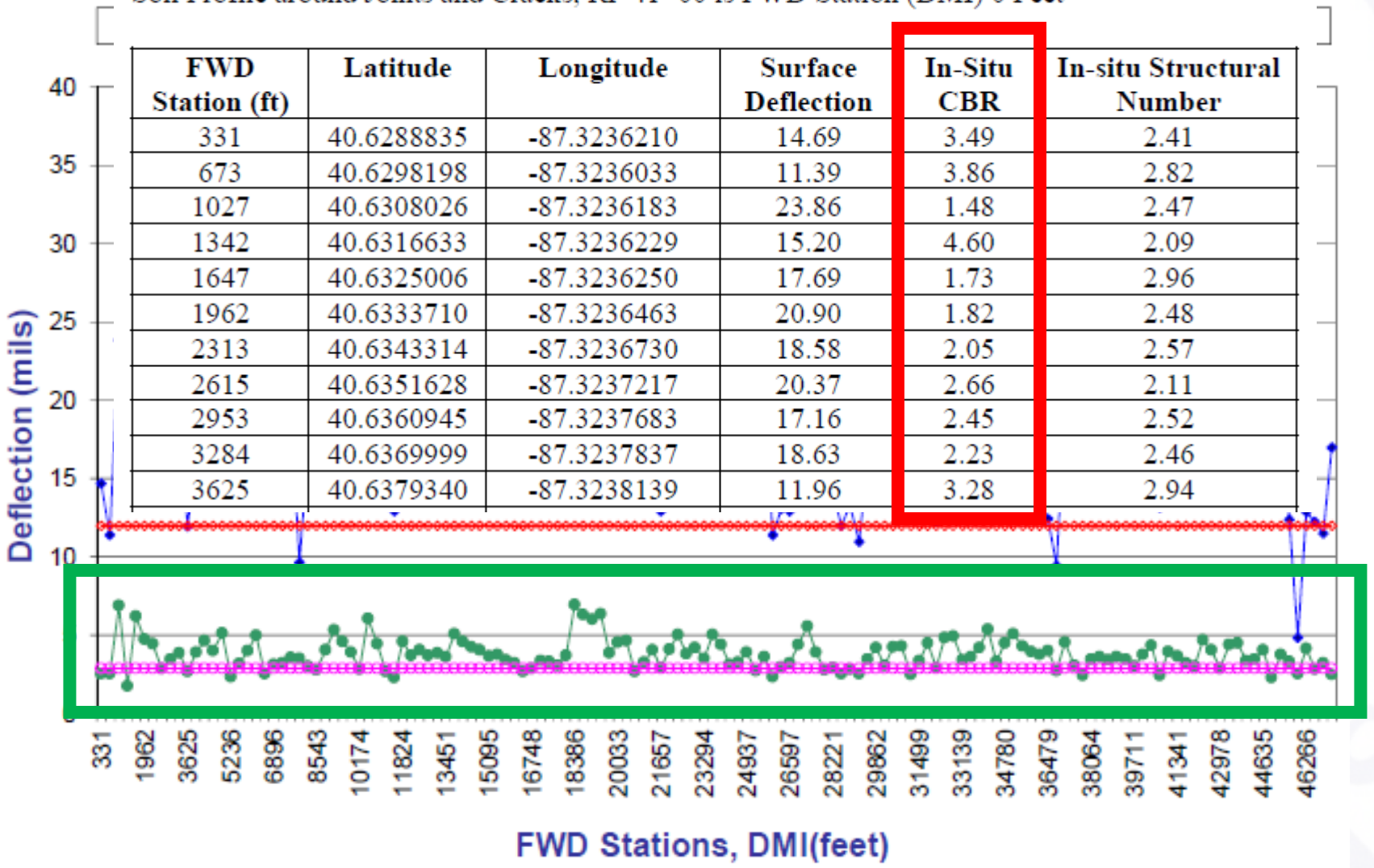
Tools to determine if FDR is the right treatment

Soil Profile around Joints and Cracks, RP 41+00 is FWD Station (DMI) 0 Feet

FWD Station (ft)	Latitude	Longitude	Surface Deflection	In-Situ CBR	In-situ Structural Number
331	40.6288835	-87.3236210	14.69	3.49	2.41
673	40.6298198	-87.3236033	11.39	3.86	2.82
1027	40.6308026	-87.3236183	23.86	1.48	2.47
1342	40.6316633	-87.3236229	15.20	4.60	2.09
1647	40.6325006	-87.3236250	17.69	1.73	2.96
1962	40.6333710	-87.3236463	20.90	1.82	2.48
2313	40.6343314	-87.3236730	18.58	2.05	2.57
2615	40.6351628	-87.3237217	20.37	2.66	2.11
2953	40.6360945	-87.3237683	17.16	2.45	2.52
3284	40.6369999	-87.3237837	18.63	2.23	2.46
3625	40.6379340	-87.3238139	11.96	3.28	2.94



- Green dots represent the deflections at the subgrade
- A CBR above 6 is desirable
- FWD is an important tool to determine if failures are due to subgrade or asphalt layers

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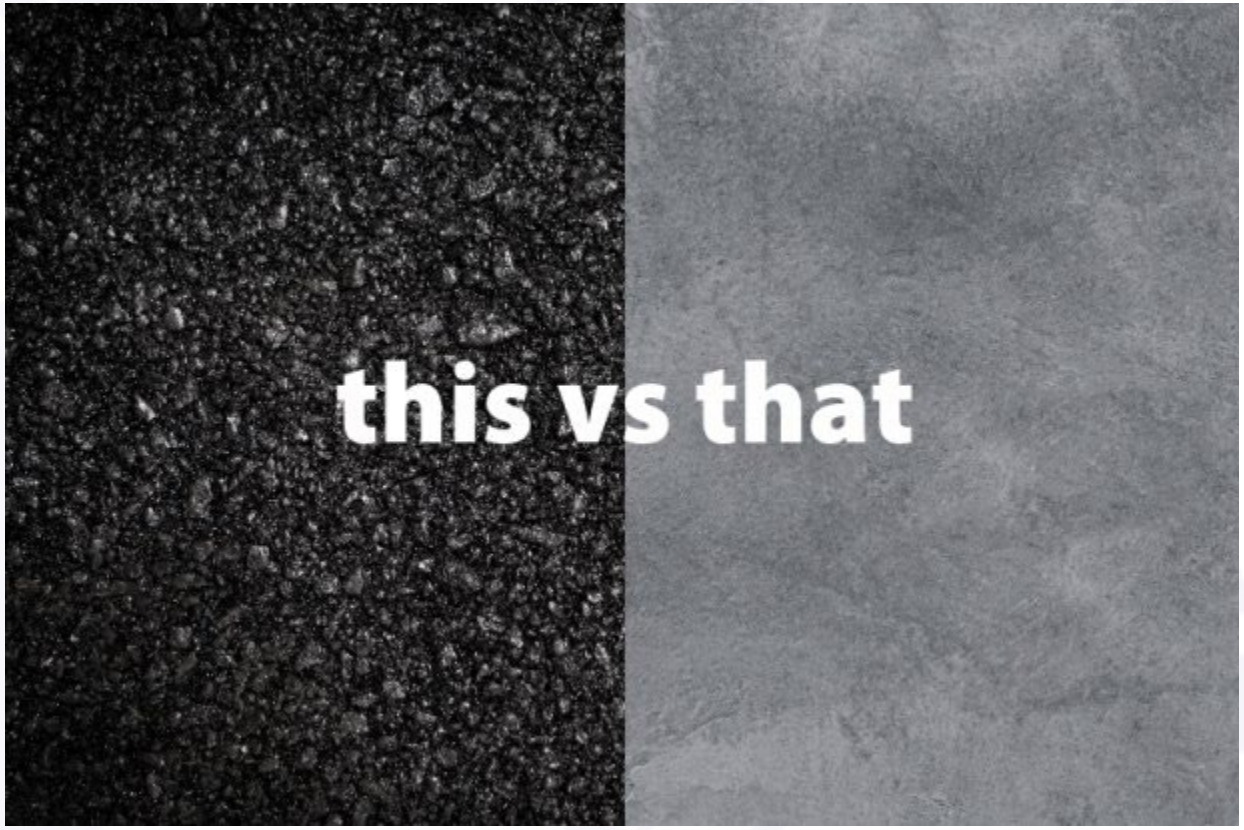
Selection of FDR Stabilization Agent

- FDR has two separate specifications with different stabilization agents
- SECTION 307 – CEMENT STABILIZED FULL DEPTH RECLAMATION, FDR
- SECTION 308 – ASPHALT EMULSION STABILIZED FULL DEPTH RECLAMATION, FDR
- FWD information is used to determine which stabilization agent



Selection of FDR Stabilization Agent

- SECTION 307 – CEMENT STABILIZED FULL DEPTH RECLAMATION, FDR
- Address both asphalt layers and subgrade layers
- Thickness 10” or 12”
- Gradation requirements – Maximum of 50 % RAP and 50% Subgrade. Prefers more subgrade soils
- Often requires a deep mill before the FDR to remove RAP to include more subgrade soils

Selection of FDR Stabilization Agent

- SECTION 308 – ASPHALT EMULSION STABILIZED FULL DEPTH RECLAMATION, FDR
- Address just asphalt layers
- Thickness 8” or 10”
- Gradation requirements – Maximum of 80 % RAP and 20% Aggregate Base. 95+% RAP is preferred.
- 0.5 % to 1.0 % - cement additive may be used with the emulsion - see specific pavement design if required

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Modeling FDR Layers in MEPDG

- Cement FDR –
  - Subgrade Soil type A-1-B
  - Resilient Modulus of 40,000 psi to 60,000 psi. More subgrade less strength
- Emulsion FDR –
  - NonStabilized Crushed Stone
  - Resilient Modulus of 80,000 psi
- Annual representative value option used
- Resilient modulus value for FDR based on FWD testing of previously completed projects

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Fort Wayne, 3, 64, SURFACE, 9.5 mm	2.0
Flexible	Cold Central Plant Recycling	6.0
Subgrade	Cement Stablized FDR (A -1-b)	12.0
Subgrade	Natural Subgrade (A-4)	Semi-infinite

Layer 3 Subgrade : Cement Stablized FDR (A-1-b)

Unbound	
Layer thickness (in)	12.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
40000.0

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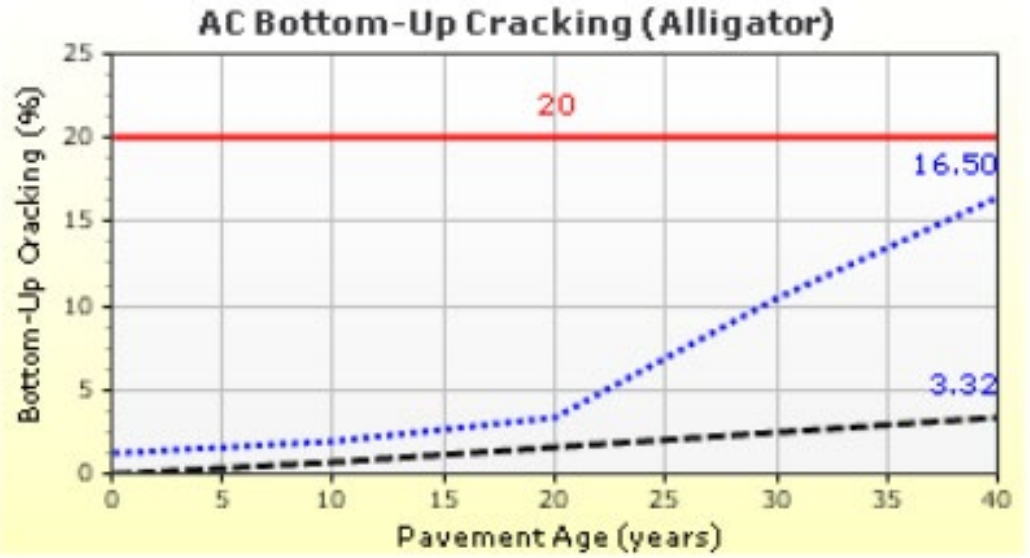
Modeling FDR Layers in MEPDG

- Minimum 15 years of structural design life (often more)
- Minimum 2 HMA or 1 HMA + 1 CCPR layers required for smoothness
- The limiting factor for the design life of FDR is typically the HMA overlay thickness and not the FDR itself
- Can increase overlay thickness to improve structural design life

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Crawfordsville PG 70-22, 9.5mm	1.5
Flexible	Crawfordsville PG 70-22, 19.0mm	2.5
Flexible	Cold Central Plant Recycling	6.0
NonStabilized	FDR w/ Cement	10.0
Subgrade	Natural Subgrade (A-6)	Semi-infinite



Roadway Design Considerations

- Edge Support –
  - Remove any existing material and provide 1-ft additional width beyond the paved shoulder on each side of the roadway for stabilization with FDR
- Widening –
  - Do not include existing aggregate or earth shoulders
  - Excavate and remove existing materials
  - Use Corrective Aggregate to fill in the excavated area. Often will use millings if the pavement is milled before the FDR.

- Quantities
  - **Stabilizing Material, Portland Cement** = 0.75 (convention factor) x 12 in (FDR depth) x 120 lbs/cft (typical density) x 0.07 (estimated % stabilizing material) = 75.6 lbs/sys

OR

  - **Stabilizing Material, Asphalt Emulsion**= 0.75 (convention factor) x 10 in (FDR depth) x 115 lbs/cft (typical density) x 0.03 (estimated % stabilizing material) = 25.9 lbs/sys

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Roadway Design Considerations

- Quantities Continued
  - Both Cement and Emulsion FDR projects will include all pay items below
  - The **Full Depth Reclamation** pay item quantity is based on the entire area that will be stabilized, include the existing pavement area and any proposed widening.
  - **Corrective Aggregate, FDR** - will be needed for supplemental material adjacent to the existing pavement for widening completed with FDR. Replace any excavated areas for the widening with the corrective aggregate. Treat the corrective aggregate as No. 53 material when converting the volume to tons.
    - If no widening is planned include 200 tons as undistributed
  - **Milling, Scarification** - after the FDR has cured (before HMA Overlay) to remove any swelling of material volume during FDR operations. Do not mill more than 0.5” in depth
  - **Asphalt for Tack Coat** - applied to the milled FDR before the HMA overlay

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When should Cold Central Plant Recycling (CCPR) be considered

- CCPR can be used when an existing pavement cannot be in-place recycled or must be removed to allow treatment of underlying materials
- CCPR is used for structural base layer
- Combines well with Cement FDR projects or deep mill and fill overlays
- WHY – to reduce the cost of reconstruction and reuse the materials already owned by the agency

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Tools to determine if CCPR is the right treatment

- Can be used anywhere in place of an HMA Base or Intermediate layer
- Generally, to achieve the same structure, an HMA layer can be replaced by a CCPR layer that is 25% thicker (eg. 1” hot mix ~1.25” CCPR)
- Constraints for CCPR usage
  - RAP Availability - Will the project create a large amount of RAP
  - Weather – Shorter paving season, requires to be placed between May to October
  - Cure Time – Needs time to cure and release moisture from the emulsion. Adds time to construction schedule
  - MOT – OK for traffic before surface, but want to limit heavy trucks

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Modeling CCPR Layers in MEPDG

- Thickness 4” to 6”
  - 5” preferred
  - 6” requires the CCPR to be placed in two separate lifts
- Use Flexible Layer Type
  - Level 1 inputs
  - Uses Dynamic Modulus values from APT
- Contact INDOT Pavement Engineering for CCPR XML input for file
- Design life can vary depending on project scope, but a minimum of 10 years

Design Structure

Layer type	Material Type	Thickness (in)
Flexible	Fort Wayne, 3, 64, SURFACE, 9.5 mm	2.0
Flexible	Cold Central Plant Recycling	6.0
Subgrade	Cement Stabilized FDR (A-1-b)	12.0
Subgrade	Natural Subgrade (A-4)	Semi-infinite

Layer 2 Flexible : Cold Central Plant Recycling

Asphalt		
Thickness (in.)	6.0	
Unit weight (pcf)	143.8	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 1)

T (°F)	0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
40	532000	652000	705000	839000	897000	973000
70	193000	267000	302000	406000	455000	521000
100	61000	93000	109000	165000	196000	237000
130	28000	39000	46000	67000	80000	100000

Roadway Design Considerations

- Quantities
  - Use pay item numbers that start with 417
  - **Stabilizing Material, Asphalt Emulsion** = 0.75 (convention factor) x 5 in (CCPR depth) x 115 lbs/cft (typical density) x 0.03 (estimated % stabilizing material) = 12.9 lbs/sys
  - The **Cold Central Plant Recycling** pay item quantity is based on the entire area that will be stabilized, include the existing pavement area and any proposed widening.
  - **Corrective Aggregate, CCPR**– Generally not required but include 200 tons as undistributed
  - **Milling, Scarification** - after the CCPR has cured (before HMA Overlay) to improve bonding between layers
  - **Asphalt for Tack Coat** - applied to the milled CCPR before the HMA overlay

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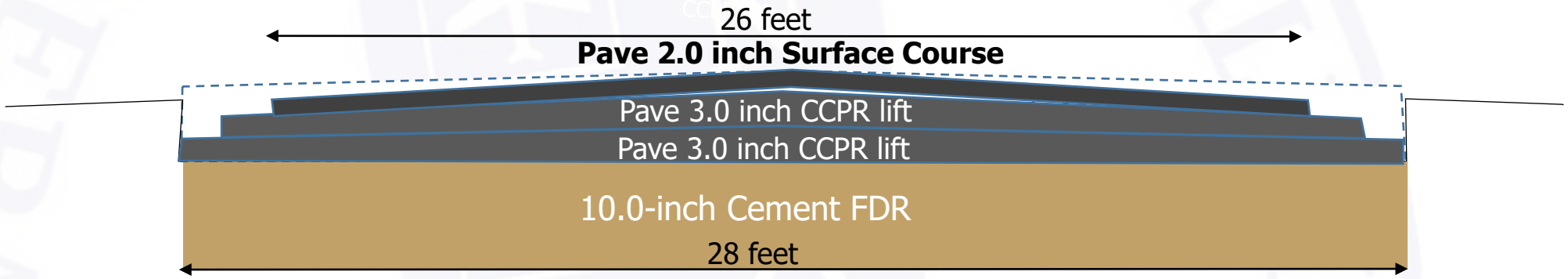
Example Cross Section with FDR and CCPR



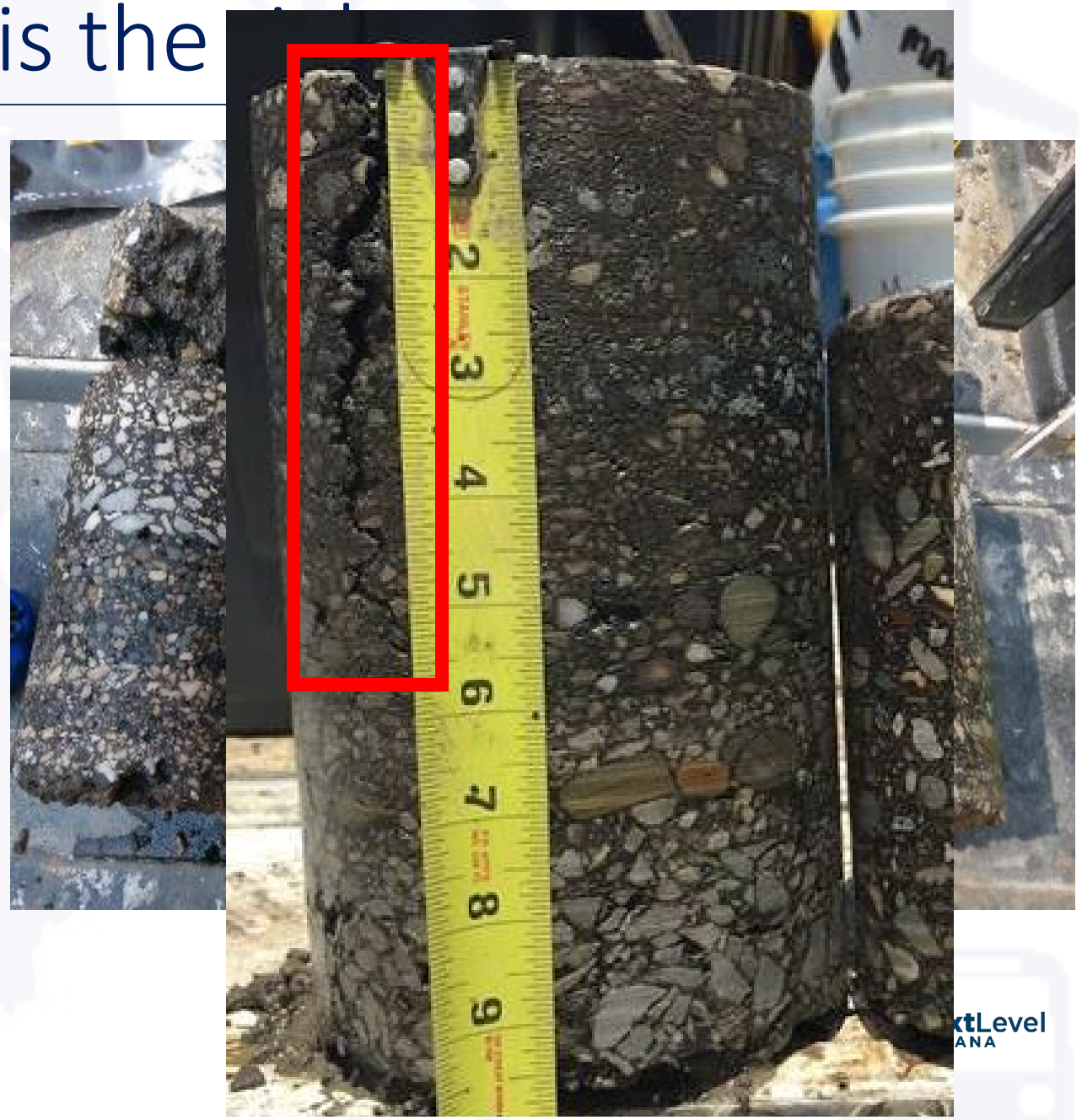
Weighted Cost Comparison- 2022 Averages	
Reconstruction with Recycling	Traditional Reconstruction
Asphalt Milling	Soil Improvements
10” Cement FDR	3” Compacted Aggregate
6” CCPR	3” HMA Base
2” HMA Surface	2.5” HMA Intermediate
	1.5” HMA Surface
80% to 85% of cost of Traditional Reconstruction	

When should CIR be considered

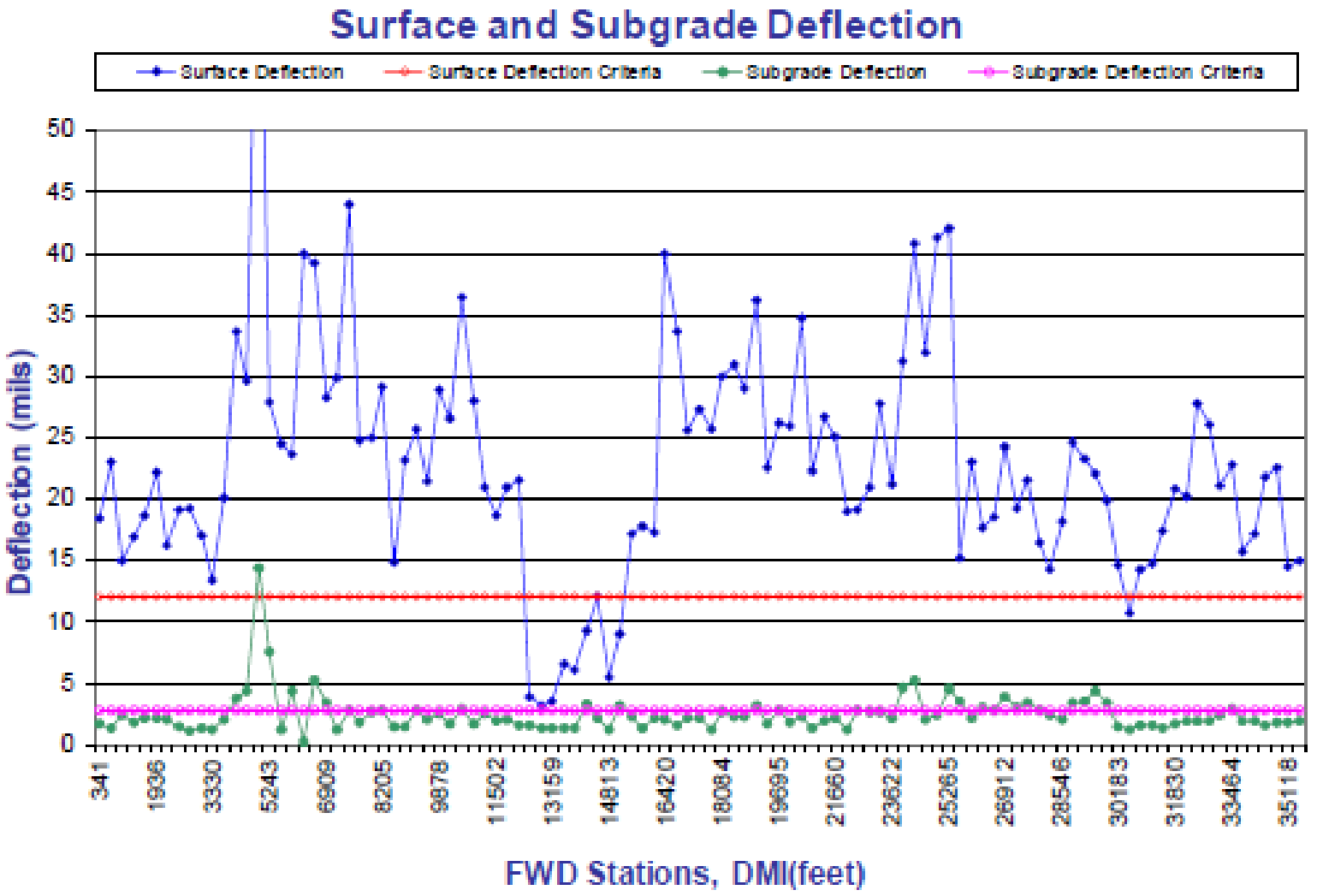
- Generally, any road that is a candidate for mill & fill is a candidate for CIR
- Ideal to Address – Raveling, Reflective Cracking, Top-Down Cracking, and Stripping in Localized Layers
- When planned partial depth patching is 8% or greater of the existing pavement area
- CIR works best when there is 1” - 2” of existing asphalt pavement below the CIR layer.

Tools to determine if CIR is the

- Cores, Cores, and More Cores
- Performance of HMA overlays is highly dependent on the condition of the underlying pavement layer
- CIR treatment depths are generally from 3 to 4 inches
- Deeper distress can be by milling the roadway before the CIR
- Hard and costly to reach deeper distress with a traditional mill and fill
- Check shoulders to make sure the thickness Matches mainline



Tools to determine if CIR is the right treatment



- Important to understand the condition of the asphalt and subgrade
- Best candidates are cracked pavements that are structurally sound
- May not a good candidate if poor performing layers are below treatment depth

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Modeling CIR Layers in MEPDG

- Currently there is no way to model CIR in the MEPDG as an existing overlay design
- The current practice is to model the CIR layer and the remaining asphalt below all as one existing material. Use level 3 HMA Rehabilitation inputs and increase the pavement structural and environmental rating by one level (for example a “fair” to “good”).
- This represents the CIR process reducing the amount of cracking/stripping of the existing materials.
- Minimum Design life of 10 years

Design Inputs

Design Life: 30 years
Design Type: ACC_ACC

Existing construction:
Pavement construction:
Traffic opening:

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	LaPorte PG 76-22 9.5mm	2.0
Flexible (existing)	Existing Asphalt 19.0mm	9.5
NonStabilized	Aggregate Base	3.0
Subgrade	A-6	Semi-infinite

HMA Rehabilitation (Input Level: 3)

Milled thickness (in)	2.00
Structural rating	Good
Environmental rating	Good
Total rut depth (in)	0.20

Roadway Design Considerations

- Pre-Milling
  - Any corrections for Grade Control, Cross-Slope, or Profile must be made with the pre-milling. Include before the CIR **Milling, Profile** if cross-slope corrections are required
  - Why? CIR thickness will be impacted!
    - Existing road at 0%, CIR 4” depth, place at 0%, CIR layer thickness will be 4.5”
    - Existing road at 0%, CIR 4” depth, place at 1%, CIR layer thickness will be 3.75”
    - Existing road at 0%, CIR 4” depth, place at 2%, CIR layer thickness will be 3.0”
- Full Depth Patching
  - Full depth patching will occur before milling similarly to a traditional mill and fill
  - Additional full depth patching is typically required after the CIR is completed
  - For future CIR projects include 0.5% Stabilizing Material, Portland Cement as an additive to help bridge localized weak subgrade spots

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Roadway Design Considerations

- Quantities
  - Use pay item numbers that start with 416
  - **Stabilizing Material, Asphalt Emulsion** = 0.75 (convention factor) x 4 in (CIR depth) x 115 lbs/cft (typical density) x 0.03 (estimated % stabilizing material) = 10.35 lbs/sys
  - **Stabilizing Material, Portland Cement** = 0.75 (convention factor) x 4 in (CIR depth) x 115 lbs/cft (typical density) x 0.005 (estimated % stabilizing material) = 1.7 lbs/sys
  - The **Cold In-Place Recycling** pay item quantity is based on the entire area that will be stabilized, include the existing pavement area and shoulders if included
  - **Corrective Aggregate, CIR**– Generally not required but include 200 tons as undistributed
  - **Milling, Scarification** - to remove any swelling of material volume during CIR operations. Do not mill more than 0.5” in depth
  - **Asphalt for Tack Coat** - applied to the milled CIR before the HMA overlay

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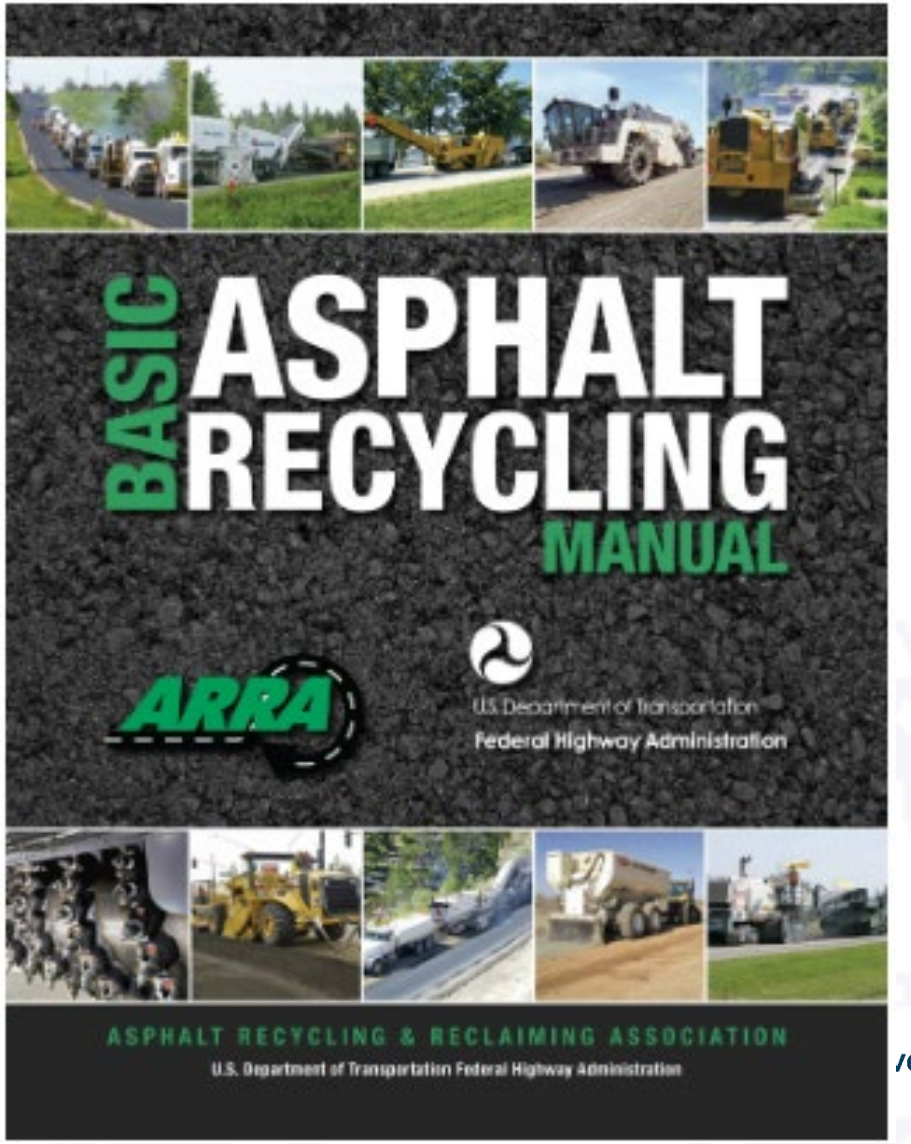
Additional Resources

- The Asphalt Recycling & Reclaiming Association (ARRA)
- https://www.arra.org/
- Publisher of the Basic Asphalt Recycling Manual
- Pocket Guides and checklists to help construction/inspection staff



INDOT Project Case Studies

- SR 236 – Putnam and Johnson Co.
- SR 28 – Tippecanoe Co.
- SR 39 – Hendricks Co.
- US 421 – Carroll and Clinton Co.

SR 39 – Hendricks County

- From US 36 to I-74
- Pavement design by BLN
- Identified early for CIR
  - Mainline
    - Full depth patching
    - 2-inch pre-mill
    - 4-inch CIR
    - Milling scarification
    - 2-inch overlay
  - Shoulders wider than 4 feet
    - 2-inch mill
    - 2-inch overlay
- Issues with MOT for 9.5 miles
  - Decided on scattered 2-mile segments

SR 39 – Hendricks County

SR 39 – Hendricks County

SR 39 – Hendricks County

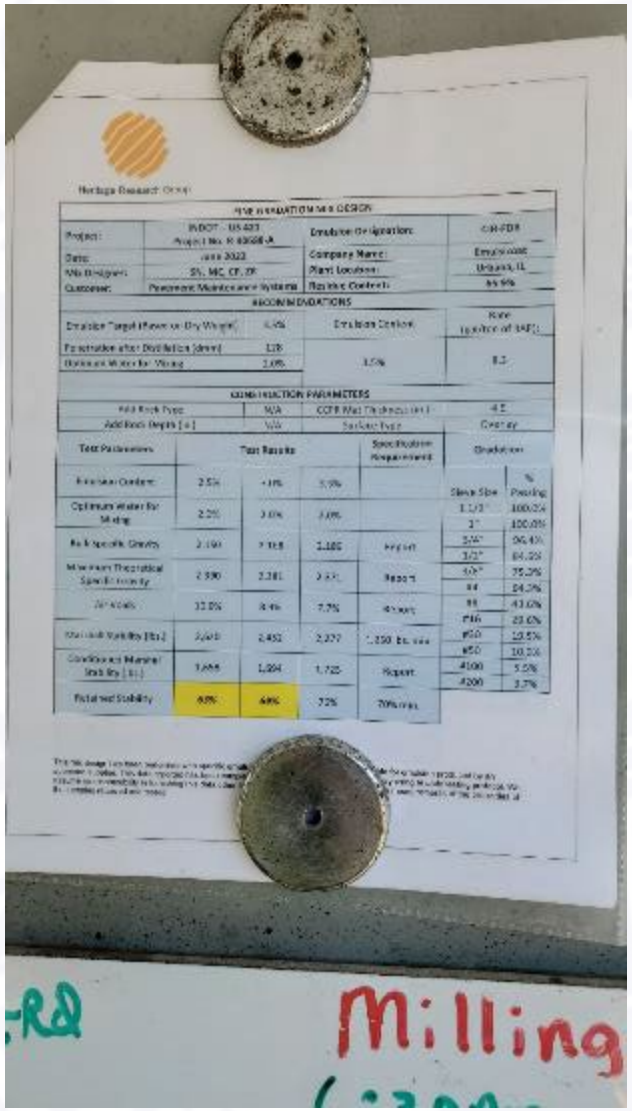
US 421 in Carroll and Clinton County

- From SR 26 to CR 200 N in Carroll
- Pavement Design by WSP
- Southern section 4-inch MSO
- PM Overlay at SR 25 Interchange
- Northern section CCPR
  - Mainline
    - Full Depth Patching
    - 6-inch Pre-mill (or to existing concrete)
    - 4.5-inch CCPR
    - Scarification mill
    - 1.5-inch Surface
  - Shoulders wider than 4 feet
    - 1.5-inch mill
    - 1.5-inch surface

US 421 in Carroll and Clinton County

US 421 in Carroll and Clinton County

US 421 in Carroll and Clinton County



US 421 in Carroll and Clinton County

US 421 in Carroll and Clinton County

SR 28 in Tippecanoe County

- From US 231 to US 52 W Jct.
- Pavement Design by Michael Baker
- Original Design - Combination FDR and CCPR
- Mainline HMA, shoulders and auxiliary lanes
  - 2-inch pre-mill
  - Excavate proposed shoulders +2 feet and use the milled material as Corrective Aggregate
  - FDR 10-inch stabilized with asphalt emulsion
  - 2 lift overlay
- Mainline Composite
  - Mill existing HMA to existing concrete and recycle
  - 4-inch CCPR (Replaced with HMA due to weather)
  - 2 lift overlay

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SR 28 in Tippecanoe County

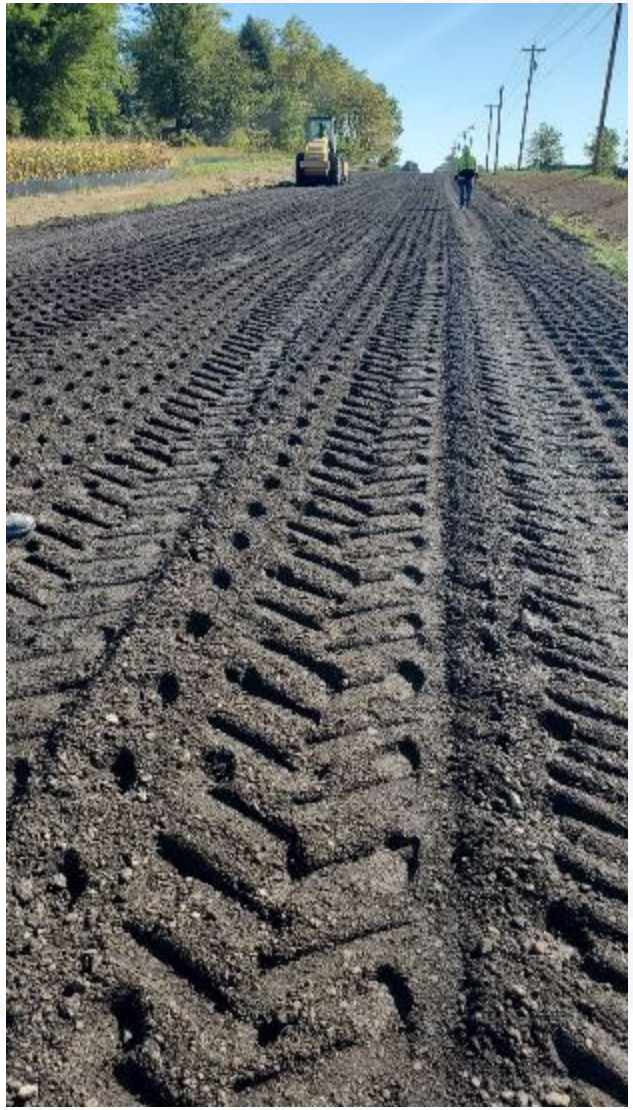
- Project Issues
  - Planned CCPR was changed to FDR due to need for profile grade changes.
  - Lack of defined drainage ditches, so planned underdrains were difficult to construct.
  - Existing concrete needed extensive patching on the east end. Was changed to standard HMA due to time constraints.
  - Partnering with the Contractor to get through issues.

SR 28 in Tippecanoe County

- FDR Process

SR 28 in Tippecanoe County

SR 28 in Tippecanoe County



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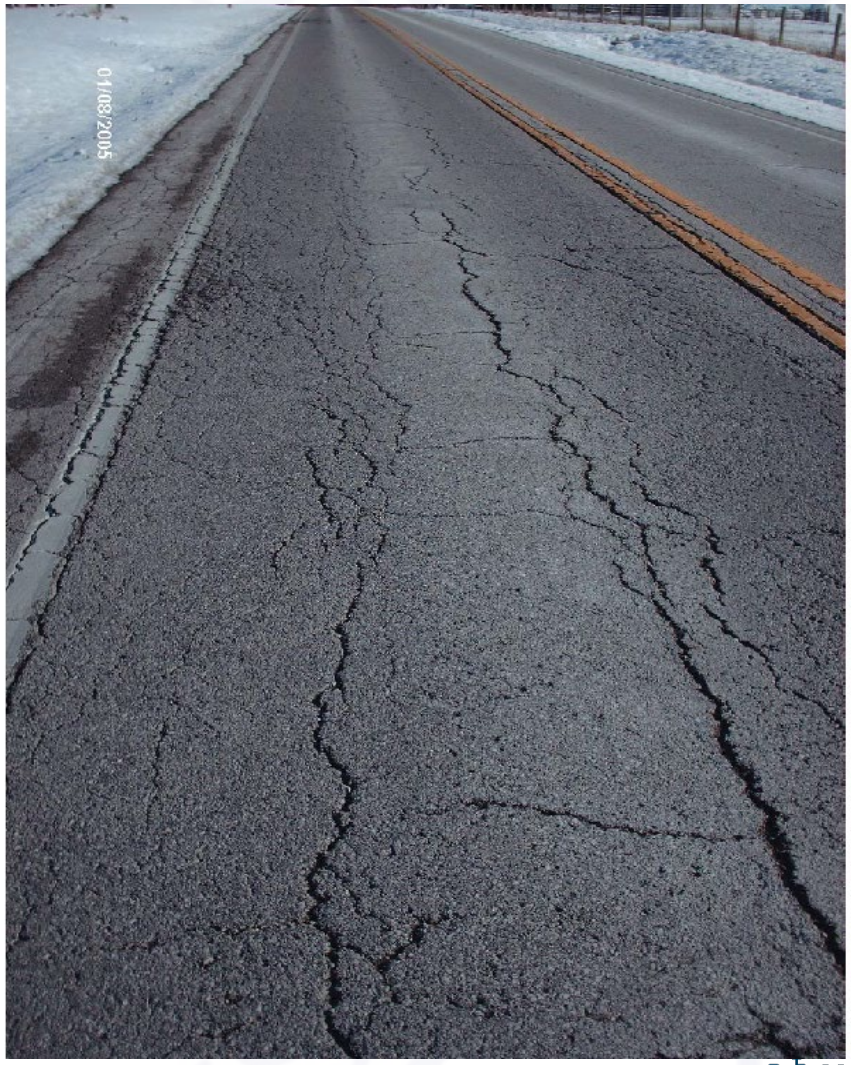
SR 236 in Putnam and Hendricks County

- From US 231 E Jct. to 0.39 mi. W of SR 75
- Design by American Structurepoint
- Originally scoped as overlay project
- Revised to Recycling Project due to pavement condition



SR 236 in Putnam and Hendricks County

Pavement Scope Revision

Surface Observations

- Longitudinal Edge Cracking
  - Longitudinal cracking and block cracking throughout majority of the area.
- Fatigue Cracking
  - Severely distressed with fatigue cracking. Premature fatigue cracking along the outside wheel path and was also observed at the locations where past overlay operations were conducted.

SR 236 in Putnam and Hendricks County

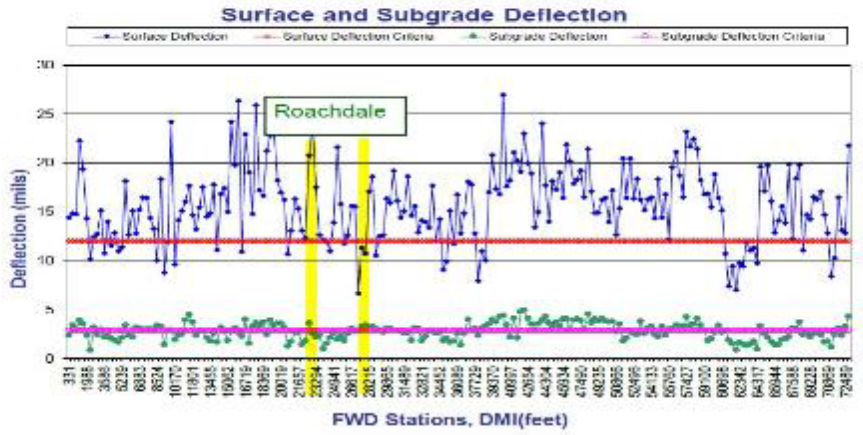
Pavement Scope Revision

Falling Weight Deflectometer (FWD) Data

- Surface Deflections
  - Nearly 90% above the deflection criteria (12 mils)
  - Typically, between 14-16 mils
- Subgrade Deflections
  - Over 30% above the deflection criteria (3 mils)
- Structural Number
  - 2.58 and 2.64 East Bound and West Bound respectively
  - Low both directions

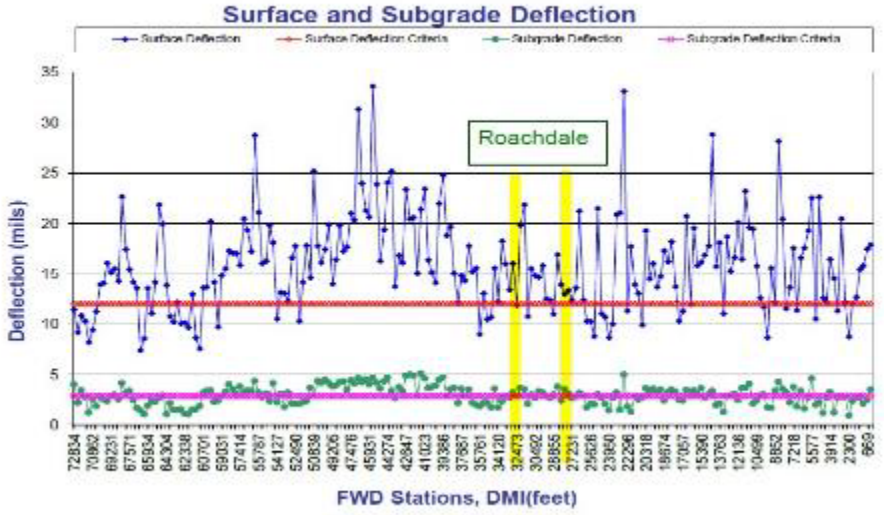
East Bound Lane from RP 18+95 to RP 32+81

Deflection Profile, RP 19+00 is FWD Station (DMI) 0 Feet



West Bound Lane from RP 32+81 to RP 18+95

Deflection Profile, RP 32+00 is FWD Station (DMI) 73182 Feet



SR 236 in Putnam and Hendricks County

Pavement Scope Revision

Pavement Cores

- Stripping
  - Throughout majority of cores
  - Depth of stripping highly variable
- Majority of cores highly deteriorated with crumbling base layers
- Cores in the Town of Roachdale were in fair to good condition

SR 236 in Putnam and Hendricks County

Pavement Treatment Recommendation

Full Depth Reclamation (FDR) Base

- In Existing Travel Lanes, Auxiliary Turn Lanes, and Shoulder Plus 1 ft. Beyond the Paved Shoulder
  - 8-inch pre-mill and stockpile the millings for CCPR
  - 1-foot additional width pre-mill for corrective aggregate that is spread across for consistent section
  - FDR remaining existing pavement and subgrade to 10-inch depth
  - Portland Cement Stabilization
  - Scarification milling
- Note that the 1-foot additional base width beyond the paved shoulder is within the existing footprint of the roadway grading.

Cold Central Plant Recycling on FDR Base

- 6-inch, ended up being placed in two lifts

Surface Cap

- 2-inch QC/QA Surface

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- Full Depth Reclamation (FDR)

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- Cement Stabilization

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- Milling Stockpile

- Sifted Stockpile

- Processed RAP for CCPR

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- Pugmill

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- Pugmill

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- Pug Mill (Continued)

- CCPR Application

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- CCPR Application

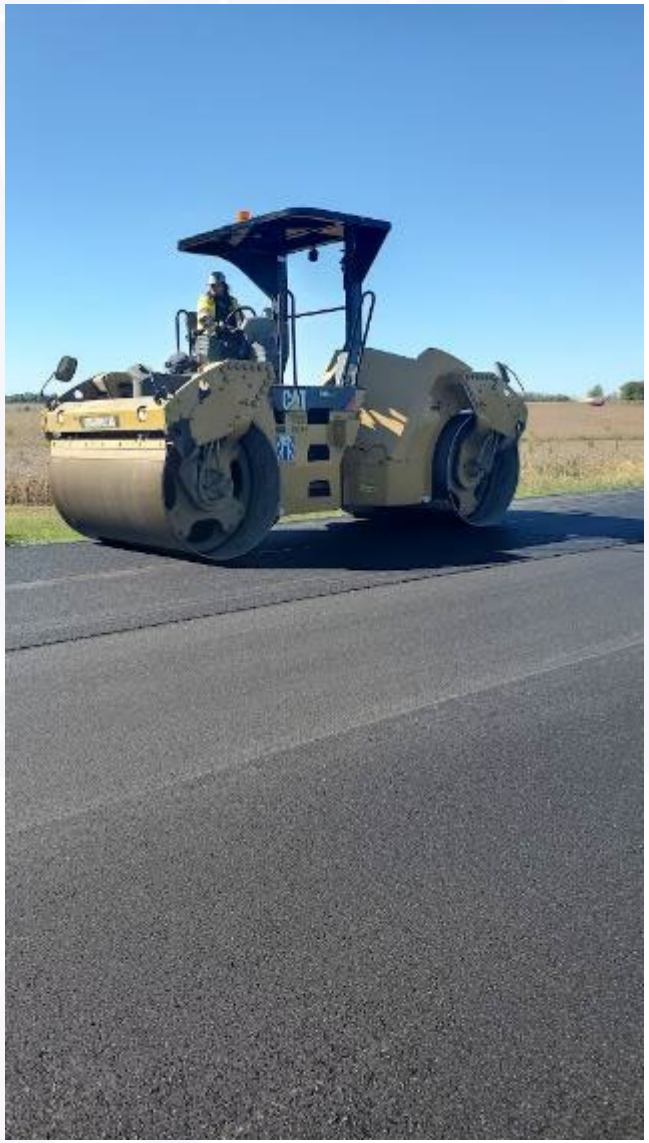
SR 236 in Putnam and Hendricks County

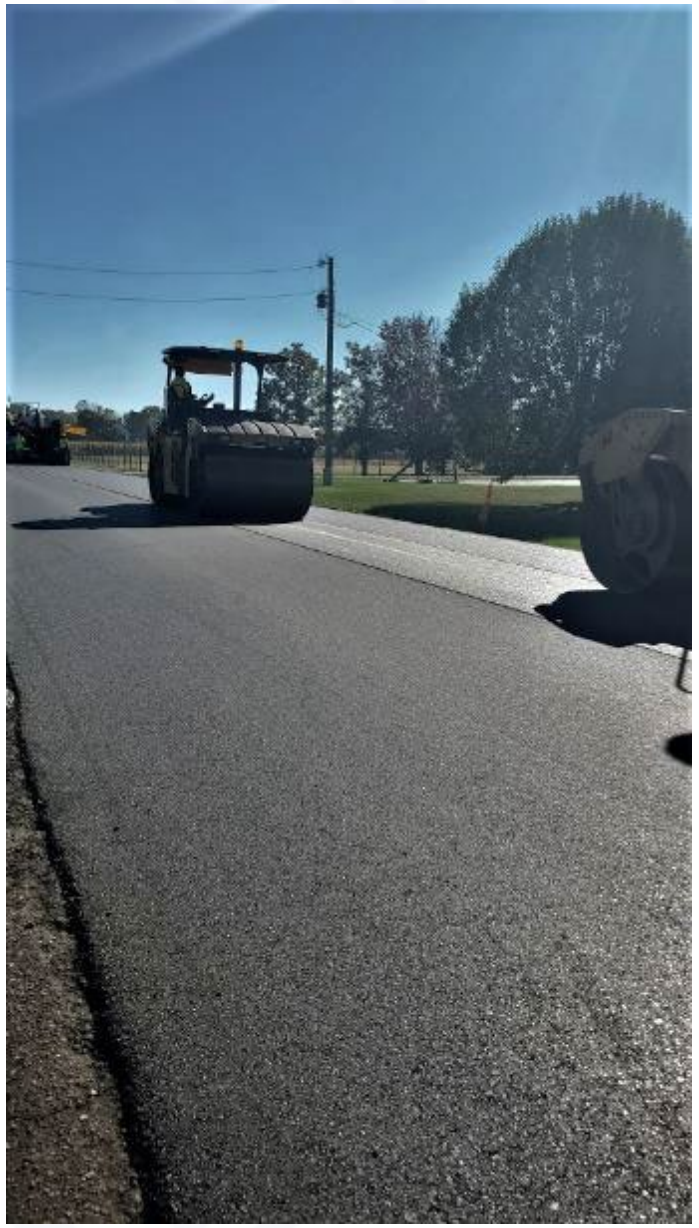
- Top Surface Application

SR 236 in Putnam and Hendricks County

SR 236 in Putnam and Hendricks County

- Surface Application





Recycled Pavement Core

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- Construction Issues
  - FDR got thinner at edges after profile milling
  - CCPR had trouble curing in shaded areas. Most of remediation in these areas.
  - Had trouble adhering the two lifts of CCPR. Several areas had to be replaced.
  - Shallow culverts and utilities required reduction or skipping of the FDR/CCPR.

SR 236 in Putnam and Hendricks County

- INDOT West Central Social Media Post

Pavement Recycling

- Questions?