



FULL DEPTH RECLAMATION (FDR)

Virginia Experience – Past and Present

 Michael Wells, P.E.

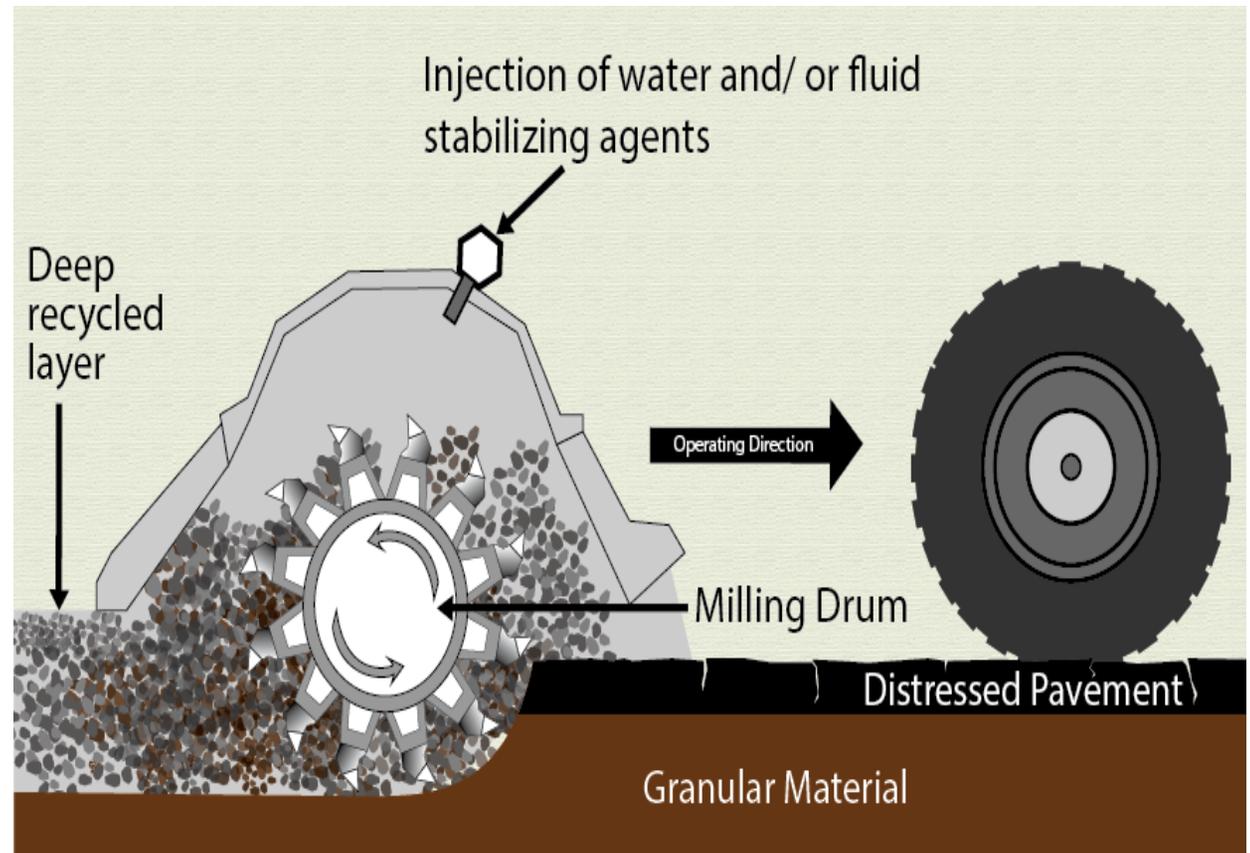
March 2, 2018

Outline

- **What is Full Depth Reclamation (FDR)**
- **VDOT Experience**

Full Depth Reclamation (FDR)

- Bound layers plus portion of unbound materials
- Mixed & treated to form stabilized base
- Depth of treatment ranges from 6 to 12 inches



VDOT Experience

- **Types of Roadways using FDR**
- **Contracting Mechanism**
- **Specification**
- **Construction Practices**
- **Pavement Design using FDR**

- **2008 is the “dividing line”**

Why 2008



Why 2008

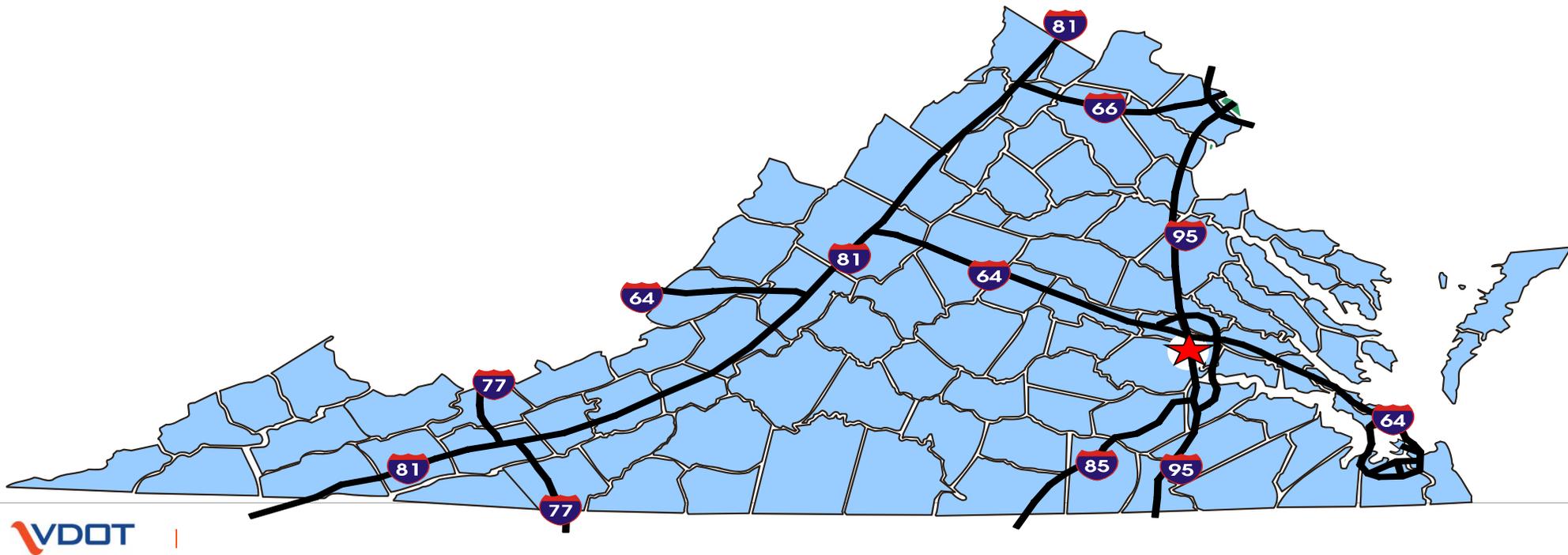


Why 2008



VDOT FDR Projects Pre-2008

FDR was used but not readily tracked



FDR Pre-2008



Pre-2008

- **Used primarily on low volume facilities**
 - Secondaries
 - Subdivision





 | Photo Courtesy Slurry Pavers



| Photo Courtesy Slurry Pavers



Pre-2008 Construction Practice



Pre-2008 Pavement Design

- **FDR not specifically identified in pavement design method used by VDOT**
 - Subdivision/Secondary Design Guide
 - AASHTO

Pre-2008 FDR Use Summary

- **Successful process to rehabilitate low volume roads**
 - Is that all?
- **No “formal” specification addressing FDR**
 - Soil Stabilization using Cement or Lime
- **Contracting**
 - Design Bid Build (DBB) – conventional contract mechanism
 - VDOT forces
- **No “formal” pavement design procedure**

Pre-2008 Discussion



Why Recycle

Recycling Benefits

- **Economical**
 - Cost Savings
 - Studies show 30-50 percent cost savings over conventional rehabilitation/reconstruction
- **Environment**
 - Reduce greenhouse gases (up to 50% has been reported)
 - Reuse of Existing materials to “rebuild” pavement
- **Construction**
 - Fix deterioration causes rather than symptoms
 - Allows for grade correction (cross-slope)
 - Allows for widening of existing pavement

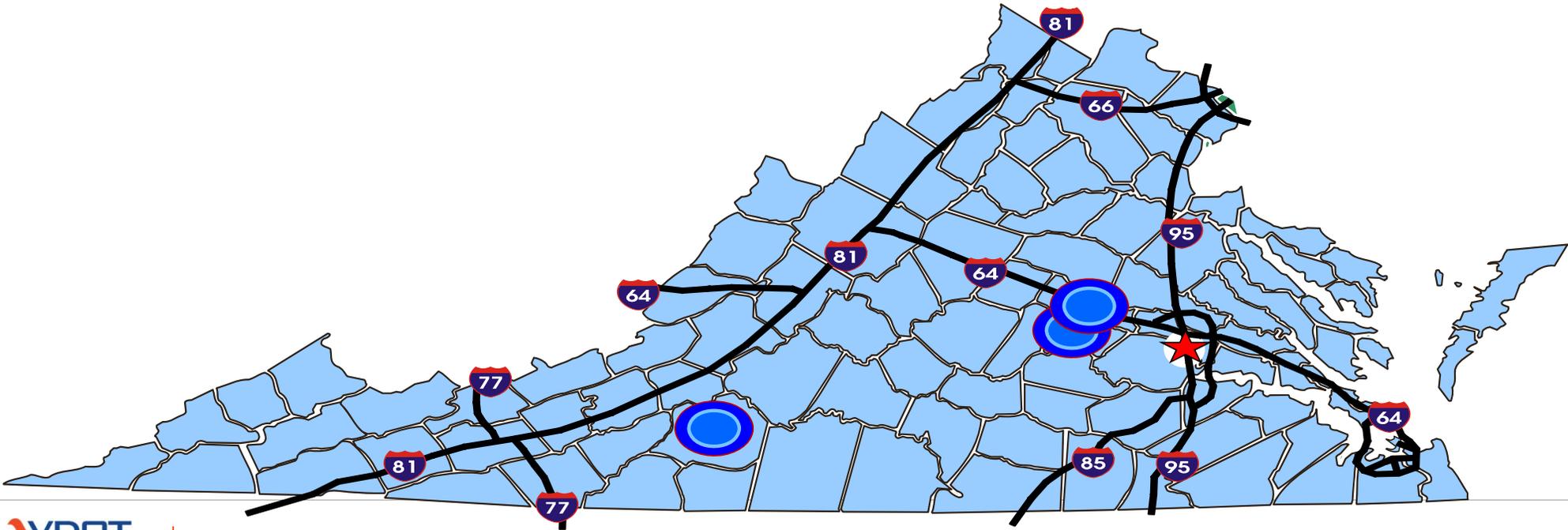
FDR 2008

And we're off



VDOT FDR Projects

 2008: SR 6, 13, 40



2008 – FDR Experience

- **Two projects**
 - Richmond District (SR 13 and 6)
 - Salem District (SR 40)
 - Part of Demo project conducted by Virginia Transportation Research Council
 - Compared different stabilizing agents (foamed asphalt + cement, asphalt emulsion)
- **Pavement Design Methodology followed AASHTO '93**
 - Layer coefficient for FDR = 0.30 to 0.33 (not identified in VDOT Guidelines)
 - Also called for Trench Widening using FDR

2008 – FDR Experience

- **Traffic**

Route	County	ADT	Percent Trucks
SR 13	Powhatan	1,700	11
SR 6	Goochland	3,800	6
SR 40	Franklin	4,400	4

- SR 13: Pavement Rating of 56
- SR 6: Pavement Rating of 40

2008 – FDR Experience

- FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
SR 13	Powhatan	8	Cement (5%)	2.75
SR 6	Goochland	8	Cement (5%)	3.5
SR 340	Franklin	8 - 10	Foamed Asphalt + 1% Cement (2.7%)	1.5
		8 - 10	Asphalt Emulsion (3.5%)	1.5

- SR 340 also had a leveling course prior to overlay

2008 – FDR Experience

- **Contracting Mechanism**
 - Design Bid Build
- **Specification**
 - No official VDOT provision, so Contract General Notes used

2008 – FDR Experience cont'd

- Governed by Contract General Notes
 - Mandated 5% cement by weight or volume
 - Contractor to supply in writing required cure time for FDR layer
 - Equipment used for FDR shall have cutting width of 96" and depth of 13"
 - Contractor shall core every 1,500 feet to verify depth. Depth to be within ± 0.5 ".
 - Repair core hole with bentonite
 - Pulverization shall yield gradation as follows
 - 95-100% passing 2" Sieve
 - 85-95% passing 1" Sieve
 - Gradation tested every 1,000 feet

2008 – FDR Experience cont'd

- Contract General Notes cont'd
 - Section shall be proof rolled (stable if no yielding or rutting greater than 1")
 - Repairs at contractors expense
 - Chip seal at completion of each workday prior to opening to traffic
 - First AC layer paved within two days of FDR completion
 - Compaction to use
 - 10 to 12 ton pad foot roller
 - 10 to 12 ton smooth drum vibratory roller



2008 Construction Practice



FDR trench widening



Courtesy Slurry Pavers

Opening to Traffic



Courtesy Slurry Pavers



Courtesy Slurry Pavers

2008 – FDR Experience

- **GPR Depth 6 weeks after construction**

Material	Route 40		Route 40		Route 13		Route 6	
	EB	WB	EB	WB	EB	WB	EB	WB
	Foamed Asphalt		Asphalt Emulsion		Cement		Cement	
HMA	2.5	2.2	2.2	2.2	3.3	3.9	3.4	3.8
FDR	10.4	8.3	9.1	10.5	9.1	9.3	10.1	8.1

2008 – FDR Experience

- Calculated Layer Coefficient from FWD testing

Months	Route 40		Route 40		Route 13		Route 6	
	EB	WB	EB	WB	EB	WB	EB	WB
	Foamed Asphalt		Asphalt Emulsion		Cement		Cement	
2	0.21	0.26	0.16	0.15	0.28	0.29	0.26	0.27
4	0.24	0.28	0.19	0.17	0.29	0.30	0.28	0.29
6	0.26	0.29	0.20	0.17	0.29	0.31	0.28	0.29
12	0.29	0.31	0.22	0.19	0.30	0.32	0.29	0.31
18	0.31	0.32	0.24	0.20	0.30	0.33	0.30	0.32
24	0.32	0.33	0.25	0.20	0.31	0.33	0.30	0.32



Is Dust an Issue?

What happened here?



2008 FDR Use Summary

- **Successful process to rehabilitate “moderate” volume roads**
- **No “formal” specification addressing FDR**
 - Need to develop provision for future projects
- **Contracting**
 - Design Bid Build (DBB) – conventional contract mechanism
- **FDR not part of VDOT pavement design procedure**
 - Layer Coefficient “assumption” appeared to be reasonable for these projects

FDR Post 2008



Post 2008 FDR Experience

- **Initially, things were slow**
- **2009**
 - Specification development
 - But no FDR projects constructed
 - Still no Pavement Design “formal” guidance



- **Specification Highlights**

Contractor Requirements

Pre-construction Meeting

Materials

Mix Design

Equipment

Construction

Acceptance Testing

Measurement and Payment

Post 2008 FDR Experience cont'd

Specification Highlights

- **Contractor Requirements**

- Successfully constructed at least 3 pavement recycling projects during last 3 years (at least 50,000 sy)
- On-site supervisor and equipment operators shall have 3 years experience within last 3 years (documented experience)
- 90 days prior to work starting, experience summary provided to Department for review and approval
- Submit QC Plan 20 days prior to start
 - Provide procedures to meet contract requirement if corrective action is needed when acceptance testing not met

Post 2008 FDR Experience cont'd

Specification Highlights

- **Pre-Construction Meeting**
 - Held 15 days prior to start of recycling
 - Department and Contractor staff
 - Clarify roles and responsibilities, construction requirements and schedule
 - *“Start Right, Stay Right”*

Post 2008 FDR Experience cont'd

Specification Highlights

- **Materials**
 - Gradation Change

Sieve Size

Percent Passing

2 inch

100%

3/8 inch

55% minimum

Post 2008 FDR Experience cont'd

Specification Highlights

- **Mix Design**
 - No longer specified stabilizing agent content
 - Primarily Based on Compressive Strength ASTM D 1633 (Cement) or AASHTO T 220 (Lime)
 - Minimum 250 psi at 7 days

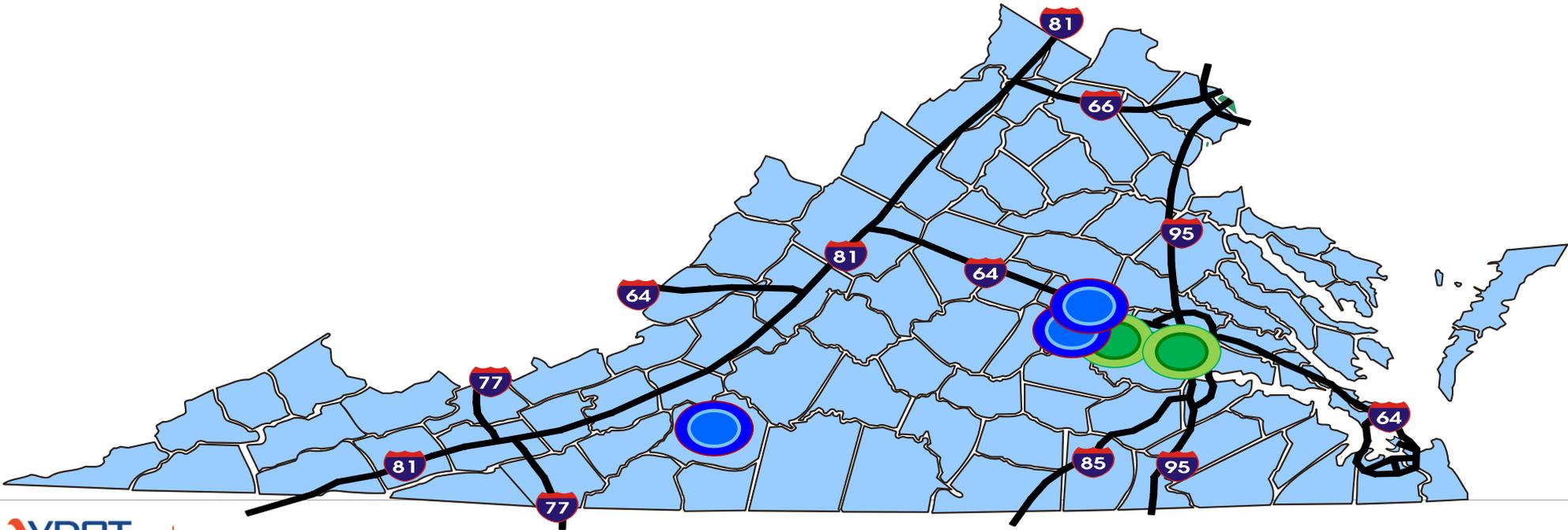
Post 2008 FDR Experience cont'd

Specification Highlights

- **Acceptance Testing**
 - Depth (Trench)
 - Density – Minimum of 97% of maximum density from Approved Mix Design
 - Unconfined Compressive Strength (AASHTO T 208)
- **Now with Spec in place, 2010 project developed.....**

VDOT FDR Projects

-  2008: SR 6, 13, 40
-  2010: US 60, Mulberry Dr



Post 2008 FDR Experience cont'd

- **2010 – US 60, Powhatan County**
 - Designed using AASHTO '93 with layer coefficient of 0.3 for FDR
- **FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
SR 13	Powhatan	12	Cement (5%)	3.5

2008 – FDR Experience

- **Traffic**

Route	County	ADT	Percent Trucks
US 60	Powhatan	26,250	5

- Pavement Rating of 26

Post 2008 FDR Experience cont'd

- **2010 – Mulberry Drive, Prince George County**
 - Subdivision Road with isolated base/subgrade failure
 - No formal pavement design
 - No mix design performed to “optimize” cement content
- **FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
Mulberry Drive	Prince George	8	Cement (5%)	2.0



Post 2008 Construction Practice



2008 – FDR Experience

- **US 60, Powhatan County**
 - Project went well overall
 - No noted issues with density or depth
 - However, project did receive an overall disincentive on Rideability

VDOT FDR Projects



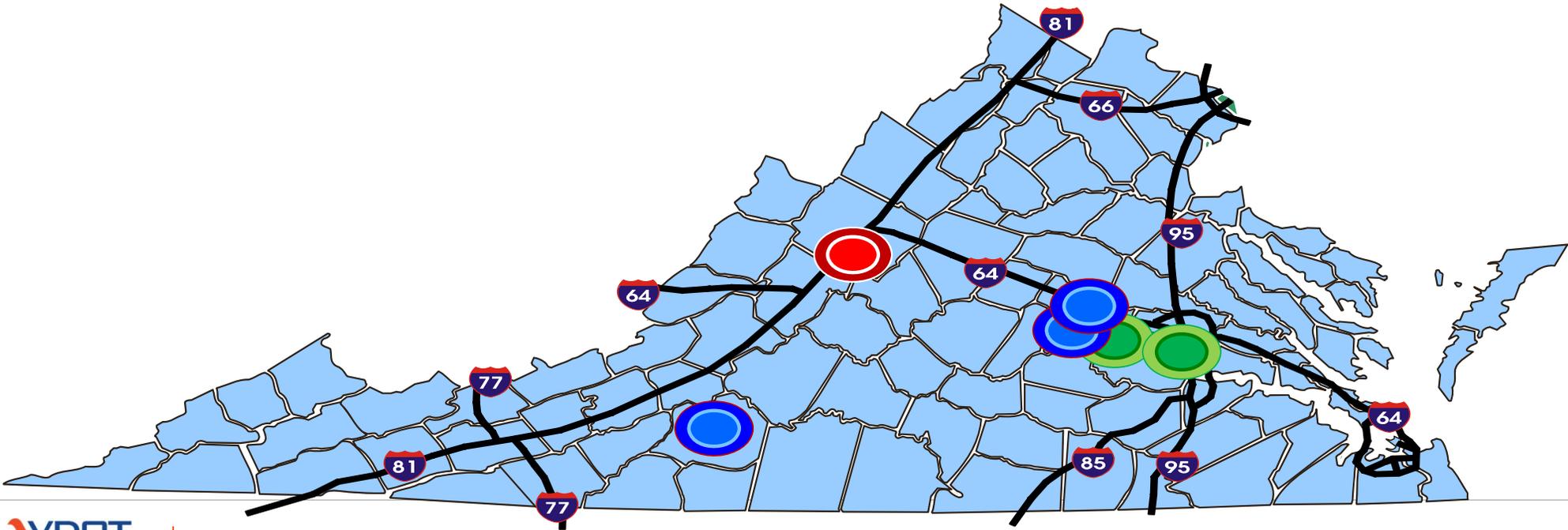
2008: SR 6, 13, 40



2010: US 60, Mulberry Dr



2011: I-81



Post 2008 FDR Experience cont'd

- **2011 – Interstate 81, Augusta County**
 - Design used modified design with 0.25 layer coefficient (somewhat empirical design)
- **Section frequently exhibited structurally related distresses**
 - Deep patching and AC mill and fill



Post 2008 FDR Experience cont'd

- Traffic

Route	County	ADT	Percent Trucks
IS 81	Augusta	23,000	28



Post 2008 FDR Experience cont'd

- **Contract was Design Bid Build**
- **Used FDR Special Provision**

Post 2008 FDR Experience cont'd

- FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
IS 81	Augusta	12	Calciment (3%)	12*

*Cold Central Plant Recycling was used as part of AC Overlay

Post 2008 FDR Experience cont'd

- **Pavement Section by lane**

Left Lane

4-in New AC

5-in CIR

Existing AC

Existing Aggregate

Existing Subgrade

Right Lane

6-in New AC

6-in CCPR

12-in FDR

Existing Subgrade



Post 2008 Construction Practice



VDOT and its prime contractor Lanford Brothers Company, Inc. of Roanoke rebuilt a section of Interstate 81 in Augusta County by recycling existing road material back into the new pavement structure. This paving method reduced construction time by about two-thirds and saved millions of dollars, earning VDOT a national award by the asphalt recycling industry.

“Using these pavement recycling methods has the potential to revolutionize how we rehabilitate our aging roads, both in Virginia and nationally,” said Governor McDonnell. “We expect to continue using these processes, where appropriate, to save money and materials as we rebuild older roads throughout the commonwealth. VDOT next plans to use cold in-place recycling to rebuild a section of U.S. 17 in Isle of Wight County in Hampton Roads during the 2012 paving season.”

VDOT rehabilitated a 3.7-mile southbound section of I-81 near Staunton in 2011 using three processes known in the paving industry as:

- *Cold in-place recycling*
- *Cold central-plant recycling*
- *Full-depth reclamation*

This was the first time these three processes were used together on a single interstate project in the United States. The processes were performed both “in place” within the roadbed and adjacent to the highway, and they reused existing material from the underlying road structure. The driving surface received a new overlay of hot-mix asphalt.

“Savings on the I-81 in-place pavement recycling project go beyond time, money and materials,” said VDOT Commissioner Greg Whirley. “It saved fuel because it reduced the need to transport as much new and old materials. It increased safety for drivers and road workers on the project, because it reduced work-zone congestion. This section of rebuilt pavement also will be stronger from bottom to top, extending its service life and reducing the need for such complex maintenance for many years.”

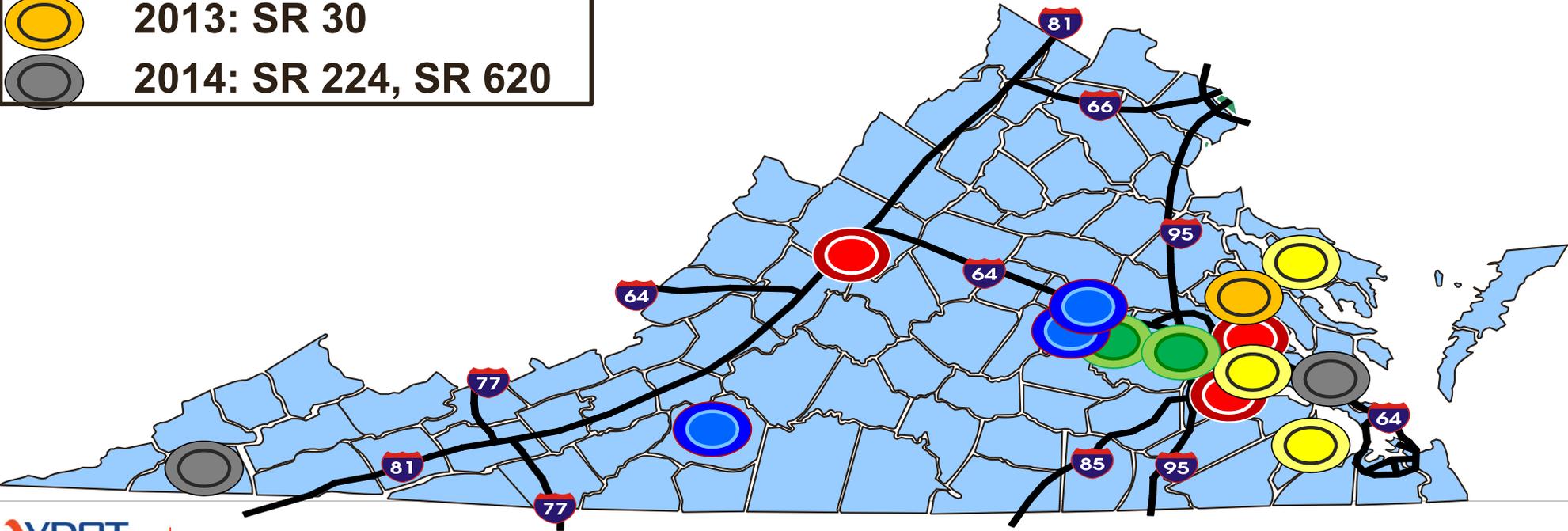
The project used a novel traffic-management plan that detoured cars onto U.S. 11 away from the construction, while large trucks used one lane on I-81 while the other lane was under construction. VDOT alerted motorists to the construction several hundred miles from the project via on-road, Web and other communication tools.

Post 2008 FDR Experience cont'd

- **2012**
 - Materials Division issues “*Project Selection Guidelines for Cold Pavement Recycling*”
 - With potential increase in use of recycling processes, including FDR, important to provide guidance to field staff
 - Defined different Cold Recycling Processes
 - Provided input on Project Selection and Forensic Investigation
 - Established Layer Coefficient for FDR (0.20) for use in AASHTO '93
 - Provided minimum AC overlay thickness for Interstate and Primary Routes (3.5”)
 - Other routes with design ESALs greater than 3 million as well
 - Noted potential “fluff” of FDR that must be accounted for in design geometrics

VDOT FDR Projects

-  2008: SR 6, 13, 40
-  2010: US 60, Mulberry Dr
-  2011: I-81
-  2012: SR 3, 10, 620
-  2013: SR 30
-  2014: SR 224, SR 620



Post 2008 FDR Experience cont'd

- **2012**
 - SR 3, Richmond County
 - SR 10, Chesterfield County
 - SR 620, Isle of Wight
- **2013**
 - SR 30, King William County
- **2014**
 - SR 224, Scott County
 - SR 620, York County

Post 2008 FDR Experience cont'd

- **All Projects designed using AASHTO '93**
- **All Projects were Design Bid Build Contract**
- **All Projects used Special Provision for FDR**
- **Construction Practice was same as previous projects**

Post 2008 FDR Experience cont'd

- FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
SR 3	Richmond	9.5	Cement (4%)	4.0
SR 10	Chesterfield	12	Cement	3.5
SR 620	Isle of Wight	8	Cement (6%)	
SR 30	King William	12	Cement	3.5
SR 224	Scott	12	Cement	4.0
SR 620	York	8	Cement (5%)	5.0

Post 2008 FDR Experience cont'd

- Traffic**

Route	County	ADT	Percent Trucks
SR 3	Richmond	6,000	6
SR 10	Chesterfield	38,250	5
SR 620	Isle of Wight	1,700	8
SR 30	King William	4,725	22
SR 224	Scott	8,000	3
SR 620	York	12,815	1



Post 2008 Construction Practice



Post 2008 FDR Experience cont'd

- **Calculated layer coefficient from FWD – Route 10**
 - Overall average of 0.35 (testing directly on FDR layer)
 - Isolated location less than 0.28 (min. 0.21)
 - 800 foot section
 - Milled and filled with Base Mix Asphalt
- **Calculated layer coefficient from FWD – Route 30**
 - 2016 layer coefficient ranged from 0.3 to 0.33

VDOT FDR Projects

2012 NCAT Test Track

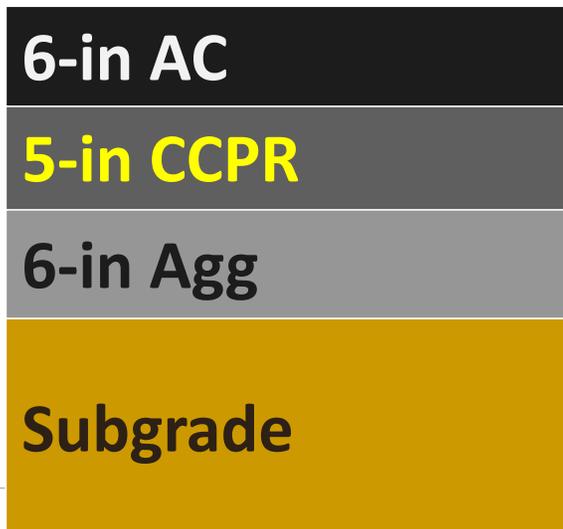


Post 2008 FDR Experience cont'd

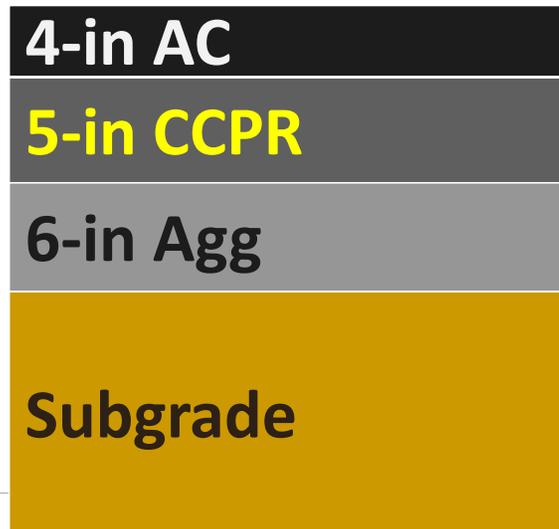
- **2012 FDR Research**

- VTRC contracted with NCAT to build three recycled sections at test track
 - Purpose was to gather as much “long-term performance” information on recycled pavement sections during 2 year evaluation

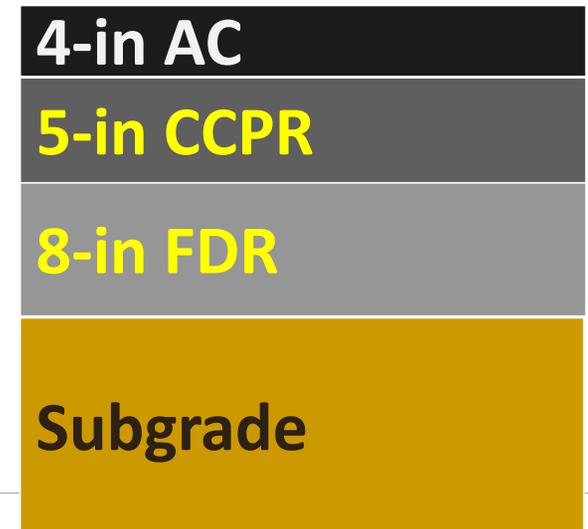
N3



N4



S12



Recycled Sections at NCAT



Post 2008 FDR Experience cont'd

- **2013**
 - **Materials Division re-issued guidance on use of recycling (MD 365-13)**
 - Initially, all designs using recycling needed to be reviewed by Materials Division
 - Cited as one “obstacle” to advertising additional recycling projects
 - Department wanted to promote use
 - Materials worked/discussed with Internal and Industry partners to determine what “flexibility” could be given
 - **From past experience on lower volume roads (secondaries), review guidance could be relaxed for these facilities**

MATERIALS DIVISION



MEMORANDUM

GENERAL SUBJECT: Pavement Design and Evaluation	NUMBER: MD 365-13
SPECIFIC SUBJECT: Notice of Revision of Secondary Road Recycling Projects Review Process	DATE: December 19, 2013
DIRECTED TO: District Materials Engineers	SIGNATURE: Charles A. Babish, PE <i>Signature on original copy of memorandum</i>

The Department's current "Project Selection Guidelines for Cold Pavement Recycling" requires the District Materials Engineer or designee to sign and seal a pavement design report and submit to the State Materials Engineer for review and concurrence prior to advertisement.

In view of the suggestions obtained from various groups, relative risk assessment and VDOT's prior experience of upgrading secondary roads with some recycling technology the current recycling project approval guideline for secondary road system is hereby adjusted. With receipt of this Memorandum, it will no longer be required for the District to submit these projects to the State Materials Engineer for review and approval. The final review and approval shall be performed at the district level with notification to the State Materials Engineer of approved projects.

The goal of this change is to expedite the project delivery for recycling projects for the secondary road system. District Materials Engineer will continue to have the authority to coordinate appropriate design process that is deemed necessary depending on the scope of the project.

The revised Project Selection Guideline may be accessed by using the link below:

<http://www.virginiadot.org/business/materials-download-docs.asp>

Post 2008 FDR Experience cont'd

- **2015**
 - **Materials Division formed Recycling Task Force**
 - Evaluate the direction of Recycling Use within Department and provide specific guidance on design, specification and training
 - **Initial Results**
 - Updated layer coefficient
 - Updated Special Provision
 - Recommended offering “Just-In-Time” Training for Recycling projects

Post 2008 FDR Experience cont'd

- **2015 cont'd**

- FDR Layer Coefficient increased to 0.25

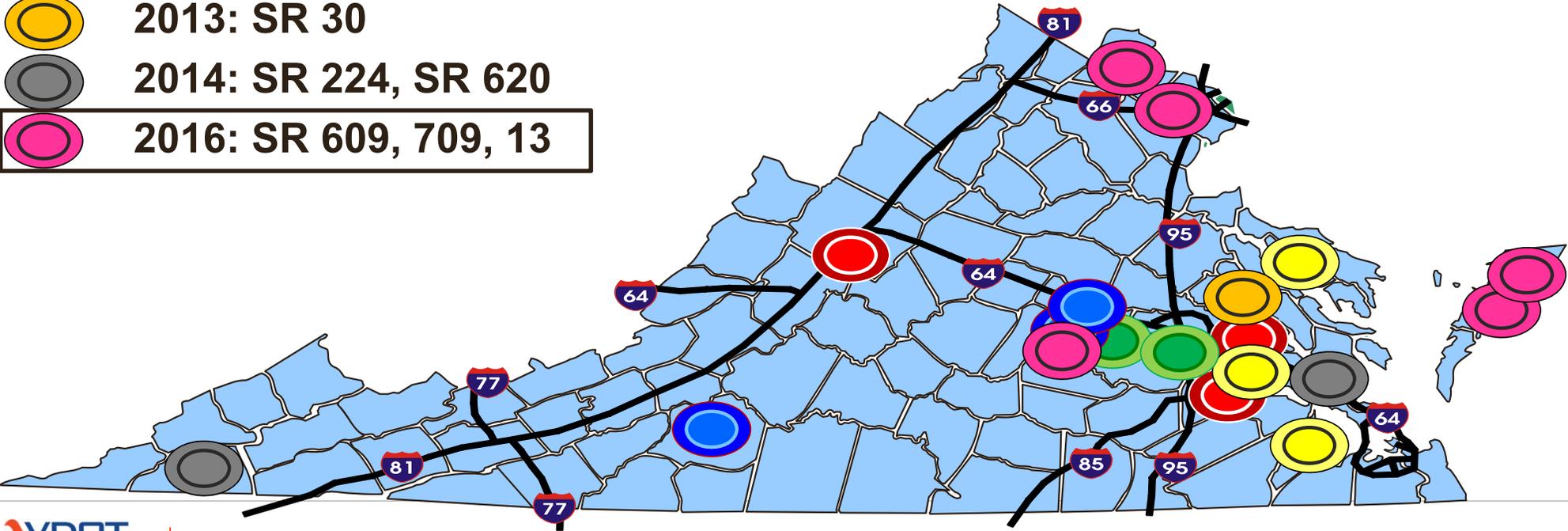
- **Special Provision Highlights**

- Updated QC Plan requirements to document contingency plan
- Compressive Strength requirement added Max 450 psi at 7 days (min 250 psi still in effect)
- Added Test Strip requirement
- Added “pre-cutting” requirement
- Lot 5,000 linear feet for testing
- Verify dosage rate
- Weather Limitations

% of Density from Approved Mix Design	% of Payment
97.0 or greater	100
96.0 to less than 97.0	95
95.0 to less than 96.0	90
Less than 95.0	75

VDOT FDR Projects

- 2008: SR 6, 13, 40
- 2010: US 60, Mulberry Dr
- 2011: I-81
- 2012: SR 3, 10, 620
- 2013: SR 30
- 2014: SR 224, SR 620
- 2016: SR 609, 709, 13



Post 2008 FDR Experience cont'd

- **2016**
 - SR 609 and 709, Accomack County
 - Projects designed using AASHTO '93 (0.25)
 - Design Bid Build Contract
 - Project used Special Provision for FDR
 - Construction Practice was same as previous projects

Post 2008 FDR Experience cont'd

- **2016**
 - SR 13, Powhatan County
 - Used **“On-call FDR Services”** Contract
 - Project used Special Provision for FDR
 - Construction Practice was same as previous projects



Post 2008 FDR Experience cont'd

- **Traffic**

Route	County	ADT	Percent Trucks
SR 609	Accomack	1,200	2
SR 709	Accomack	910	4
SR 13	Powhatan	2,000	9

Post 2008 FDR Experience cont'd

- FDR Operation and Overlay**

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
SR 609	Accomack	8	Cement (5%)	4.5
SR 709	Accomack	8	Cement (5%)	2.0
SR 13	Powhatan	10	Cement (4%)	2.75*

*AC overlay placed under separate contract



Post 2008 Construction Practice



Post 2008 FDR Experience cont'd

- **2017**
 - **IS 85, Brunswick County - Design Bid Build Contract**
 - Two sections (NB and SB)
 - Used FDR Special Provision
 - Similar project to I81 recycling (2011)
 - **I64, York County – Design Build Contract**
 - Cement treated recycled material (RCA or RAP) meeting FDR Special Provision
 - Modified Provision due to lump sum contract
- Construction Practice was same as previous projects

Post 2008 FDR Experience cont'd

- Traffic**

Route	County	ADT	Percent Trucks
IS 85	Brunswick - NB	11,000	20
	Brunswick – SB	11,000	21
IS 64	York	94,000	9

Post 2008 FDR Experience cont'd

- Pavement Design was AASHTO '93 (0.25)
- FDR Operation and Overlay

Route	County	FDR Depth	Stabilizing Additive	AC Overlay Thickness
IS 85	Brunswick - NB	10	Cement (3.5%)	7.0
	Brunswick – SB	10	Cement (2.5%)	7.0
IS 64	York	12	Cement (5%)	9.5*

*5.0 inches of CCPRM, 4.5 inches of HMA (2.0 inch OGD)

Post 2008 FDR Experience cont'd

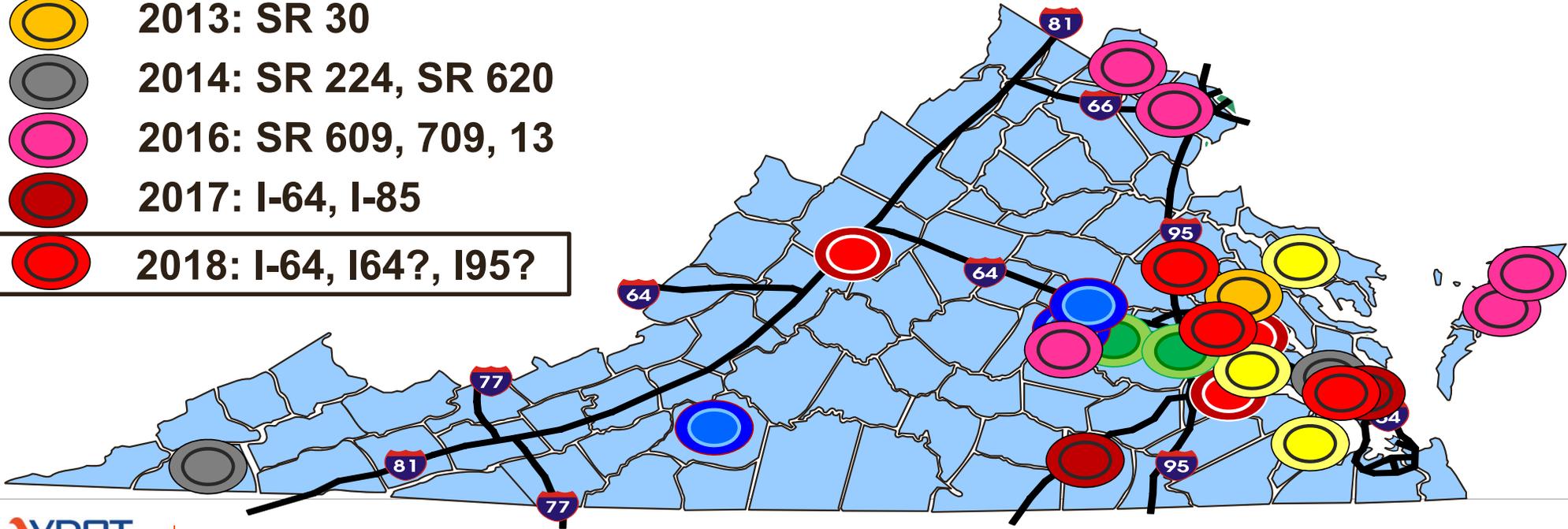
- **IS 85, Brunswick County**
 - “Just-in-time training” session was held for project staff
- **I64, York County**
 - Department and Industry conducted two Quality Workshops (Just-In-Time Training)
 - Highlight expectations and share experience from previous projects
 - Good forum to ensure project would “Start Right/Stay Right”





VDOT FDR Projects

-  2008: SR 6, 13, 40
-  2010: US 60, Mulberry Dr
-  2011: I-81
-  2012: SR 3, 10, 620
-  2013: SR 30
-  2014: SR 224, SR 620
-  2016: SR 609, 709, 13
-  2017: I-64, I-85
-  2018: I-64, I64?, I95?



Post 2008 FDR Experience cont'd

- **2018 and beyond**
 - **Projects designed using MEPDG**
 - Current projects used AASHTO 93 as designed prior to Jan 1, 2018 implementation
 - Expect to use existing FDR provision
 - Contract Mechanism is Design Build
 - Expecting Construction Practice to be same as previous projects
- I64, York/James City County: 12" FDR (?% cement) with 5.0" CCPRM and 4.5" AC Overlay
- 74,000 with 8% Trucks

Post 2008 FDR Use Summary

- **Successful process to rehabilitate “low to high” volume roads**
- **Specification treated as “living” document**
 - Document “Lessons Learned” from projects and assess need for updates
- **Contracting**
 - Design Bid Build (DBB)
 - Design Build (DB)
- **Use of FDR in Pavement Design evolved for AASHTO '93 and morphed into MEPDG**

THANK YOU

