FDR IN CALIFORNIA: LESSONS LEARNED FROM FDR PROJECTS ON THICK ASPHALT SURFACINGS

David Jones, PhD

University of California Pavement Research Center

94th Transportation Research Board Annual Meeting

Washington, DC, January 2015

Summary

- Introduction
- UCPRC research focus areas
- Lessons learned
  - Project design
  - Mix design
  - Construction
- Conclusions

Introduction

- FDR-FA introduced to California in 2000
- International research focus
- California research focus
  - Thick, severely cracked AC
    - "Evolved roads"
  - Road must be open to traffic by dark
  - Mix design limited to ITS test
  - No contractor experience
- First pilot project built in 2001

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UCPRC Research Focus

- Recycling/sustainability strategic initiative
- Phase 1: FDR-NS and FDR-FA study
  - Literature review
  - Mechanistic sensitivity analysis
  - Field performance assessment
  - Limited accelerated pavement testing
  - Laboratory study
  - Preliminary guidelines and specifications
- Phase 2: FDR-PC and FDR-EE
  - As for Phase 1 (comprehensive dry and wet APT)
  - ME performance models
  - Single guideline for FDR in California

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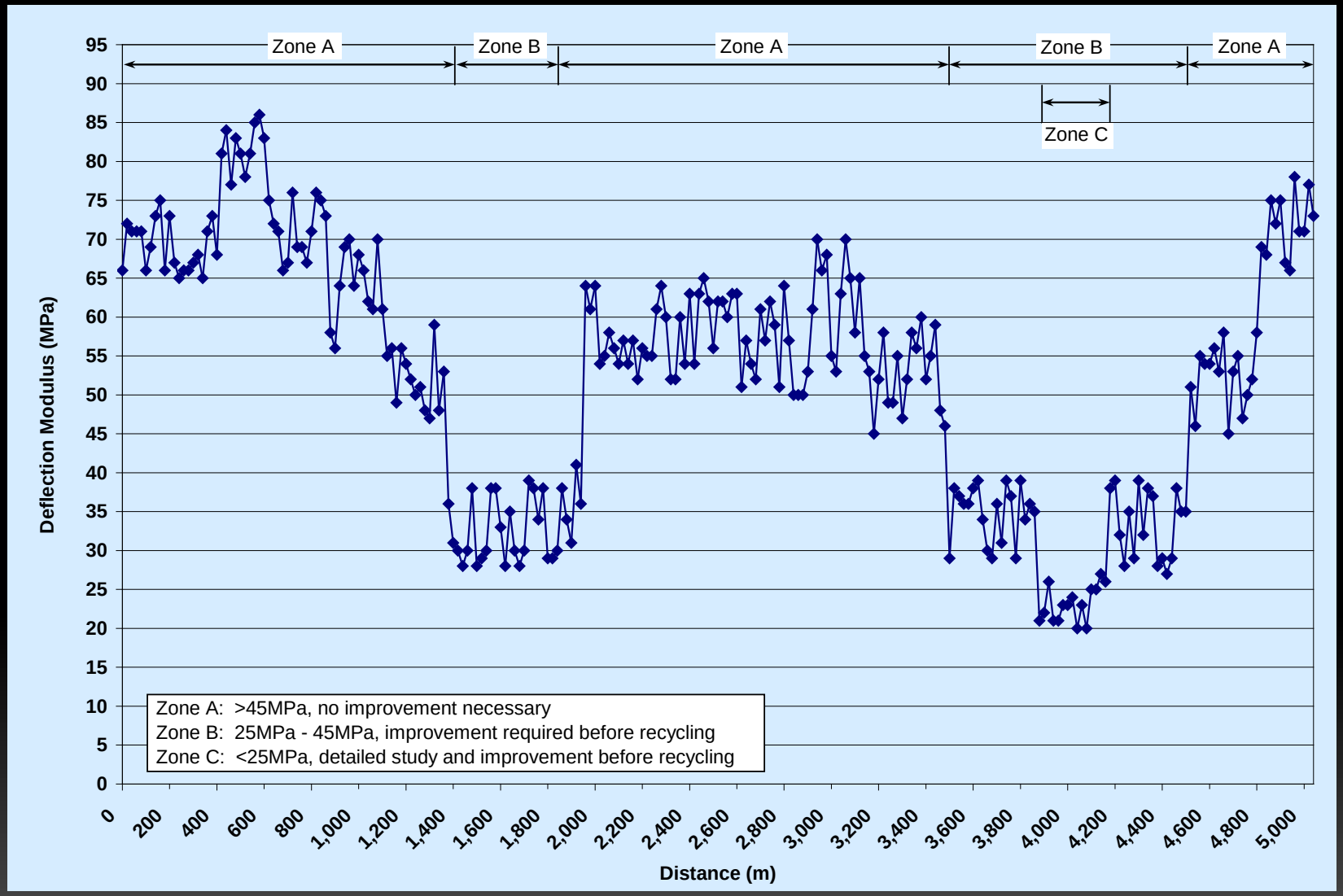
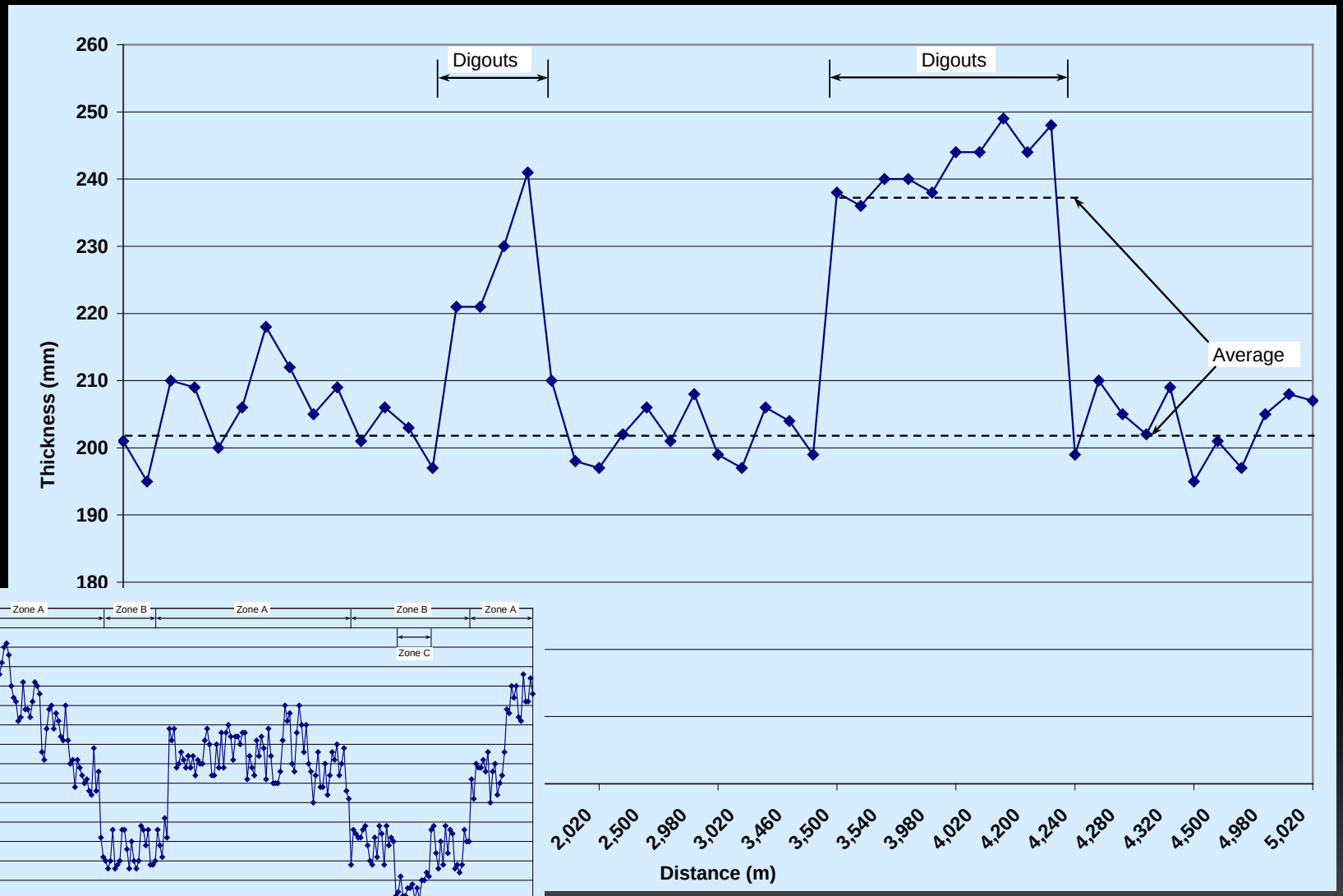
Project Design

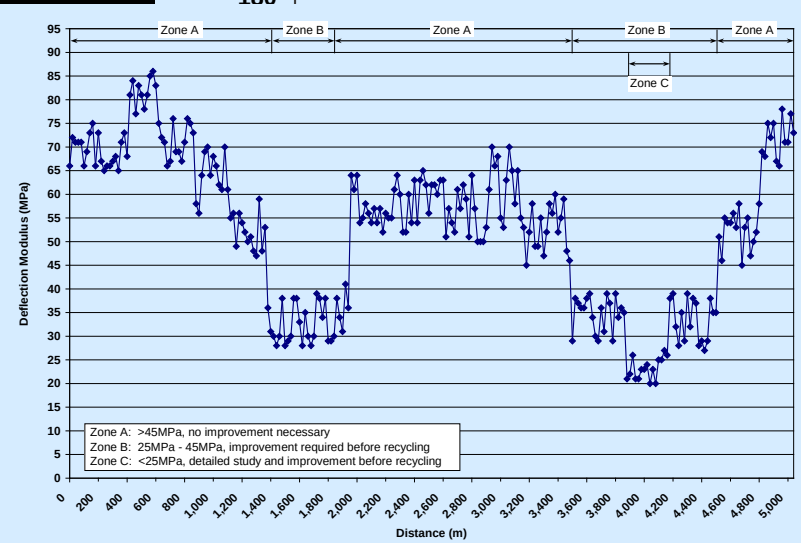
- Lessons learned on project design
  - All projects must be designed
  - Check variability along project length
    - FWD, GPR, cores, DCP, etc.
    - Understand reasons for earlier failures

Subgrade Stiffness - FWD



Layer Thickness Assessment

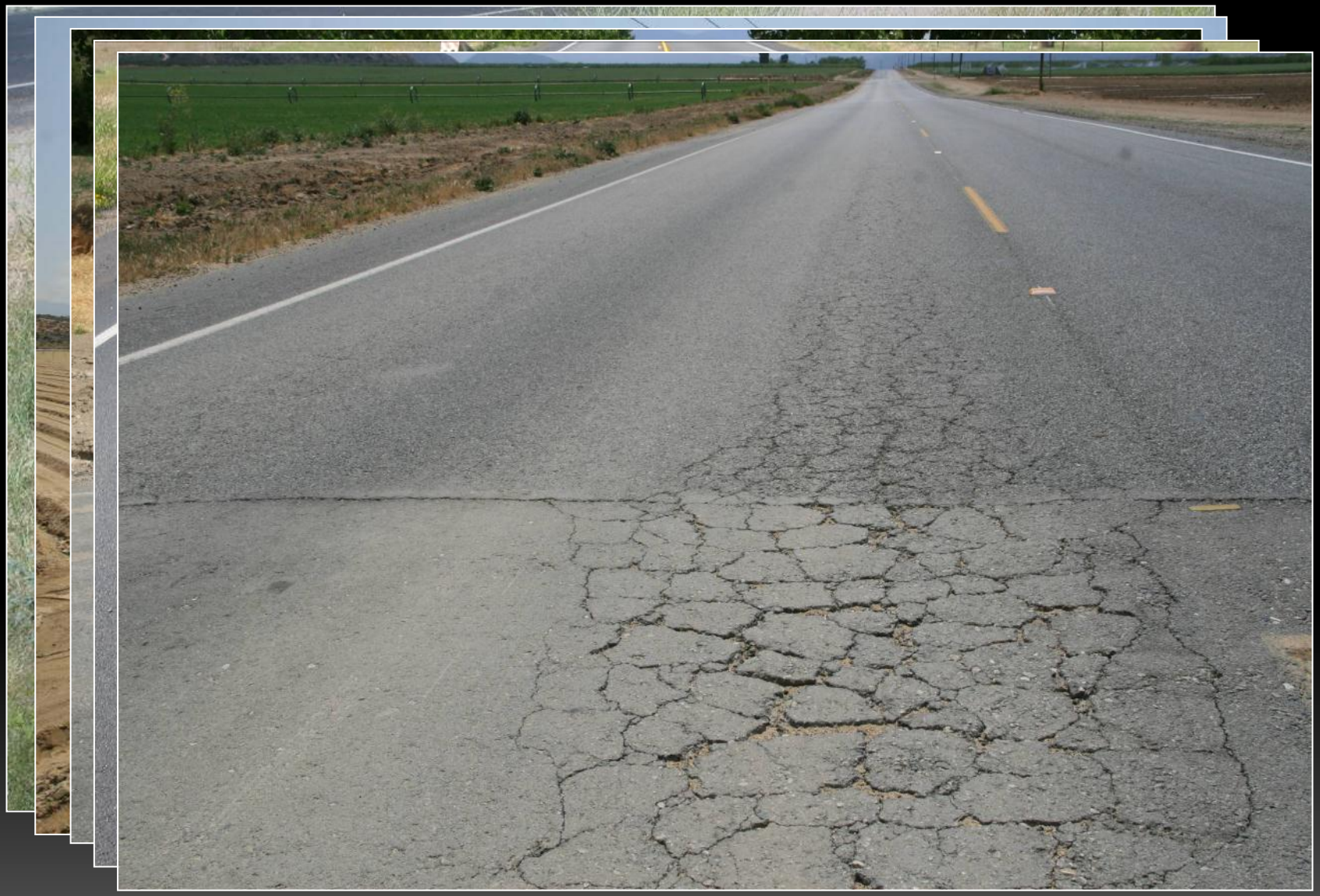




Project Design

- Lessons learned on project design
  - All projects must be designed
  - Check variability along project length
    - FWD, GPR, cores, DCP, etc.
    - Understand reasons for earlier failures
  - Drainage and land use

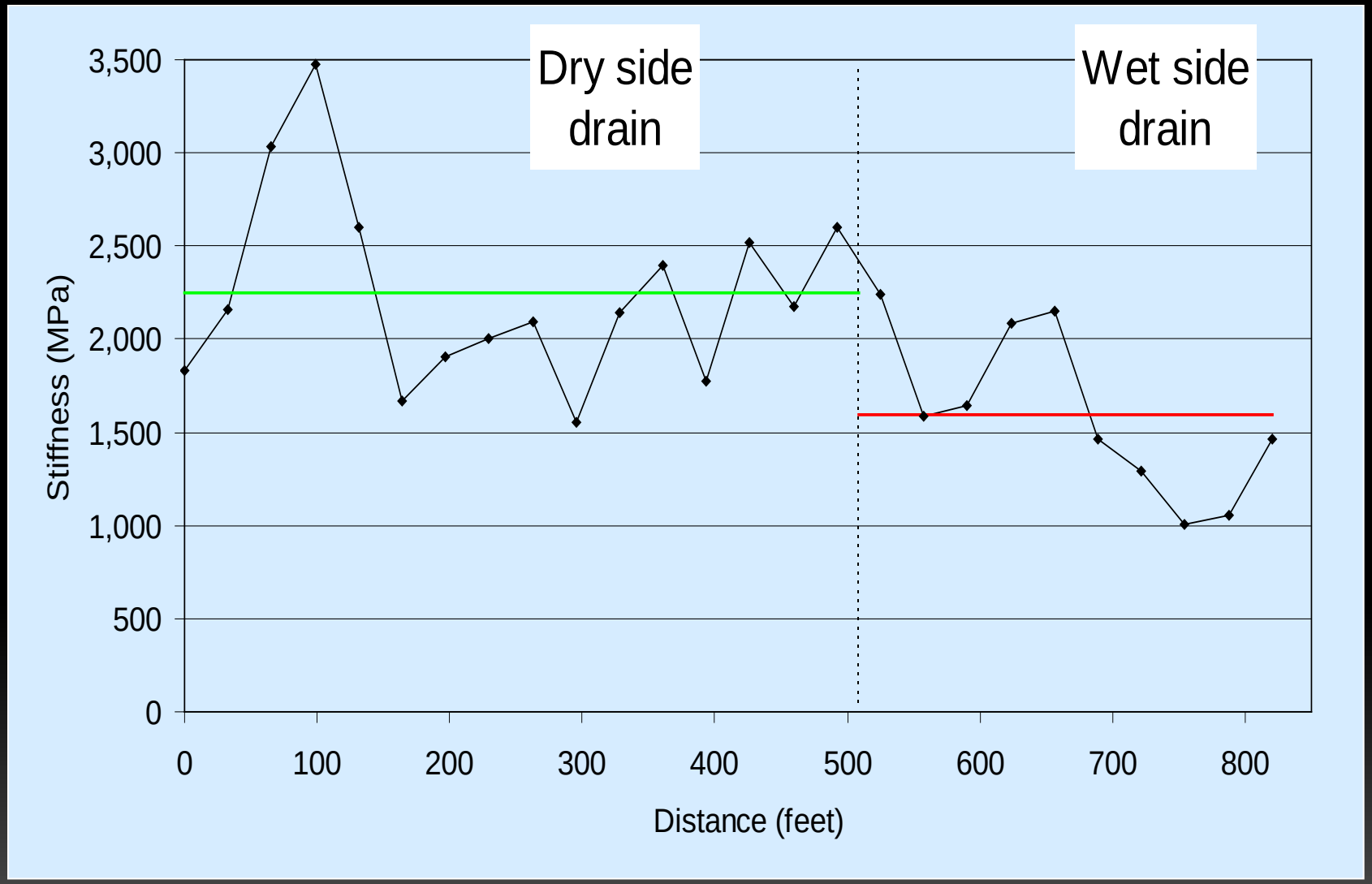
Drainage and Land Use



Drainage and Land Use

Drainage and Land Use

Drainage and Land Use



Drainage and Land Use

E_{FA} (MPa)

0

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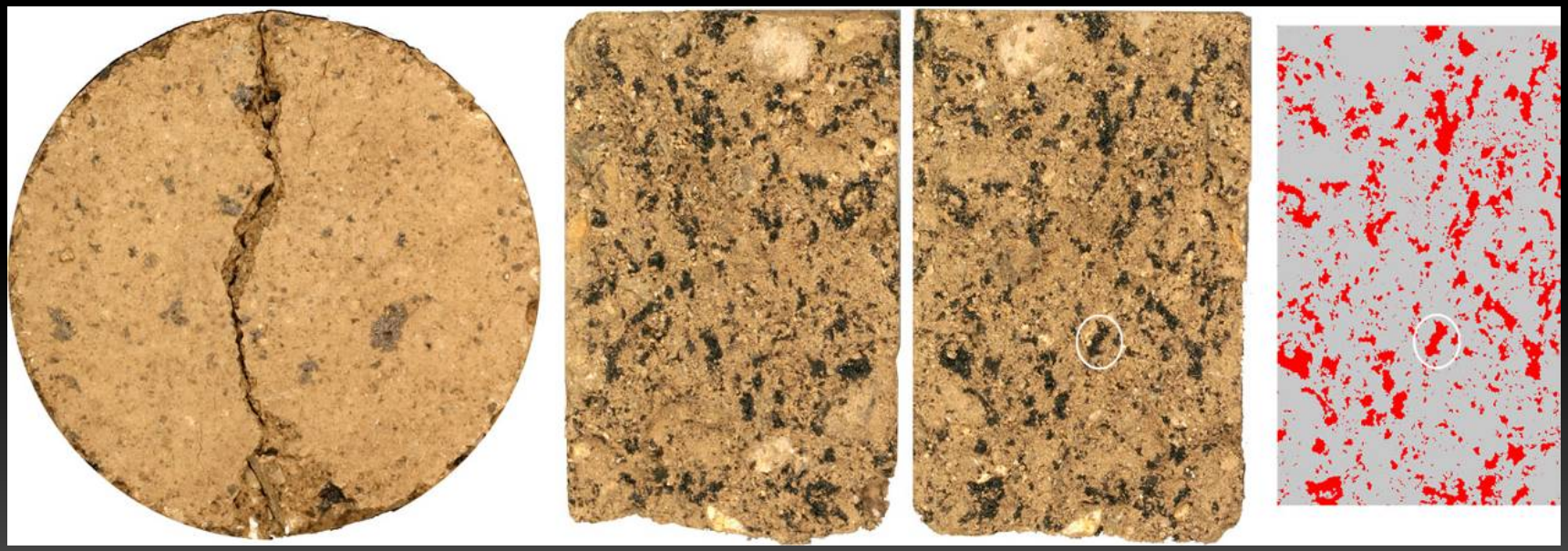
Mix Design

- California mix design based on a comprehensive laboratory test program
  - >4,000 specimens, 8 tons of RAP, ~100 buckets of asphalt binder

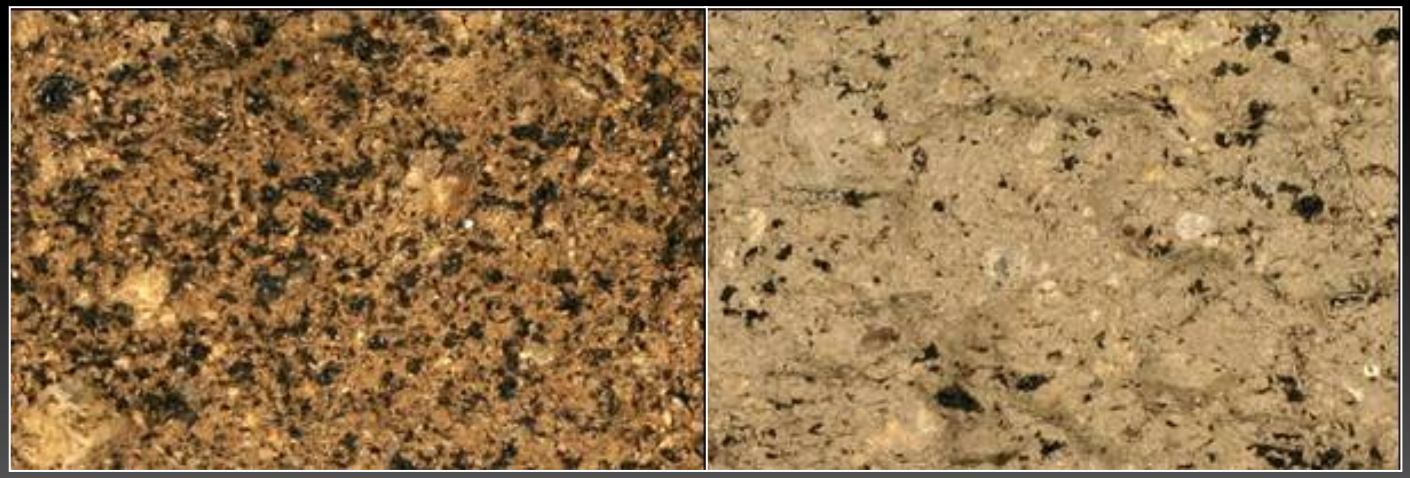


Mix Design

- Lessons learned on binders
  - Highly variable in California, depending on crude source(s)
  - Anti-foamants are used (residual effect)
  - Softer binders have best foam characteristics
  - Foamability requirements should be linked to likely pavement temperature during construction
  - Use a consistent procedure for determining half life

Mix Design

- Lessons learned on aggregate
  - Keep lab aggregate temperature above 20°C (68°F)
  - Keep fines content (passing 0.075mm [#200]) at 5 to 12%
    - Moisture sensitive if more than 15%
    - Binder content usually increases with higher fines content
  - Marginal aggregates can break down under multiple recycler passes



Mix Design

- Lessons learned on laboratory test methods
  - Focus on addressing field issues:
    - Know laboratory testing capability
      - ITS test ok with replicates
    - Check traffic management during/after construction
      - Same-day opening to traffic can dictate active filler content
    - Separate asphalt and asphalt-plus-active filler tests
      - Understand influence/role of each
    - Do soaked and unsoaked tests
    - Use soaked test result (not TSR) for mix design
    - Learn from the fracture faces
  - Typical mix in CA = 3% FA + 1.5% cement

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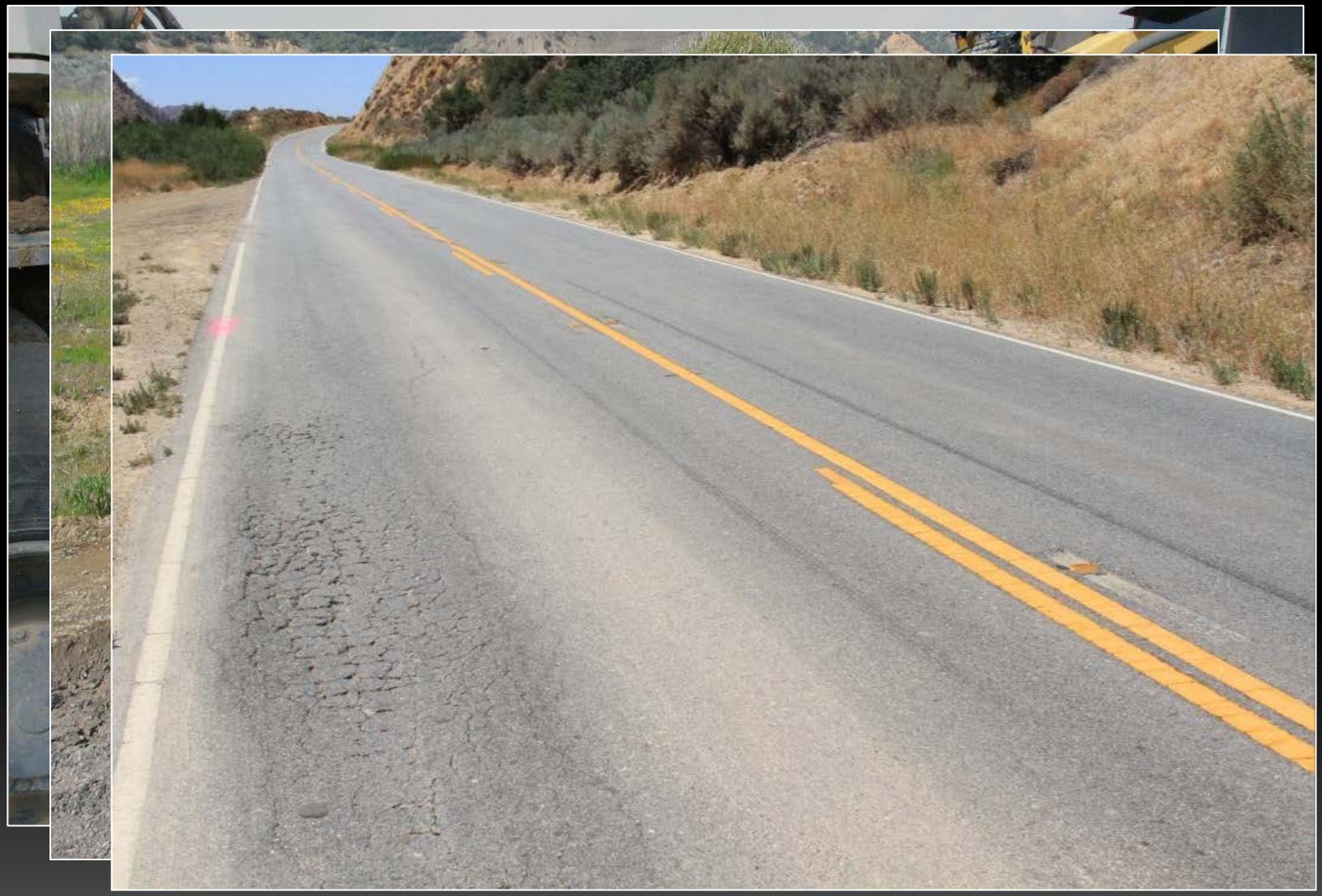
Construction - Benchmark

Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision

Construction – Equipment Issues



Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision
  - Cement/active filler spreading

Construction – Cement Spreading

Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision
  - Cement/active filler spreading
  - Temperatures

Construction - Temperature

Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision
  - Cement/active filler spreading
  - Temperatures
  - Compaction moisture

Construction – Compaction Water

Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision
  - Cement/active filler spreading
  - Temperatures
  - Compaction moisture
  - Compaction

Construction - Compaction

Construction - Compaction

Construction

- Lessons learned on construction
  - Pre-pulverization
  - Equipment issues
  - Training / supervision
  - Cement/active filler spreading
  - Temperatures
  - Compaction moisture
  - Compaction
  - Quality control

Construction – Quality Control

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Conclusions

- FDR is an excellent rehabilitation strategy (state, county and city)
- Projects can go wrong, but the FDR approach is not usually to blame
- Important to capture learning in guidance documents, specifications, and training

Thank you!

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FDR in Texas: Lessons Learned from FDR projects on Expansive Clays

Tom Scullion
Texas A&M Transportation Institute

Critical Issues

1. **Handling Project variability**
2. **Problems on expansive soils**
3. **Early opening of FDR projects in Energy Sector**

Critical Steps in the FDR process

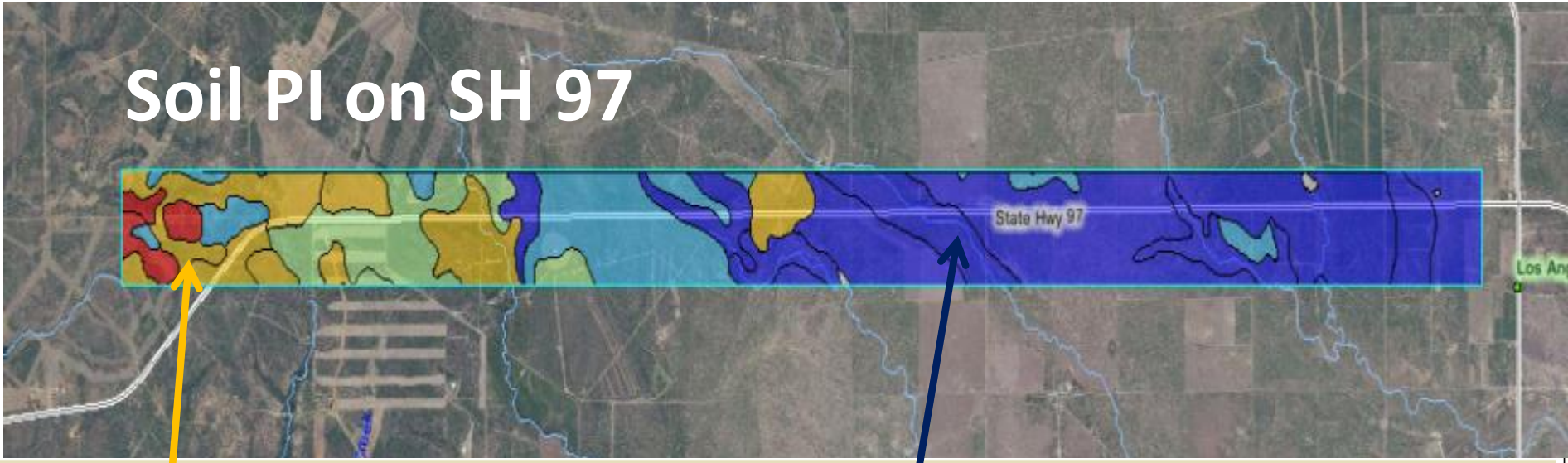
1. Assembling Background Information
2. NDT Evaluation and Section Breakdown
3. Verifying Pavement Structure and Sampling
4. Laboratory Mix Design - Stabilizer Selection
5. Pavement Thickness Design
6. Special Considerations in final design
   1. Expansive High PI Soils
   2. Ensuring Surface bonding
   3. Microcracking
   4. Early Traffic
   5. Sulfates
   6. Cold Weather
7. Construction Quality Assurance
8. Feedback - addressing Performance problems

Assembling Background Information

Using the Web Soil Survey

- http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Press the green “start WSS” button
- Define the Area of Interest (AOI)
- Use Soil Map for soil series information
- Use the Soil Data Explorer for use limitations and soil properties (such as plasticity index or sulfate content)
  - Maps are generated and can be printed or saved

Soil PI on SH 97



Summary by Map Unit — La Salle County, Texas (TX283)

Map unit symbol	Map unit name	Rating (percent)	Acres in AOI	Percent of AOI
BZB	Brystal very fine sandy loam, gently undulating	11.0	124.5	3.1%
CBB	Caid very fine sandy loam, gently undulating	9.8	67.6	1.7%
CDB	Chacon clay loam, gently undulating	27.6	16.7	0.4%
CEB	Charco-Altita complex, nearly level	20.9	9.6	0.2%
Ch	Cochina clay, occasionally flooded	36.5	417.3	10.5%
CUA	Cotulla clay, nearly level	37.5	1,623.1	40.9%
DLC	Dilley fine sandy loam, gently undulating	7.3	80.3	2.0%
LAB	Lasalle clay, gently undulating	37.5	103.9	2.6%
MCC	Maverick clay, gently undulating	31.8	616.9	15.5%
MGC	Moglia clay loam, gently undulating	25.8	41.6	1.0%
Pt	Poteet very fine sandy loam, occasionally flooded	6.1	21.6	0.5%
W	Water		8.8	0.2%
WCB	Webb very fine sandy loam, gently undulating	13.2	492.4	12.4%
ZVB	Zavco sandy clay loam, gently undulating	19.3	345.0	8.7%
Totals for Area of Interest			**3,969.3**	**100.0%**

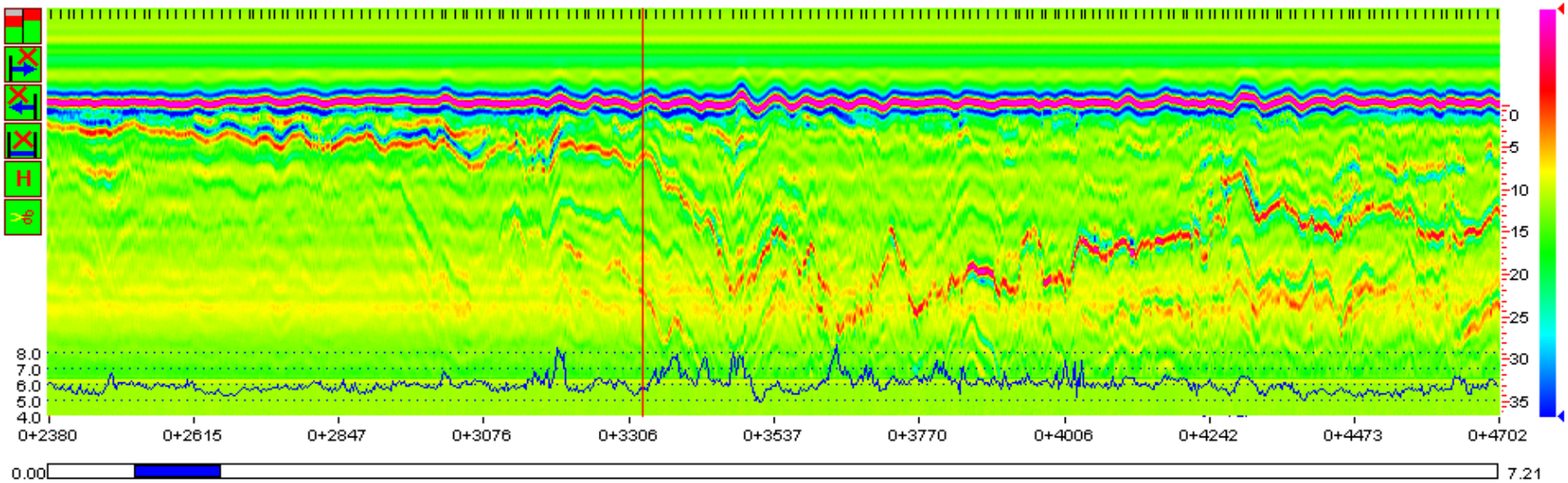
Section 1

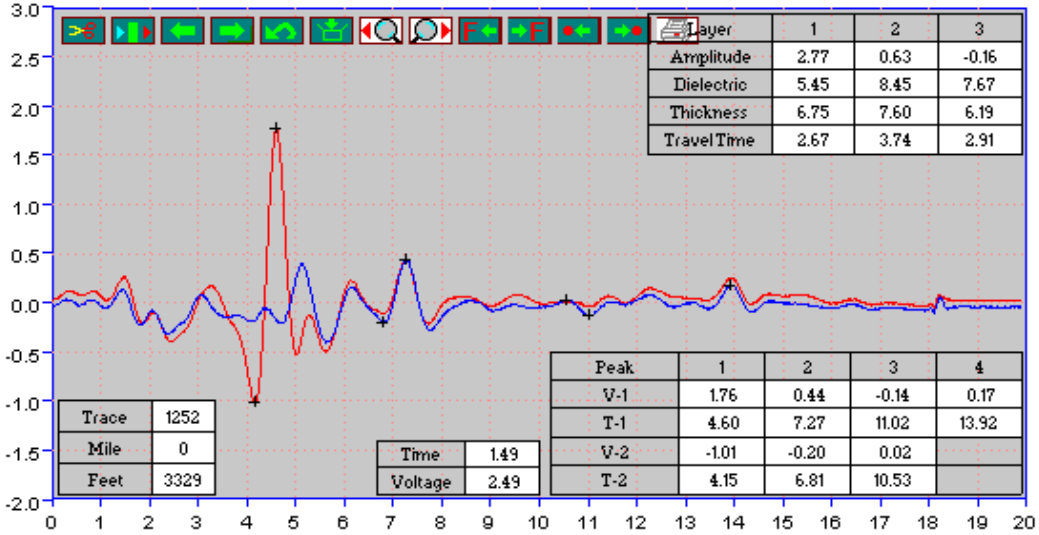
NDT Evaluation and Section Breakdown

- GPR
  - Estimate structure and thickness variability
  - Identify section breaks
  - Choose sample locations

- FWD
  - If structural problems suspected
  - Strength variability, subgrade stiffness

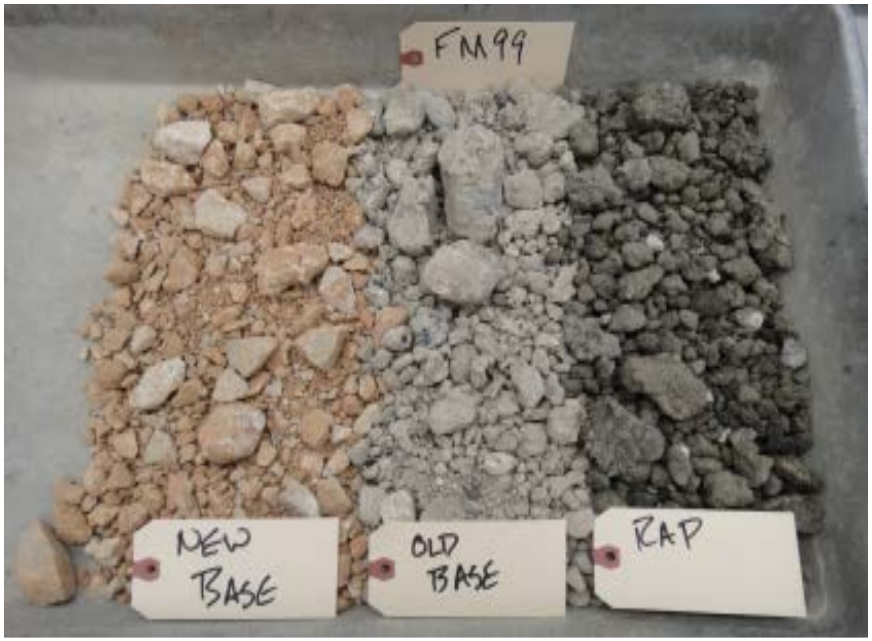
Example GPR Profile





Verifying Pavement Section and Sampling

- Use history and NDT to select locations
- Sampled by auger for layer thickness verification and for laboratory design
- Augur gradation similar to that under reclaimer

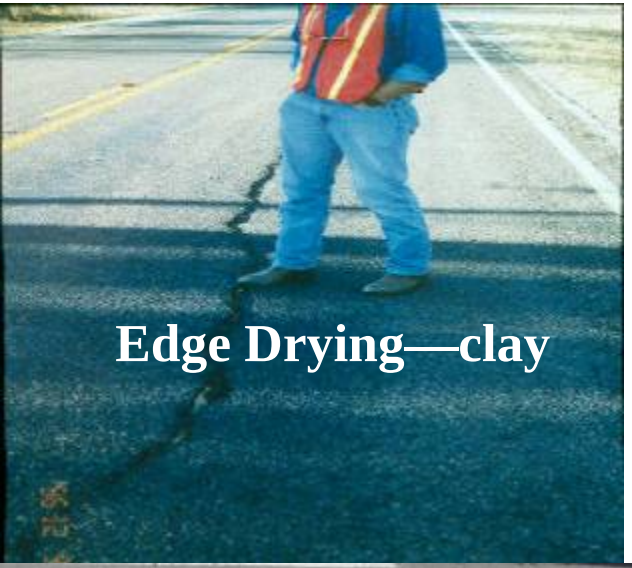


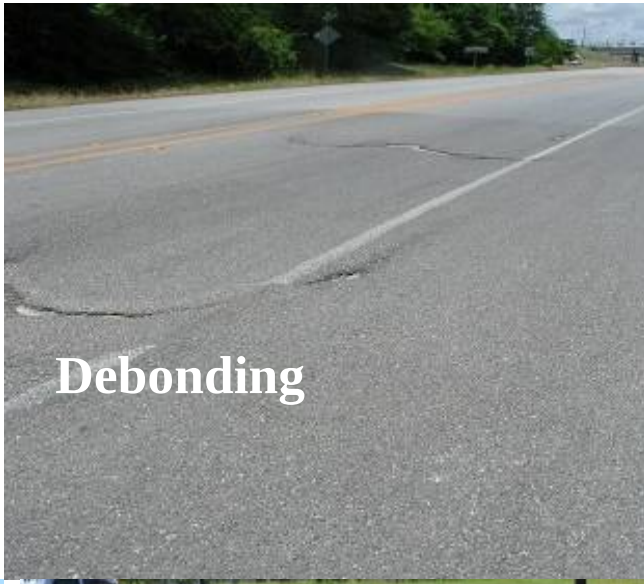
TTI's Lab Equipment

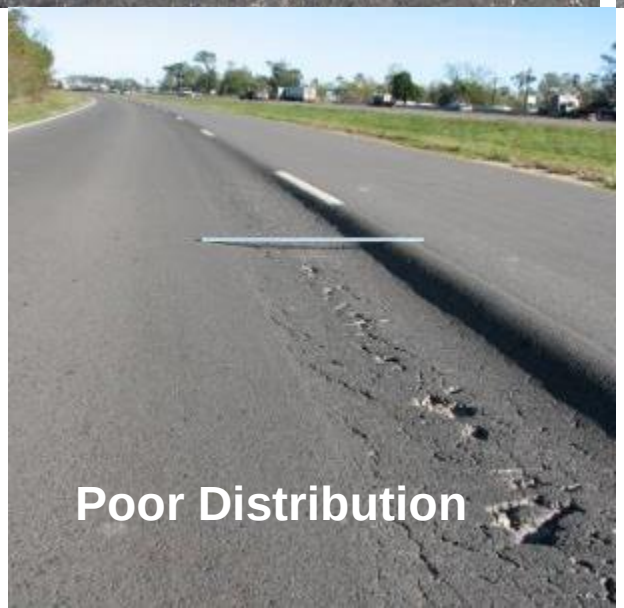
Lab Testing:

- Run PI, OMC, MDD, Sulfates,
- Strength design: Move to small samples to
  - Handle project variability
  - Vary add rock
  - Evaluate multiple stabilizers

Performance Problems with FDR Projects







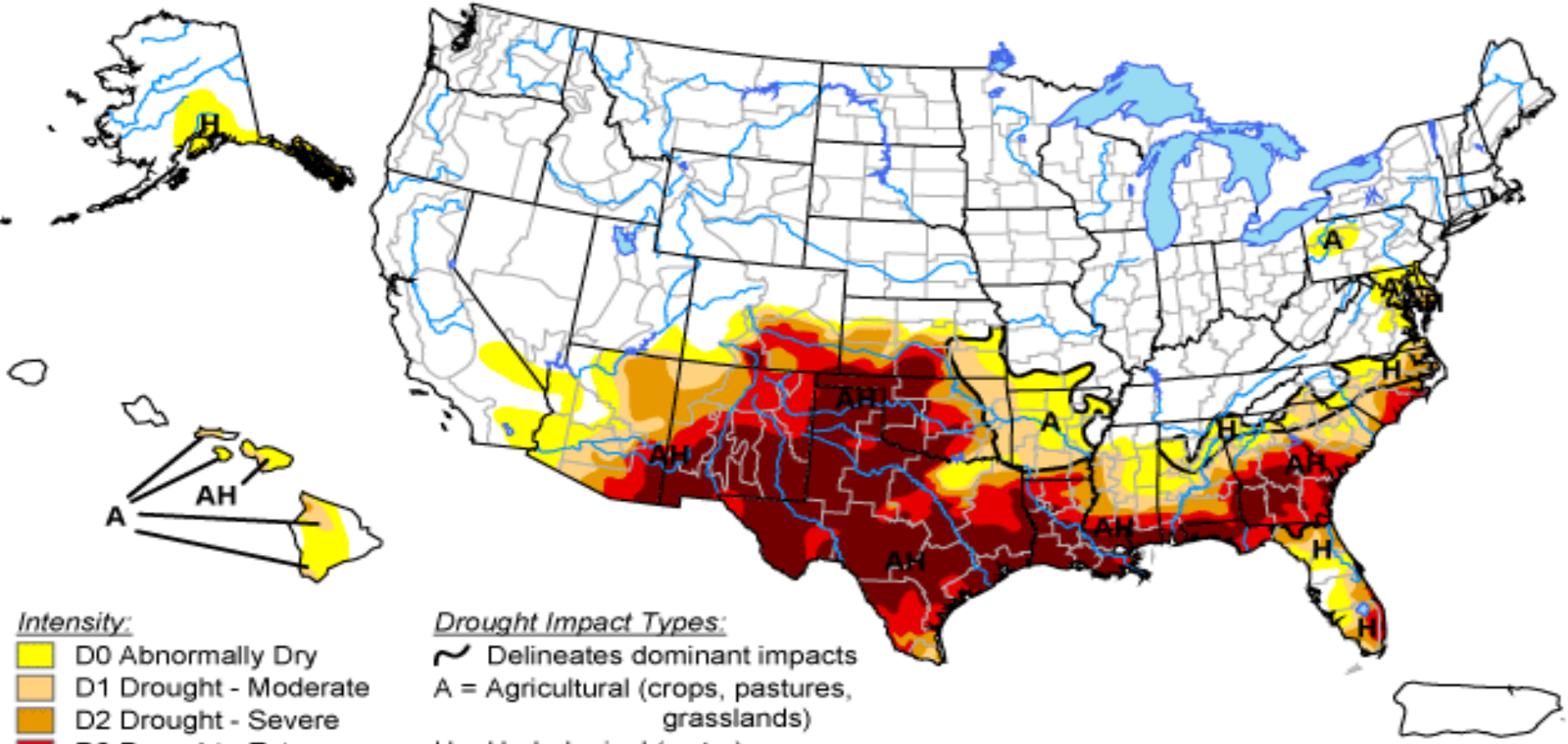
Expansive Clay
Longitudinal Cracking Problems

Causes of Longitudinal Cracking
(Mid 1990's survey)

- **Cracks Originating in Subgrade where:**
  - **PI > 35**
  - **Trees near edge**
  - **Summer droughts**
  - **Stiff bases**
  - **Steep Side slopes**
  - **Lack of edge support**

U.S. Drought Monitor

July 12, 2011
Valid 8 a.m. EDT



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

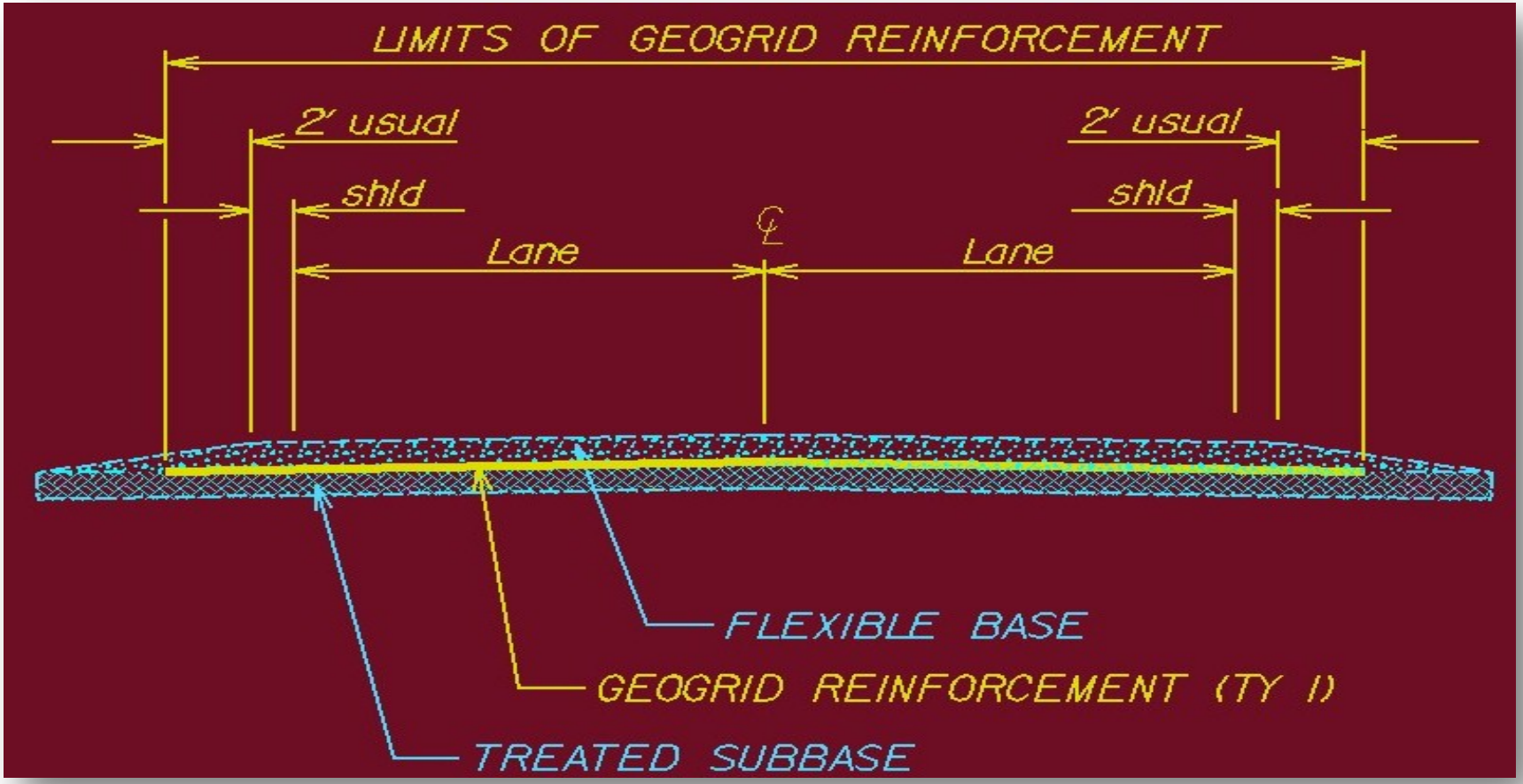
~ Delineates dominant impacts
A = Agricultural (crops, pastures, grasslands)
H = Hydrological (water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

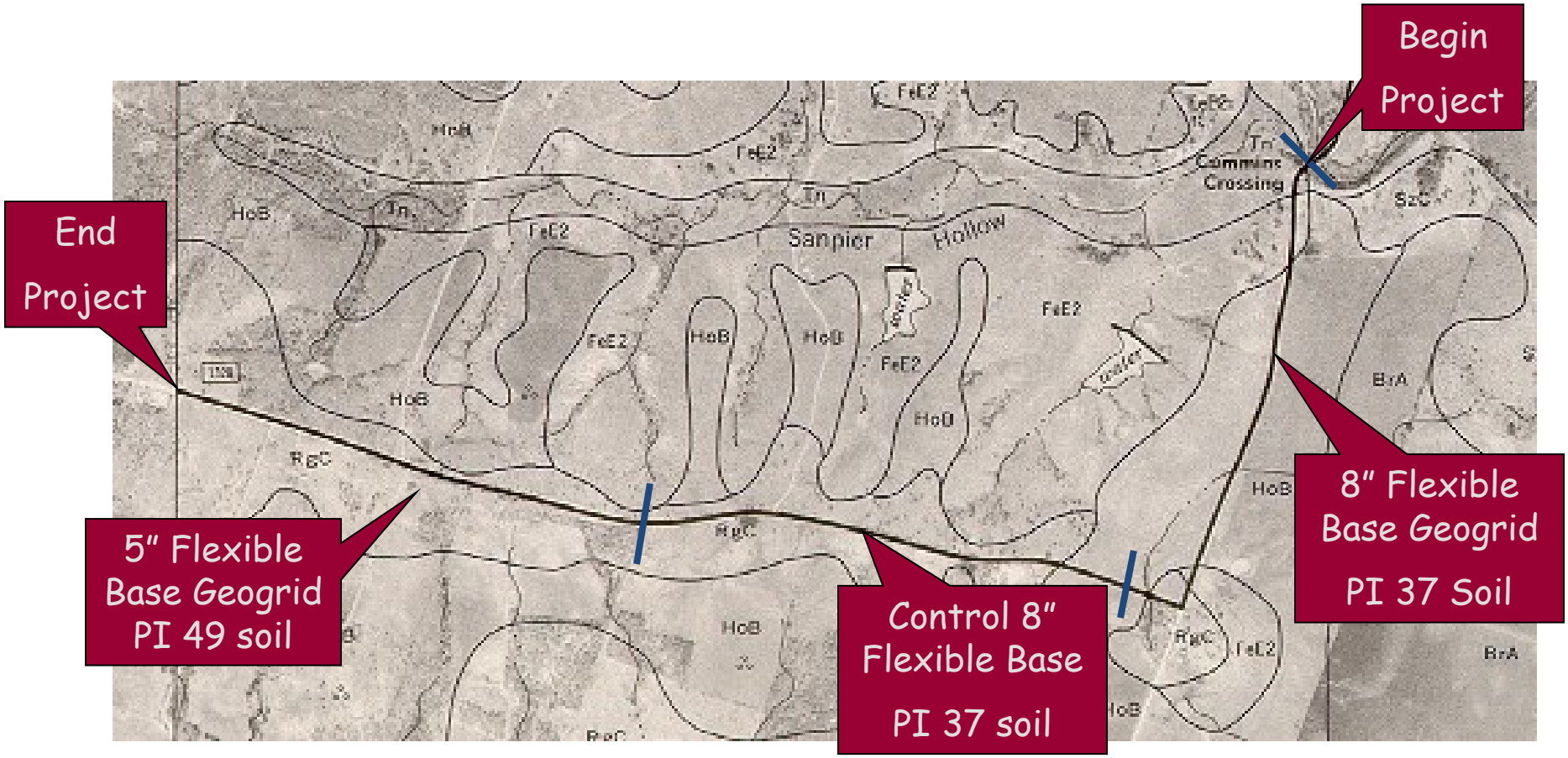
Released Thursday, July 14, 2011
Author: David Miskus, NOAA/NWS/NCEP/CPC

Proposed Typical Section showing Geogrid (mid 1990's, Darlene Goehl)



FM 1915 – Reconstructed in 1997 Bryan District

USDA Service Soil Survey Map



All sections have 10" lime treated subbase (5% lime) and seal coat surface.

Fm1915 – 5 & 16 years after reconstruction

distances measured from Little river relief bridge

GEOGRID SECTION 1
0.65 MILES

2001

2013

GEOGRID SECTION 2,
2.2 miles

2001

2013

Fm1915 – 5 & 16 years after reconstruction

distances measured from Little river relief bridge

CONTROL SECTION,
1.3 miles

2001

2013

CONTROL SECTION,
0.83 MILES

2001

2013

TxDOT Design Approach

(Darlene Goehl Bryan District)

- **Utilize the U.S.D.A maps to identify possible problem soils. Define testing locations based on this information.**
  - **This is in addition to the District's standard one mile testing frequency.**
- **Perform soils tests to a depth of seven feet below the pavement.**
  - **This depth is based on the moisture fluctuation within the district.**
- **Define the limits of potential problem areas based on the soil testing.**
- **Analyze the FWD data, looking for areas of weak subgrade.**
- **Drive the project and look for existing problems and areas maintenance has already repaired.**
- **Combine all the information to define the limits of Geogrid reinforcement.**

Repairing Energy Sector Roads with FDR.

FM 99 Corpus Christi District Summer 2014

Challenges Repairing Roads in the Energy Sector

- Thin weak pavements with often marginal materials
- Exceptionally heavy traffic operating 24/7- many overloads
- No detours: roadway must be opened at end of work day
- Traditional approaches not working

FM 99 Combined Effort

- TxDOT Corpus Christi
- TTI
- Wirtgen Inc.

Up-front Testing and lab Design by TTI

Roadway widened 3 ft on either side

Add base 4 inches

Stabilize with 1.5% cement and 2.4% Foamed Asphalt

Final surface 2 CST

State of The Art Reclaimer provided by Wirtgen

Wirtgen supervised construction

Application of Cement/Foamed asphalt

11 Inch one pass 1.5% cement/2.4% asphalt

Final surface 2 CST

Traffic Allowed on section 1 hour after compaction

FM 99 Open for Business

FM 99 Section Cement/ Foam Asp section	Average Deflection @9000 lbs. (mils)	Backcalculated Base Modulus (ksi)
2 weeks	10.0	495
6 weeks	10.1	433

Recommendations to Date from FM 99

- Foamed asphalt appears viable solution – holds up under early trafficking
- Treatment appears moisture resistant – section while under traffic received 4 in. of rain without damage before placing final surface
- Foam asphalt requires full engineering evaluation with upfront testing, sampling, and lab design
- More testing to arrive at design Modulus – after 2 weeks value of over 400 ksi found

Special Thanks to TxDOT Staff

Research and Technology Transfer Division, Austin

Darlene Goehl Area Engineer Bryan District

Oscar Soliz Area Engineer Corpus Christi District

Valente Olivarez Director of Construction Corpus

Long Term Performance of Full Depth Reclamation (FDR) with Expanded (Foamed) Asphalt in Cold Regions

Becca Lane, P.Eng.
Materials Engineering and Research Office
Ministry of Transportation Ontario, Canada

Outline

- Introduction
- Advantages of Full Depth Reclamation (FDR) with expanded (foamed) asphalt
- Hwy 17, Wawa demonstration project
- Long term performance
- Other projects
- Conclusions

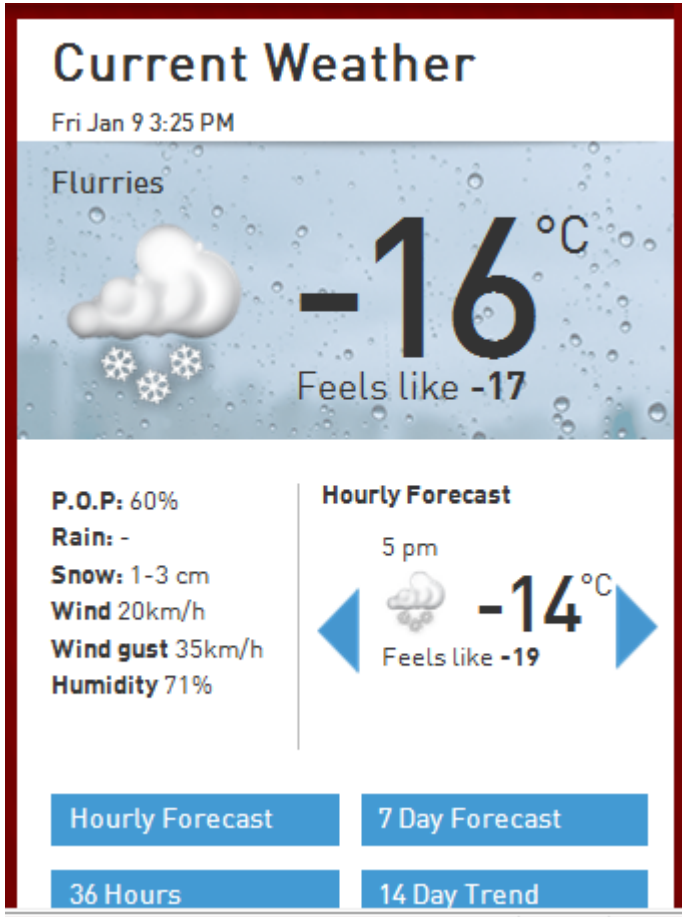
Introduction

- MTO constructed its first Full Depth Reclamation (FDR) with expanded (foamed) asphalt stabilization project on the Trans Canada Highway north of Sault Ste. Marie, Ontario in the summer of 2001.
- This presentation focuses on the results of long term performance monitoring of that project and highlights the performance of subsequent projects.

Project Location is in a Cold Region!!

- Highway 17 within the boundaries of Lake Superior Provincial Park.
- Project length 22.5 km

Typical winter…



Why use Expanded Asphalt Stabilization (EAS)?

- Need to conserve natural resources
  - No aggregate extraction within park boundaries
  - EAS pulverizes and reuses existing materials, uses asphalt stabilization to strengthen the granular base, and saves a lift of hot mix asphalt
- In place process reduces transportation of materials
  - Trucking, energy and emissions reduced
- Previous challenging experience in the local area with CIR
  - Moisture-related concerns in cool, damp, foggy microclimate – difficult to cure and remove moisture from CIR mat

Pavement Design

- In-place full depth reclamation (FDR) of the existing HMA and granular base to a depth of 200 mm
  - 50:50 blend, max size 26.5 mm
- Stabilize reclaimed material by adding 2.8-3.0% expanded (foamed) asphalt:
  - In this process, a small amount of cold water is added to hot asphalt cement causing it to rapidly expand (foam). The foamed asphalt is uniformly mixed into the reclaimed materials.
- Grading/placing and compacting
- 80 mm HMA overlay placed following a minimum 2 day curing period

Construction: August 2001


13687


AUG 13 2001


AUG 13 20

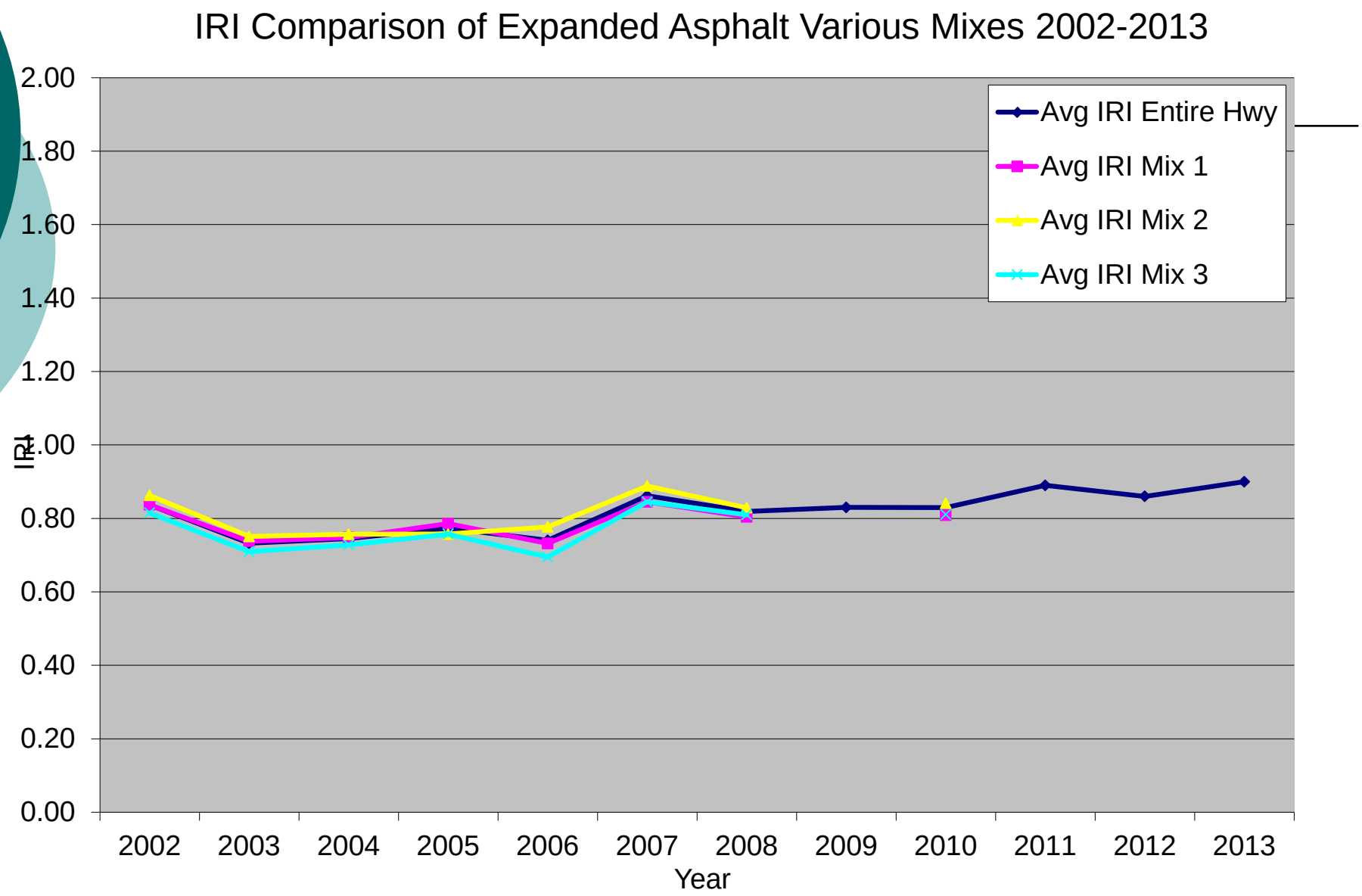

AUG 13 2001

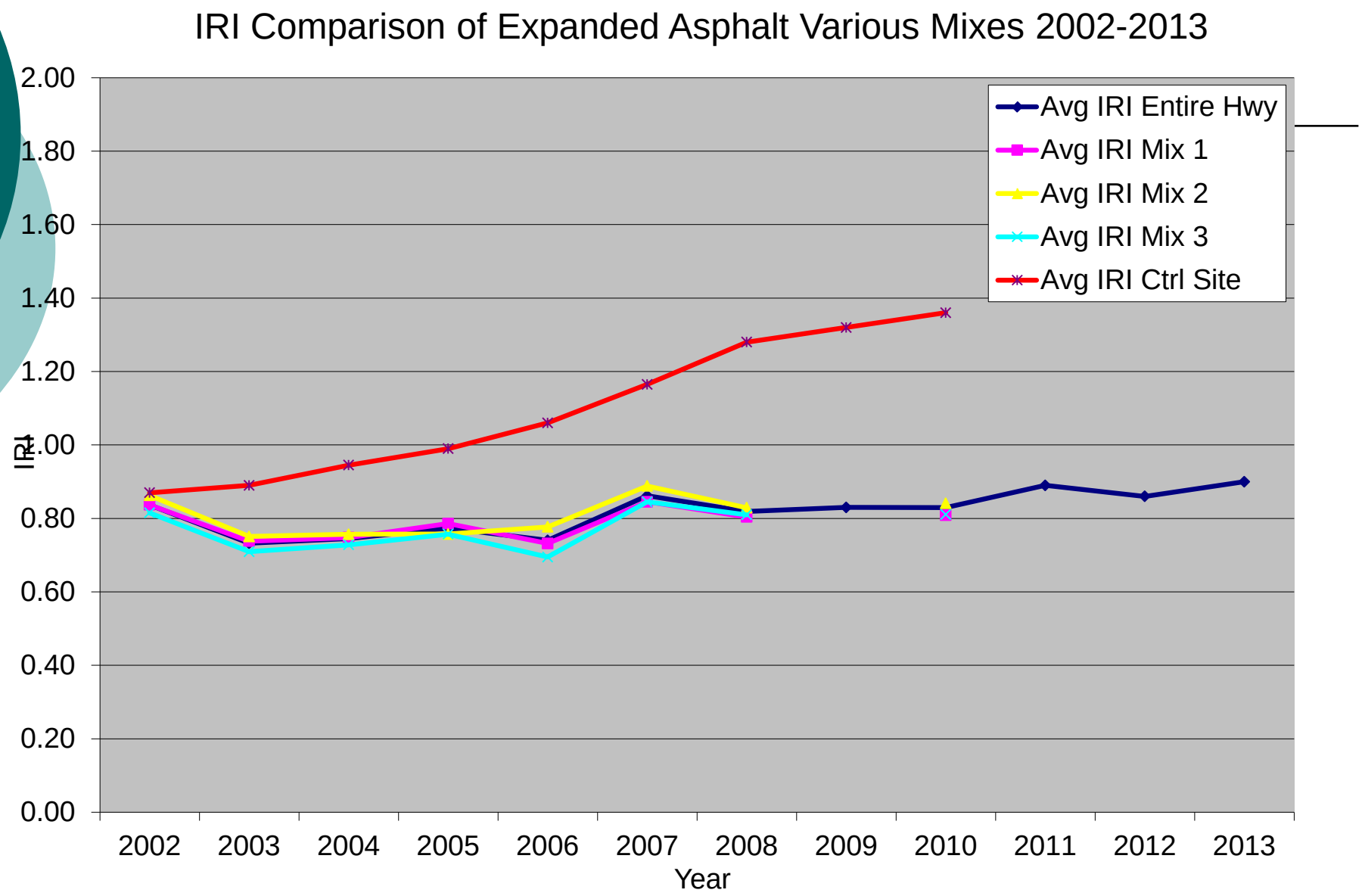

Crossfall
correction

Long Term Performance

ARAN Monitoring

- To monitor pavement performance, MTO carried out annual ARAN testing:
  - Roughness (IRI) and rutting surveys
  - Visual distress data collection (DMI)
    - IRI & DMI used to calculate Pavement Condition Index (PCI)


IRI Comparison of Expanded Asphalt Various Mixes 2002-2013
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
IRI
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Avg IRI Entire Hwy
Avg IRI Mix 1
Avg IRI Mix 2
Avg IRI Mix 3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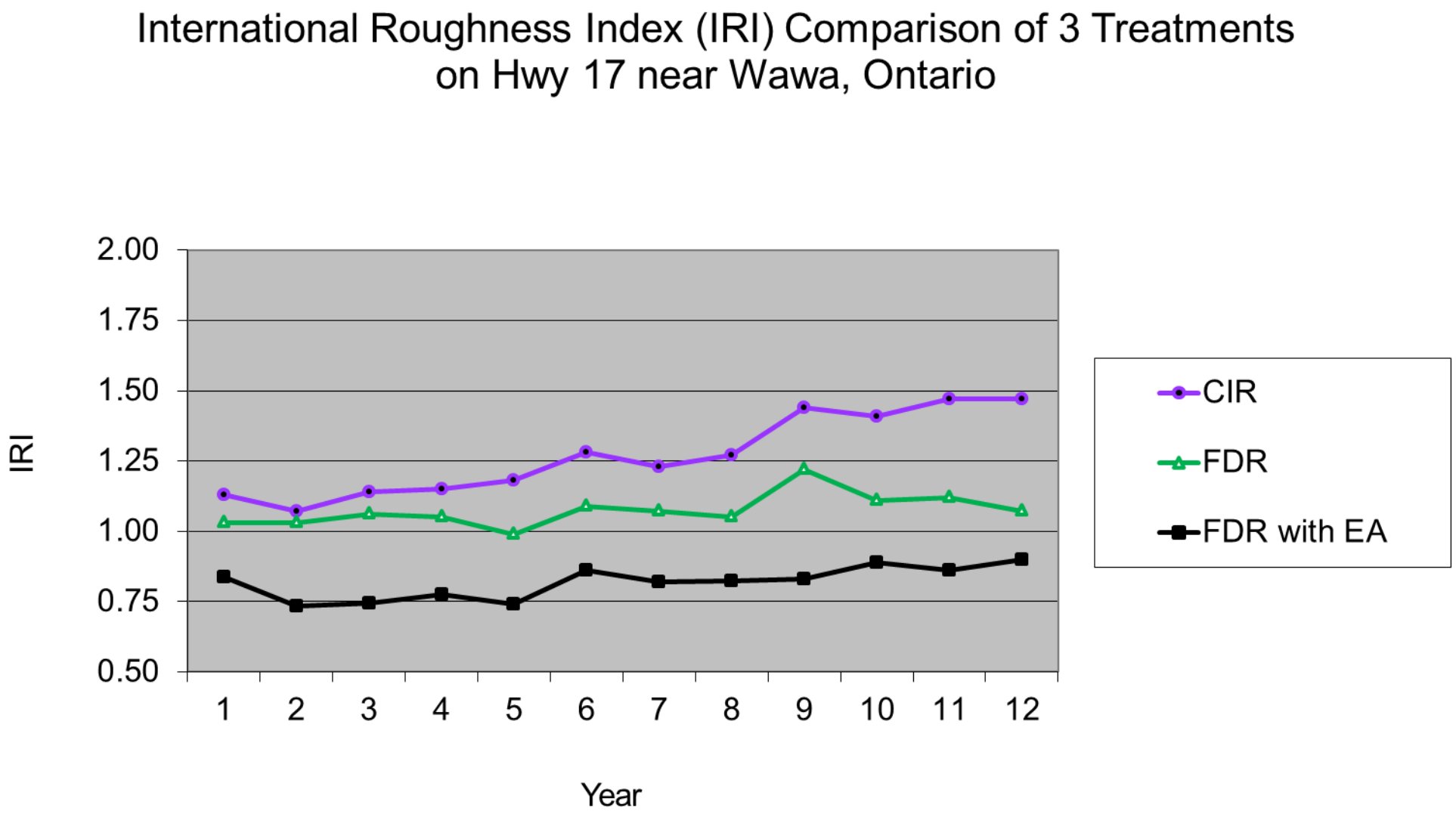
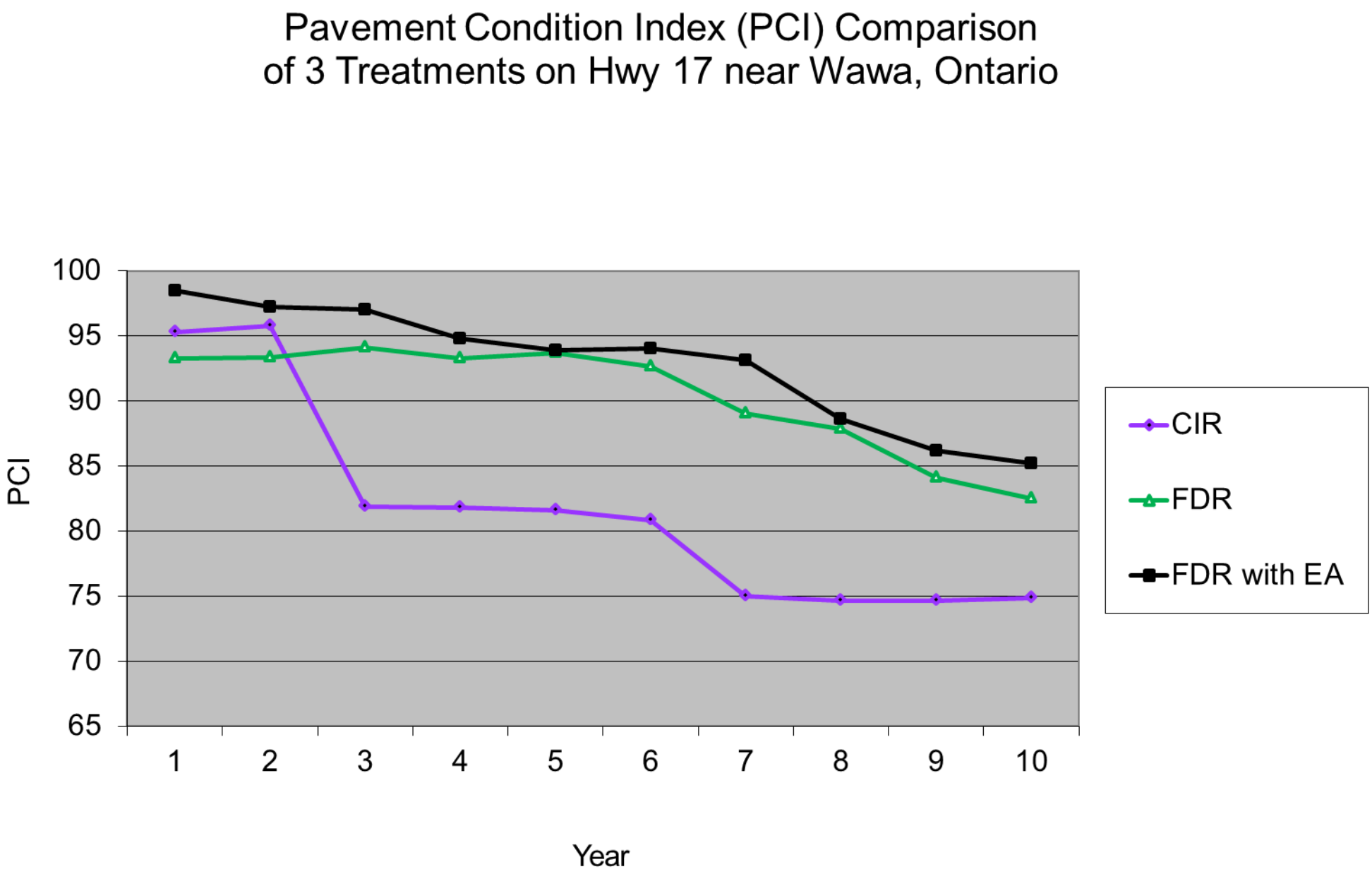
0.40
0.20
0.00
IRI
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year
Avg IRI Entire Hwy
Avg IRI Mix 1
Avg IRI Mix 2
Avg IRI Mix 3
Avg IRI Ctrl Site

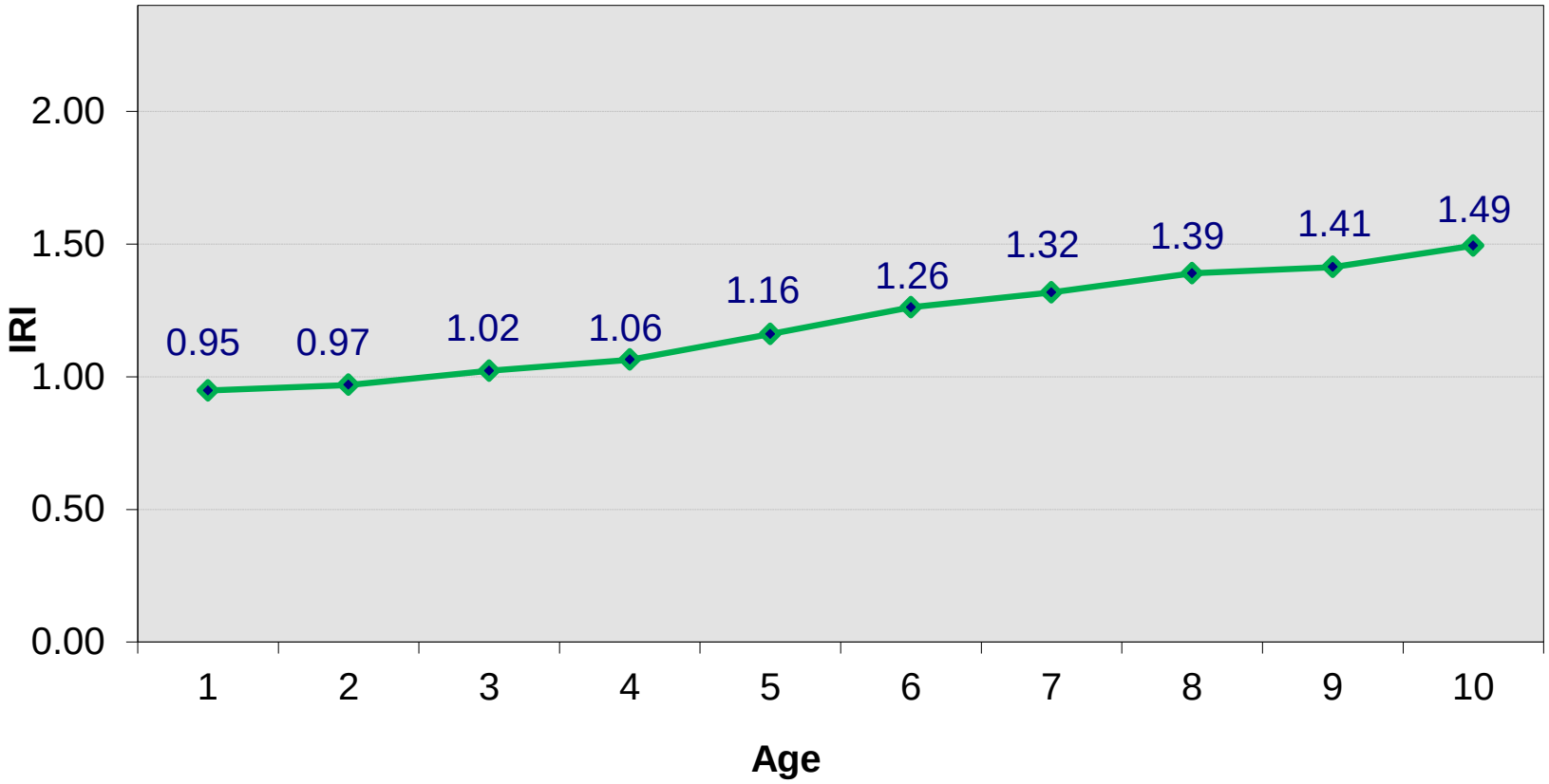
Summary of Long Term Performance (Hwy 17, Wawa)

- Results of ARAN surveys carried out in the years following construction found that the pavement has remained smooth (IRI<1) and in excellent condition (PCI>85) after 10 years in service.
- The three different mix designs, two with corrective aggregate and one without, performed similarly over the 10 year period.
- A control section of FDR with 80 mm HMA overlay started off with similar performance but deteriorated at a much faster rate.

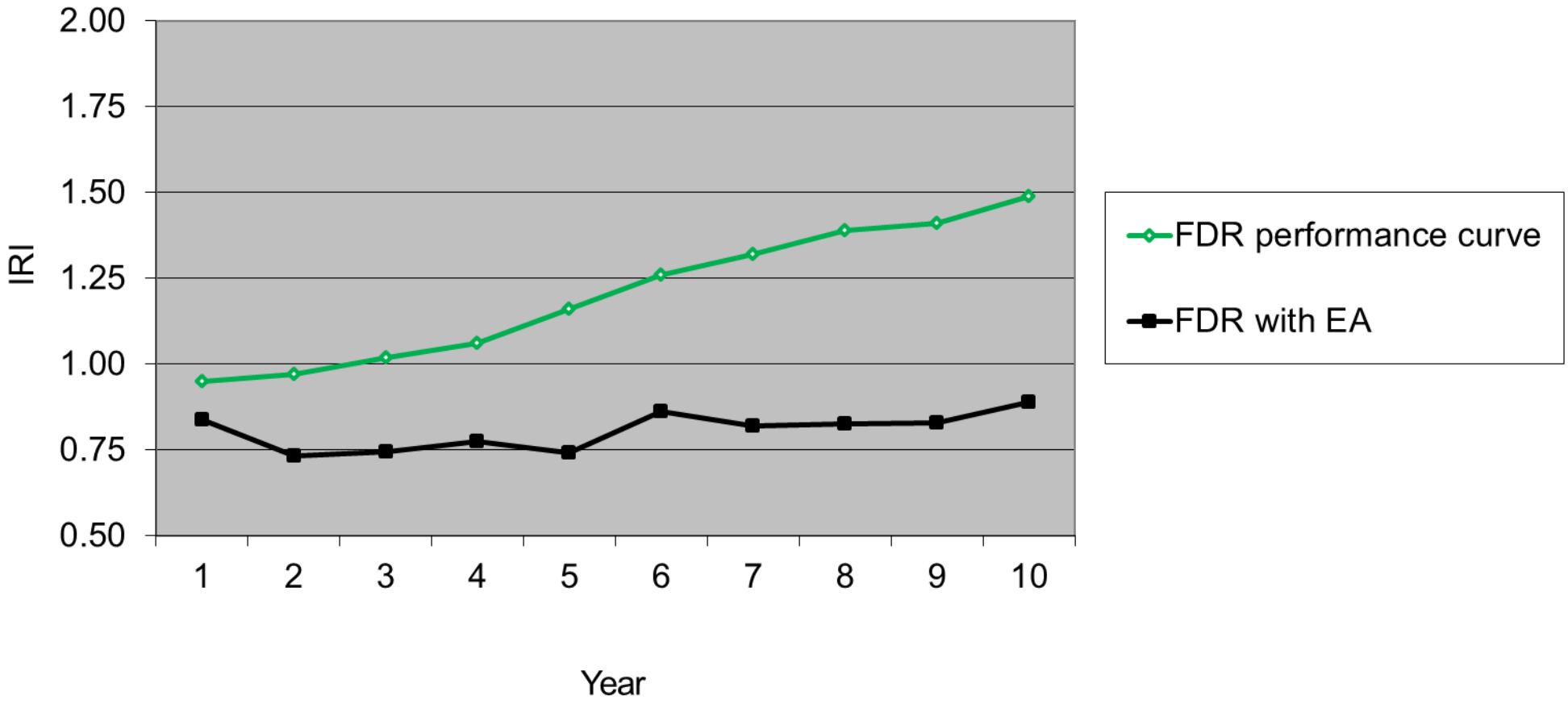

International Roughness Index (IRI) Comparison of 3 Treatments on Hwy 17 near Wawa, Ontario
IRI
2.00
1.75
1.50
1.25
1.00
0.75
0.50
1
2
3
4
5
6
7
8
9
10
11
12
Year
CIR
FDR
FDR with EA

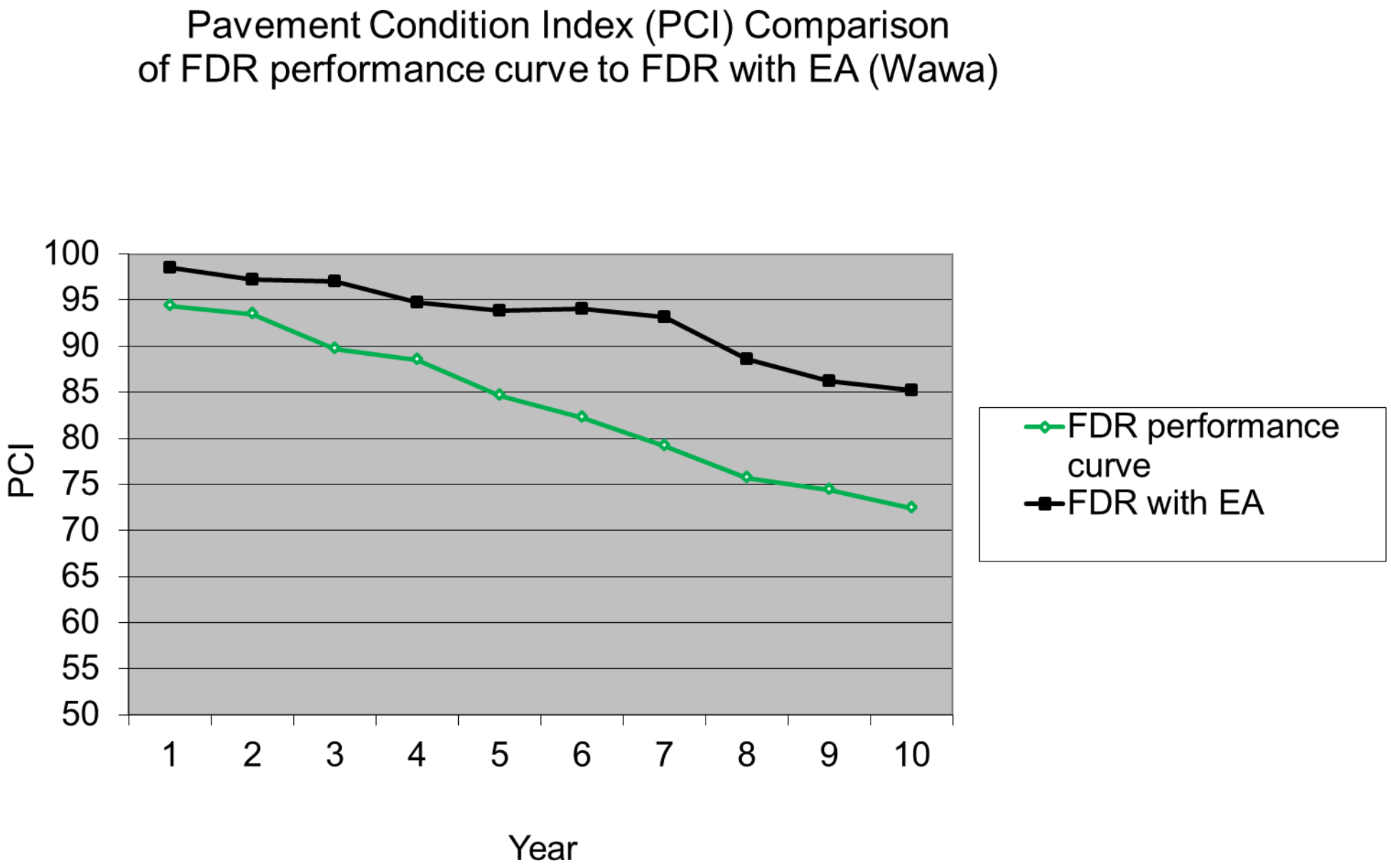

Pavement Condition Index (PCI) Comparison
of 3 Treatments on Hwy 17 near Wawa, Ontario
100
95
90
85
80
75
70
65
PCI
1
2
3
4
5
6
7
8
9
10
Year
CIR
FDR
FDR with EA

IRI Performance of 100 Full Depth Reclamation Contracts



10 Year International Roughness Index (IRI) Comparison of FDR performance curve to FDR with EA (Wawa)




Pavement Condition Index (PCI) Comparison
of FDR performance curve to FDR with EA (Wawa)
100
95
90
85
80
75
70
65
60
55
50
PCI
1
2
3
4
5
6
7
8
9
10
Year
FDR performance curve
FDR with EA

Summary…

- Results also indicate that the EAS with a two lift HMA overlay rehabilitation strategy performed better than adjacent CIR and FDR projects.
- Performance of the Hwy 17, Wawa EAS project was compared to the ministry's established IRI and PCI performance curves for FDR with HMA overlay
  - the FDR with EAS is outperforming the average FDR project both in terms of roughness (IRI) and pavement condition (PCI).

10 Other Projects

- MTO’s first FDR with Expanded Asphalt project was in 2001 and more than 10 projects have been carried out since.

Introduction of “Paver Laid” EAS

2003

Introduction of “Compacting Paver”

2003

Addition of Lime

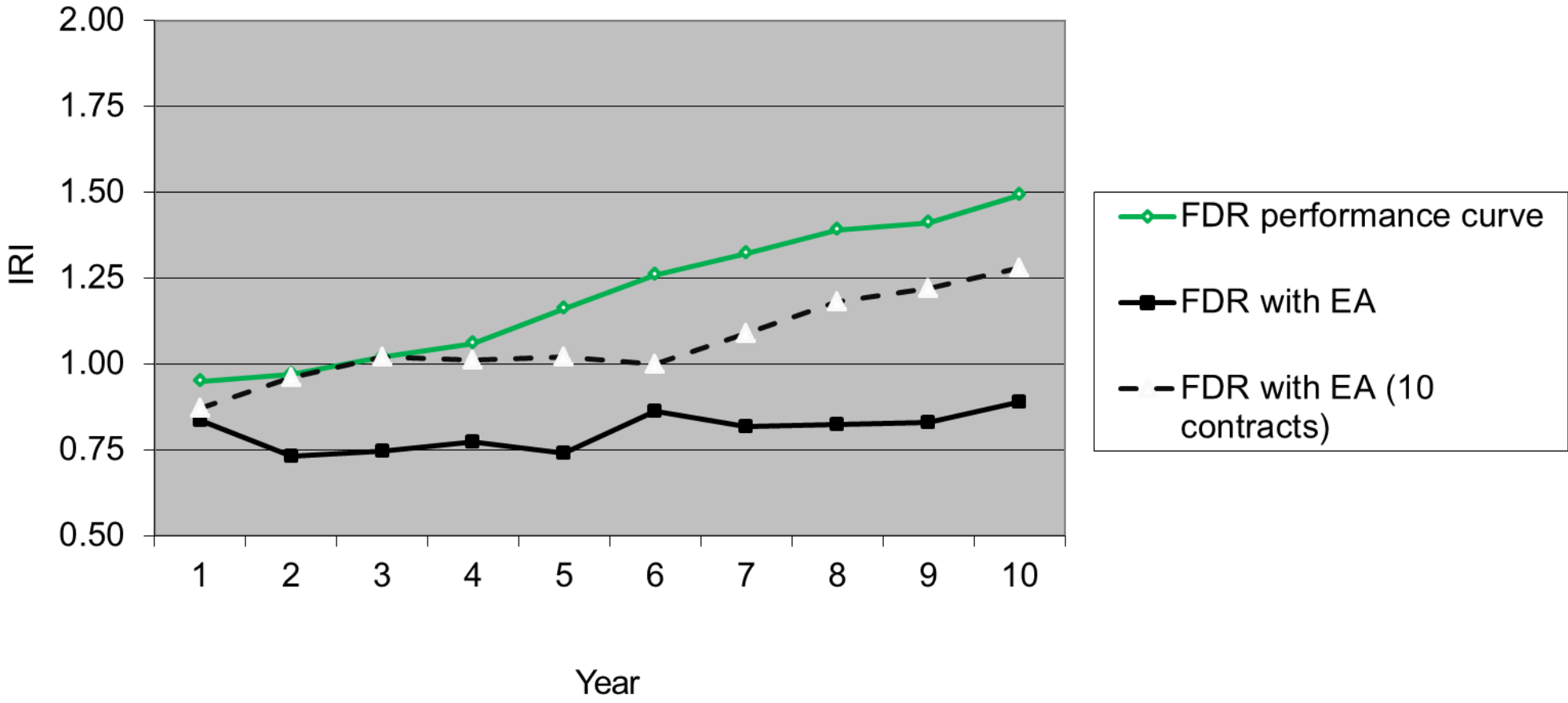
2004

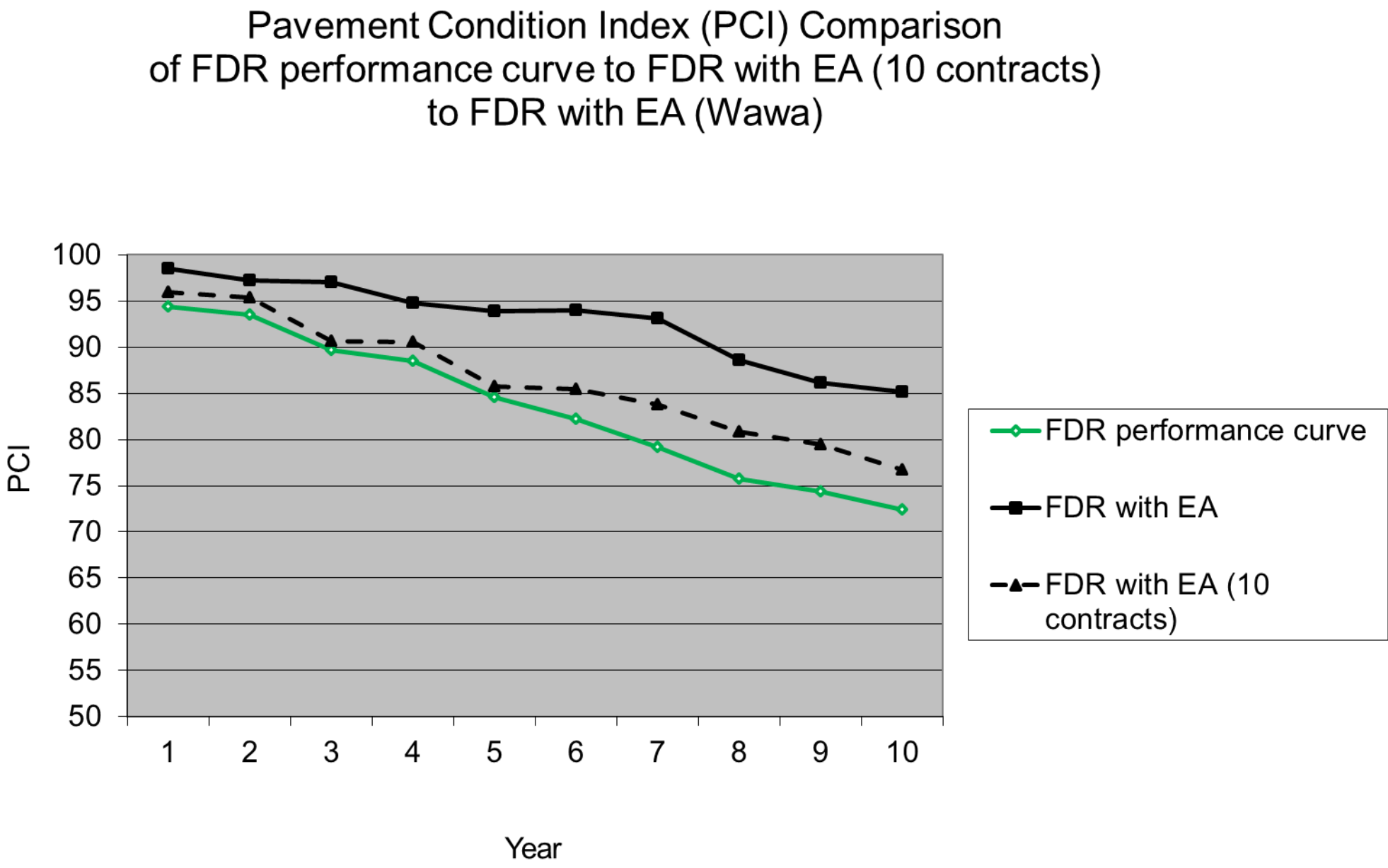
Some issues with over-asphalting

Experiment with Widenings

2006

10 Year International Roughness Index (IRI) Comparison of FDR performance curve to FDR with EA (10 contracts) to FDR with EA (Wawa)




Pavement Condition Index (PCI) Comparison
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PCI
100
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50
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2
3
4
5
6
7
8
9
10
Year
FDR performance curve
FDR with EA
FDR with EA (10 contracts)

Conclusions

- FDR with expanded (foamed) asphalt stabilization has been shown to provide an acceptable in-place recycling rehabilitation strategy that conserves natural resources and provides an economic alternative to conventional FDR with HMA overlay, particularly in areas where aggregates are in short supply.

Thank you!

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Lessons Learned from Using FDR on Virginia DOT Highways

Brian Diefenderfer, PhD, PE

Overview

- Agency methods to begin using FDR
  - Specifications
  - Guidelines
- Research to extend use of FDR
  - Long-term performance monitoring
  - Instrumented pavements
  - Laboratory testing

Pavement Recycling

- A set of cost-effective and environmentally sensitive techniques for pavement rehab
- Benefits
  - 30 to 50 percent cost savings
  - 50 percent less greenhouse gases emitted
  - Fix deterioration <u>causes</u> rather than <u>symptoms</u>
- Used by VDOT
  - Full-depth reclamation, cold in-place recycling, cold central-plant recycling

Full-Depth Reclamation

- Mechanical stabilization
  - Additional aggregate or RAP
- Asphalt stabilization
  - Foamed asphalt
  - Emulsified asphalt
- Chemical stabilization
  - Cement
  - Lime
  - Fly ash (type C or F)
  - Cement / lime kiln dust

VDOT Pavement Recycling History

- Pre-2008
  - Regional focus, no monitoring
- 2008-2011
  - 8 projects, 2-year FDR study
  - I-81 project
  - NCAT test sections constructed
- 2012-today
  - Specs and usage guidelines
  - NCAT test sections continuation

Specifications

- Experience requirement
- Quality control plan
  - Corrective action list
- Acceptance requirements
  - Field density
  - Stability / indirect tensile / compressive strength
  - Gradation
  - Depth
  - Stabilizing agent dosage

Maximum!

Specifications

- Mix design
- Recycling equipment
  - Roller weights, etc.
- Test strip construction
- Weather limitations

Guidelines

- Length of project
- Distress rating
- Maintenance history
- Overlay thickness requirements
  - Generally meet SN calculations
  - 2-course overlay on interstate
  - May specify thickness for given traffic levels
- Directives / carrots
  - First consideration for greater than 4 inches?
  - Dedicated pot of funding

I-81

- 23,000 AADT
- 28% trucks
- 7.2 lane miles
- Constructed 2011

I-81

4-inch New AC	6-inch New AC
8-inch CCPR	6-inch CCPR
12-inch FDR	
Subgrade	

Right Lane

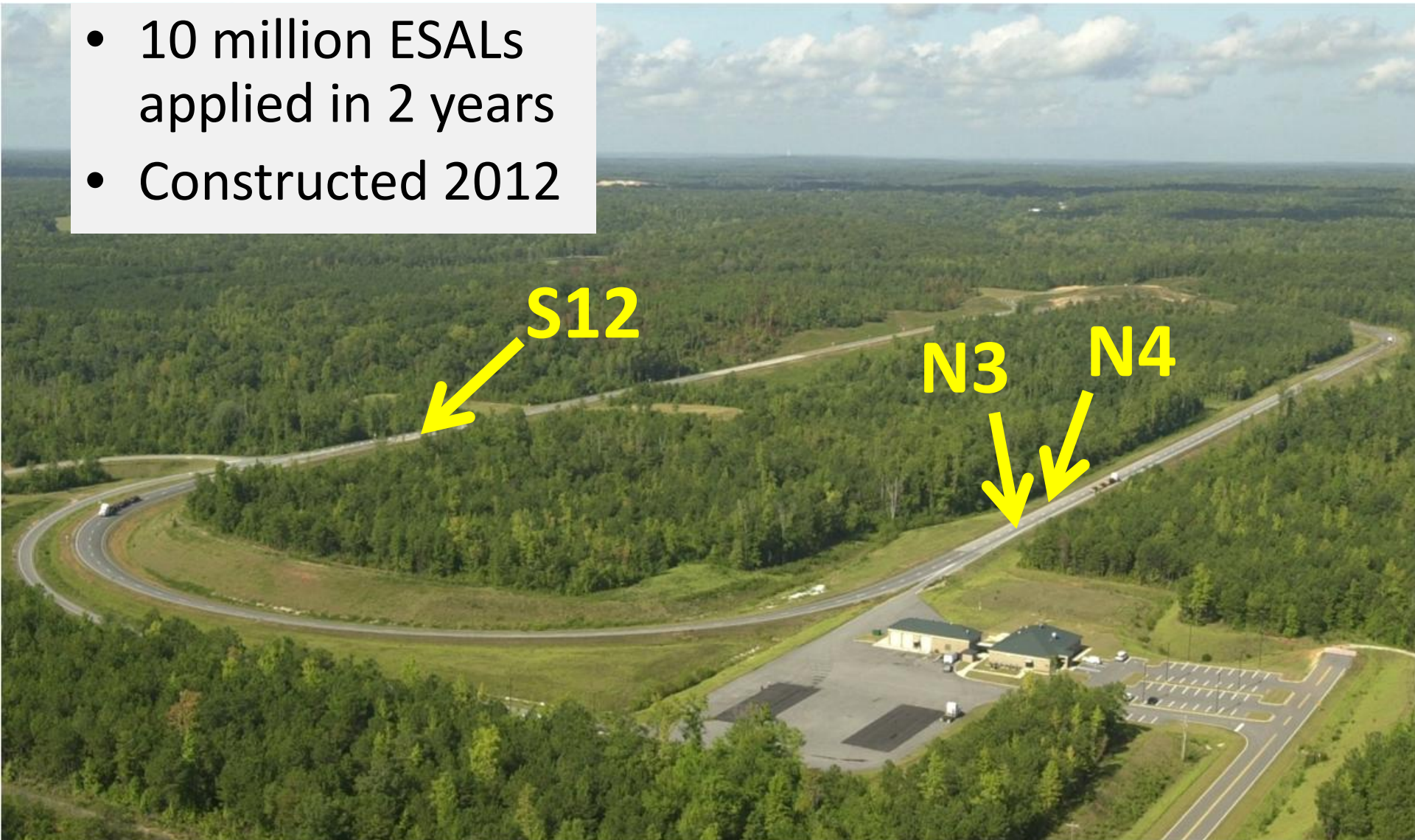

WR 2400
WATER TRUCK
NON
POTABLE
WATER
2
1
7
5

Using What We Learned – I-81

- Recycling performs well on a high volume road
- Summer 2014 (4 years), excellent performance
  - ~ 7 million ESALs in the right lane
  - Rutting less than 0.1 inches
  - Ride quality range = 45-55 inches/mile
- Layer coefficients from this project (lab & field)
  - FDR + CCPR ~ 0.37
  - CCPR range = 0.36 to 0.44
  - CIR range = 0.35 to 0.39
  - www.virginiadot.org/vtrc/main/online_reports/pdf/15-r1.pdf

NCAT

- 10 million ESALs applied in 2 years
- Constructed 2012



NCAT

N3

6-inch AC

5-inch CCPR

6-inch Agg Base

Subgrade

N4

4-inch AC

5-inch CCPR

6-inch Agg Base

Subgrade

S12

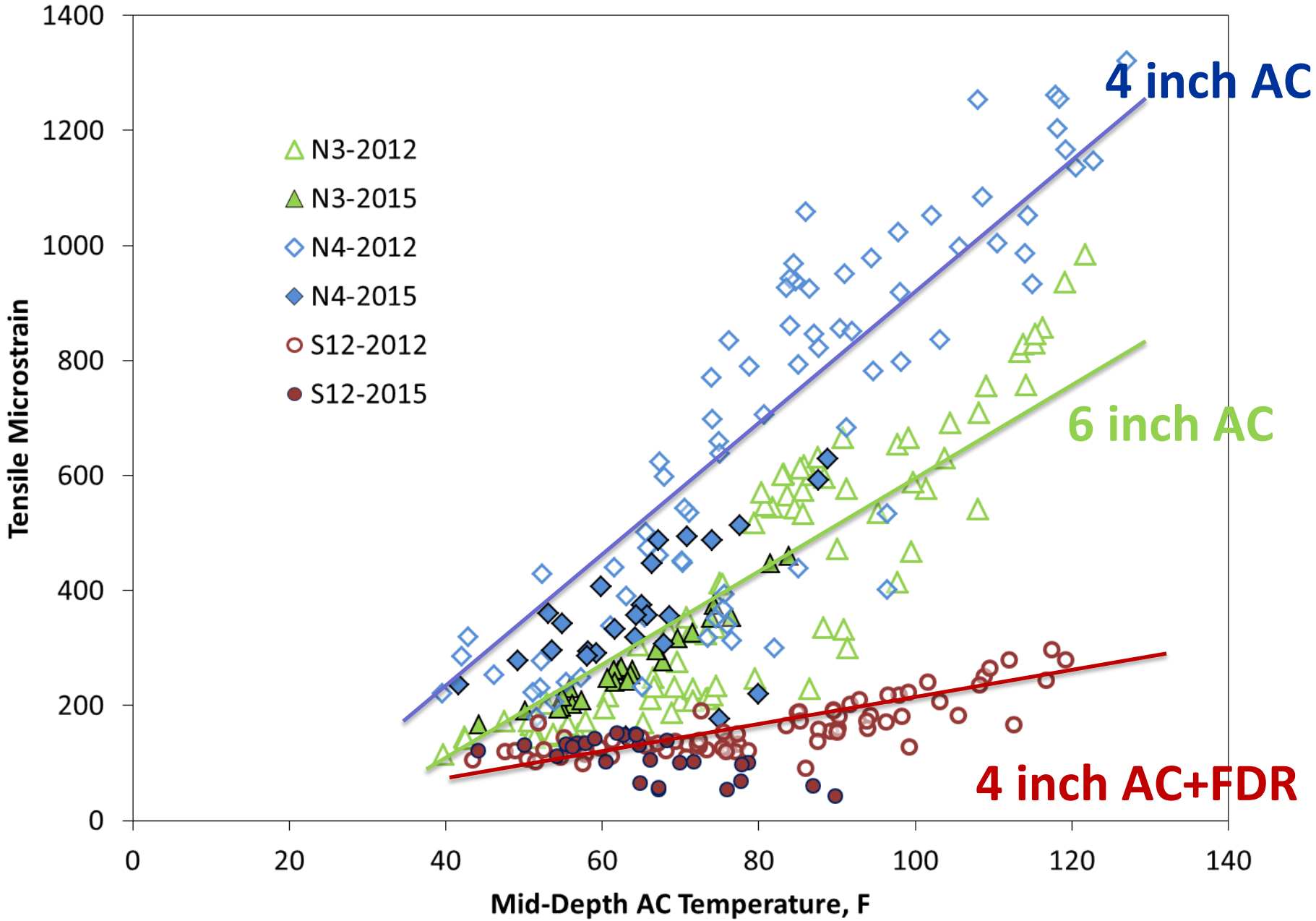
4-inch AC

5-inch CCPR

8-inch FDR

Subgrade


WR 2000
Wirtgen


1400
1200
1000
800
600
400
200
0
Tensile Microstrain
0
20
40
60
80
100
120
140
Mid-Depth AC Temperature, F
N3-2012
N3-2015
N4-2012
N4-2015
S12-2012
S12-2015
4 inch AC
6 inch AC
4 inch AC+FDR

Using What We Learned - NCAT

- Recycling performs well on a <u>high volume</u> road

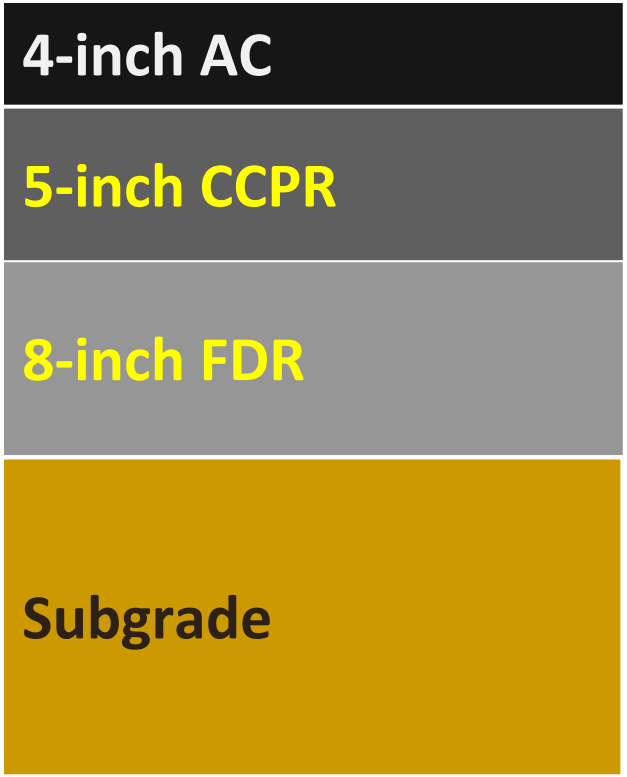
- No cracking at 11.5+ million ESALs
- Ride quality steady
- Rutting < 0.25 inch

- Is FDR section perpetual?
  - Presence of stabilized base reduced strain by 80% for same overlay thickness
  - Will a recycled layer behave the same as an AC material at low strain levels?

NCAT

- 17 inches manipulated
  - Layer 1 = 12.5% recycled
  - Layer 2 = 30% recycled
  - Layer 3 = 100% recycled
  - Layer 4 = 100% recycled
- Entire cross section
  - 80% recycled
- Perpetual section for reconstruction?

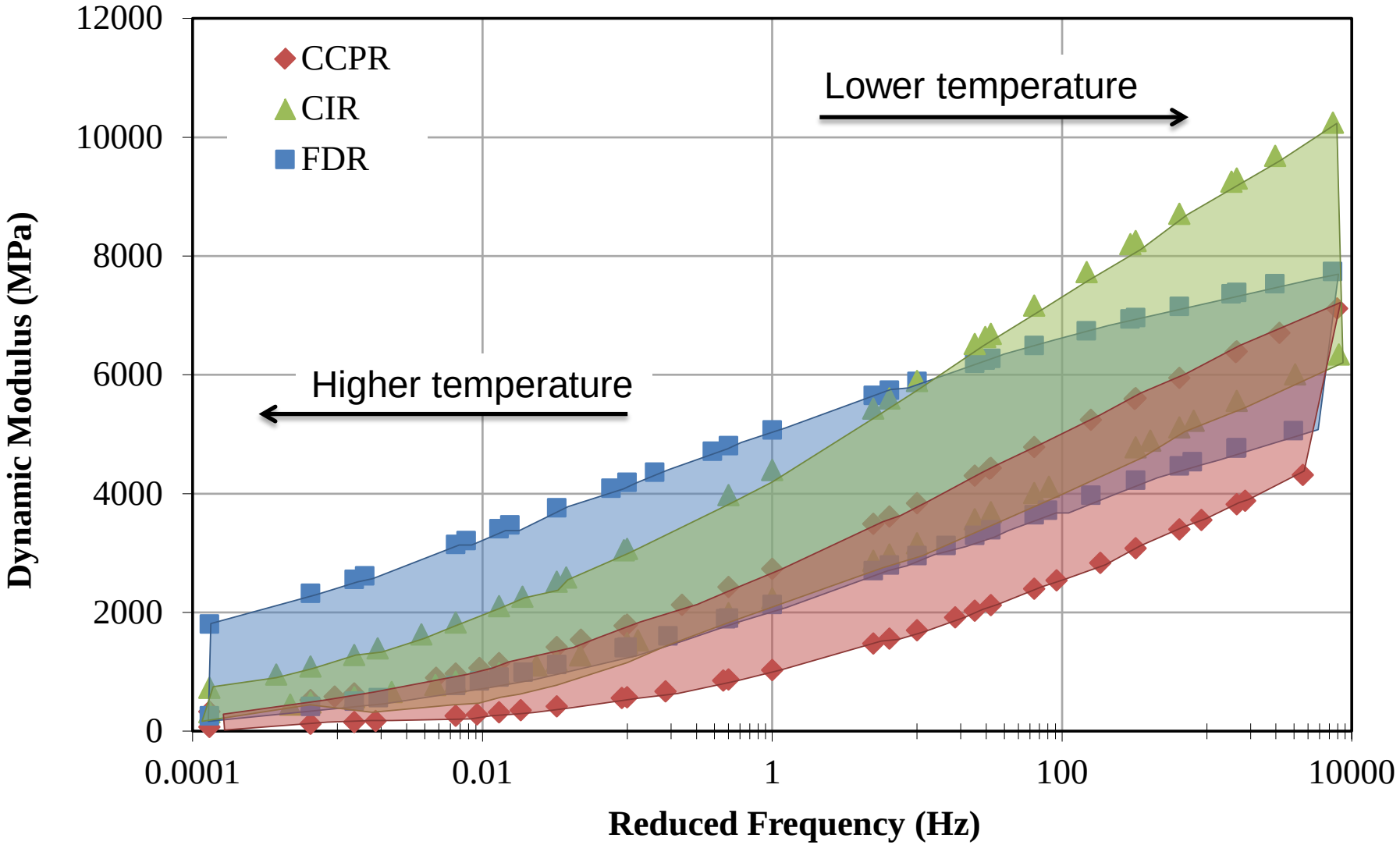
S12



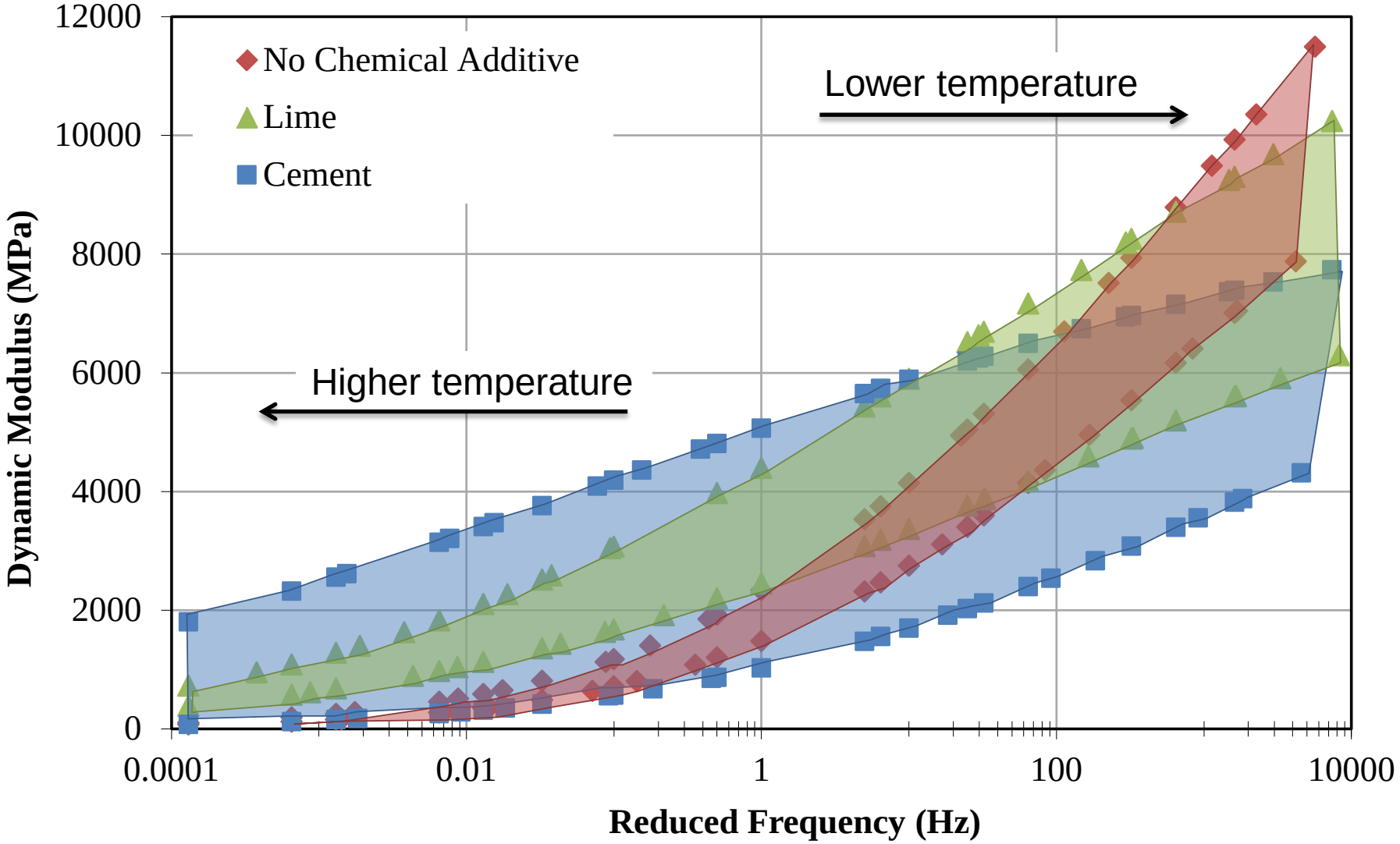
NCHRP 9-51

- *Material Properties for CIR and FDR for Pavement Design*
- Cores from 24 projects
- Partners
  - Univ of Maryland
  - Virginia DOT
  - Wirtgen
  - Colas Solutions

NCHRP 9-51


CCPR
CIR
FDR
Lower temperature
Higher temperature
Dynamic Modulus (MPa)
12000
10000
8000
6000
4000
2000
0
0.0001
0.01
1
100
10000
Reduced Frequency (Hz)

NCHRP 9-51


No Chemical Additive
Lime
Cement
Lower temperature
Higher temperature
Dynamic Modulus (MPa)
12000
10000
8000
6000
4000
2000
0
0.0001
0.01
1
100
10000
Reduced Frequency (Hz)

Summary

- FDR can be a successful part of a high-truck volume pavement
- FDR provides a significant stiffening effect
  - Perpetual performance?
    - If what we know about asphalt pavements is transferable, “yes”