Cold Central Plant Recycling – A Proven Paving Approach Using 100% Recycled Materials

Acknowledgments

- Webinar Sponsored by AFD60 – Design of Flexible Pavements Committee, Dr. David Timm – Chair

Facing Reality…

- Uncertain Highway Funding at National and State Levels
- Transition from Construction to Reconstruction, Rehabilitation and Maintenance by Agencies
  - Growing Milling Piles in Urban Areas
  - Limits on RAP Percentages in New, Conventional Asphalt Mixes
- Tighter Permitting Processes
  - New Plants
  - Quarries
  - Refineries
- Commitment by Industry and Agencies to be More Sustainable

Sustainable Practices for Pavements…

- Use of Recycled and "Waste" Products in New Pavement Materials
  - All levels of roadways
  - Limits set by owner/agency
- In-Place Reclaiming and Recycling Processes for Existing Roads (i.e., CIR and FDR)
  - Primarily preformed on lower level traffic volume routes
  - Base or sub-base material layers
- On and Off-Site Production of New Asphalt Materials using 100% or Nearly 100% RAP (i.e., Cold Central Plant Recycling)
  - Initially considered for lower volume routes, but expanding to higher levels
  - Replacing aggregate layers and conventional base asphalt layers

Presenters

- Donald Matthews, P.E. – Technical Manager for Pavement Recycling Systems, Inc.
- Dr. Brian Diefenderfer, P.E. – Senior Research Scientist for Virginia Center for Transportation Innovation and Research
- Dr. David Timm, P.E. – Brasfield and Gorrie Professor for Auburn University

Production, Placement and Mix Design for CCPR

Donald M. Matthews, PE
Technical Manager
Pavement Recycling Systems, Inc.

Cold Central Plant Recycling (CCPR)

Clean RAP = New Pavement:

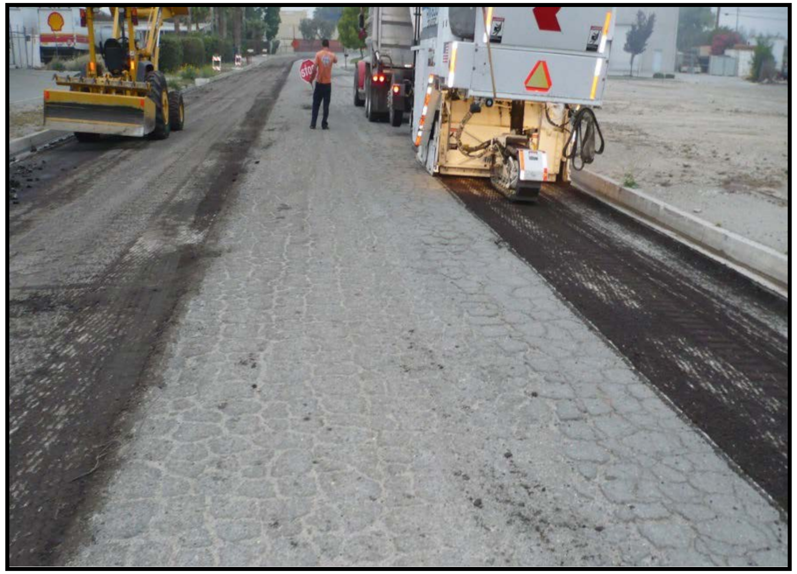
1) Mill and Stockpile RAP and keep clean
2) Size RAP to required gradation
3) Supplement with new aggregate if needed
4) Mix with water, recycling agent and recycling additive as needed
5) Transport to lay down area
6) Pave recycled mix
7) Compact to specified density
8) Protect for temporary traffic
9) Cure and Reroll if necessary
10) Apply Final Surfacing as required

From RAP

to Pavement

1) Mill and Stockpile Reclaimed Asphalt Pavement (RAP)

- **Onsite CCPR** - Cold Milled from Roadway and Recycled Back to Same Roadway



- **Imported CCPR** – RAP is Brought from One Project and Recycled to Another

- **Central Facility CCPR** – RAP Stockpiled from Various Projects for Future Use

2) Size the RAP

- Scalp at the Feed Hopper (Typically 1.5” Max)
- Crushed and Screened to Maximum Size (Typically 1” to 1.5” Max)

RAP is then Sized (Typically 1” to 1.5” Max)

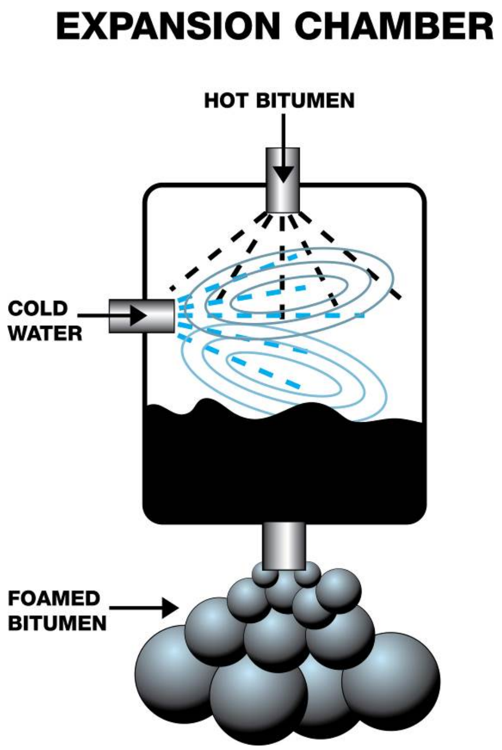
Using a Scalping Screen on the Feed Hopper of Processing Plant

RAP Fractionization

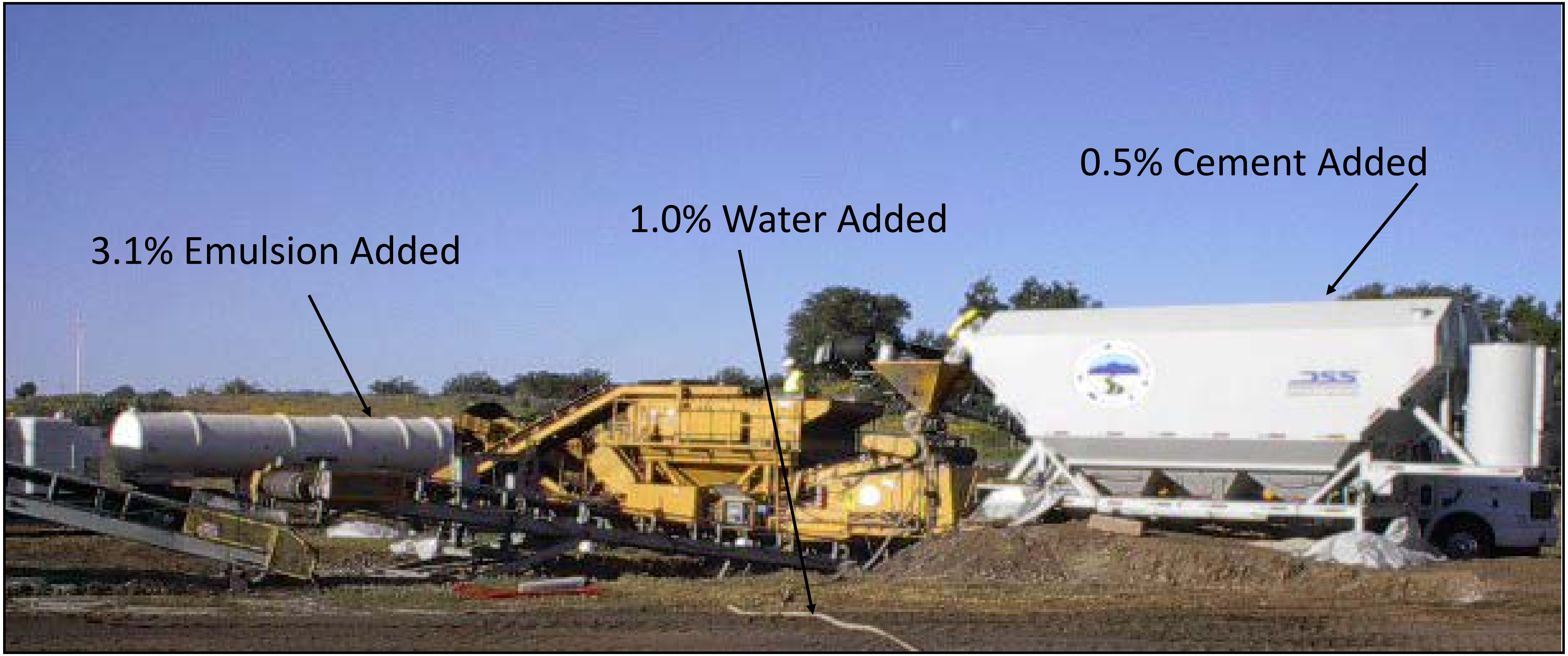
3) Can Supplement with New Aggregate

4) Mix with Water and Recycling Agent
Add Recycling Additives if Necessary

- Recycling Agents
  - Emulsified Asphalt
    - Engineered Emulsions
    - Polymer Modified Emulsions
    - Solvent Based Emulsions (CMS2s) with Lime
  - Expanded Asphalt (Foam)
- Recycling Additives (added in small quantities)
  - Cement Dry
  - Lime Slurry



Recycling Agent, Water and Additive Combined



Specialized Mixing Plant

1.0% Cement Added

5) Loaded into Trucks and Transported To Laydown Area

Swept and Tacked Prior to Paving

6) Pave Recycled Mix

7) Compact to Specified Density

- Compacting Equipment
  - Pneumatic-tired roller at least 22 to 25 tons
  - Double drum vibratory steel-wheeled roller at least 10 tons
  - All rollers must have working water spray systems.

Surface Before Sealing

8) Protect for Temporary Traffic

- After rolling is completed
- Apply fog-seal to minimize raveling
- Apply sand blotter to avoid pickup of fog seal
- Release to traffic

9) Cure and Reroll if Necessary

Curing, if required, typically 2 to 3 days and/or to a specified residual moisture content (<= less than 2.0%)

Reroll (supplemental compaction) if required (typically for emulsified asphalt)

10) Final Surfacing

Because of higher void ratio
Cold recycled surfaces must be sealed

Slurry or Micro Surfacing –
Low Volume Shoulders and Lots

Chip Seal – Low
Volume Highways

HMA Overlay – Higher Volume Highways
High Shear Areas

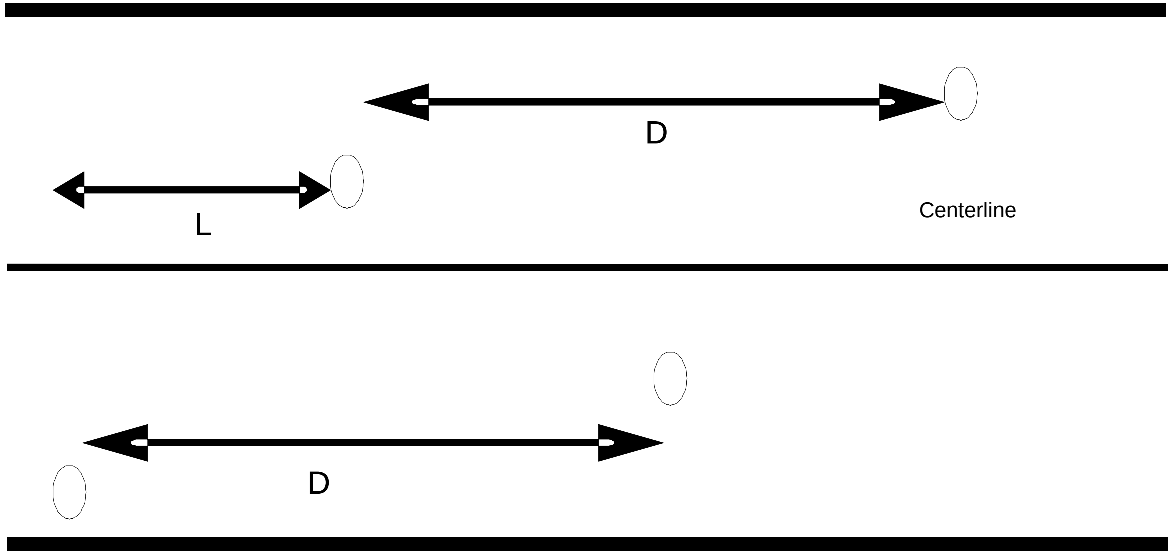
Mix Design

- Use actual processed RAP that is stockpiled if there is time

- Core and crush for onsite projets

Coring – For Use In Mix Design

Cores measured to the nearest 1/8-inch (3-mm) and placed in separate containers and labeled



Cores cut in lab to planned recycling depth and only that portion to be recycled used for mix design

Dynamic Cone Penetrometer (DCP)

Alerts to Subgrade Issues

DCP	Acceptable	Marginal	Poor
Each Set of 10 Blows	< 6 Inches <150 mm	6 to 10 inches 150 mm to 250 mm	> 10 Inches > 250 mm
Inches per Blow **mm per Blow**	0.6 15	0.6 to 1.0 15 to 25	> 1.0 > 25

Mix Design

Performance and Volumetric Testing to Address:

- Gradation and Quality of RAP
  - Extracted and Unextracted
  - Activity of Extracted Binder
- Density and Compaction
- Air Voids
- Rutting
- Raveling
- Moisture Sensitivity
- Stability and Strength

Cold Central-Plant Recycling

The Virginia Interstate 81 Rehabilitation Experience and Beyond

Dr. Brian Diefenderfer, P.E. – Senior Research Scientist for Virginia Center for Transportation Innovation and Research

I-81 Recycling Project

- Objectives
- Design
- Performance
  - Functional
  - Structural
- Summary
- Future Project

I-81 Objectives

- Repair a rapidly deteriorating roadway
    - Overlays had a 2-3 year service life
- It later became a recycling trial

I-81 Options

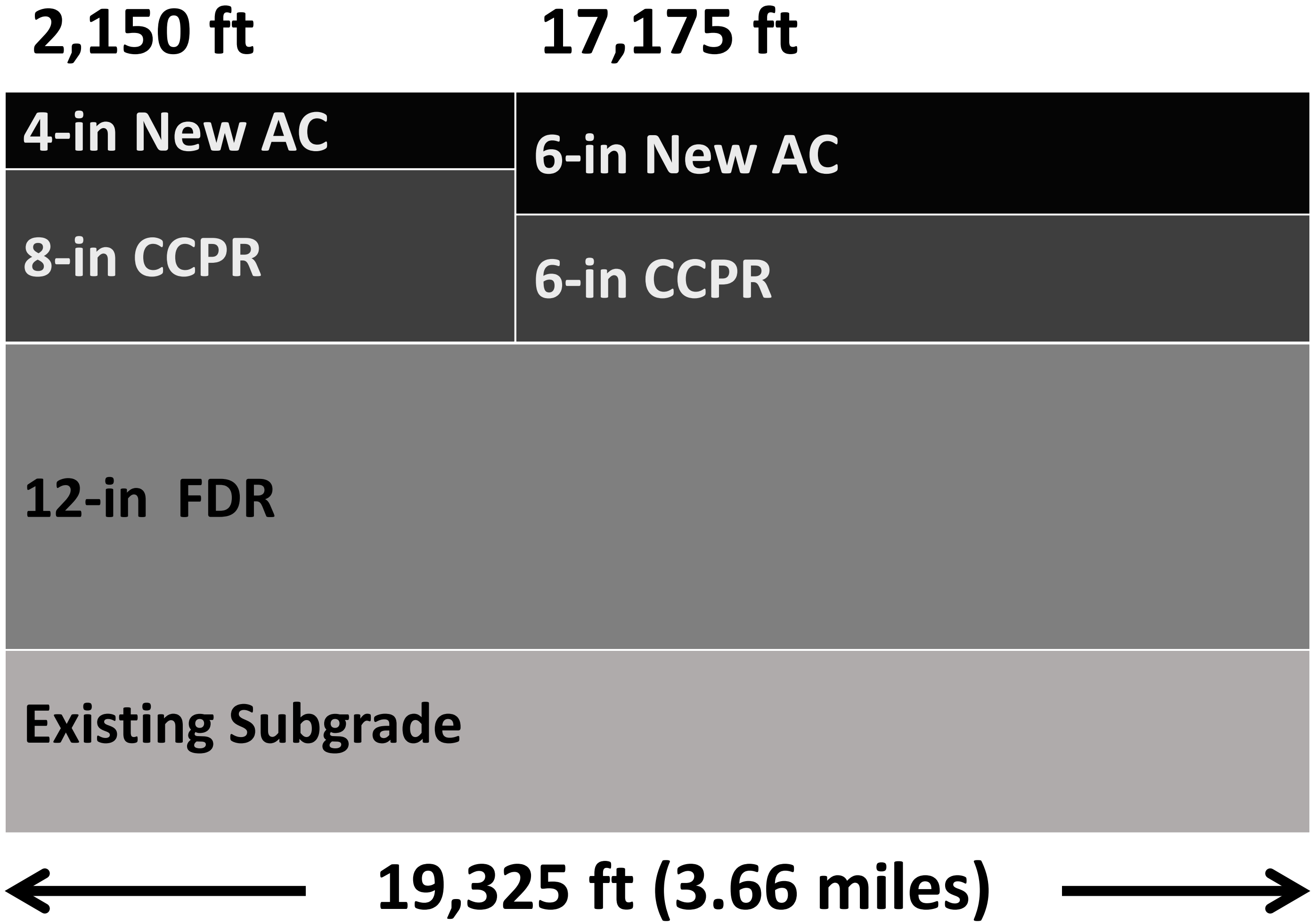
- Conventional reconstruction
  - 2 years
  - Traffic management required a third lane
  - **$16 million**

- Recycling
  - 8 months
  - Innovative traffic management
  - **$10 million**

I-81 Structural Design

- 30 year design
  - 102 million ESALs
  - 7.86-8.02 required SN
  - AADT = 23,000 with 28% trucks
- Right lane
  - Mill 10 inches
  - FDR 12 inches
  - Place CCPR and overlay with asphalt

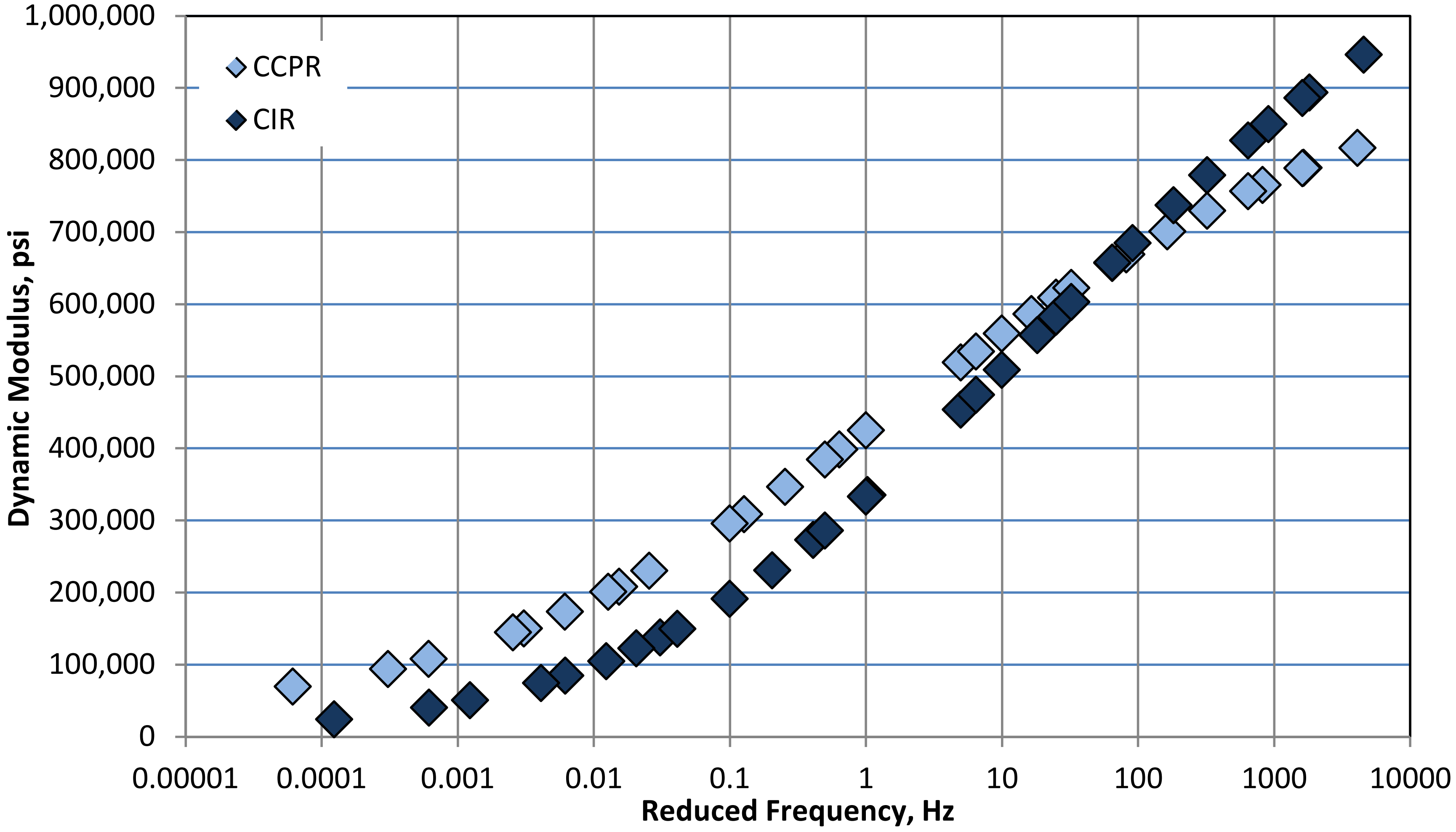
I-81 Structural Design, Right Lane



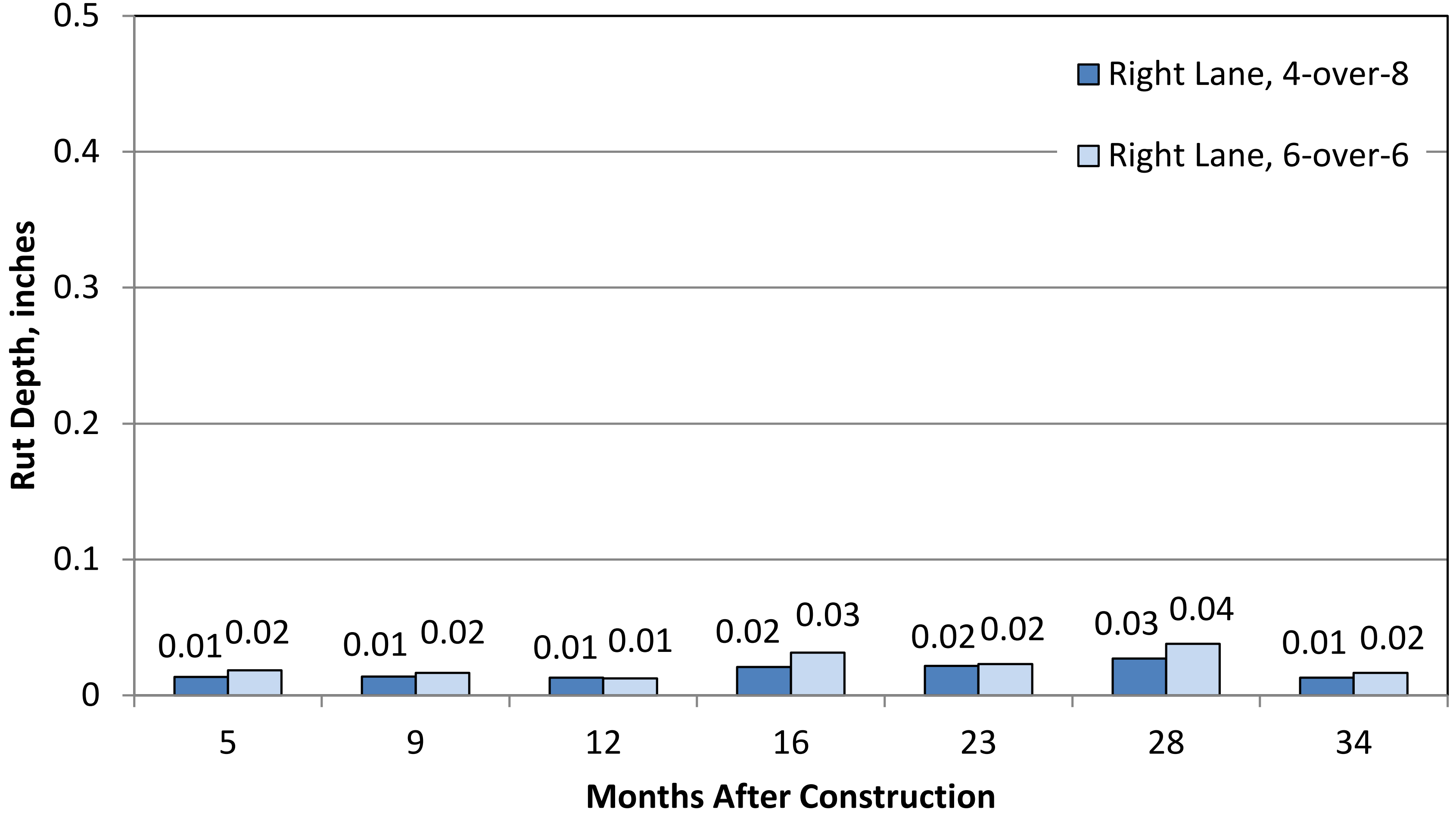
Assessment Methods for CCPR Layer

- Coring
  - Dynamic modulus
- Rut depth and ride quality
  - Inertial profiler
- Structural capacity
  - FWD

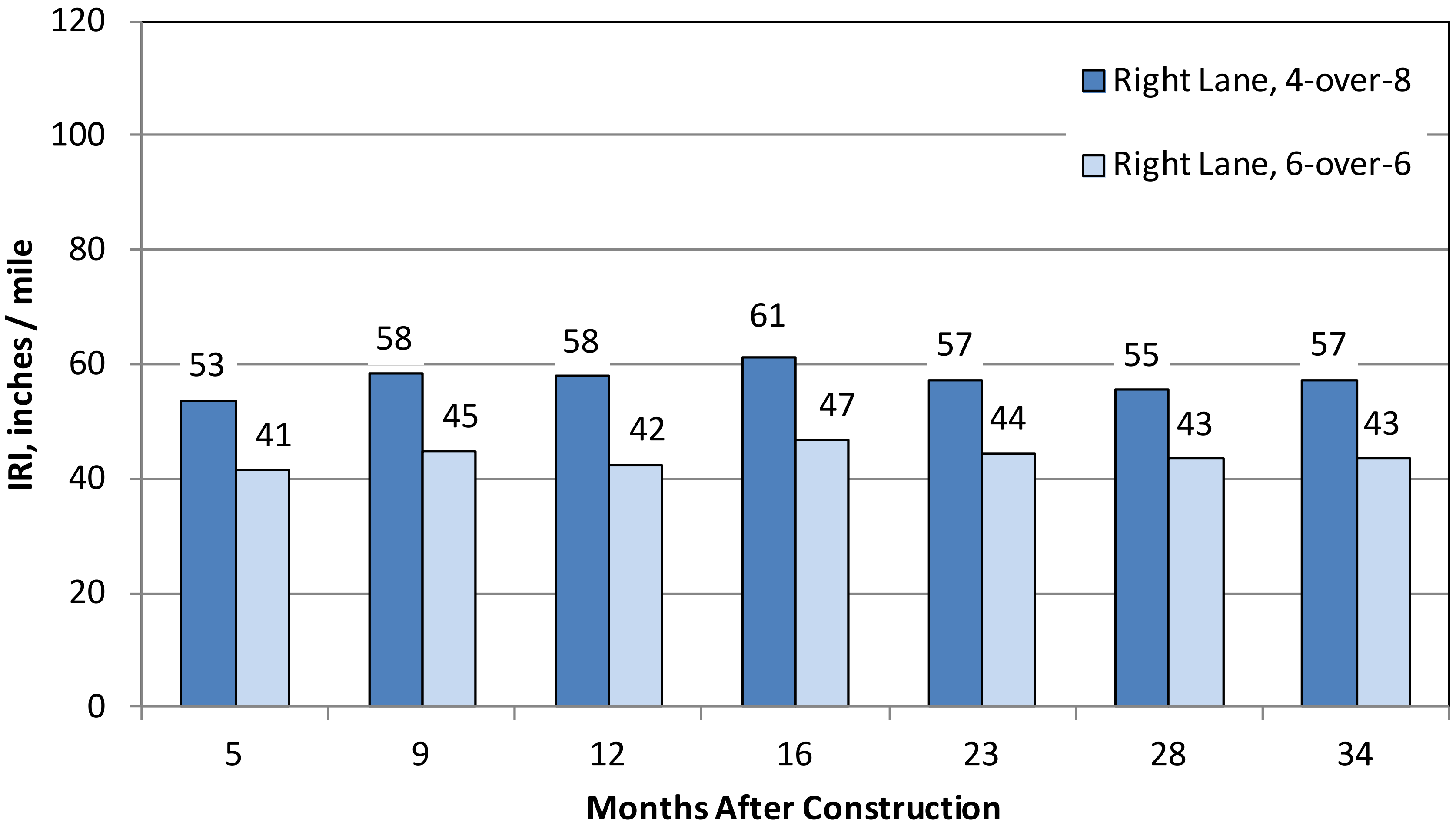
Dynamic Modulus



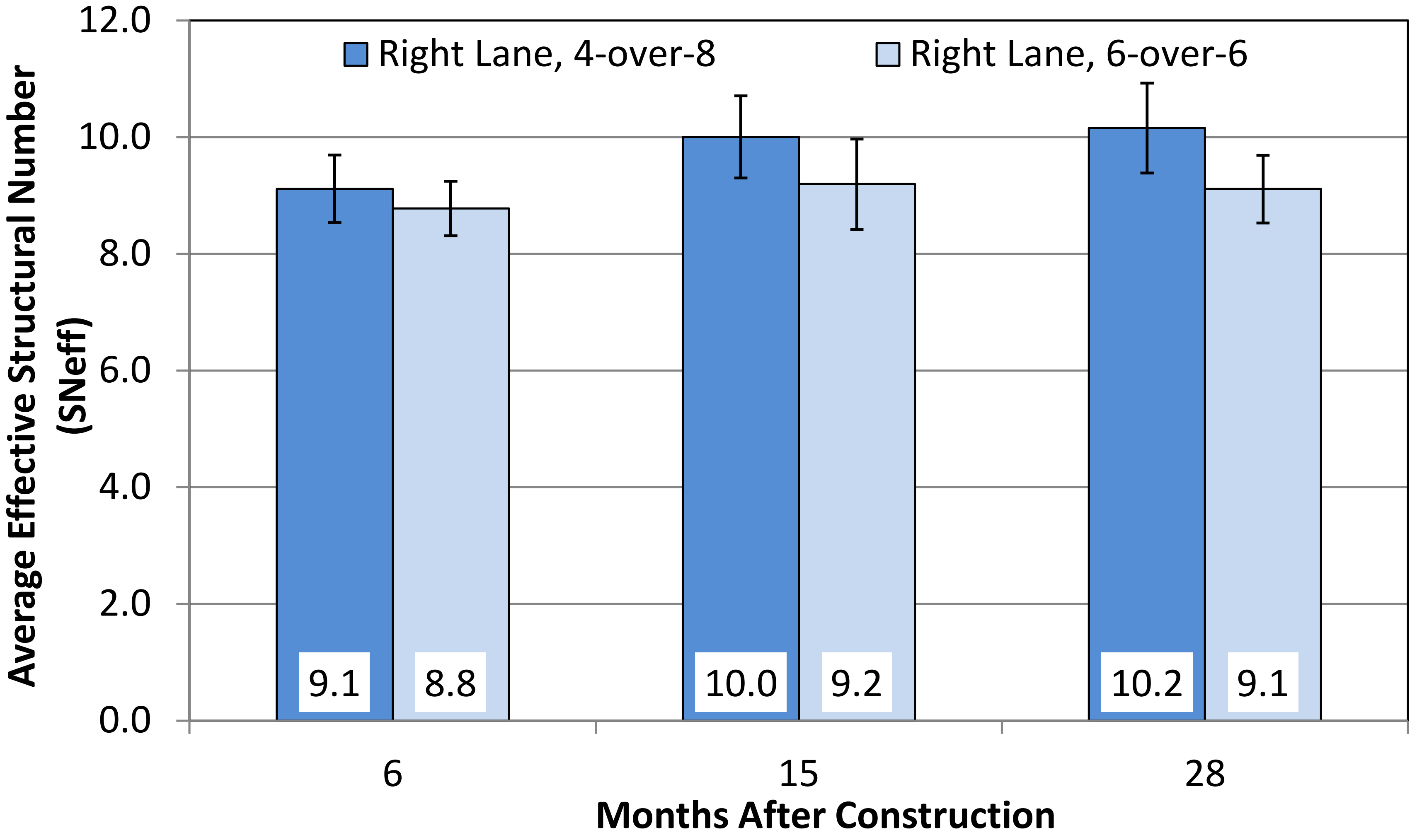
Rutting Performance



Ride Quality



Structural Capacity



Layer Coefficients

- From analysis of FWD data
  - $SN_{eff} = a_1 \times D_1 + a_2 \times D_2 + a_3 \times D_3$

- Right lane
  - CCPR and FDR were not separated in analysis
  - Combined layer coefficient = 0.37

- Value agrees with ranges from AASHTO correlations with lab test results

I-81 Performance Summary

- More than 8 million ESALs applied over 4 years
- Both sections in right lane performing similarly
  - Structural capacity greater than estimated at design
    - Increased during first 28 months
  - Rutting is negligible
    - < 0.1 inches
  - Ride quality is "excellent"
    - IRI < 60 inches / mile

Using What We've Learned

- Revised VDOT recycling guidelines
  - Layer coefficient
    - CCPR/CIR raised to 0.35 and FDR to 0.30
  - High volume roadways
    - Including interstate projects

- Still studying…
  - Effects from gradation changes
  - Influence of virgin aggregate / RAP combinations
  - Hydraulic cement alternatives

Next Major Pavement Rehab Project

- 2016-17 interstate lane widening, 7 miles
  - Two existing lanes of jointed concrete (1960s)
  - Poor load transfer, thin asphalt overlay

1) Build a new lane and 12ft shoulder to the inside
   - Stabilize imported material with FDR, CCPR base
2) Shift traffic and reconstruct two existing lanes
   - Stabilize existing subbase with FDR, CCPR base

- Estimated savings ~ $12 million

Cold Central-Plant Recycling

Taking It to the Track

Dr. David Timm, P.E. – Brasfield and Gorrie Professor for Auburn University

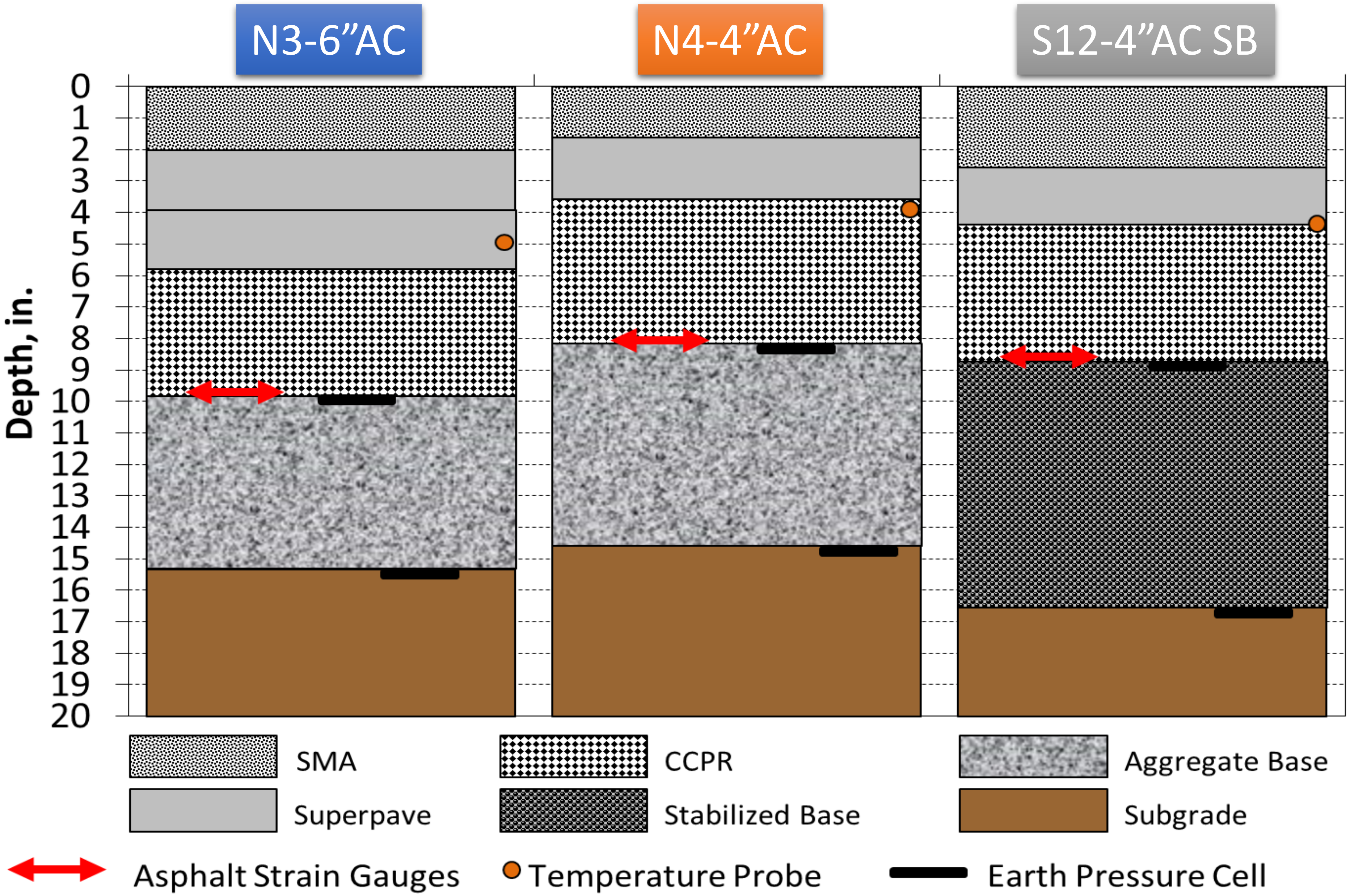
VDOT CCPR Sections at the NCAT Test Track

Objectives & Scope of Work

- Objectives
  - Characterize field performance of CCPR
  - Characterize structural characteristics of CCPR
  - Compute structural coefficient of CCPR

- Scope of Work
  - 3 test sections used RAP from I-81 project
  - Accelerated trafficking (10 million ESAL in 2 years)
  - Weekly performance measurements
  - Frequent FWD testing
  - Measurements from embedded instrumentation

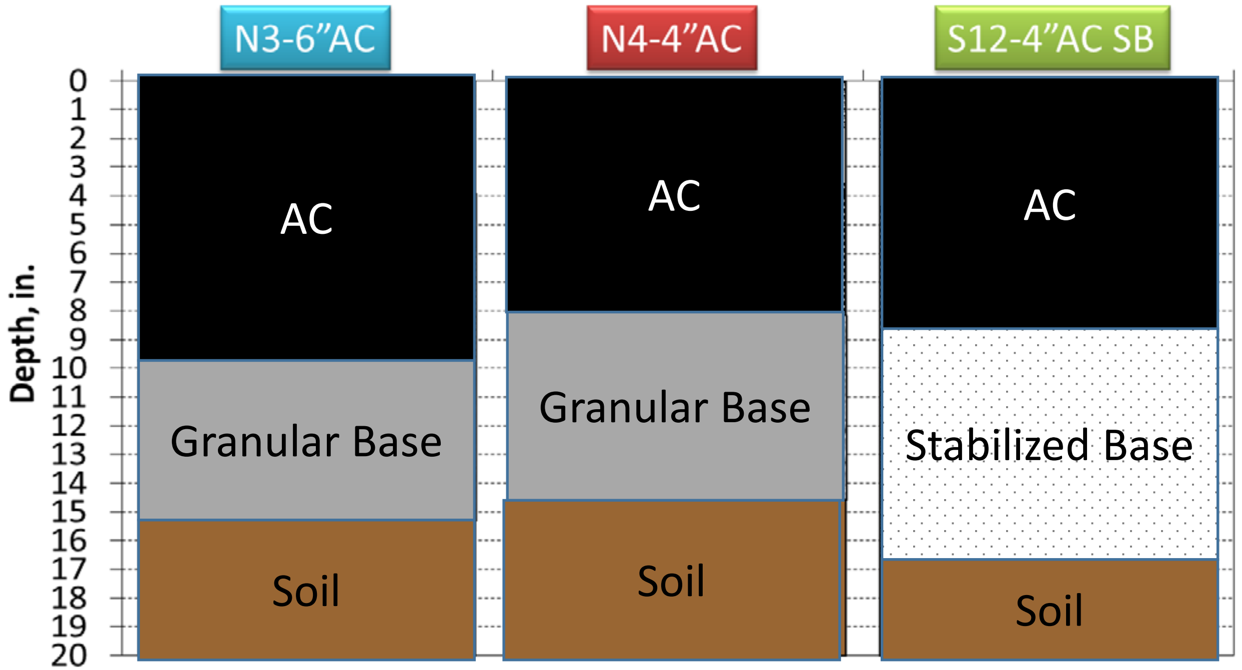
Test Sections



Layer Parameters

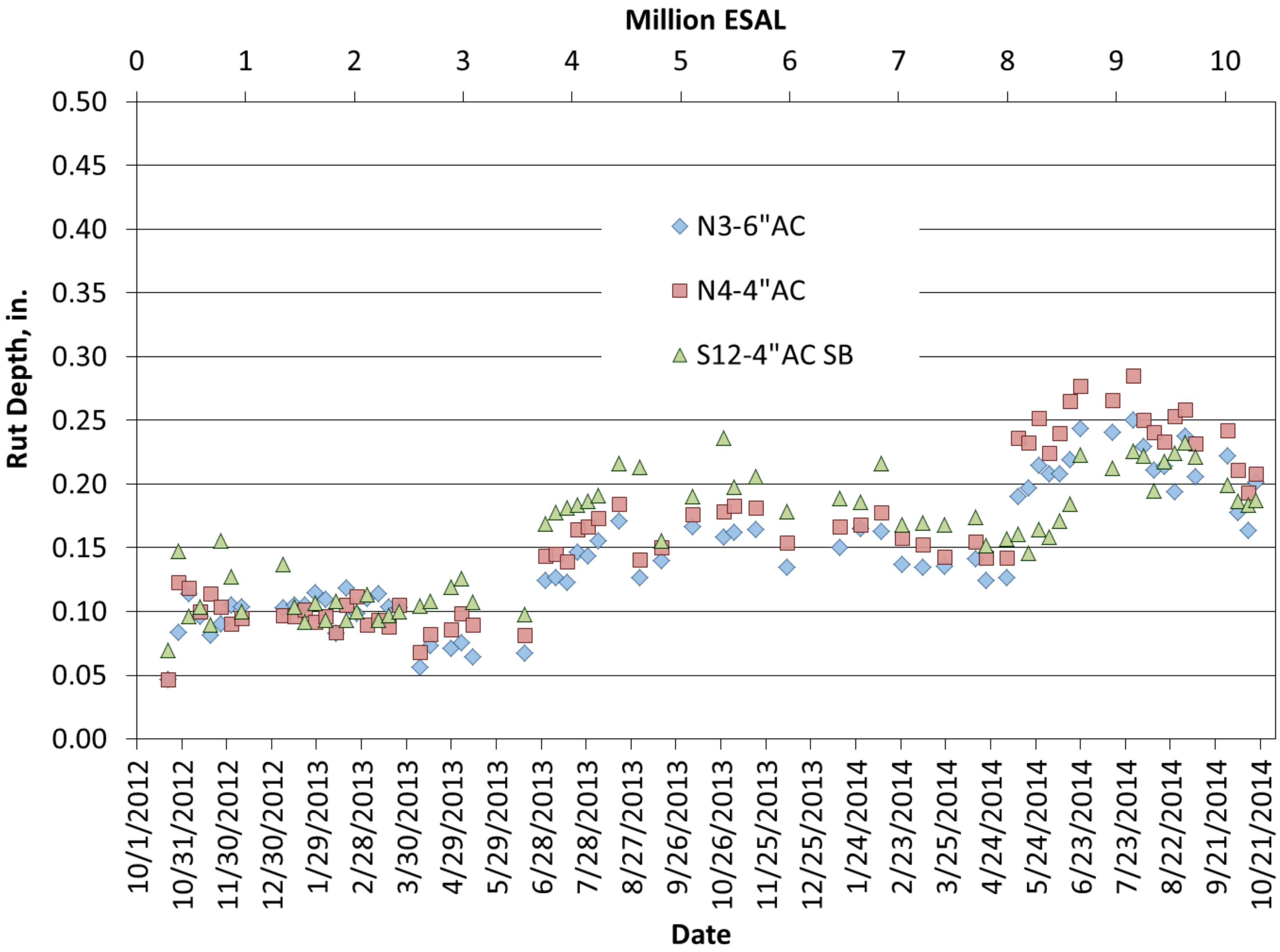
Section	N3-6"AC	N4-4"AC	S12-4"AC SB
Layer Description	Lift 1-19 mm NMAS SMA with 12.5% RAP and PG 76-22 binder		
Binder Content, %	6.1	6.0	6.1
$\%G_{mm}$	95.7	95.3	95.8
Layer Description	Lift 2-19 mm NMAS Superpave with 30% RAP and PG 67-22 binder		
Binder Content, %	4.6	4.6	4.7
$\%G_{mm}$	92.9	7.4	93.3
Layer Description	Lift 3-19 mm NMAS Superpave with 30% RAP and PG 67-22 binder		
Binder Content, %	4.4	NA	NA
$\%G_{mm}$	93.6	NA	NA
Layer Description	CCPR-100% RAP with 2% Foamed 67-22 and 1% Type II Cement		
Layer Description	Crushed granite aggregate base		6" Crushed granite aggregate base and 2" subgrade stabilized in-place with 4% Type II cement
Layer Description	Subgrade – AASHTO A-4 Soil		

FWD Testing & Backcalculation

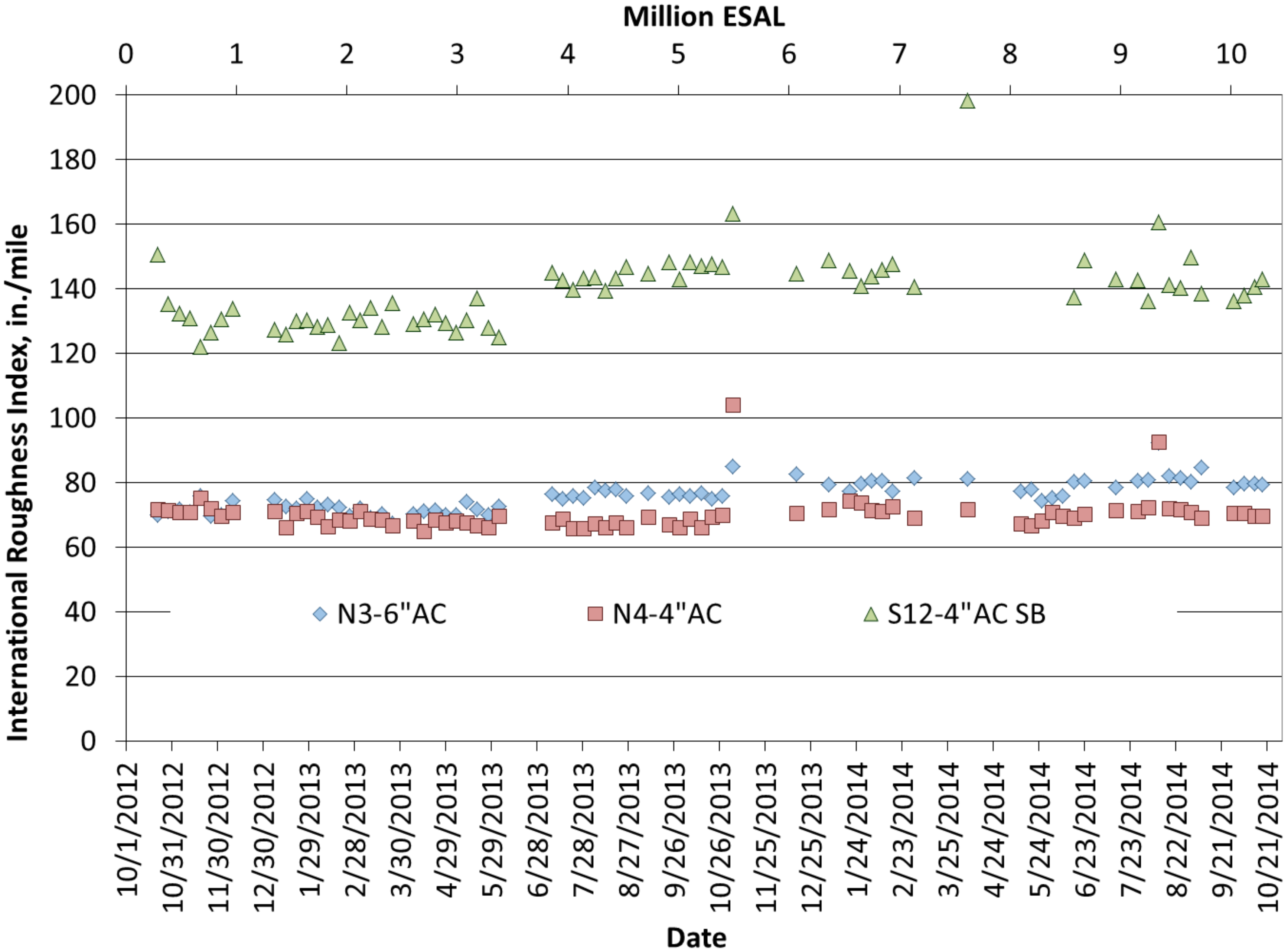


Cracking Performance

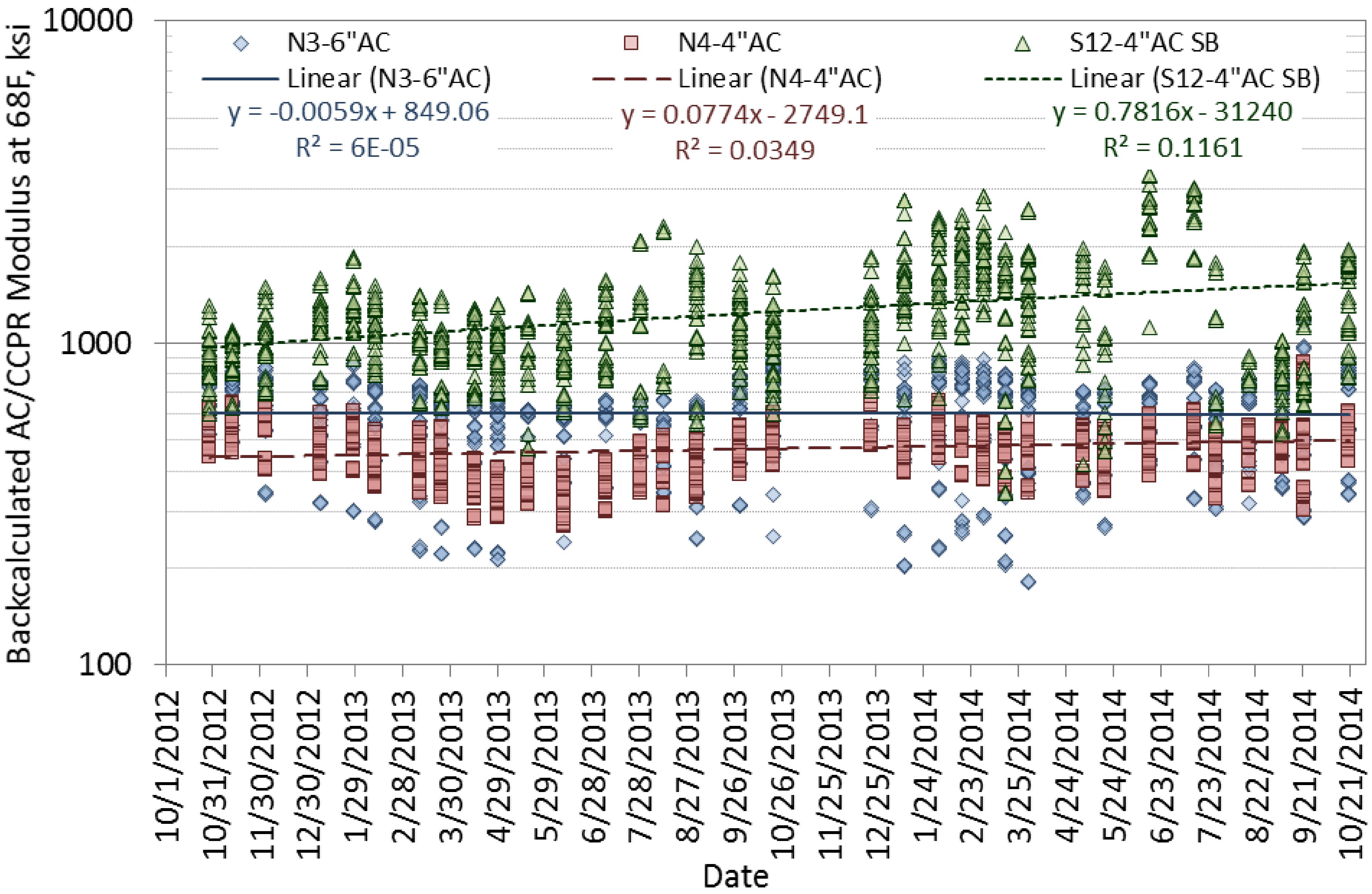
Rutting Performance



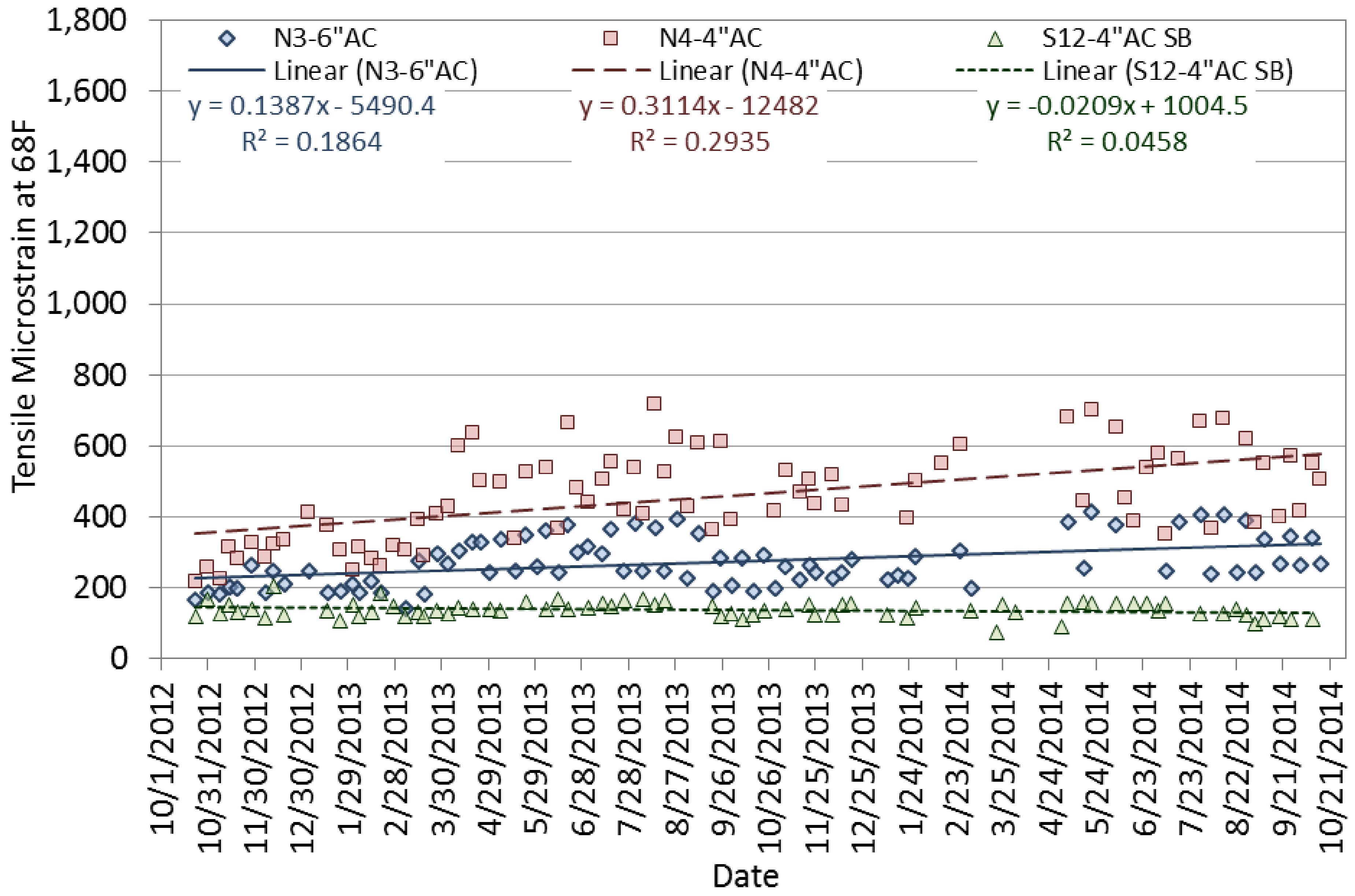
Ride Quality



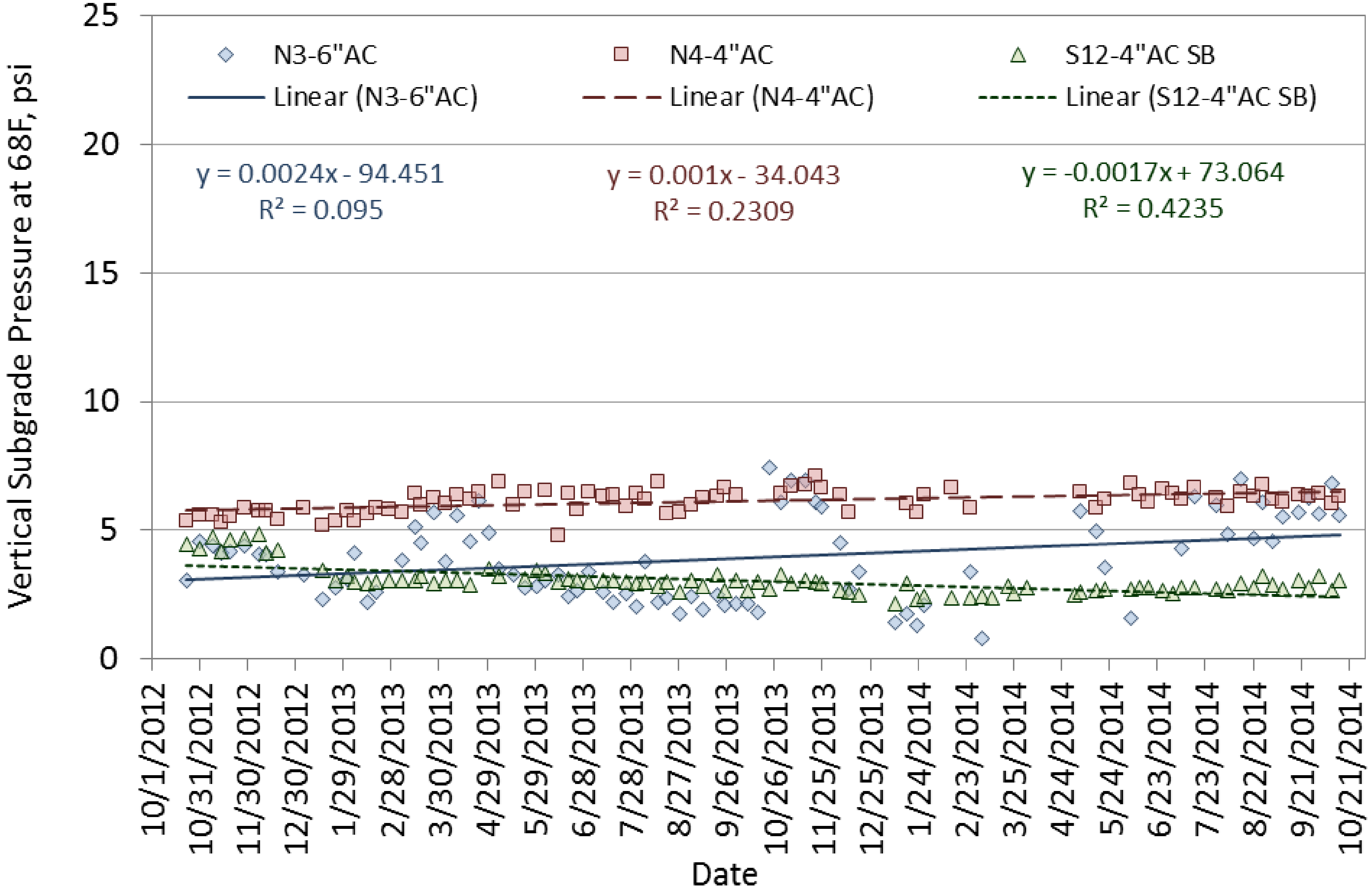
Backcalculated AC Modulus @ 68F



Tensile Strain @ 68F



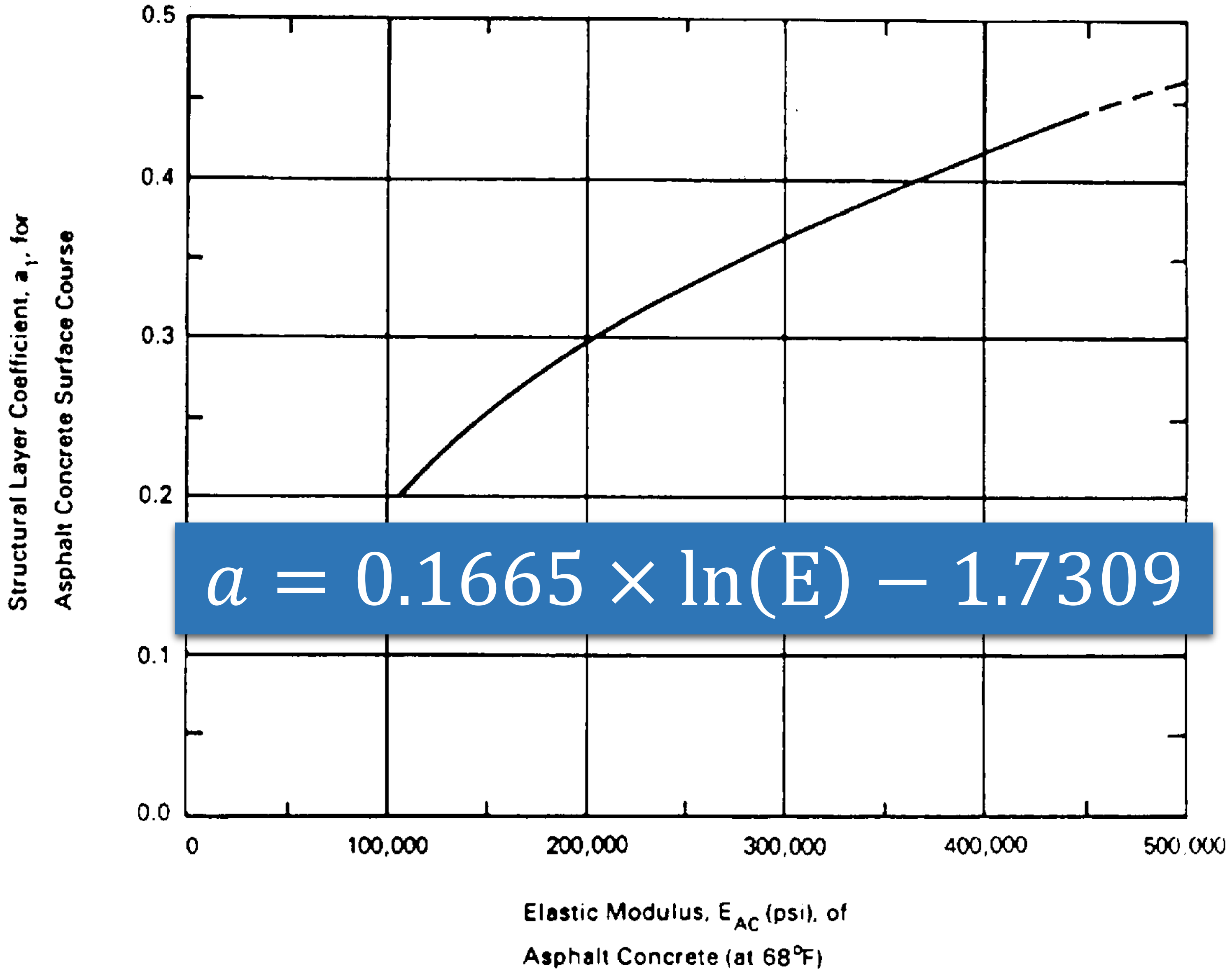
Subgrade Pressure @ 68F



Determination of CCPR Structural Coefficient

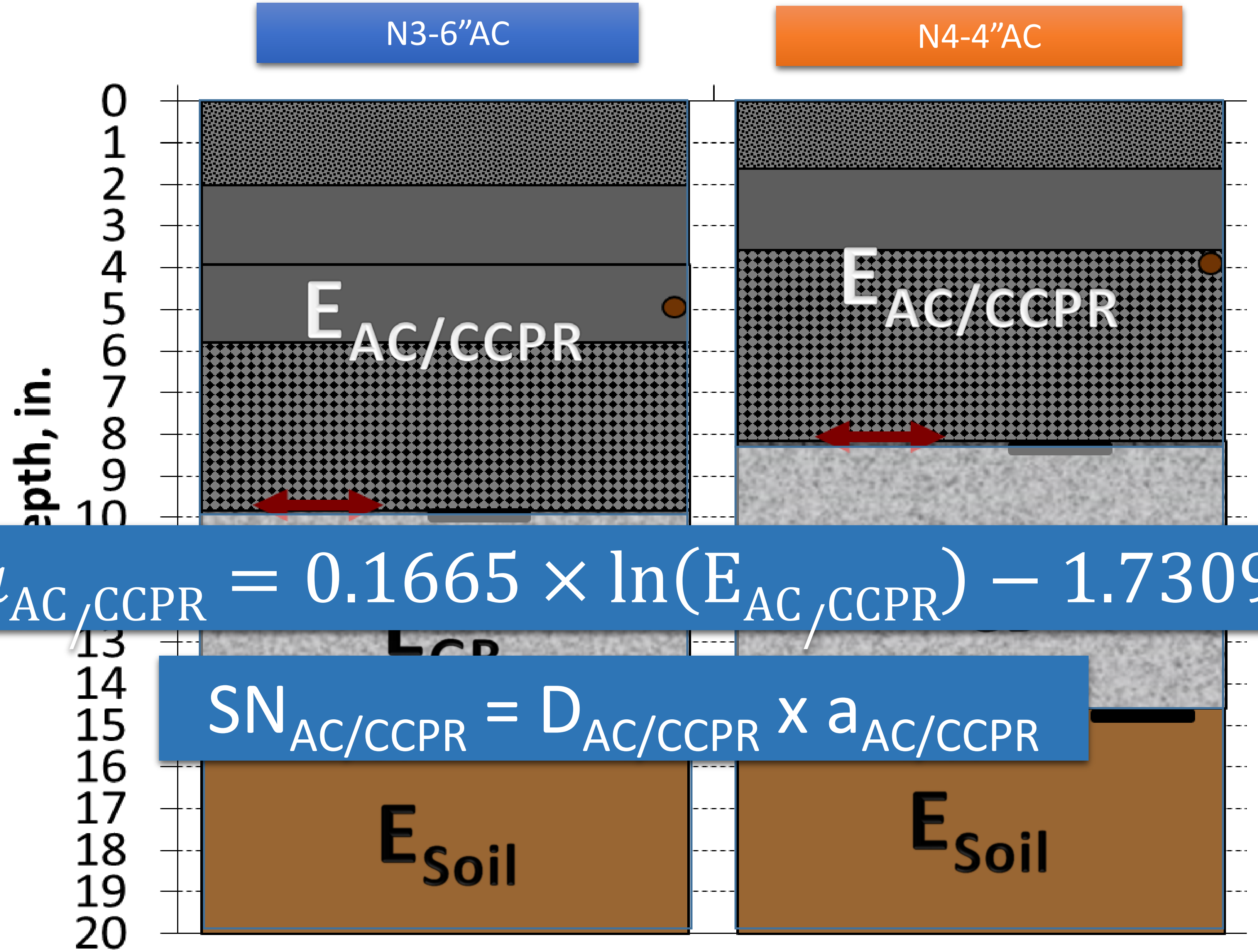
- Need a_{CCPR} to use AASHTO 93 Design Guide
- Has varied between granular base and AC in practice (0.2 to 0.48)
- Most recent computation by Diefenderfer and Apeagyei (0.36 to 0.48)

Methodology - Establish a vs E_{AC}



$$a = 0.1665 \times \ln(\mathrm{E}) - 1.7309$$

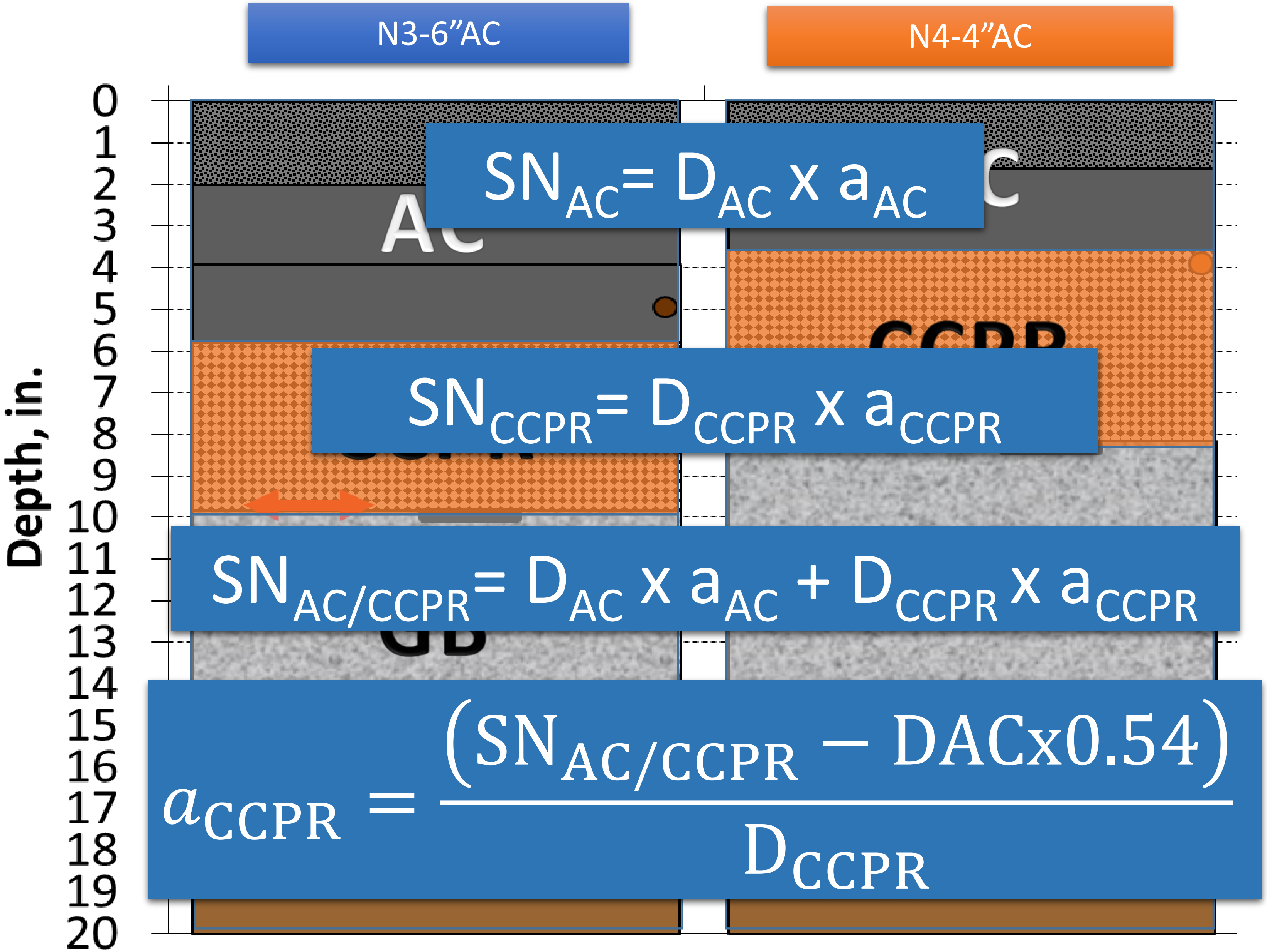
Methodology – Compute $SN_{AC/CCPR}$



$$a_{AC/CCPR} = 0.1665 \times \ln(E_{AC/CCPR}) - 1.7309$$

$$SN_{AC/CCPR} = D_{AC/CCPR} \times a_{AC/CCPR}$$

Methodology – Compute a_{CCPR}



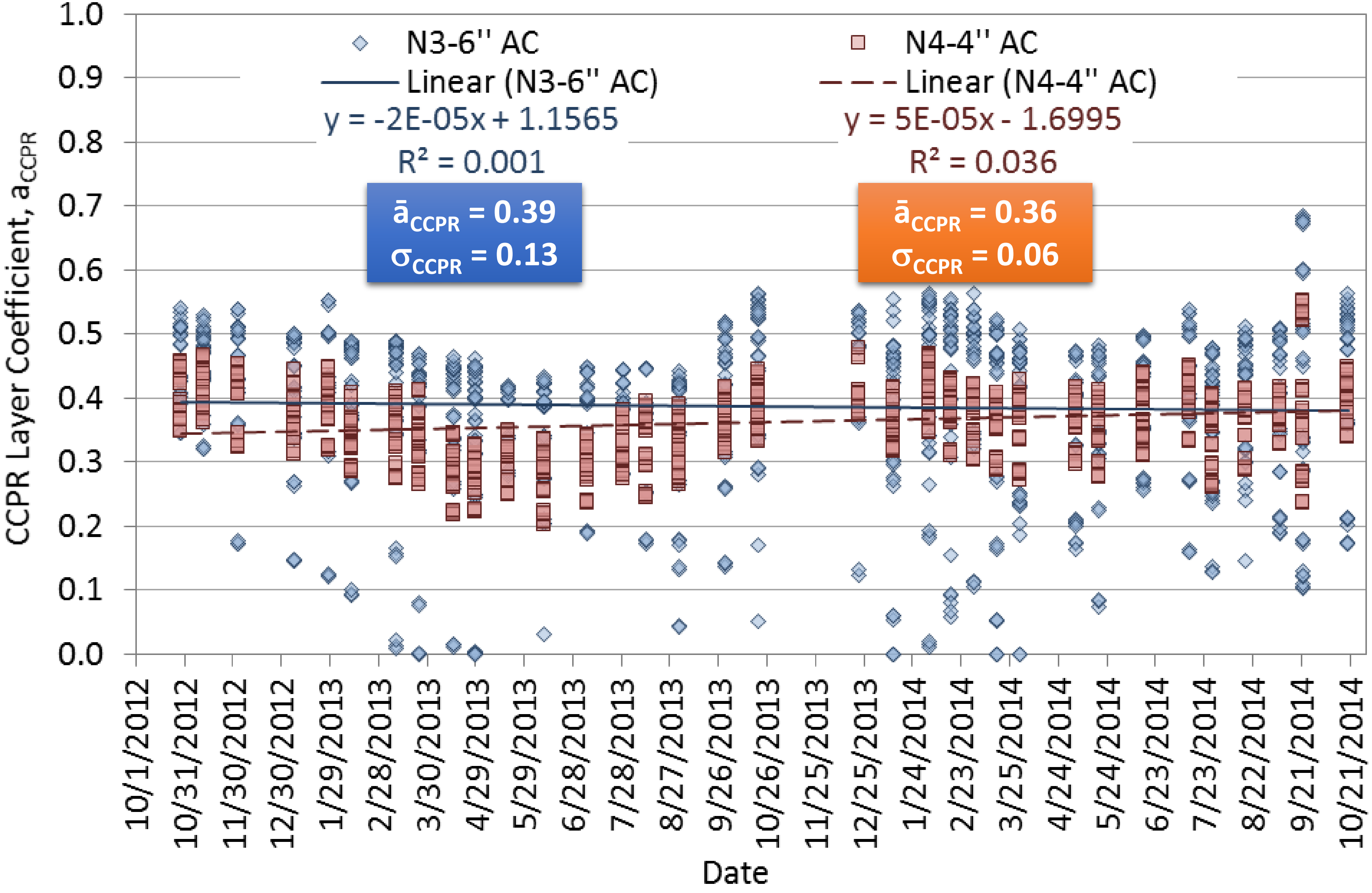
$$SN_{AC} = D_{AC} \times a_{AC}$$

$$SN_{CCPR} = D_{CCPR} \times a_{CCPR}$$

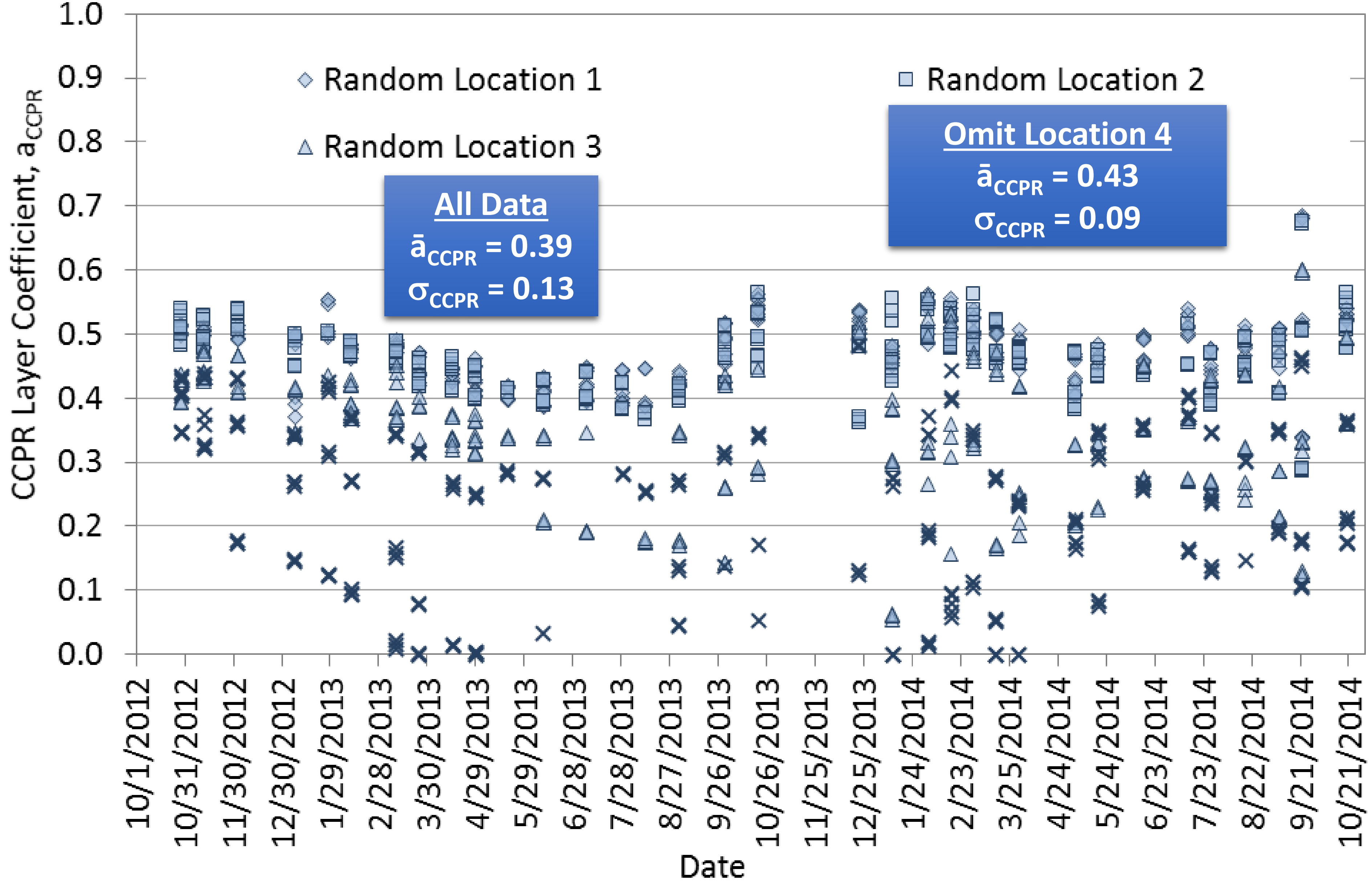
$$SN_{AC/CCPR} = D_{AC} \times a_{AC} + D_{CCPR} \times a_{CCPR}$$

$$a_{CCPR} = \frac{\left(SN_{AC/CCPR} - DACx0.54\right)}{D_{CCPR}}$$

Results - a_{CCPR}



Results – a_{CCPR} – Section N3 By Location



Conclusions & Recommendations

- Excellent performance from all sections
  - No cracking
  - Little difference in rutting performance (<0.3”)
  - Steady IRI over time
  - *Continued monitoring recommended*
- CCPR behaved like AC materials
  - Backcalculated modulus strongly affected by temp
  - Strain strongly affected by temp
  - *Model as AC within M-E approaches*
- Cement-stabilized layer affected S12 backcalculated results
  - *Further backcalculation investigation needed*

Conclusions & Recommendations

- Very little change in modulus over time in N3/N4 indicates structural health
  - S12 appears to be curing over time
  - *Further investigate stabilized base in laboratory*
- Additional 2” of AC in N3 was beneficial compared to N4
  - 40% tensile strain reduction at 68F
- Stabilized base in S12 significantly reduced tensile strain
  - 50% lower in S12 compared to N3
- a_{CCPR} ranged from 0.36 to 0.39
  - *Further validate once performance deteriorates*
- *Continue monitoring sections into 2015 Test Track research cycle*

Summary…

- CCPR is a Proven Technology
  - It does not need to be HOT to work!
  - Eventually all mixes are COLD!
- Specialized or Modified Asphalt Plants Can Produce the Mix
- Existing Paving Equipment Can Place and Compact the Mix
- In-Place Strength Comparable to Most Asphalt Base Mixes and Stronger than Aggregate Base Material

What Is Still Needed…

- Nationally Endorsed Mix Design Process
  - Currently, ARRA has procedure
  - Some agencies have procedure
  - No AASHTO approved procedure
- Formalized Quality Assurance Program
  - Similar to mix design process, ARRA or agency defined
  - Mix design approval and production monitoring
  - Placement and compaction testing
  - No AASHTO approved procedure
- Agreement on Use in Pavement Designs
  - Layer coefficients developed for 1993 AASHTO Pavement Design
  - Materials characterization for Mechanistic-Empirical Pavement Designs

Time for a Few Questions