



The art of doing more with what's already there

COLD RECYCLING, SUSTAINABILITY, AND RESILIENCE

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US Terminology

WE'RE ALL TALKING ABOUT THE SAME THINGS...



COLD IN-PLACE RECYCLING (CIR)

- Within the bound (asphalt) layers only
- Usually 50 to 120 mm thick



COLD CENTRAL PLANT RECYCLING [CCPR]

- Mobile plant
- New or existing RAP
- Layers usually 70 to 150 mm thick
- Multiple layers can be placed



FULL DEPTH RECLAMATION [FDR]

- Creates a stabilized base
- Includes bound and unbound layers
- Usually 100 to 300 mm thick



US Terminology

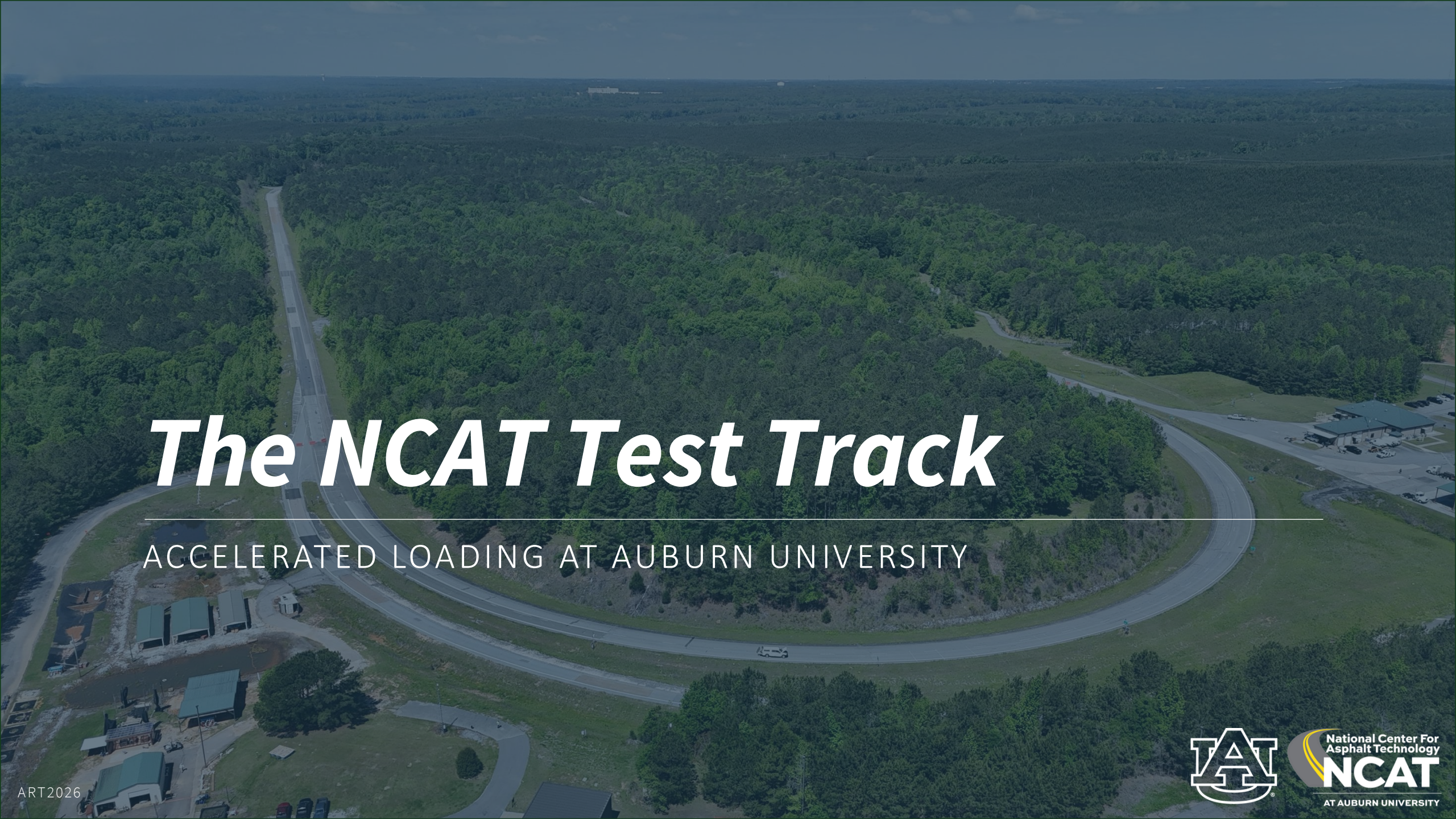
Stabilizing Agent (umbrella term)

- Asphalt Stabilizing Agent (aka Bituminous)
 - Asphalt emulsion, including engineered emulsions
 - Foamed asphalt
- Chemical Stabilizing agent
 - Hydraulic cement
 - Lime
 - Other similar chemical-stabilizers

Active Filler

- Small dose of lime or cement, often $<1\%$





The NCAT Test Track

ACCELERATED LOADING AT AUBURN UNIVERSITY



NCAT Test Track

Full scale accelerated loading facility

- 2.74 km in length
- 46 test sections (60 meters each)

Legally loaded triple trailers

- Average truck weight = 71,212 kg
- 5 trucks simultaneously driven
- Driven 2x 8 hr shifts, 5 days a week

Apply 10M Equivalent Single Axle Loads
every 2 years, 1 year for
forensics/reconstruction



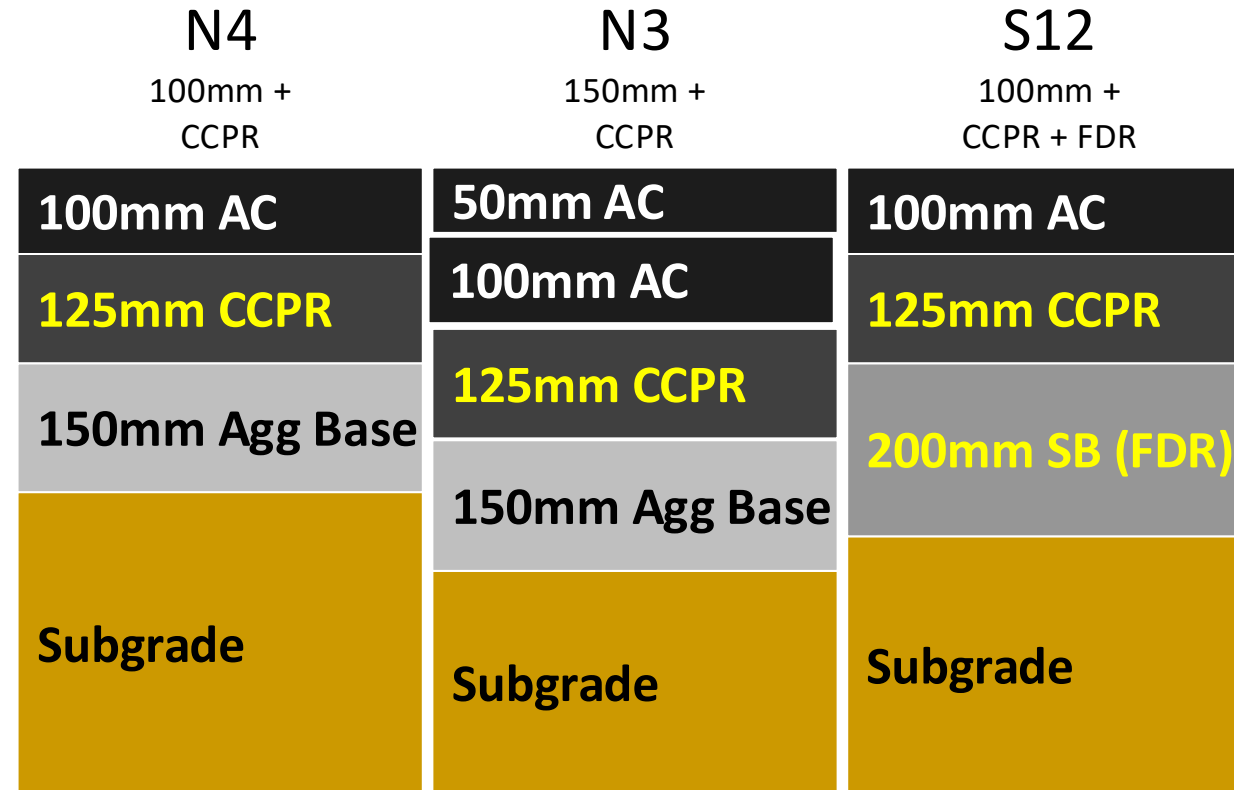
History Lesson

Virginia DOT constructed 3 distinct sections

- Test the limits of CCPR
- Quantify the benefit of FDR under CCPR

Installed strain gauges, pressure plates, and temperature probes

Distress and FWD data collected at regular intervals



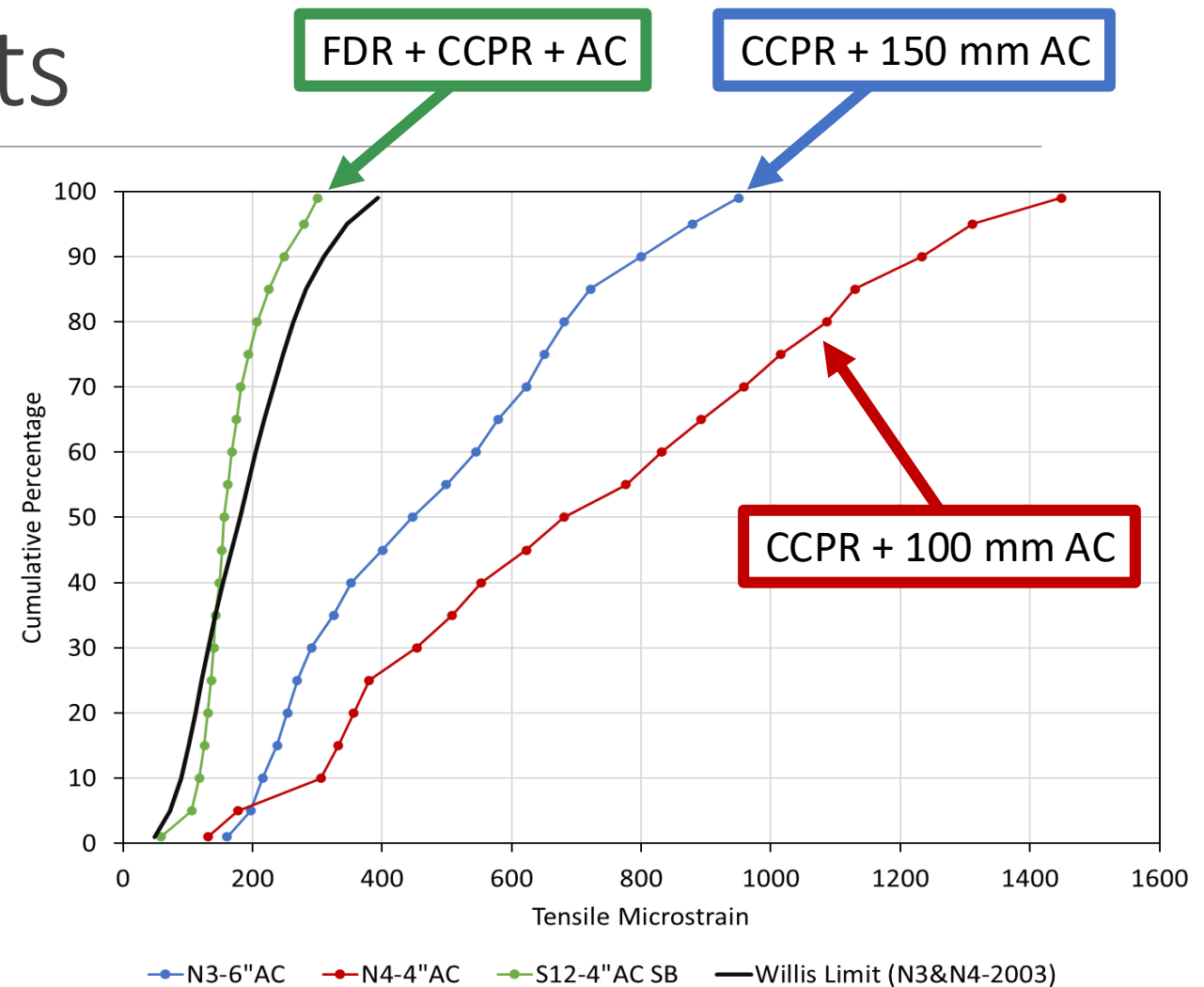
Perpetual Pavements

A pavement is considered “perpetual” if it is to the left of the “Willis Limit”

Section S12 is behaving perpetually

- FDR + CCPR + AC

Section N4 is too, visually, but not according to the strain data....





So, how did they do?

Incredibly well...

- 150 mm AC + 125 mm CCPR
 - Zero cracking
 - Offline at 20 MESALs
- 100 mm AC + 125 mm CCPR + 200 mm FDR
 - Zero cracking
 - Offline at 30 MESALs
 - Perpetual
- 100 mm AC + 125 mm CCPR
 - Cracked at 29.7 MESALs
 - Lasted to 40 MESALs

Section N4 – 100 mm of AC over 125 mm CCPR



Trench in wheelpath

Section N4 – 100 mm of AC over 125 mm CCPR



Pressure plate
has seen better
days

Trench in wheelpath

Takeaways from VDOT study

Constructed a perpetual, “long-life” pavement with CCPR + FDR

Typical asphalt fatigue cracking observed in CCPR

- Other studies have found a “crumbling” effect, but the fatigue finding was interesting
 - Byproduct of high ITS strengths?

VDOT adopted a structural layer coefficient of 0.35 for CCPR based on research at NCAT and in Virginia

- Use a 0.44 for hot mix asphalt

FDR as an adaptation approach

FOR RESILIENT PAVEMENT SYSTEMS

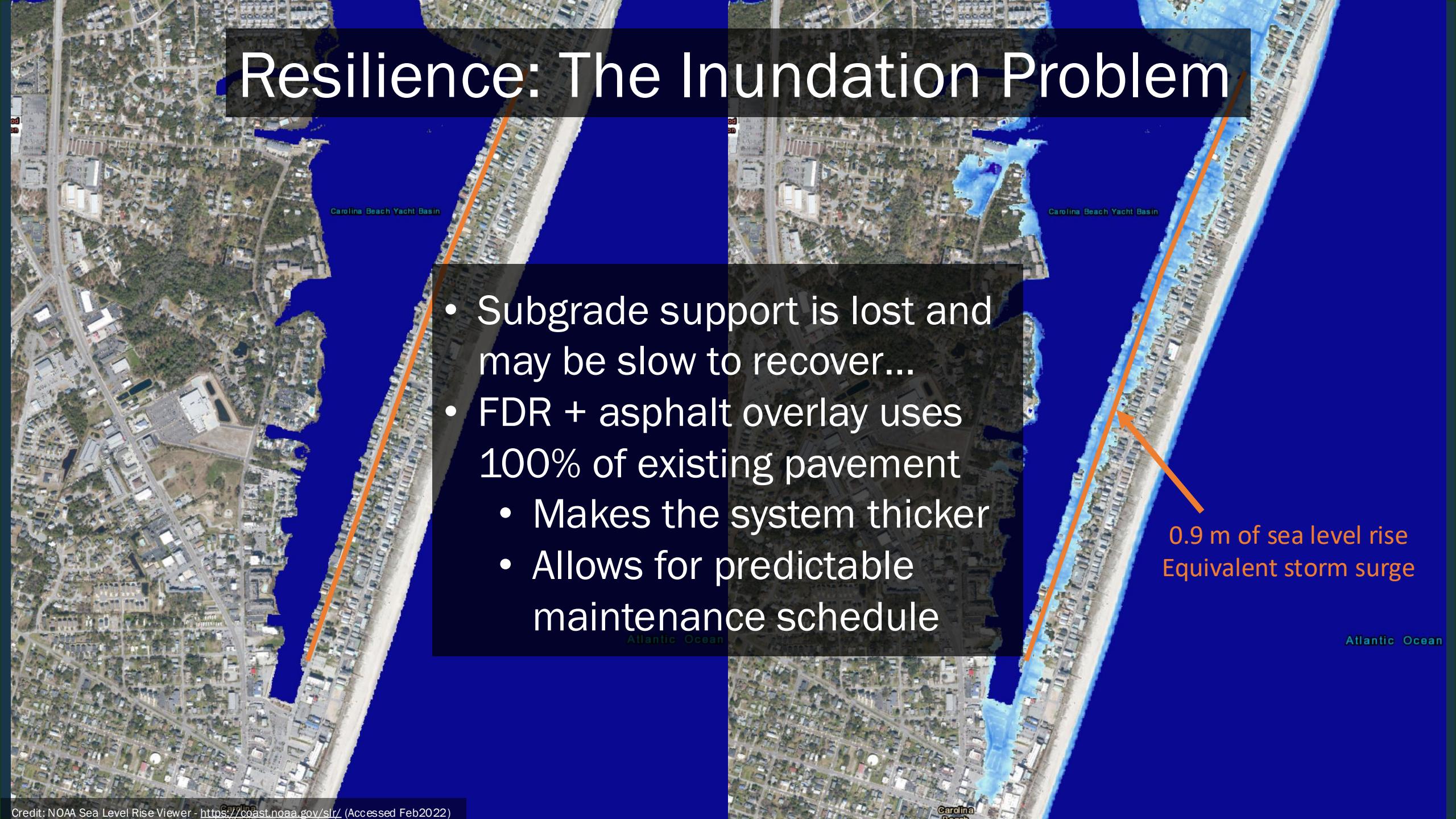


Resilience: The Inundation Problem

- Carolina Beach, NC
- Effect of sea level rise – 3 ft
- Can be used to look at storm surge impacts
- *What solutions might we be able to use here?*

0.9 m of sea level rise
Equivalent storm surge

Resilience: The Inundation Problem



- Subgrade support is lost and may be slow to recover...
- FDR + asphalt overlay uses 100% of existing pavement
 - Makes the system thicker
 - Allows for predictable maintenance schedule

0.9 m of sea level rise
Equivalent storm surge

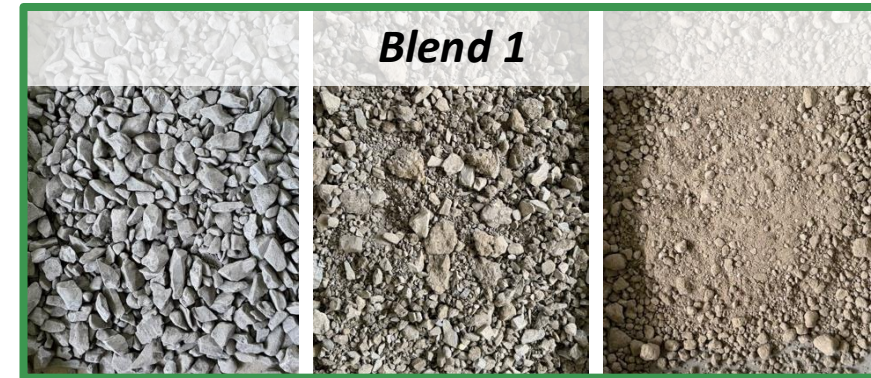
Research approach

Can FDR be used as an adaptation approach for roadways subject to flooding?

Materials

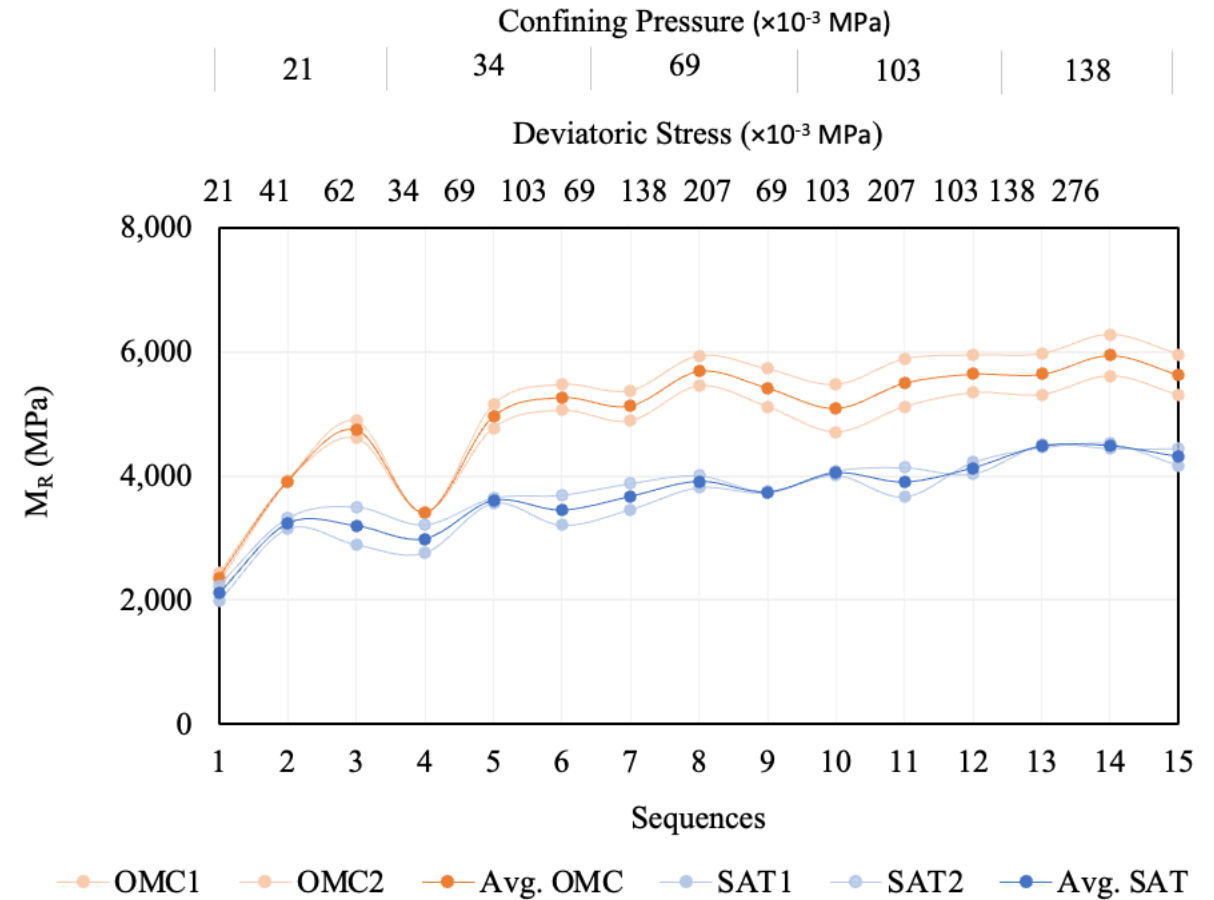
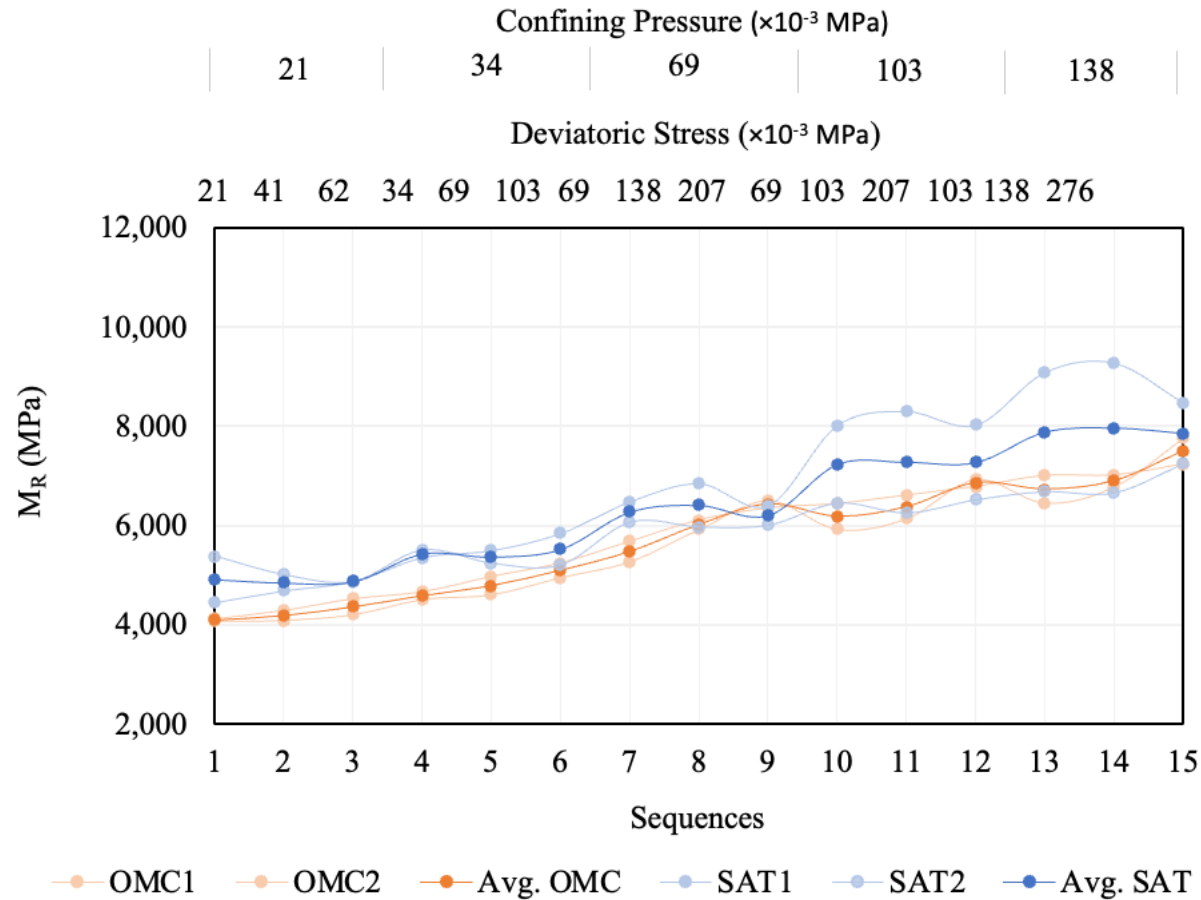
- Blend 1 - “Typical” blend of materials
 - (Aggregate + RAP + Soil)
- Blend 2 - Recycled Concrete
- Blend 3 - #10 screenings (fines)
- Three stabilizing agents: Foamed asphalt, asphalt emulsion, hydraulic cement

Tests: Resilient Modulus; Performance tests



Results

- Compressive strength and ITS testing did not differentiate with longer conditioning times
- Resilient modulus stable for cement and emulsion, foam saw a decrease though not practically significant



Rejuvenation

WHAT HAPPENS WHEN WE REJUVENATE?



Test Track '21 Offramp Study

Six sections were constructed on the offramp at NCAT

- 100 mm of asphalt
- 100 mm of Foamed CCPR
- 100 mm of Engineered Emulsion CCPR
- 100 mm of CCPR with Emulsified R1 rejuvenator
- 100 mm of CCPR with R2 rejuvenator
- 100 mm of CCPR with Emulsion + R3 rejuven.

All sections surface with a
25 mm thin hot mix overlay



Experience with rejuvenated CCPR

Three designs performed by NCAT

- Foamed Asphalt; Rejuvenator (R2); Rejuvenator (Emulsion + R3)

Bulk dry density **increased** when rejuvenator was added

- RAP gradation, etc. was the same
- Activation binder is assumed to be the cause

All mix designs performed with the same RAP source/gradation

Density	Foam	Rejuvenator	Emulsion + Rejuvenator
Bulk Dry Density (kg/m ³)	2028	2153	2097

Plant Options

Wirtgen KMA 240i – Foamed Asphalt & Engineered Emulsion



Plant Options

Pugmill Systems Portable Pugmill

- Rejuvenated mixes all produced using this plant



Test Track '21 Construction

Compacted until refusal for density; Checked with nuclear gauge.



Foam



Engineered
Emulsion



Emulsified R1



R2



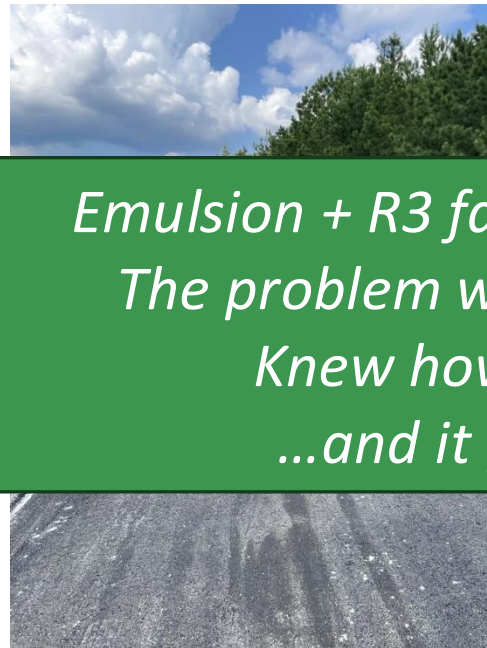
Emulsion + R3

Test Track '21 Construction

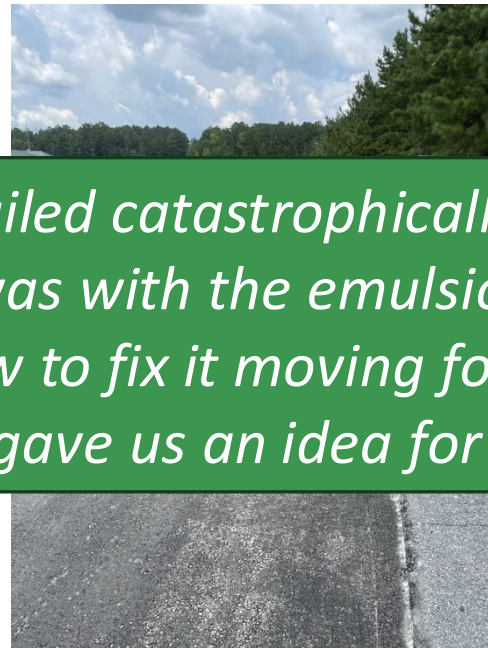
Compacted until refusal for density; Checked with nuclear gauge.



Foam



Engineered
Emulsion



Emulsified R1



R2



Emulsion + R3

*Emulsion + R3 failed catastrophically and quickly...
The problem was with the emulsion selection...
Knew how to fix it moving forward...
...and it gave us an idea for 2024...*

Test Track 2024 - Can we pave rejuvenated CCPR as a surface mix?

Materials

- Same RAP used for the TT24 hot mix asphalt mix designs
- Used 3.5% cationic emulsion, HiMA modified
- Added Delta-S rejuvenator

Used same mix design approach as TT21 – Target dry MS of 5.56 kN

- Avg dry strength = 7.04 kN
- Avg conditioned strength = 6.53 kN
- Density = 1990 kg/m³

Construction

Placed at 127 mm thick

No overlay placed

No fog-seal or any other treatment at this time

- Will add at a later date if necessary

Compacted to maximum achievable density









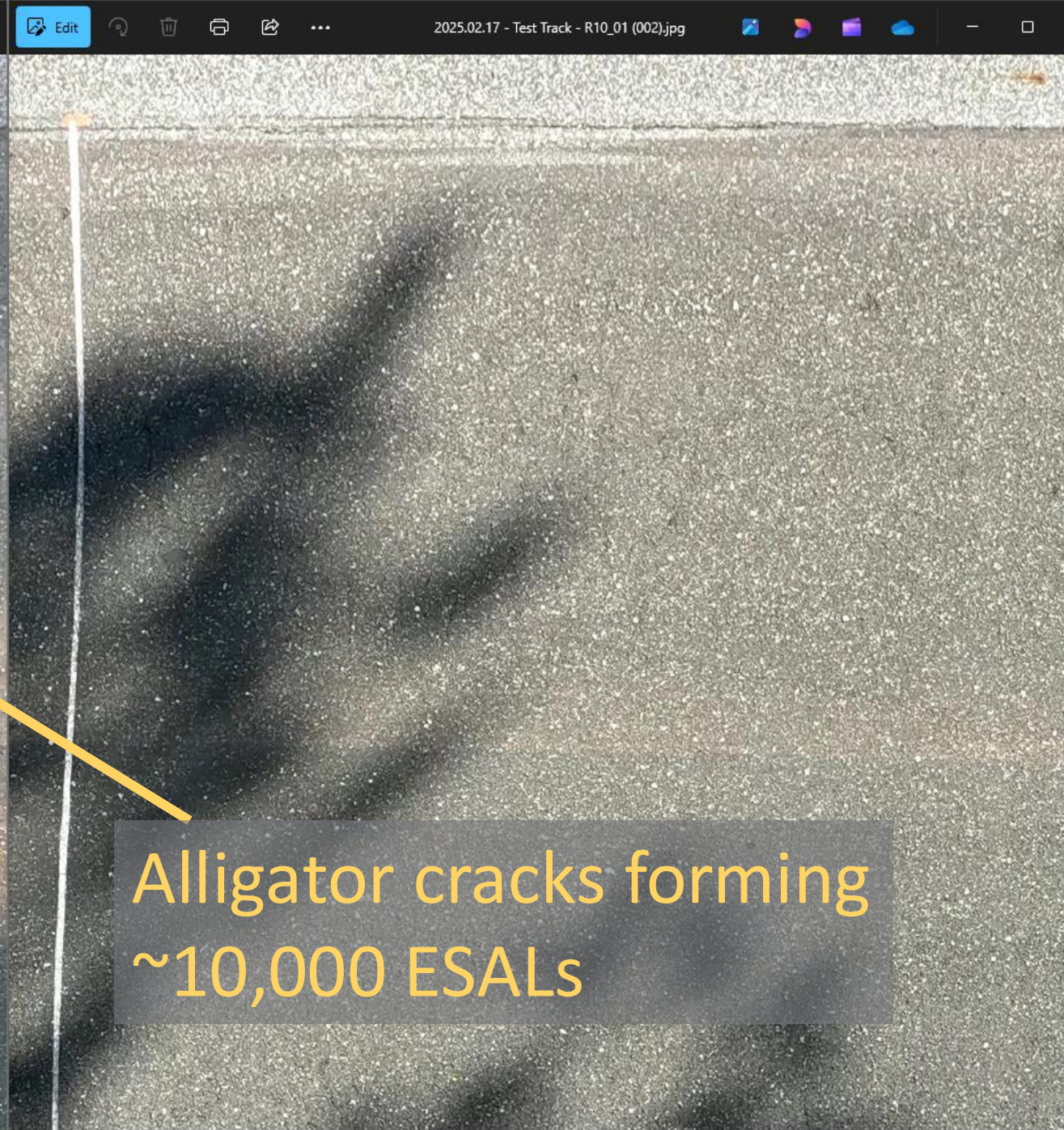


Initial compaction the day of
paving



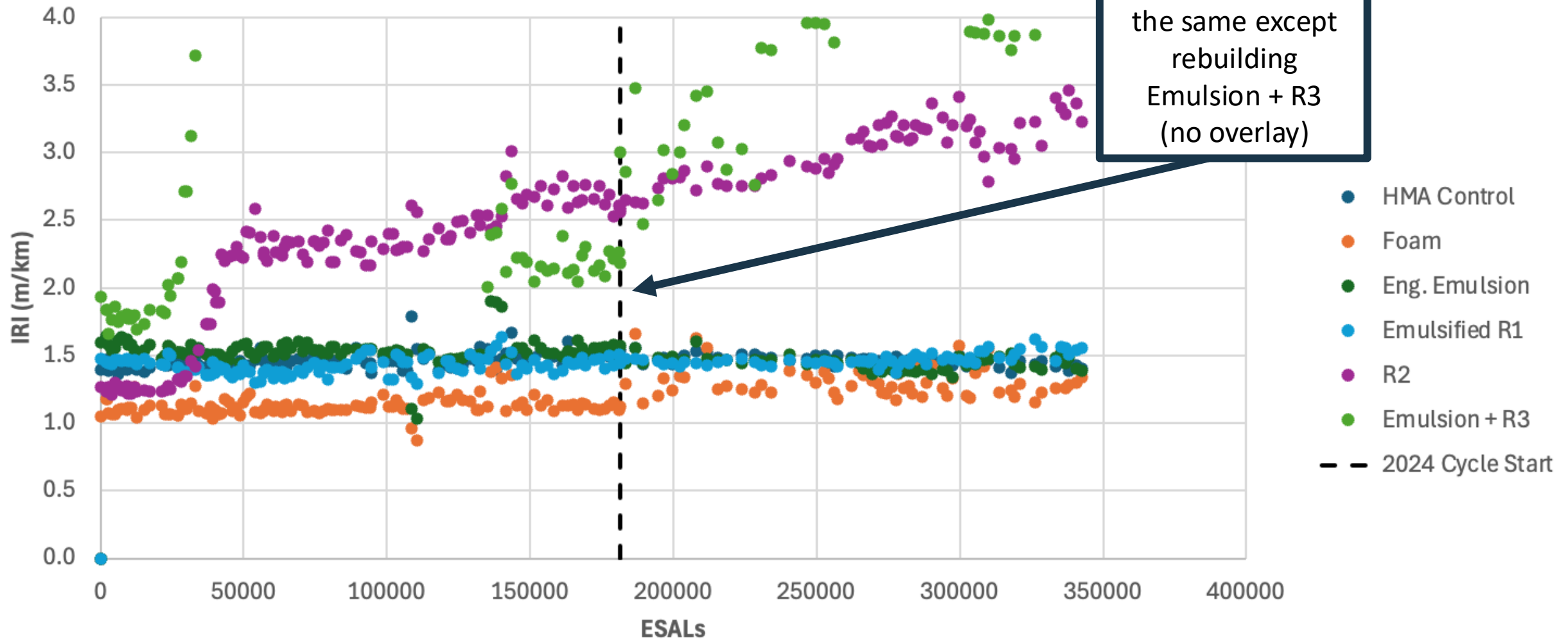
Secondary compaction the
next day



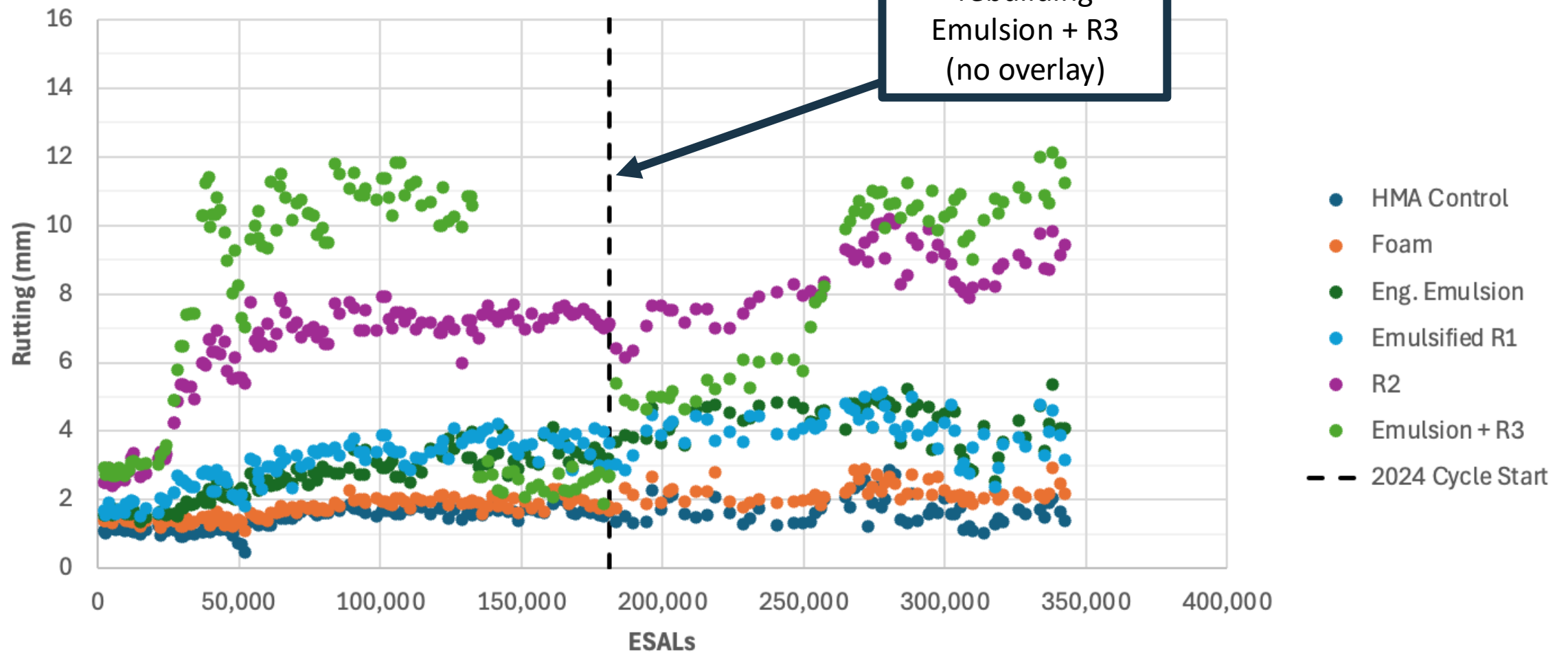


Alligator cracks forming
~10,000 ESALs

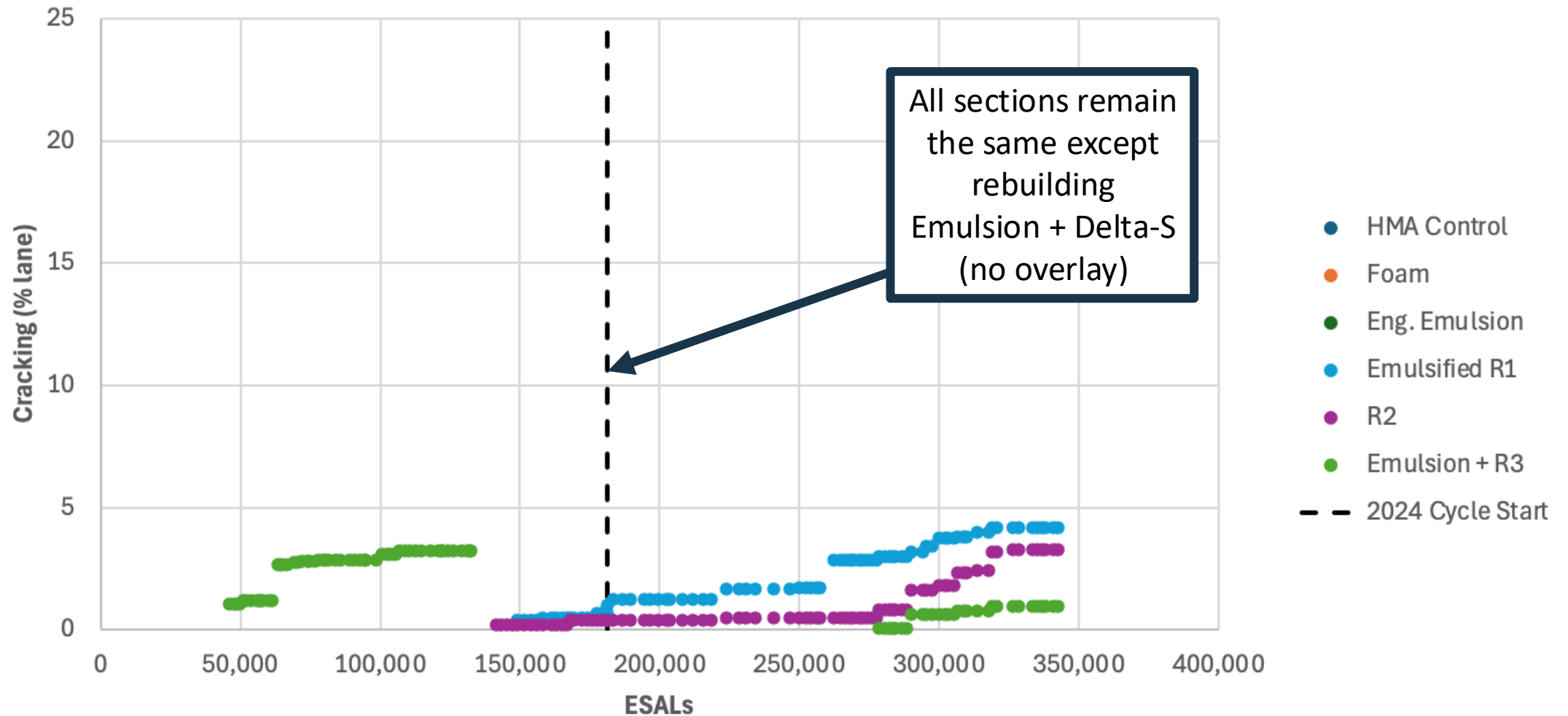
IRI (Draft Performance)



Rutting (Draft Performance)



Cracking_(Draft Performance)



Life Cycle Assessment

QUANTIFYING ENVIRONMENTAL BENEFITS



Life Cycle Assessment

ARRA just published a life cycle assessment of main products

- Covers the USA + Canada
- Conducted by WAP Sustainability Consulting

PCR is currently being drafted by committee, expect to be out for public comment by the end of the year.

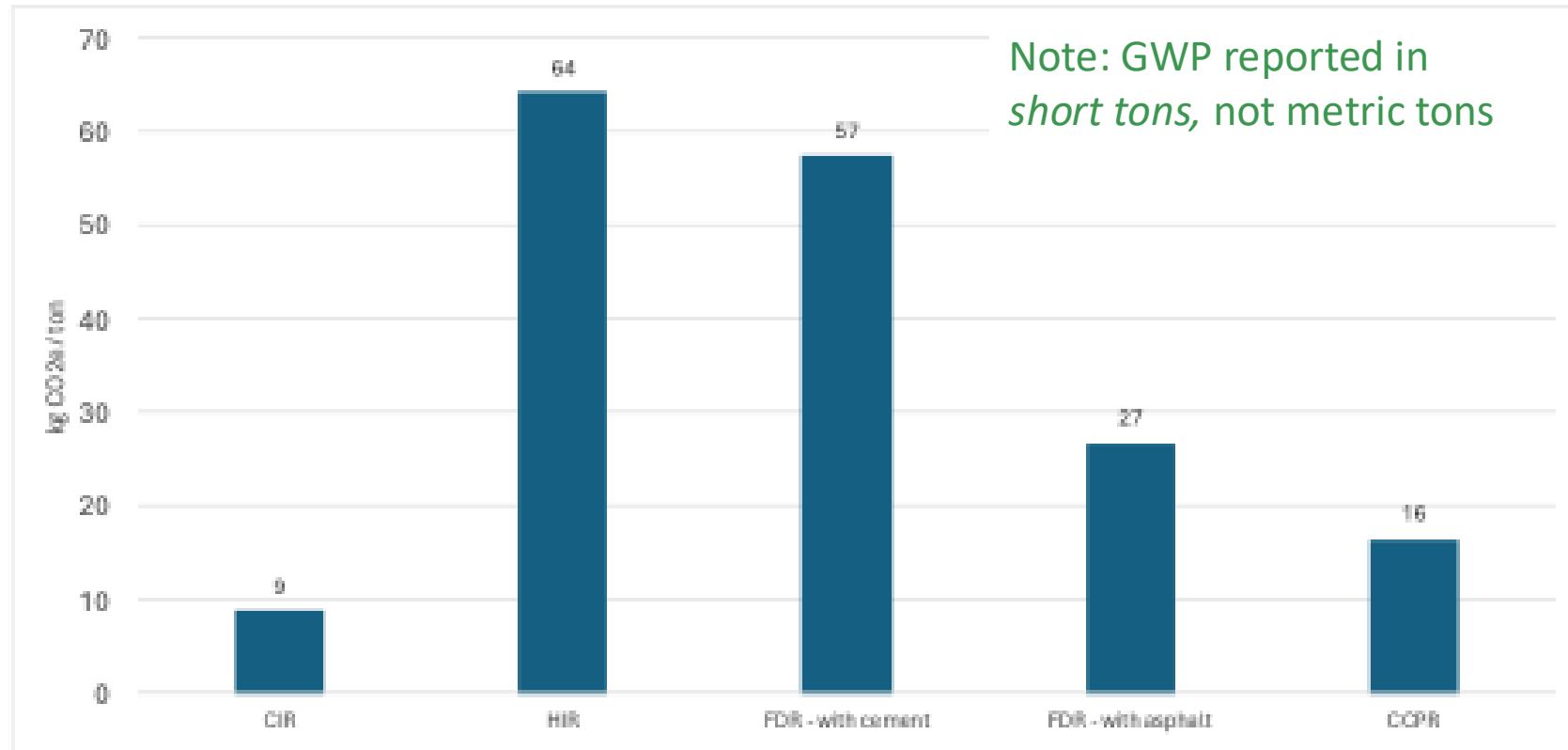


Figure 1: Global Warming Potential per declared unit

Overall Takeaways

FDR + CCPR can be used to build perpetual, “long-life” pavements.

CCPR *can* fail in fatigue, like conventional asphalt pavements.

FDR can be a useful pavement adaptation to manage roadways subject to flooding.

- Field trials or accelerated loading studies should be conducted to verify.



Overall Takeaways

A thin overlay on CCPR can manage heavily loaded trucks

- Reminder: This is at a lower loading rate than the main Test Track

Indications thus far are that we can pave roads using rejuvenated CCPR without any surfacing and get decent performance

- Ideal for local/low volume routes that do not have adequate funding





Thank you

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