VIRGINIA TECH
TRANSPORTATION INSTITUTE

Extending Full Depth Reclamation (FDR) Service Lives

2025 APT Monthly Webinar

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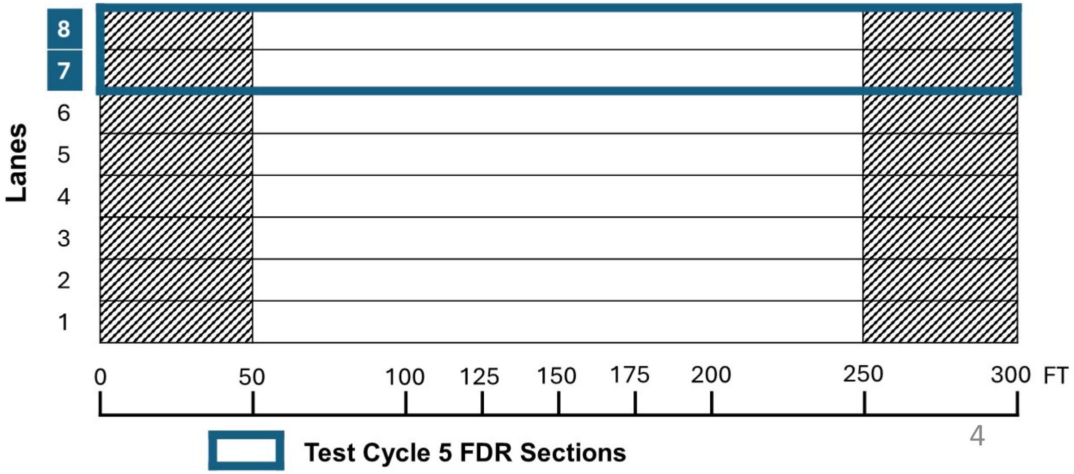
Overview

- **Overview of VA APT-Program**
- **Extending FDR Service Lives**
  - Background
  - Experimental Design
  - Laboratory and Field Activities
  - Results
    - *mix design, pavement responses, forensics*
- **Study Conclusions**

Virginia APT Program

Facility Location



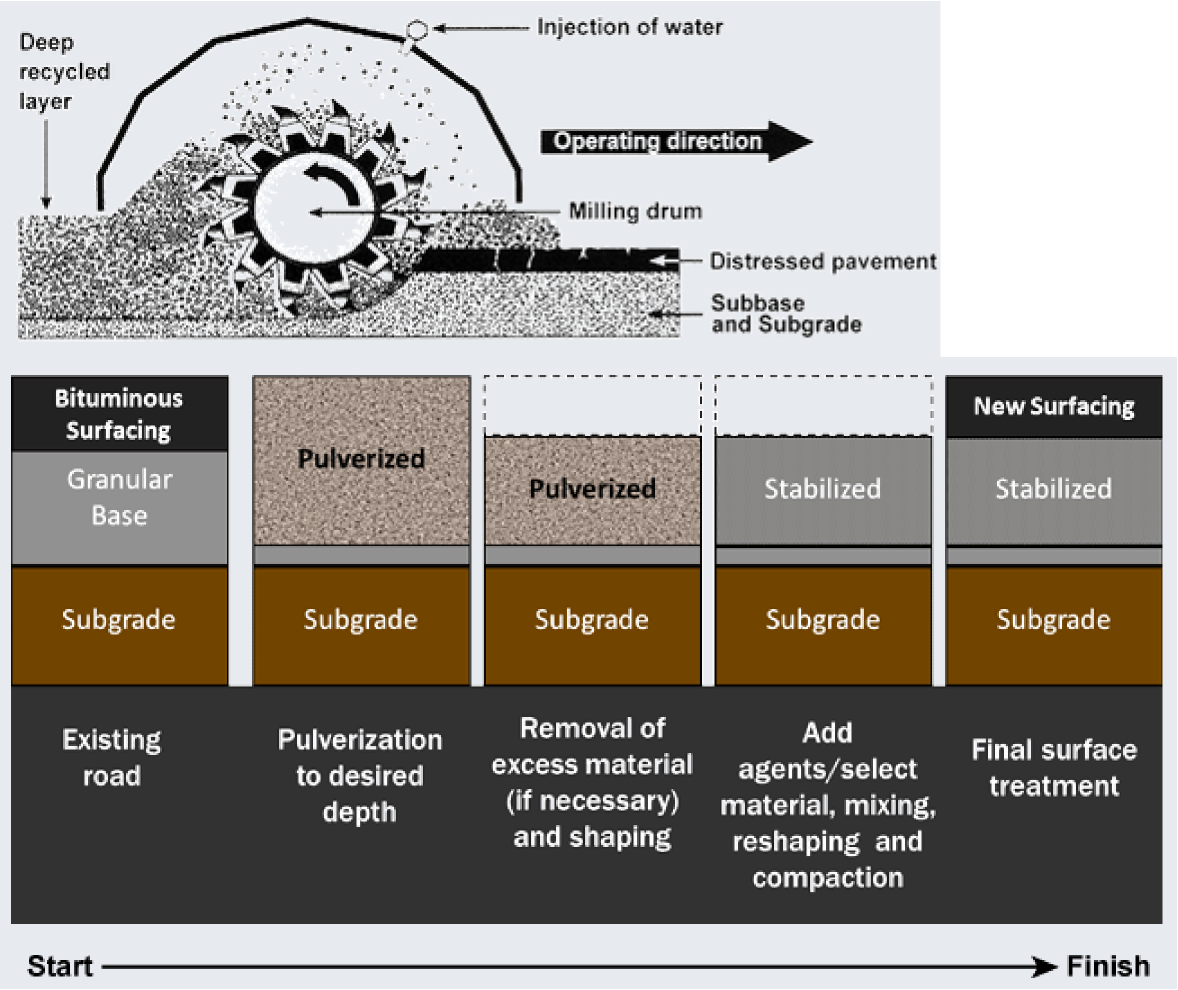
VDOT APT Program

Overview of Experiments

#	Dates	Research Topic	Status
1	2015-2016	CCPR with Thin Surfacing	Completed
2	2016	Reduced Gyration Levels	Completed
3	2016-2018	Reflection Cracking Mitigation	Completed
4	2019-2023	Balanced Mix Design of Dense Graded Surface Mixtures	Completed
5	**2023-2025**	**Extending FDR Service Lives**	**Completed**
6	2024-2026	Thick Lift Paving	Ongoing

Full Depth Reclamation in VA

Conventional FDR Process



- Since **2008** demo projects
- Over **600 lane-miles** in VA
  - **Cement-stabilized** FDR
- **Interstates**, primary and secondary roads.
  - **I-81 and I-64 projects**

Extending FDR Service Lives

Problem Statement

- Transverse cracking (shrinkage) is a predominant mode of failure for VDOTs cement-based FDR sections

Mitigation Approaches

- Can the potential for shrinkage be evaluated during design?
- Can micro-cracking and/or fog sealing be used to mitigate?

Laboratory Activities

Mix Design

- **Develop a test method to assess shrinkage**
  - Possible submission to AASHTO as a standard
  - Followed ASTM standards for shrinkage cracking
- **Assess use of #10 screenings (secondary testing)**
  - Consider with 450 psi strength ceiling

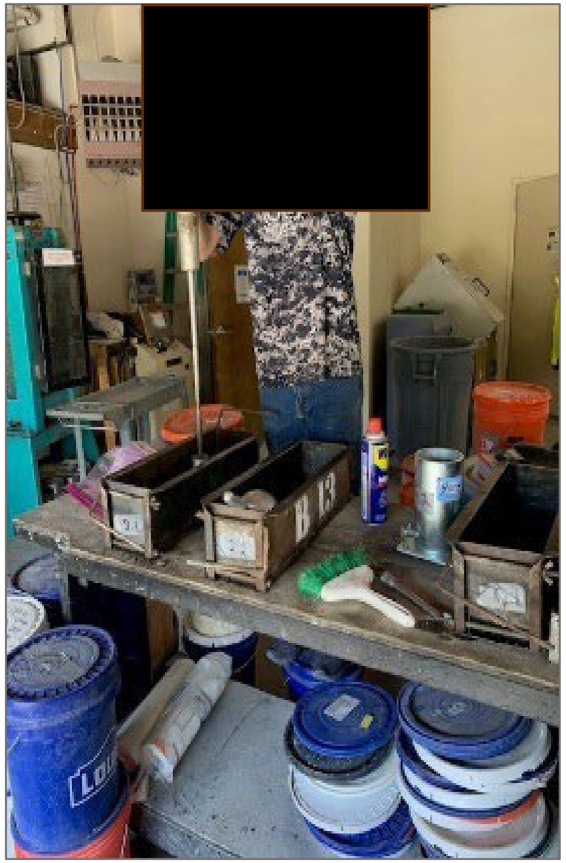
Materials properties testing

- **Compressive strength vs modulus of rupture**
  - Relationships exist for concrete but not FDR

Laboratory Activities

Mix Design

- ASTM C78: Modulus of Rupture



Mix Design

- ASTM 469: Static Modulus of Elasticity

Laboratory Activities

Mix Design

- ASTM 469: Static Modulus of Elasticity

Laboratory Activities

Mix Design

- ASTM C157: Length Change

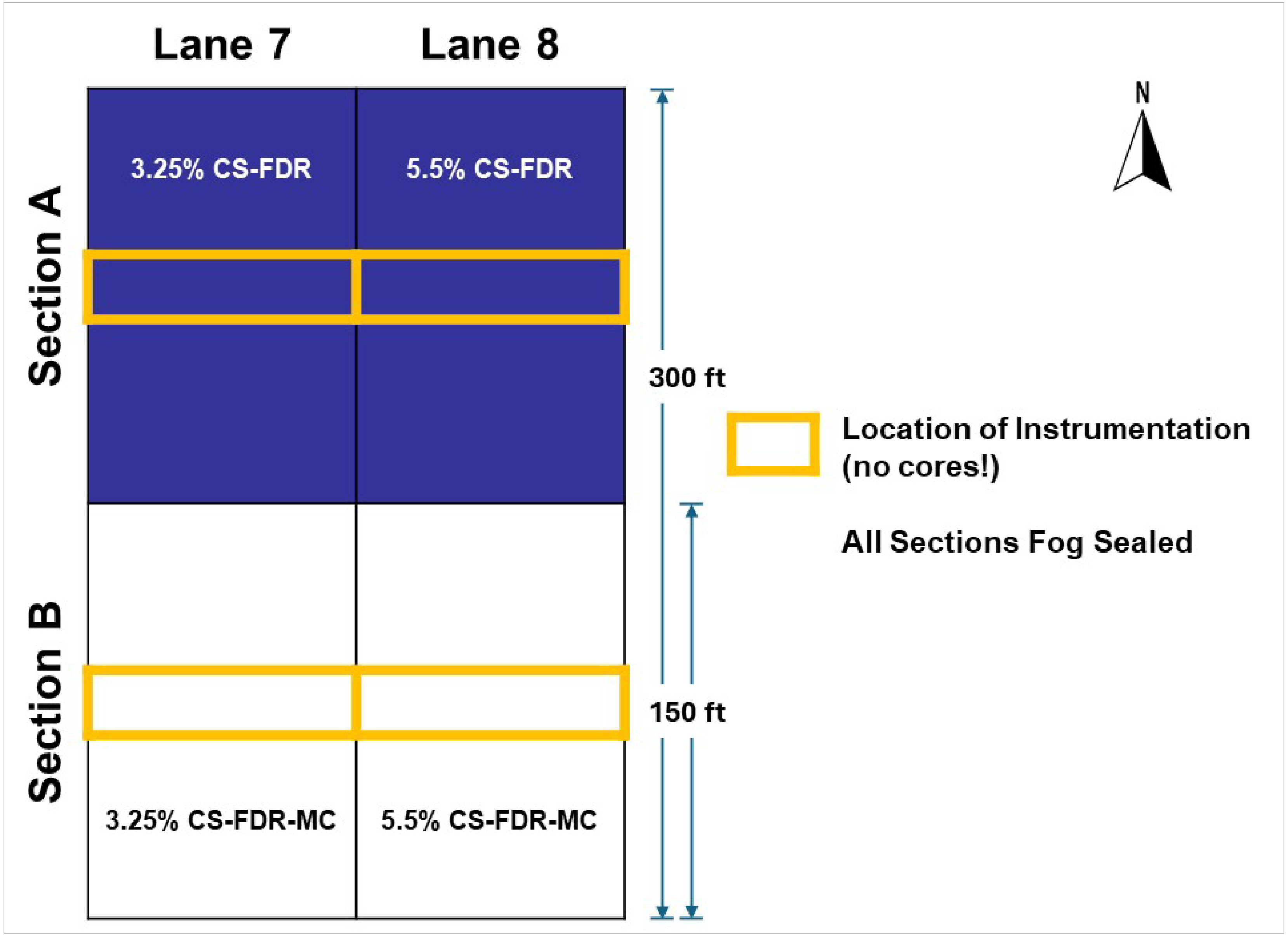


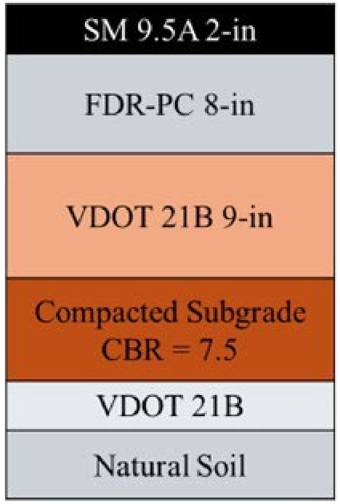
Laboratory Activities

Mix Design

- ASTM C157: Length Change

Experimental Design





Field Activities

FDR Construction

- Monitor Proctor, gradation, and thickness
- Instrument 2 cells per lane with sensors

After FDR Construction

- Microcrack half of Lanes 7 and 8
- Fog seal all lanes
- Collect cores after construction
- Time between FDR and asphalt (2 weeks)

Field Activities – FDR Construction

Pre-spreading of Cement

Dosage Rate Control

Field Activities – Paver-laid FDR Construction

Milling to Seat Paver

FDR Paving

Field Activities – FDR Construction

Compaction

Microcracking

Field Activities – FDR Construction

Compaction

Microcracking

Field Activities – FDR Construction

Microcracking

Fog Sealing

Field Activities – FDR Construction

- Some cracking observed prior to overlay

Field Activities – HMA Paving

Tack Coat

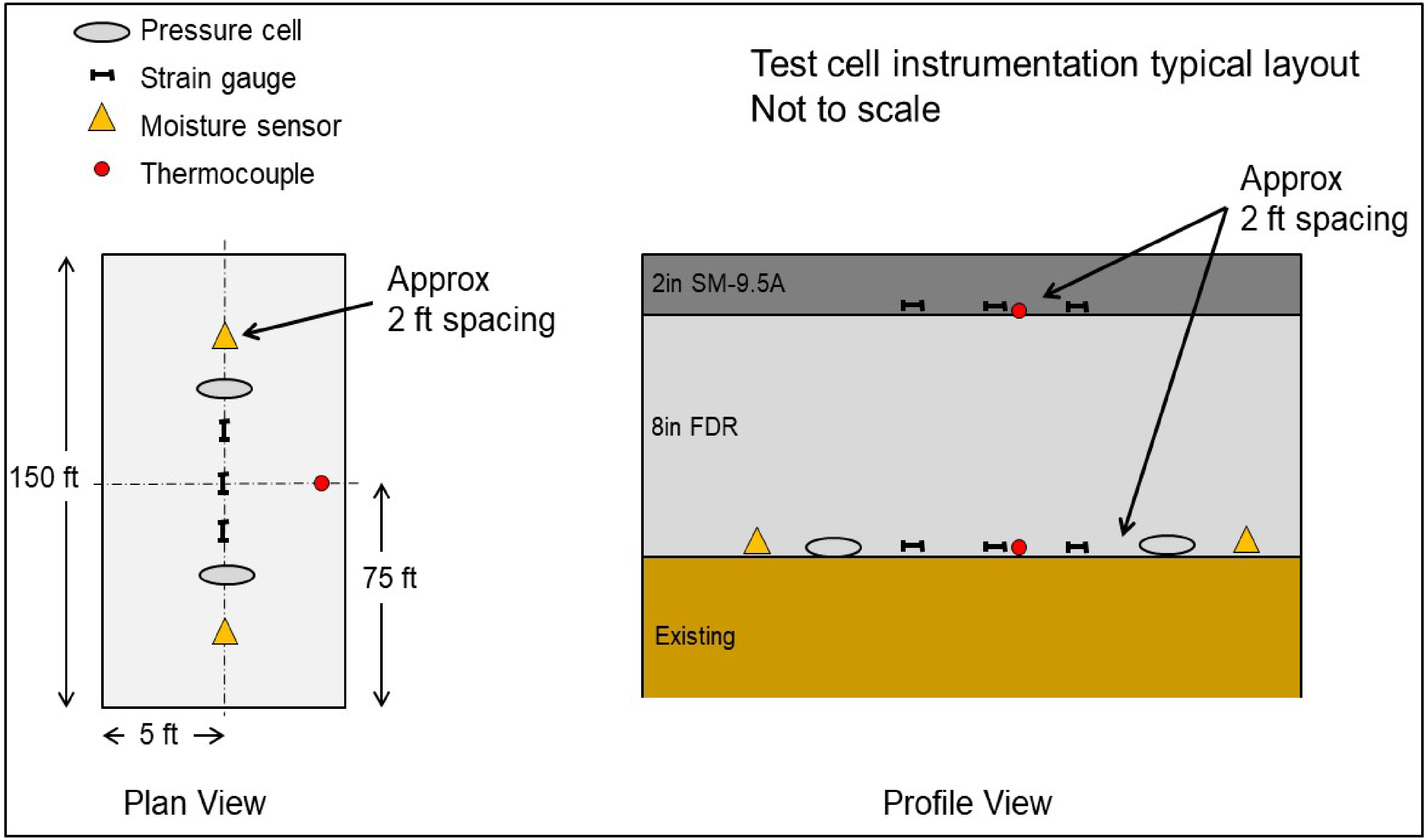
HMA (SM 9.5A) Paving

Field Activities – HMA Paving

Compaction

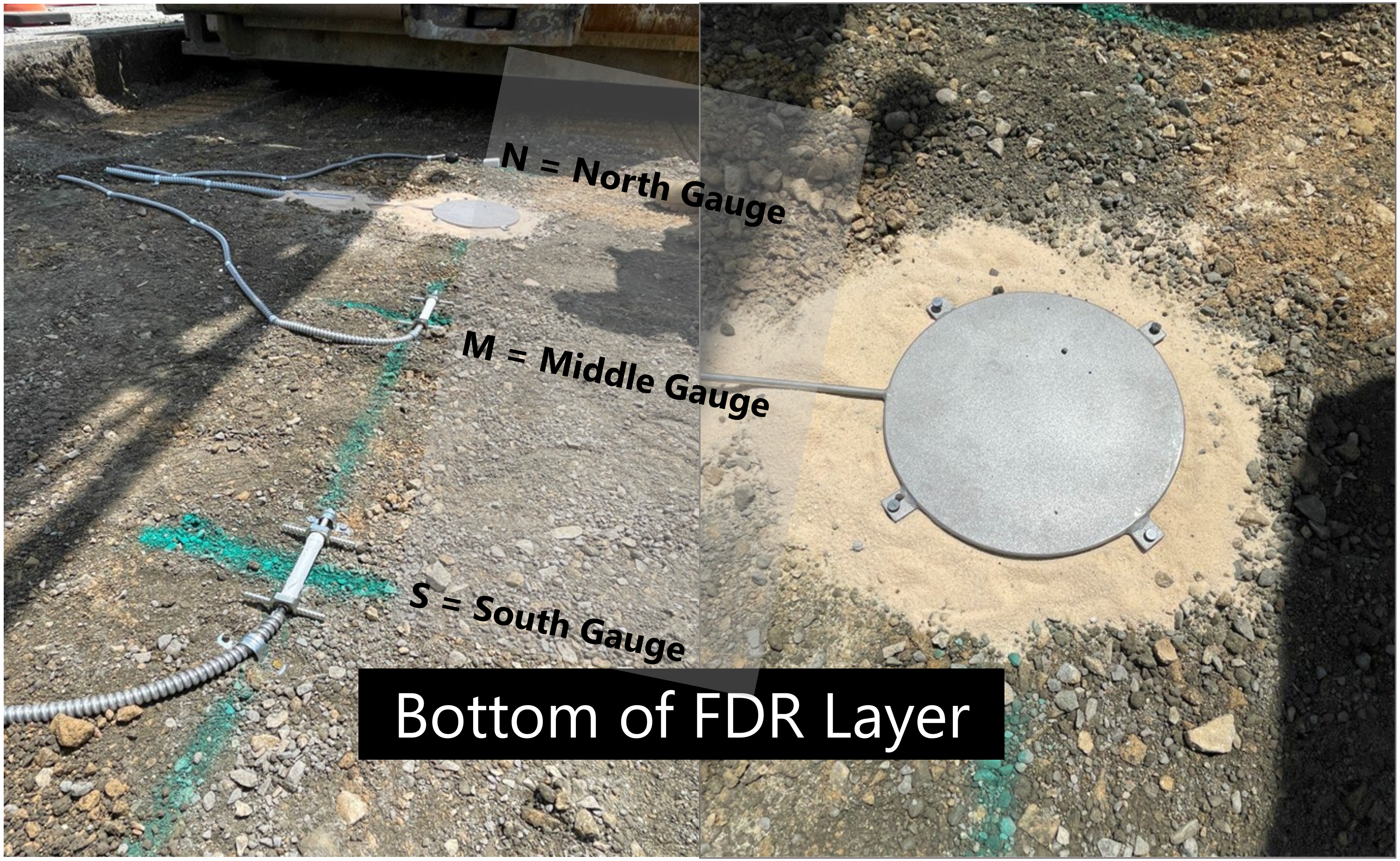
Field Activities - Instrumentation

Layout

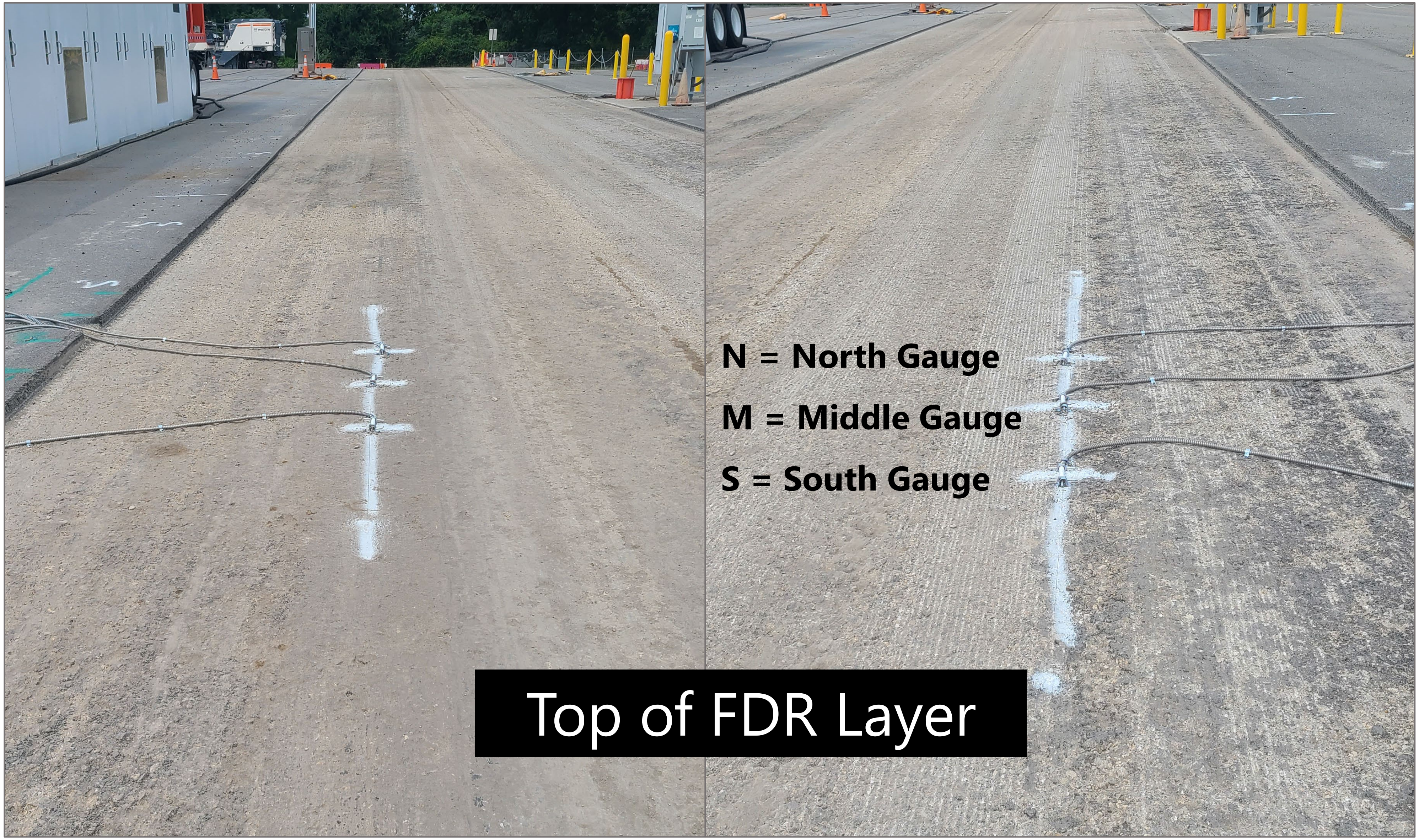


Field Activities – Instrumentation

Field Activities – Instrumentation



Field Activities – Instrumentation



Field Activities – FWD Testing

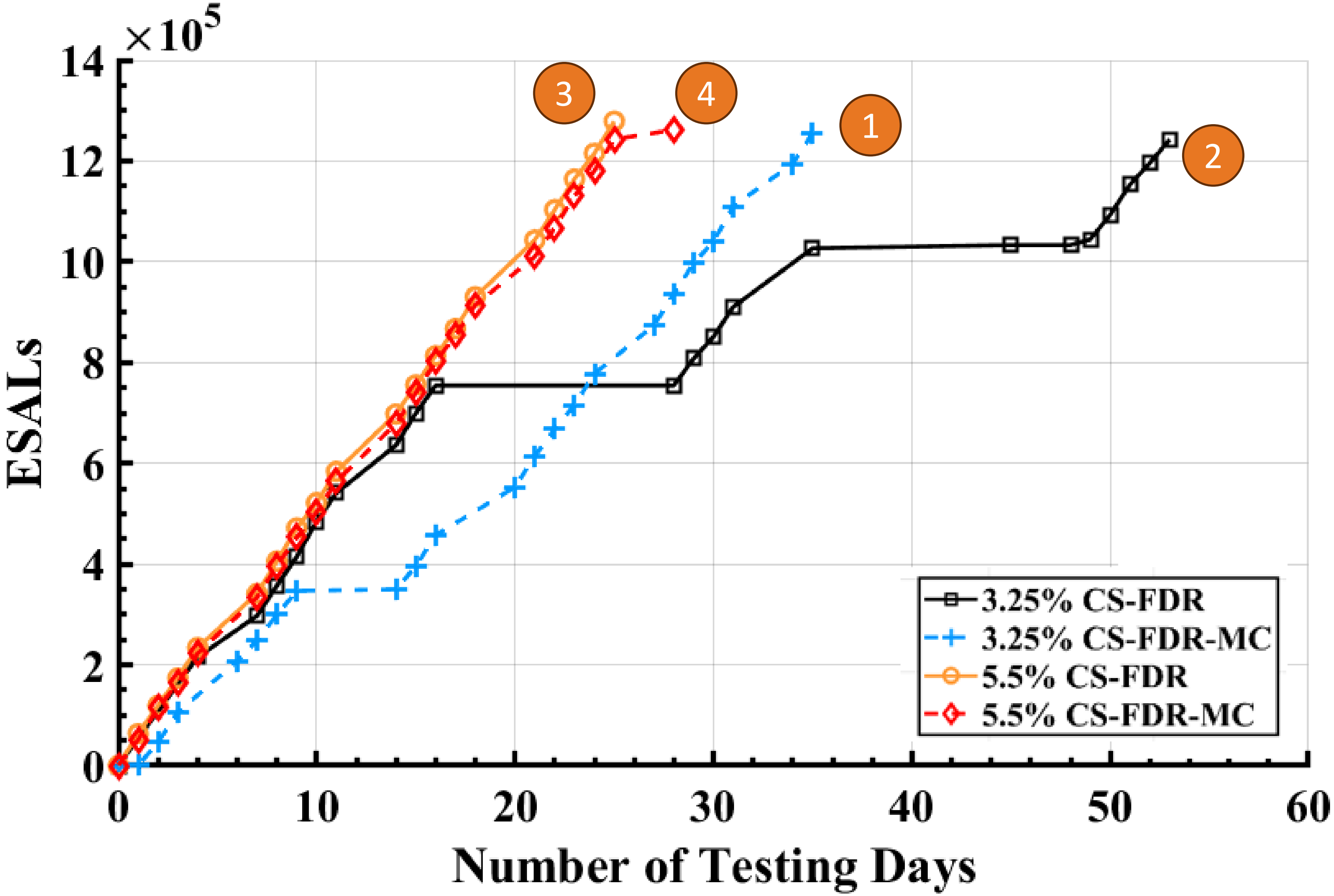
HVS Testing – Loading Plan

Test Section - Round	Stabilization Strategy	Start Date	End Date	Wheel Load (kips)	Cum. ESALs
Lane 7B - I	3.5% cement**	10/19/2023	11/28/2023	15	1,194,710
Lane 7A - I	3.5% cement*	12/05/2023	01/26/2024	15	1,242,414
Lane 8A - I	5.5% cement*	02/05/2024	03/01/2024	15	1,278,863
Lane 8B - I	5.5% cement**	03/11/2024	04/11/2024	15	1,261,617
Lane 7B - II	3.5% cement**	05/13/2024	06/24/2024	15	3,042,013
Lane 7A - II	3.5% cement*	07/15/2024	11/6/2024	15	3,009,820
Lane 8A - II	5.5% cement*	11/18/2024	1/24/2025	15	3,023,041
Lane 8B - II	5.5% cement**	03/03/2025	04/08/2025	15	3,005,940

* = all sections fog sealed ** = microcracked

HVS Testing – Loading Protocol

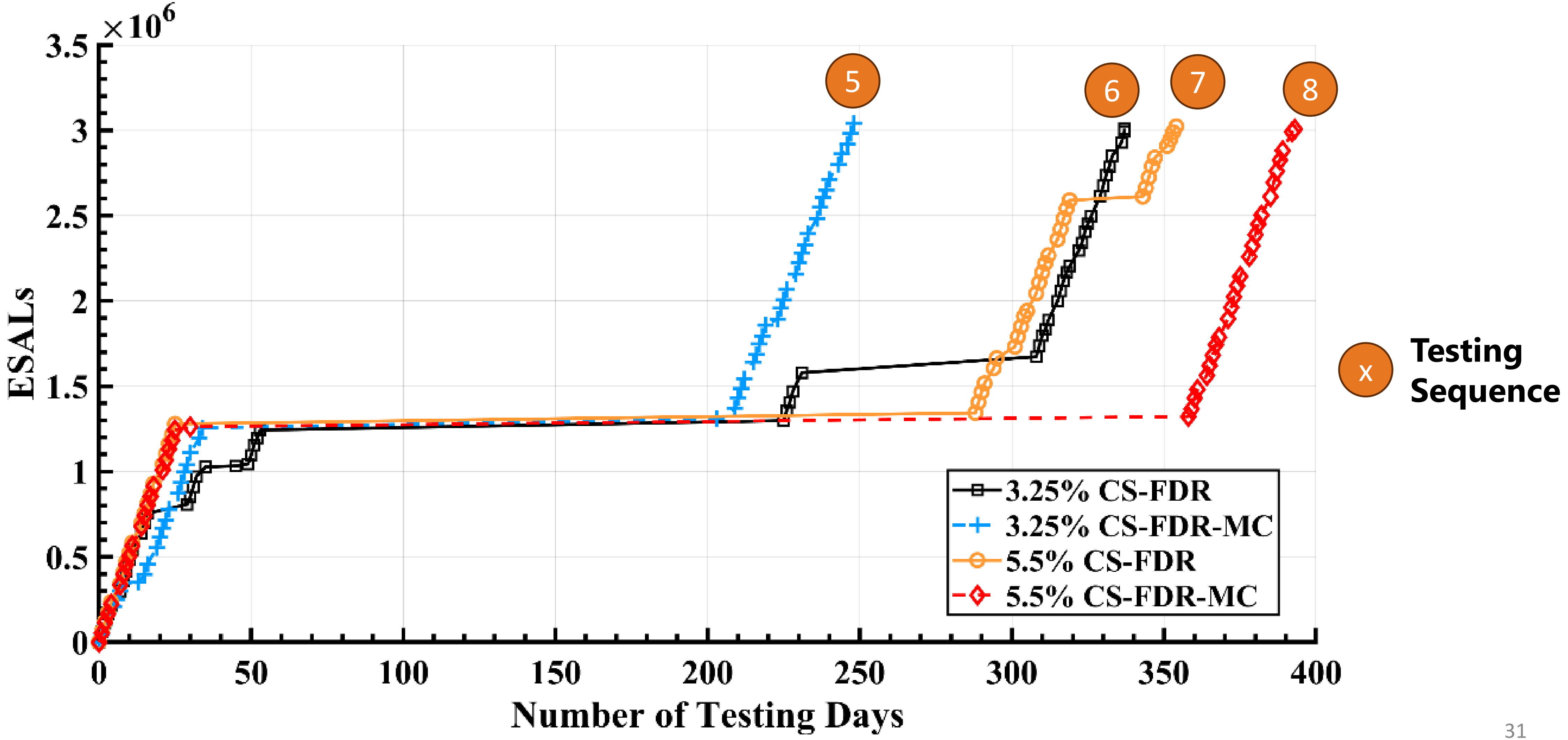
Round I



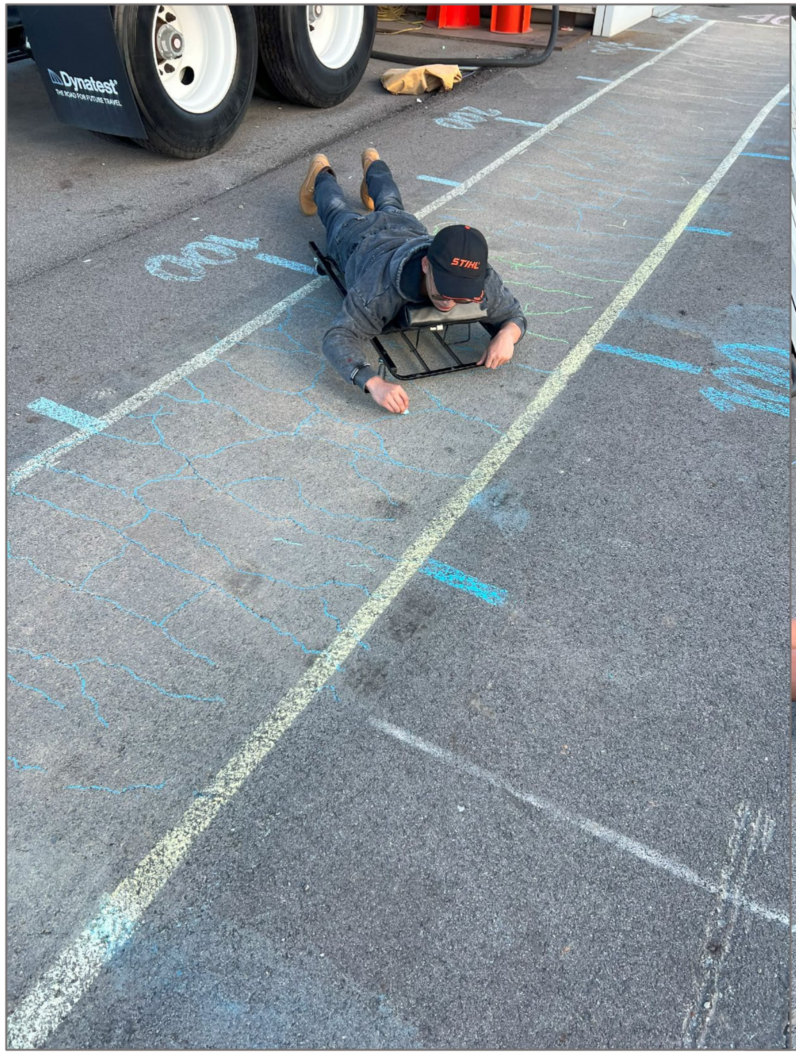
x Testing Sequence

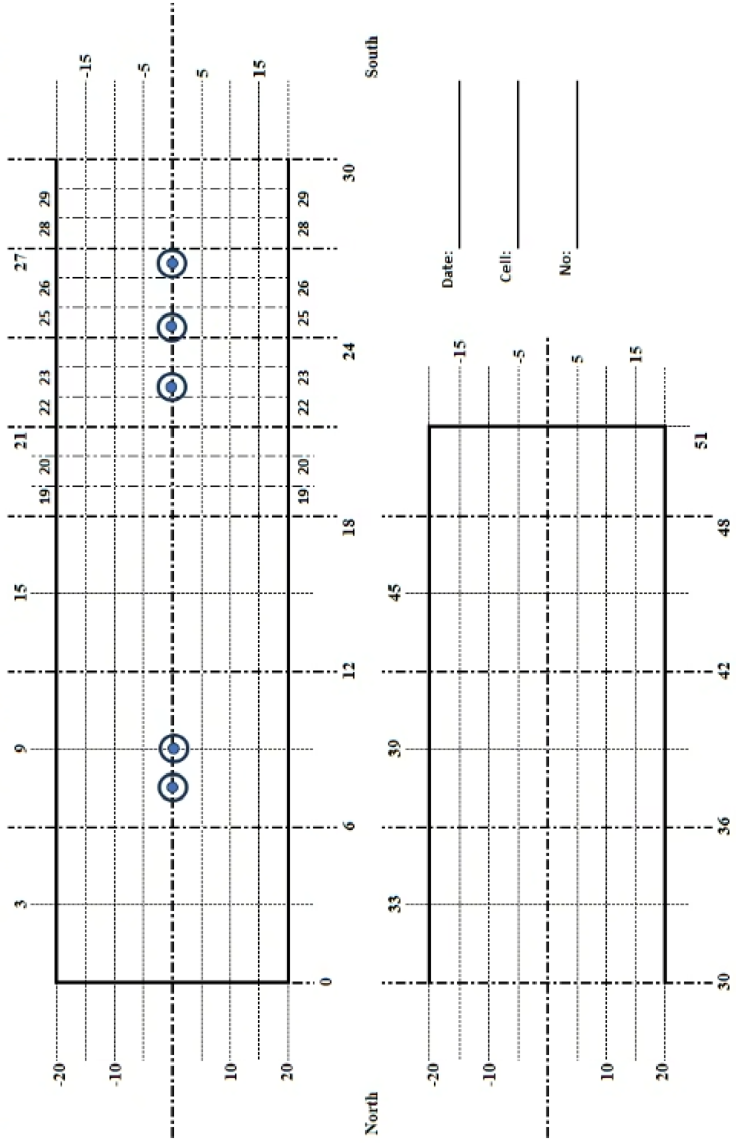
HVS Testing – Loading Protocol

Rounds I & II

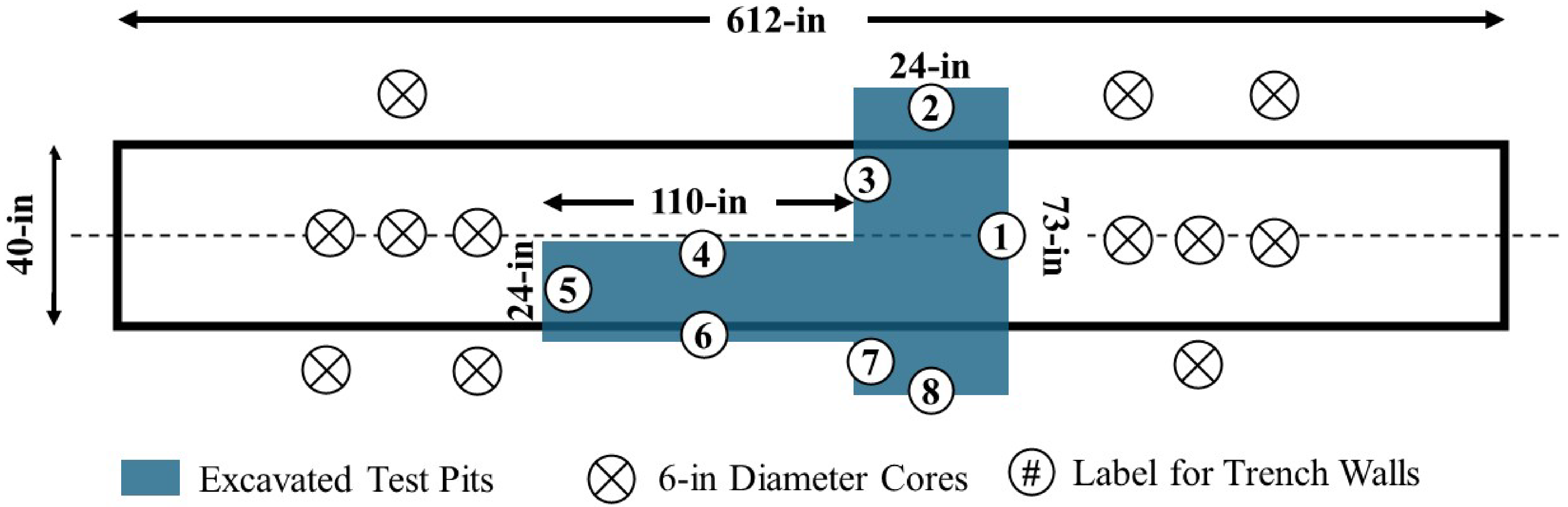


HVS Testing – Crack Survey



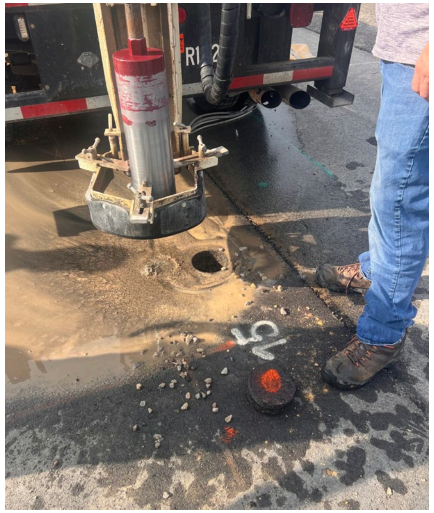


Forensic Study – Trenching & Coring

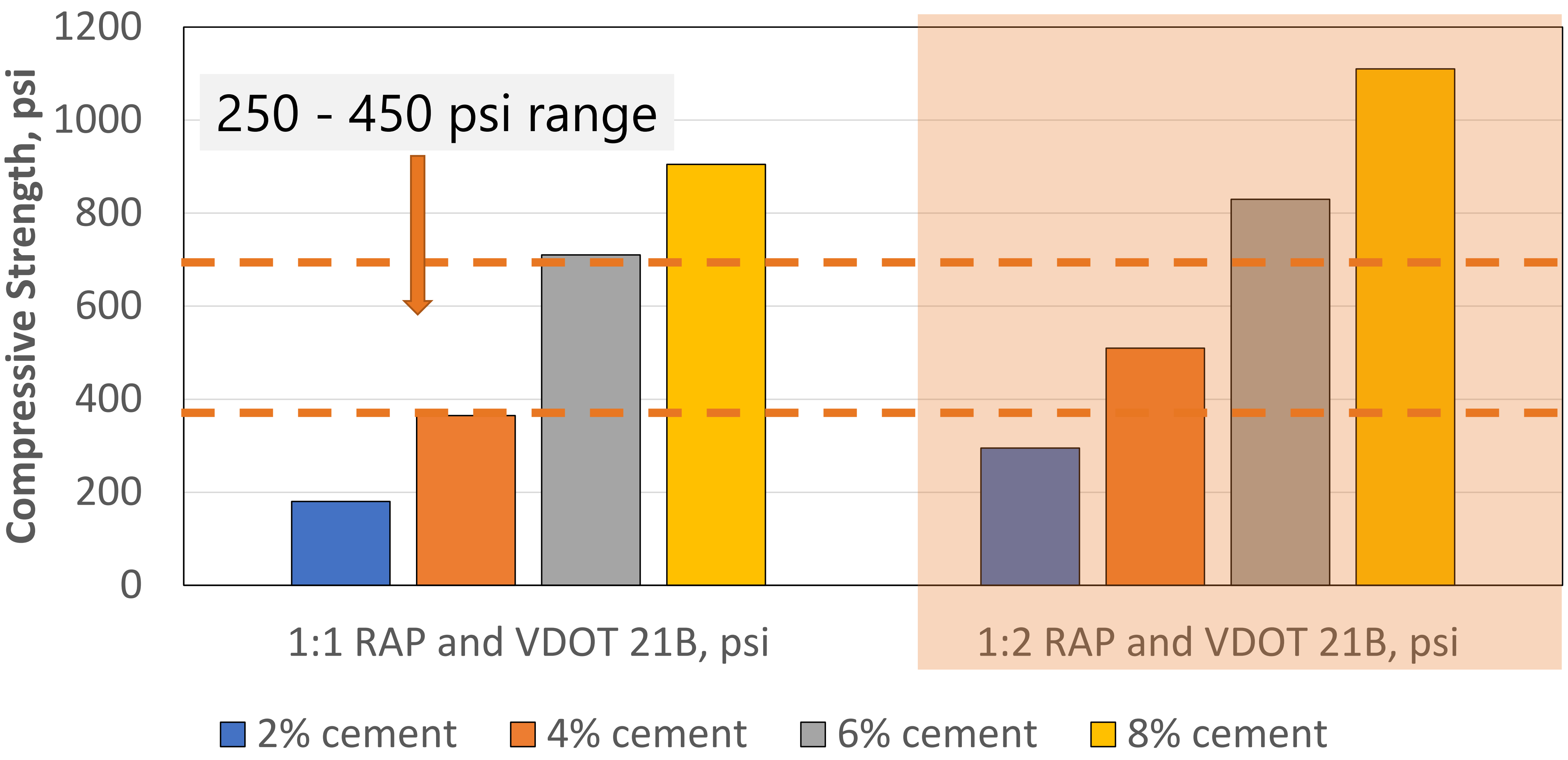


- 12-inch-deep trenches

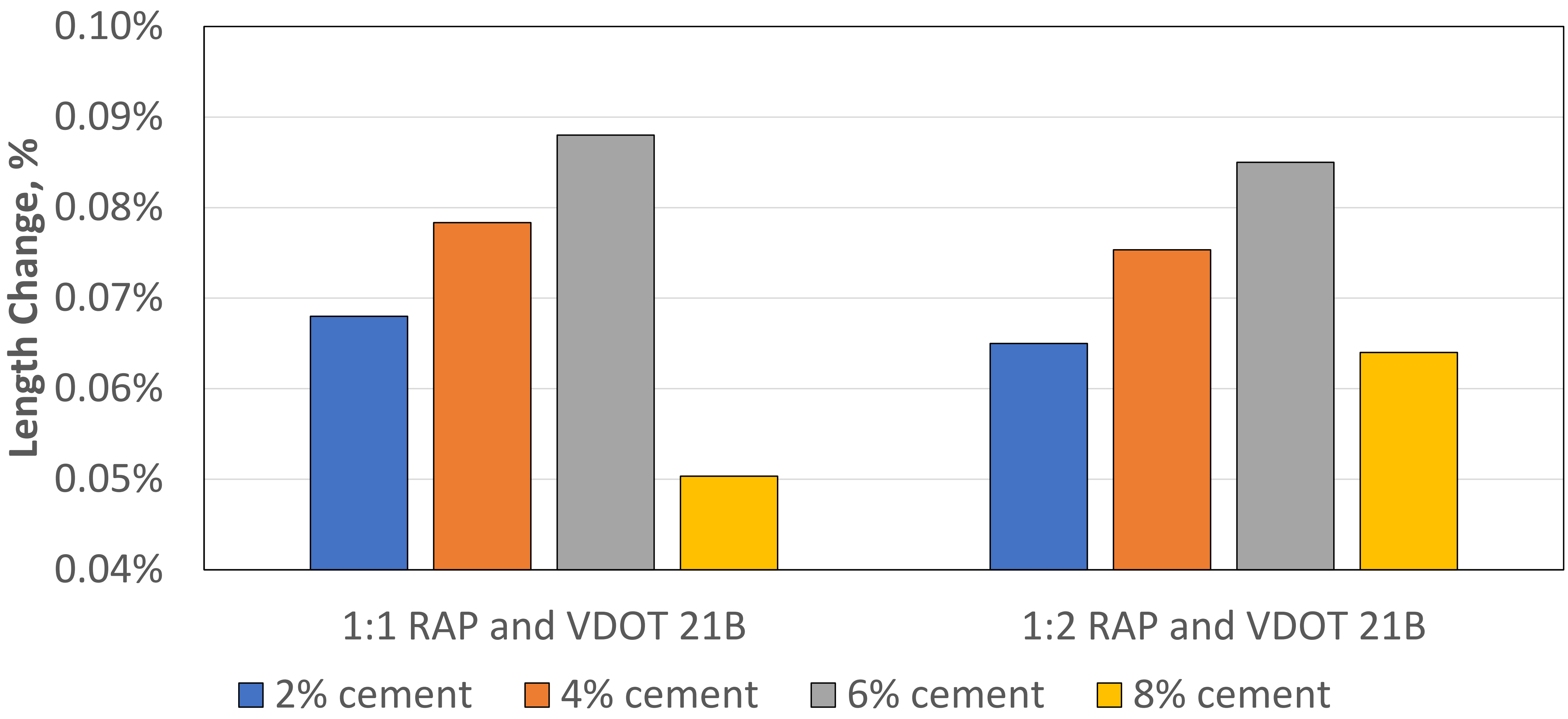
Forensic Study – Trenching & Coring



Results – Mix Design

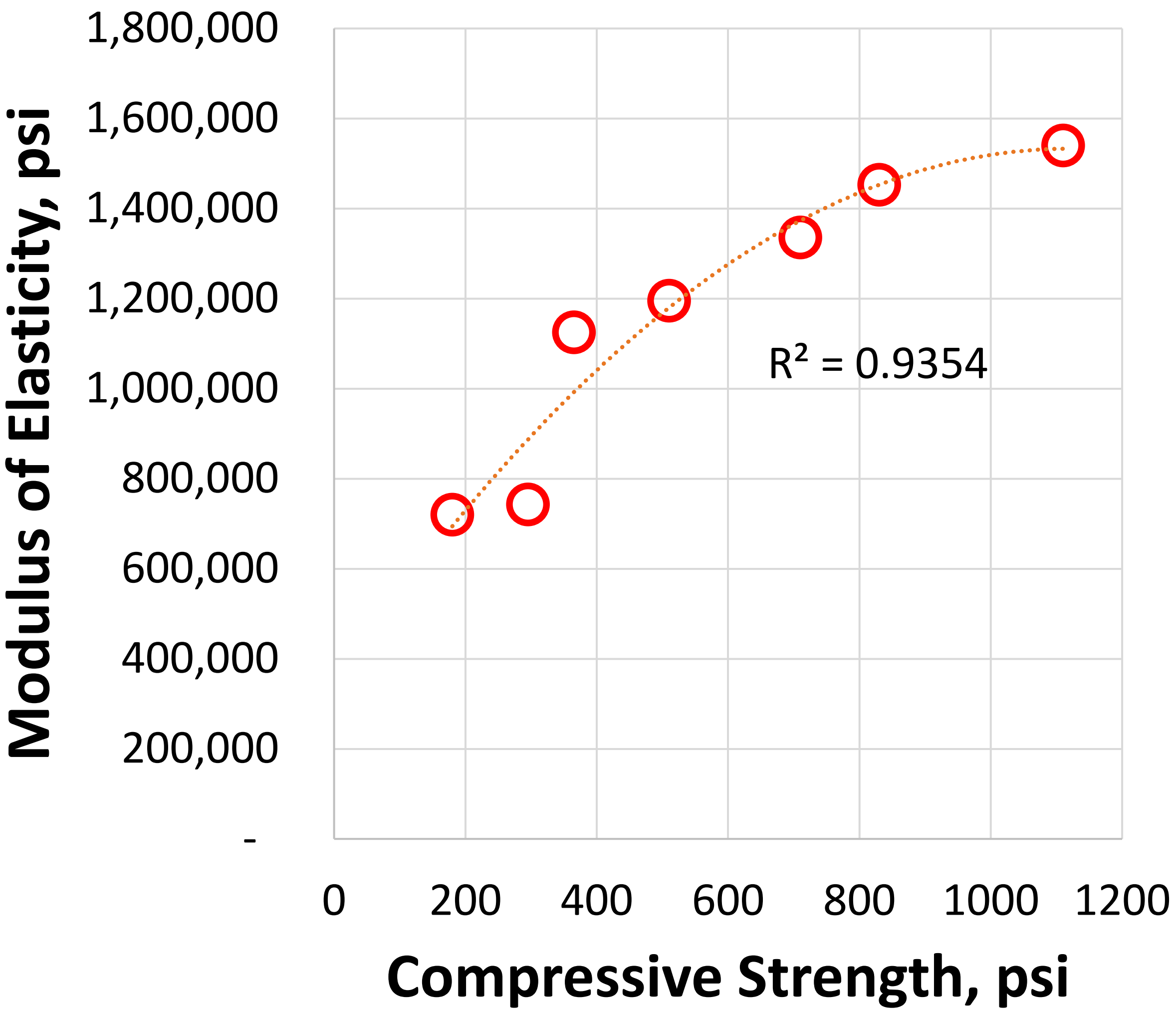


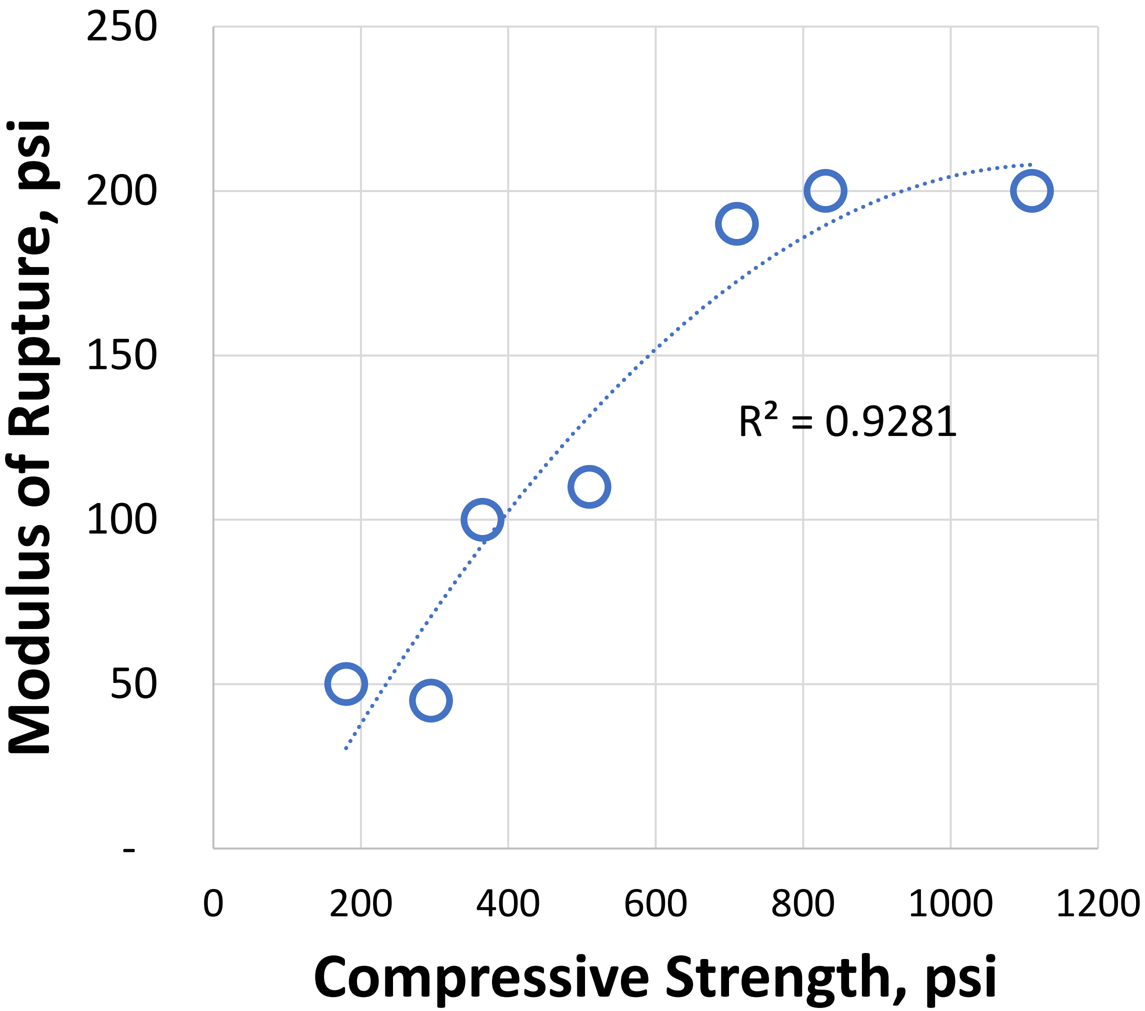
Results – Mix Design (Shrinkage?)



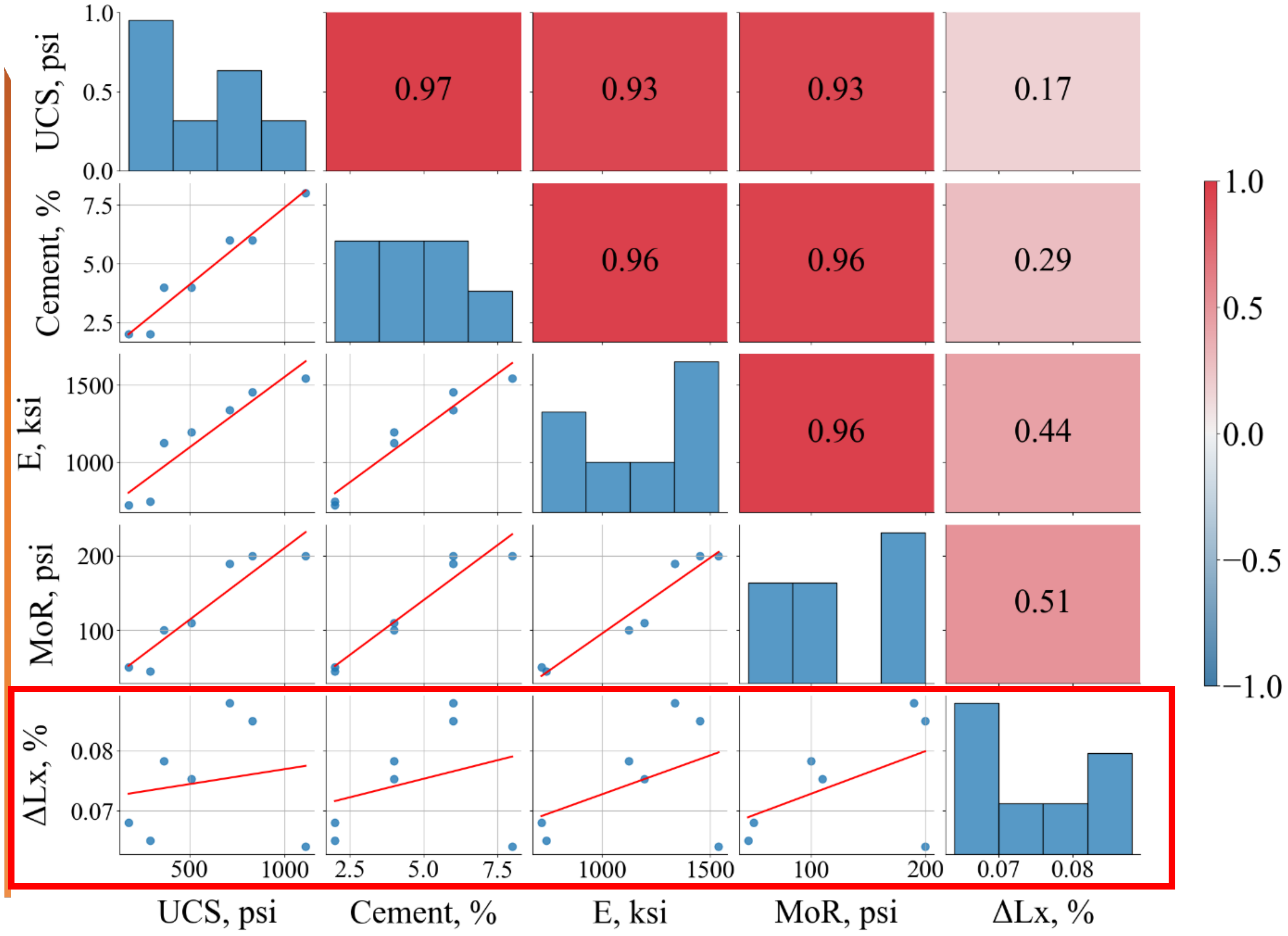
Results – Mix Design

Compressive Strength vs Modulus of Elasticity | Rupture



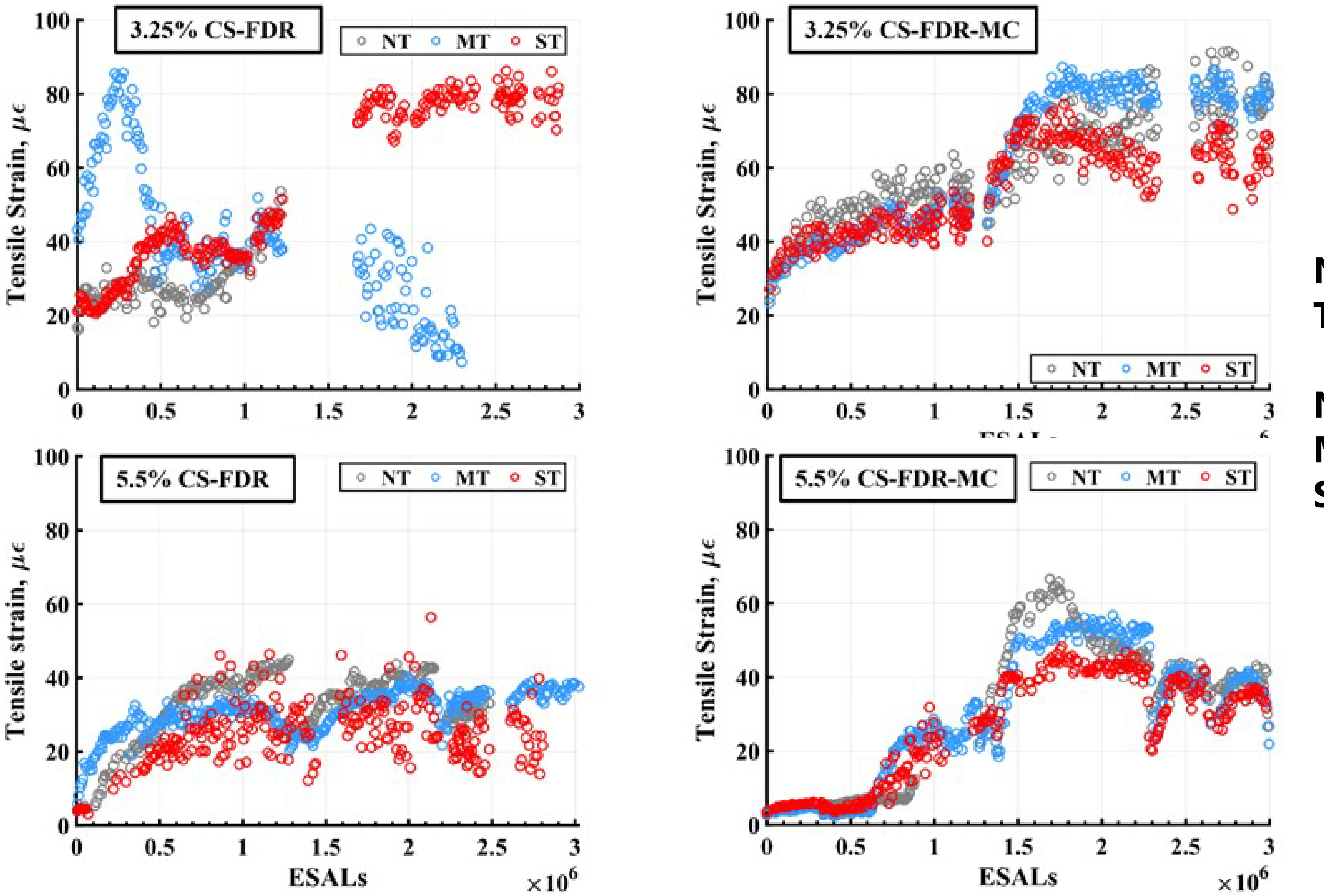


Results – Correlations b/n Strength Tests



- Good correlation b/n UCS and E, MoR
- Not good b/n length change and other tests

Results – Tensile Strains (AC Layer)



Note:
T = Top-FDR

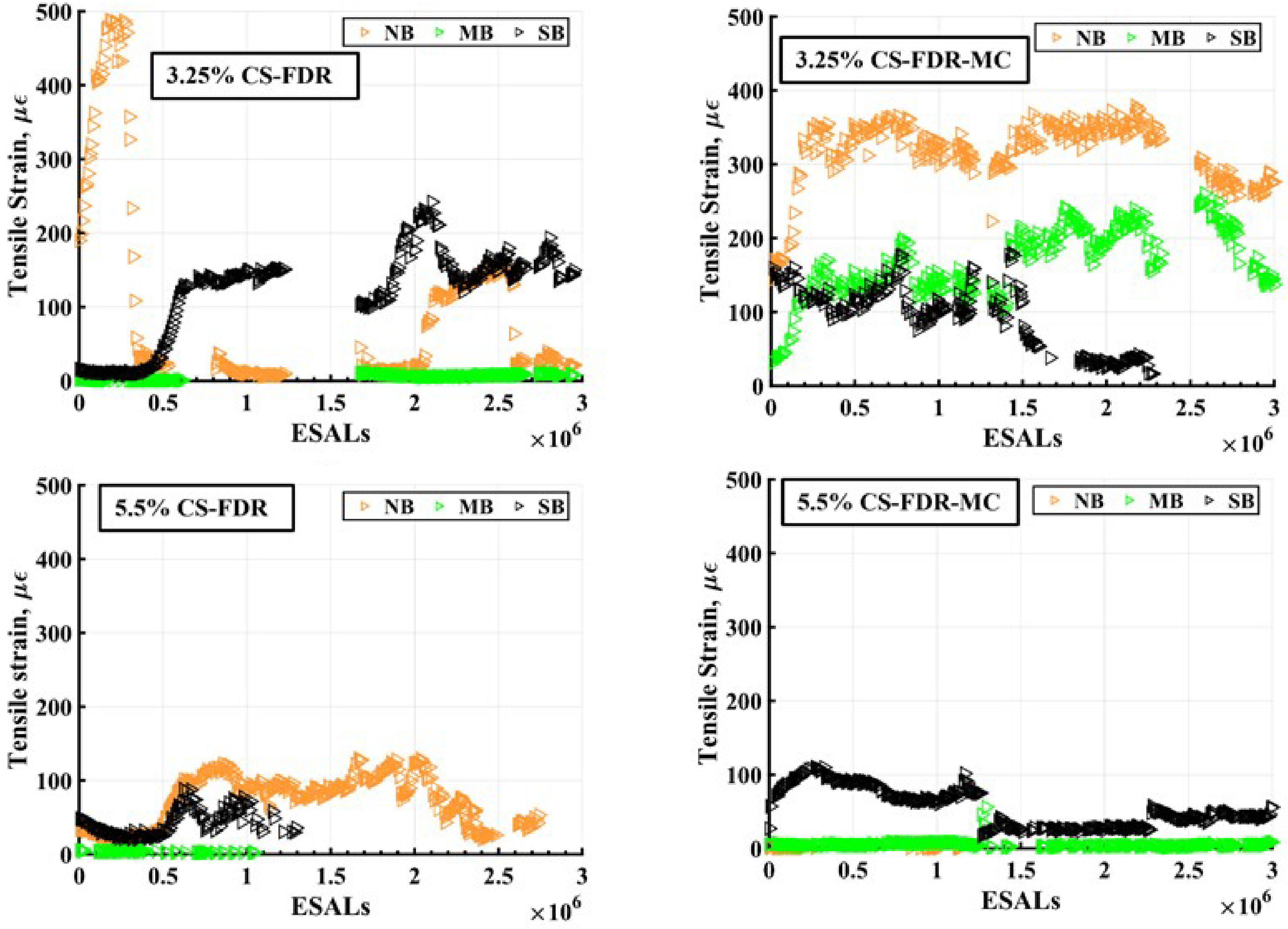
N = North Gauge
M = Middle Gauge
S = South Gauge

Results – Tensile Strains (AC Layer)

Test Section	$\varepsilon_{AC\ initial}$	$\varepsilon_{AC\ peak}$	$\Delta\varepsilon_{AC}$ %
3.25% CS-FDR	21.1	86.2	307.7
3.25% CS-FDR-MC	**26.3**	**77.9**	**196.0**
5.5% CS-FDR	4.5	51.8	1060.3
5.5% CS-FDR-MC	3.1	52.9	1587.4

- mean tensile strains higher for lower cement contents
- % change in strains lower in lower cement contents

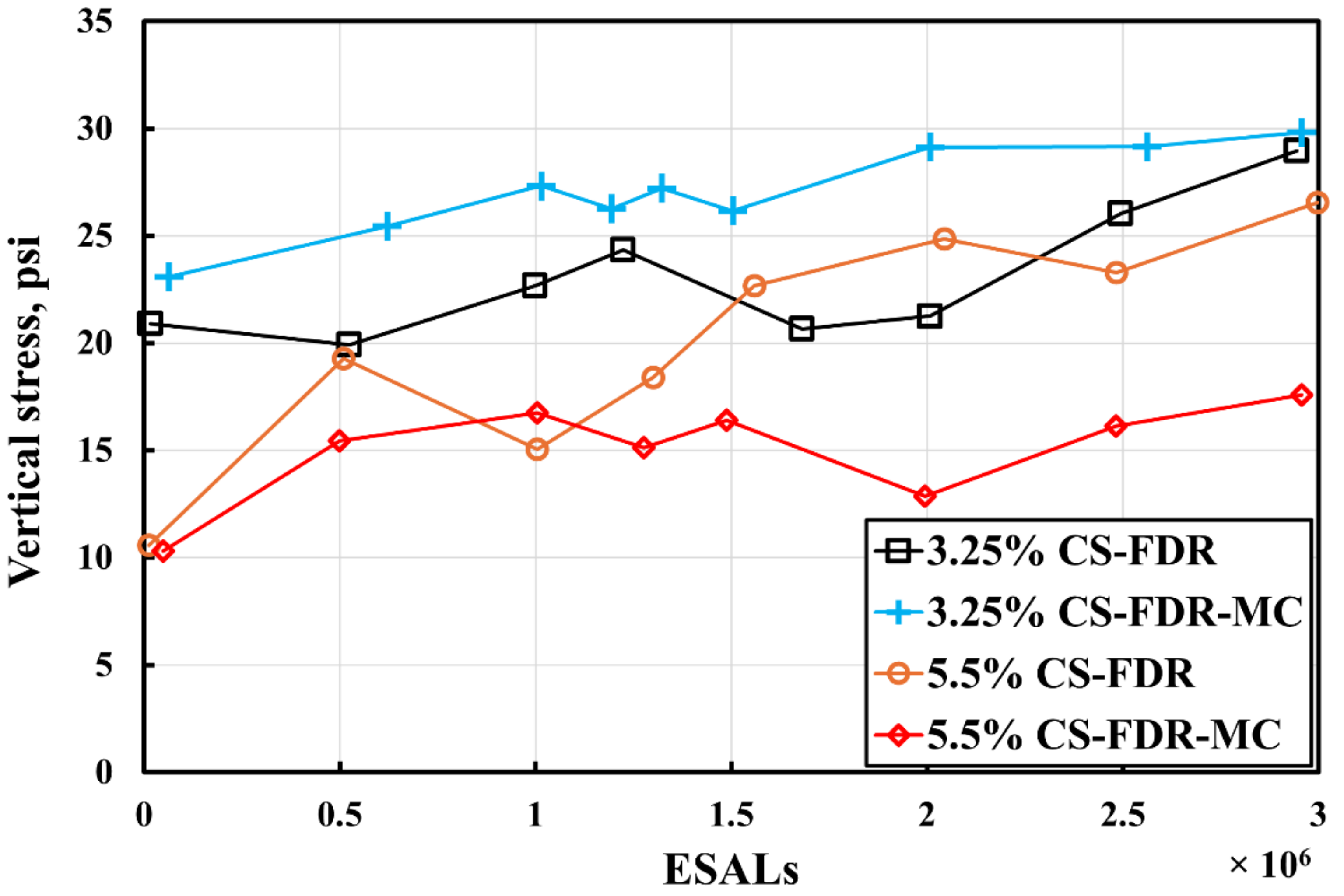
Results – Tensile Strains (FDR Layer)



Note:
B = Bottom-FDR

N = North Gauge
M = Middle Gauge
S = South Gauge

Results – Vertical Stress (Below FDR Layer)

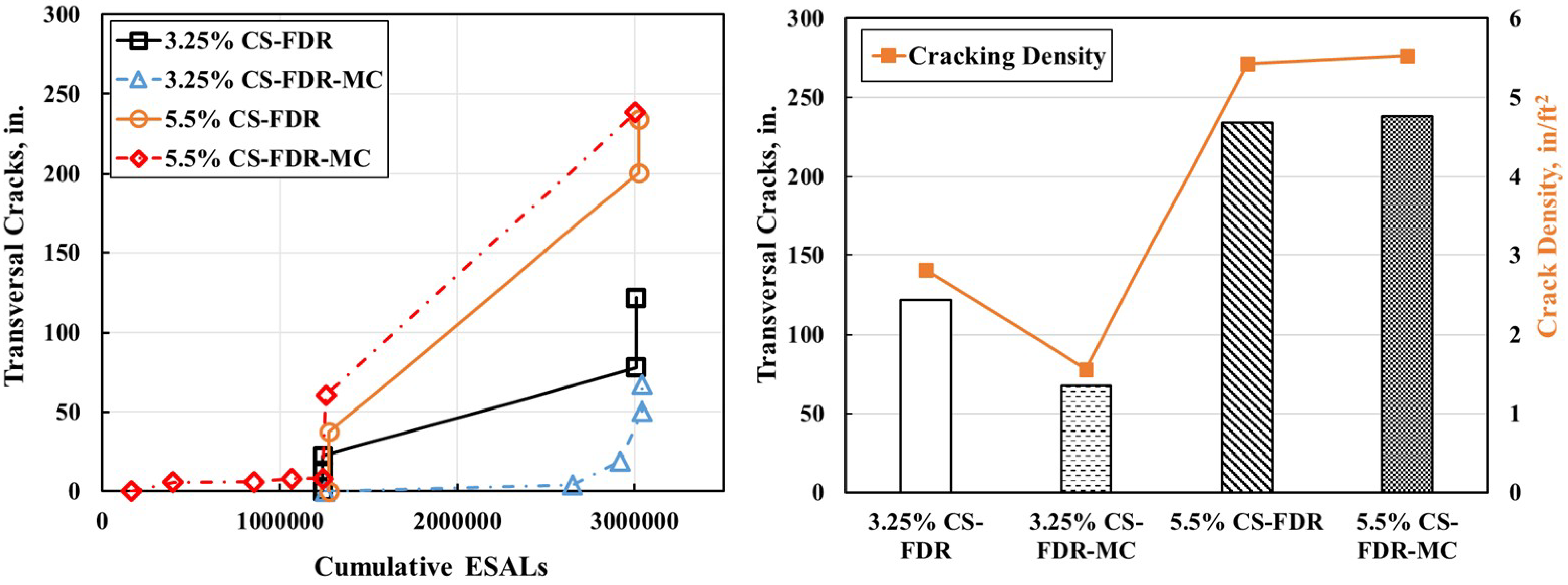


- Higher stresses in lower cement content sections

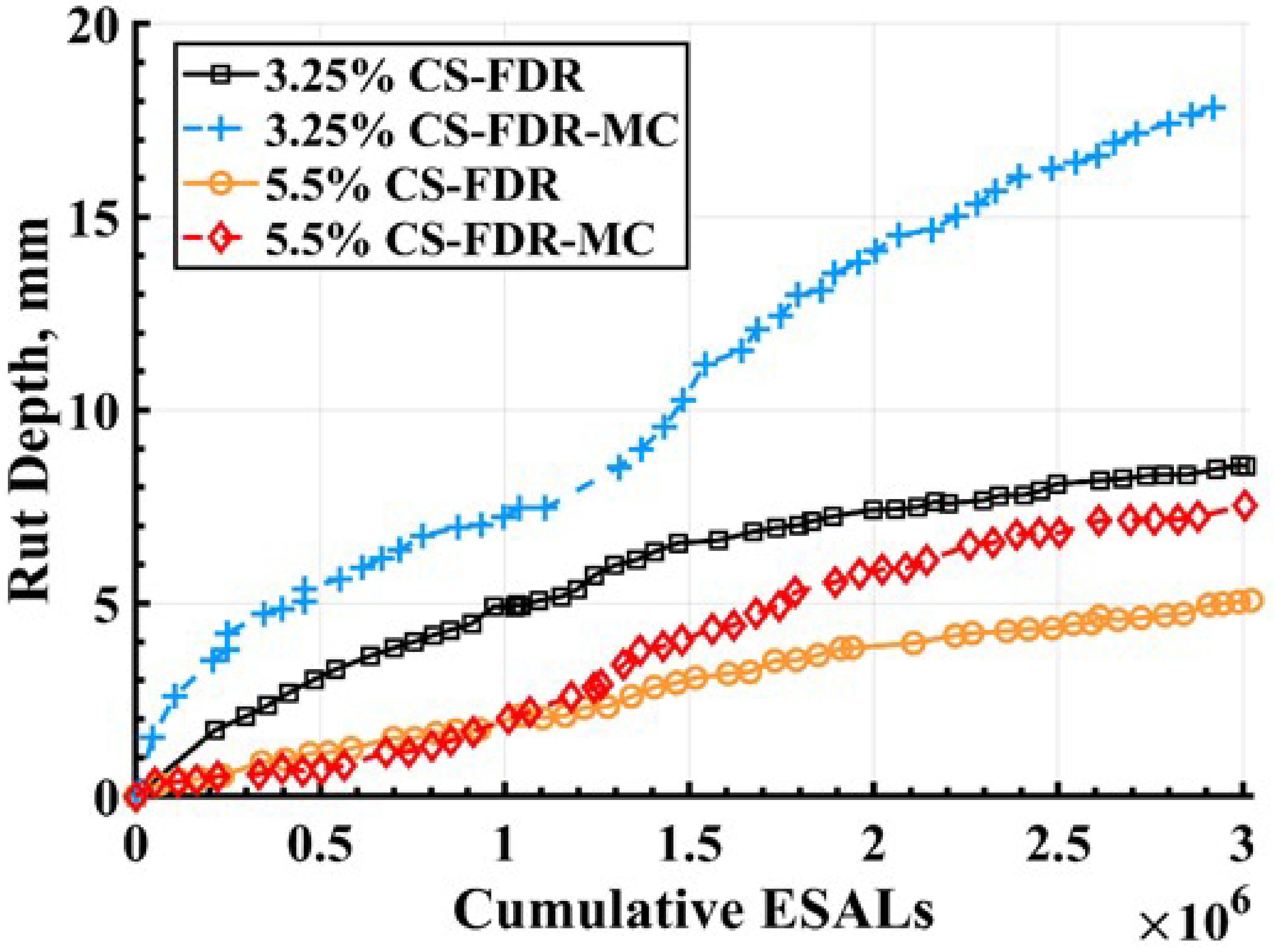
Results – Vertical Stress (Below FDR Layer)

Test Cell	$Stress_{end}$ (psi)	ΔStress (%)	Σ_{avg} (psi)	COV_{avg} (%)
3.25% CS-FDR	29.0	38.5	1.9	8.3
3.25% CS-FDR-MC	29.8	**29.2**	8.1	29.5
5.5% CS-FDR	26.6	151.2	3.7	22.3
5.5% CS-FDR-MC	17.6	**70.7**	5.3	34.5

HVS Testing – Surface Cracking Trends



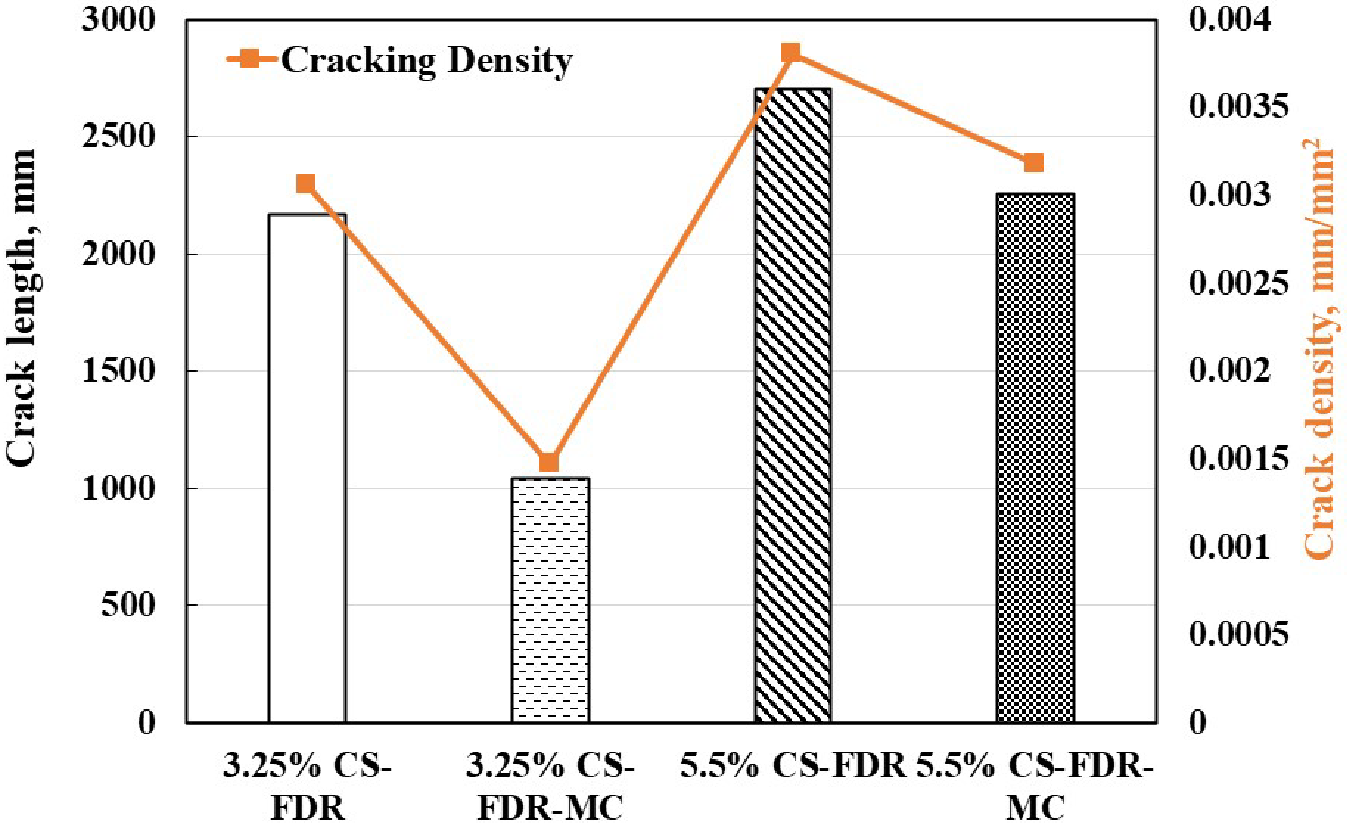
HVS Testing – Rutting Trends

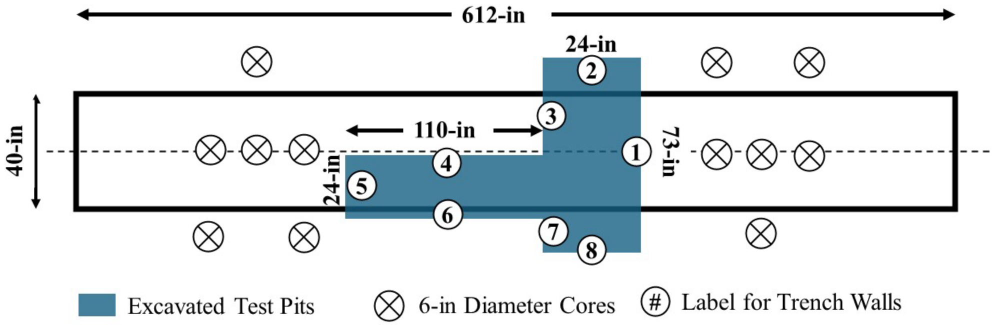


Test Cell	Median Rut depth, mm
3.25% CS-FDR	8.6
3.25% CS-FDR-MC	**17.8**
5.5% CS-FDR	5.1
5.5% CS-FDR-MC	7.5

- Increased rut depths in
  - lower cement contents
  - microcracked sections

Forensic Results – Crack Evaluation

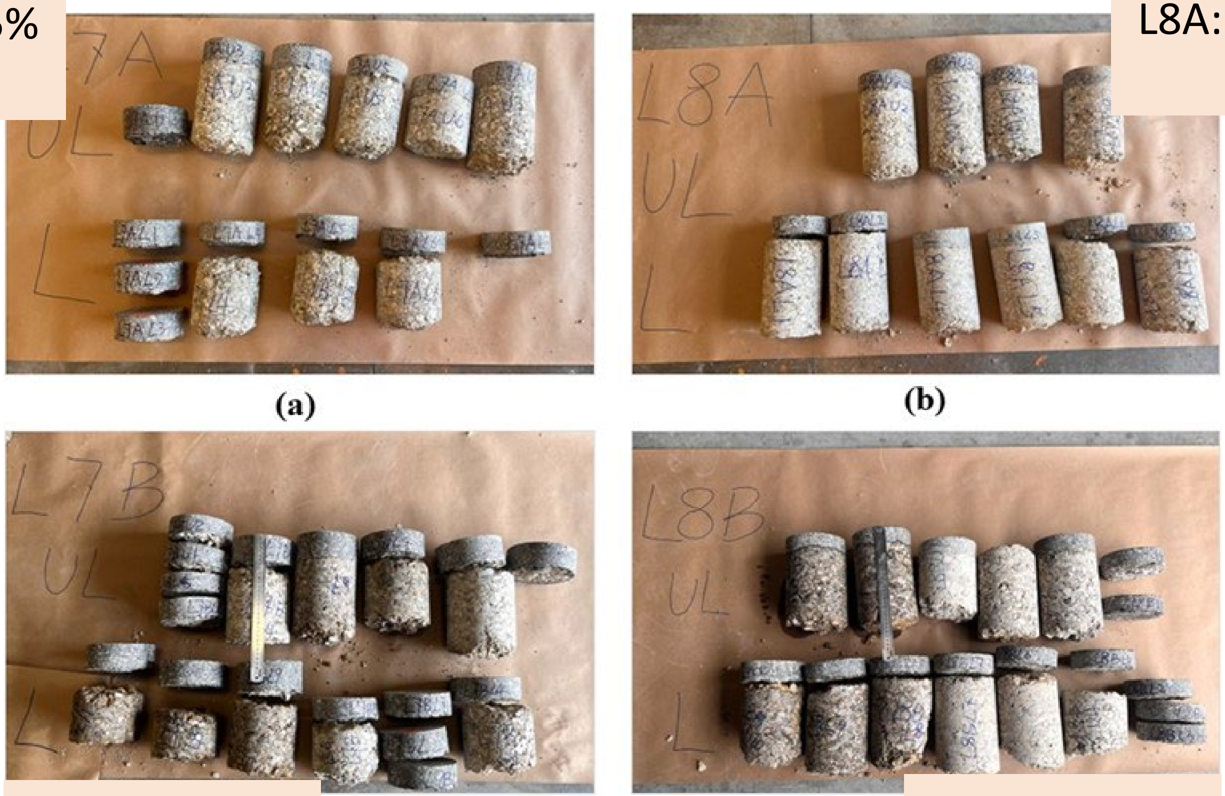




Forensic Results – Evaluation of Cores

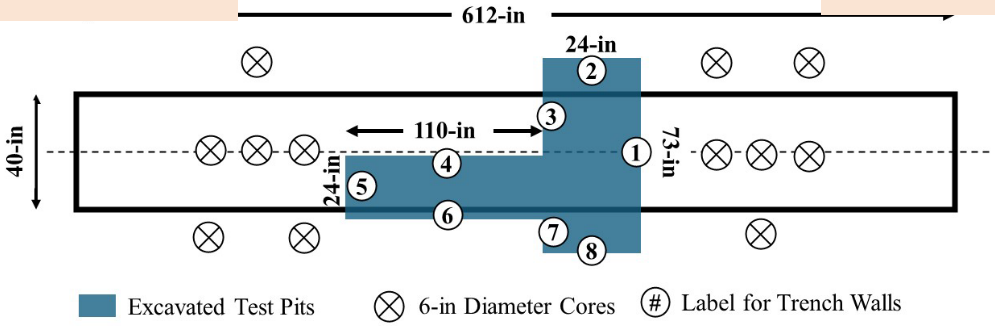
L7A: 3.25% CS-FDR

L8A: 5.5% CS-FDR



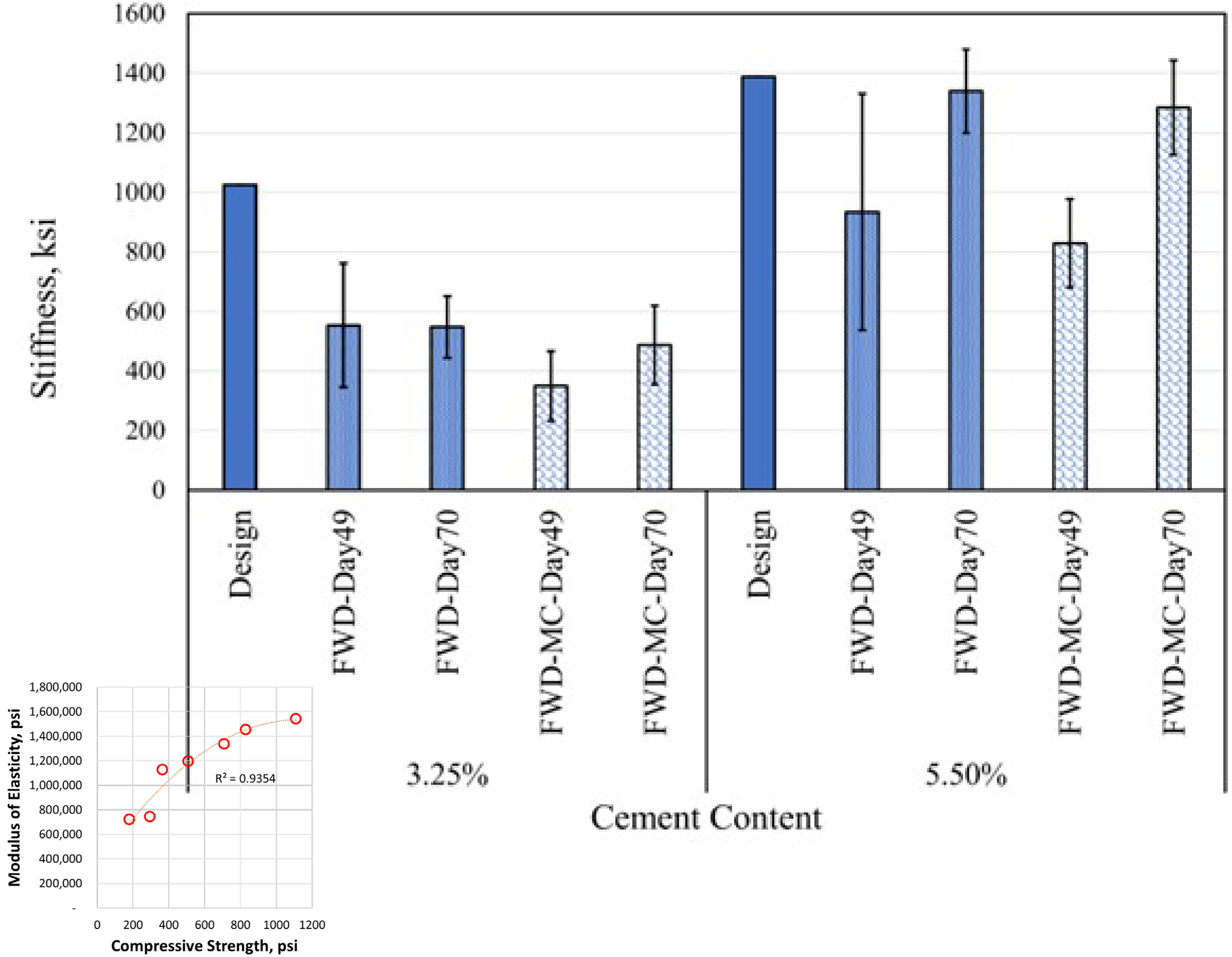
L7B: 3.25% CS-DFR-MC

L8B: 5.5% CS-FDR-MC



- Lower AC layer thickness in unloaded areas
- Similar FDR layer thickness except **thinner for 3.25% CS-FDR-MC-L section**

Design vs Field FDR Stiffness



- Reduced stiffness observed in MC sections at both cement contents at day 49
- MC vs non-MC stiffness at day 70 were similar

Conclusions

- **UCS test** results correlated well with **elasticity test and flexural strength** test for FDR materials.
- **Microcracked** cells showed **reduced peak tensile strain and tensile strain changes** (**at low cement**) and **reduced vertical stress changes** across **both cement levels**
- **Microcracked** cells showed **fewer surface and FDR-layer cracks** but **greater rutting at low cement contents**
- The **reduction of stiffness** at early ages from microcracking is mostly or **fully recovered** at later ages

Future Work

- Further Laboratory Evaluations
  - alternatives to evaluate stiffness of FDR materials
  - evaluating optimal water content and length change at different cement contents
- Exploring other methods to evaluate effectiveness of microcracking on FDR materials in lab and field
  - x-ray scanner
- Evaluating the impact of fog-sealing in FDR applications

Title
Thank You!
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