Effects of Binder, Curing Time, Temperature and Trafficking on Moduli of Stabilized and Un-stabilized Full Depth Reclamation Materials

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Outline

- **Background**
- **Research Objective**
- **General Approach**
- **Data Collection**
- **Results and Discussion**
- **Summary and Conclusions**

Background

- **FDR = Full Depth Reclamation/Recycling**
- **Caltrans' use of FDR**
  - Started since 2001
  - Mostly using combination of foam asphalt (FDR-FA) and cement (FDR-PC) as stabilizing agent
  - Sometime no stabilization (FDR-NS)
  - Growing interest for using engineering emulsion (FDR-EE)

Research Objective

- **Revised guidelines and specification language for FDR in California**
- **Mechanistic-Empirical (M-E) design and performance parameters for FDR layers**
  - In-situ Stiffness
  - Fatigue damage
  - Rutting (permanent deformation under traffic)

What did others find about FDR stiffness?

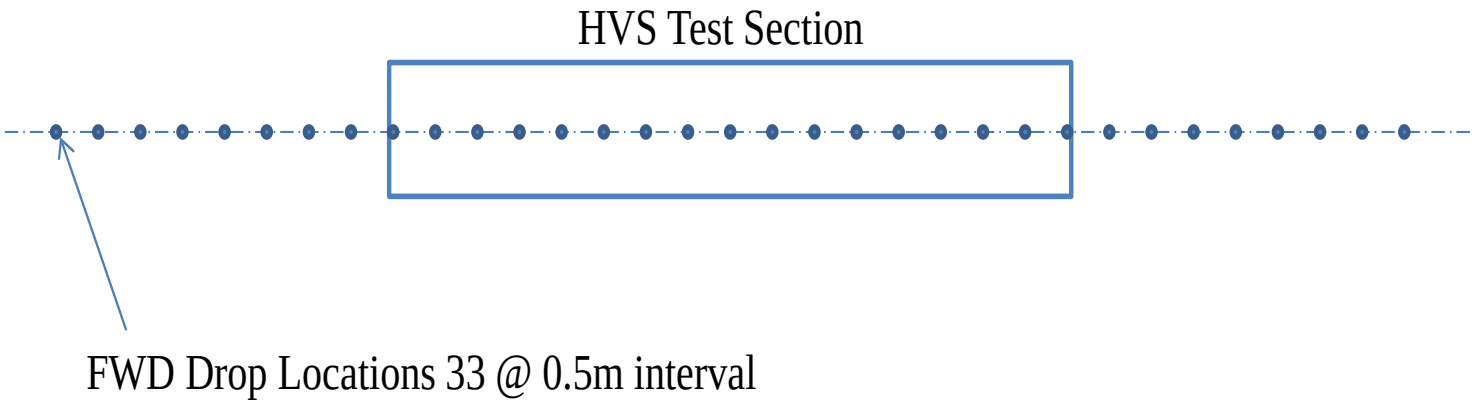
- **Quick and Guthrie (2011)**
  - FDR with emulsion
  - Consistently low in the first 2 weeks
  - Increase dramatically by 4 months
  - Decrease considerably by 1 year
- **Mohammad et al. (2003)**
  - FDR-FA layer
  - More than doubled in the first month
- **Syed and Scullion (2001)**
  - FDR-PC (i.e., cement)
  - Higher cement% leads higher stiffness

General Approach (1/3)

- **Work around the accelerated pavement testing (APT) study**
  - Test cells constructed for the APT
  - Trafficking using heavy vehicle simulator (HVS)
- **FWD at different occasions**
  - Right after construction
  - Right before HVS trafficking
  - Right after HVS trafficking

General Approach (2/3)

- **FWD Testing Protocol**
  - Twice for each occasion: early morning and mid afternoon
  - For testing around HVS:
    - 4-m (before) + 8-m (within) + 4-m (after)
    - 0.5 m interval



General Approach (3/3)

- **Back-calculation**
  - Kalman-Filter based search algorithm
  - Multilayer linear elastic system

Data Collection – The Test Cells

4 lanes at 3.7m wide each,
each cell is 37 m long

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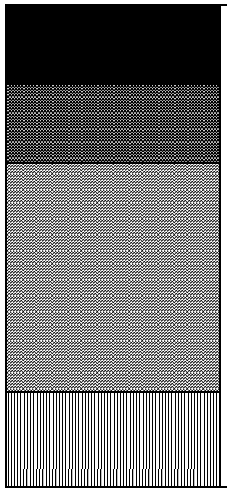
Pavement Structure

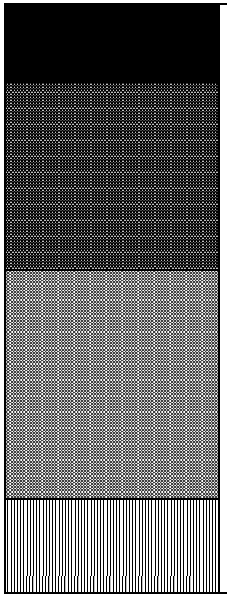


Layer: RHMA-G/RWMA-G
Thickness: 60 mm (0.2 ft.)

Layer: HMA
Thickness: 60 mm (0.2 ft.)

Layer: Imported Class 2 Aggregate Base Course
Thickness: 450 mm (1.5 ft.)

Layer: Prepared Subgrade
Thickness: Semi-infinite



Layer: HMA
Thickness: 60 mm (0.2 ft.) or 120 mm (0.4 ft.) HMA

Layer: Recycled
Thickness: 250 mm (0.83 ft.)

Layer: Imported Class 2 Aggregate Base Course
Thickness: 320 mm (0.9 ft.)

Layer: Prepared Subgrade
Thickness: Semi-infinite

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Data Collection - FWD Testing Schedule

FDR Material	Occasion	Days After Construction
FDR-NS (under 60mm HMA)	After construction	19
	Before Trafficking	57
	After Trafficking	161
FDR-FA	After construction	19
	Before Trafficking	126
	After Trafficking	240
FDR-PC	After construction	19
	Before Trafficking	239
	After Trafficking	540
FDR-NS (under 120mm HMA)	After construction	19
	Before Trafficking	195
	After Trafficking	314

Reaults and Discussion

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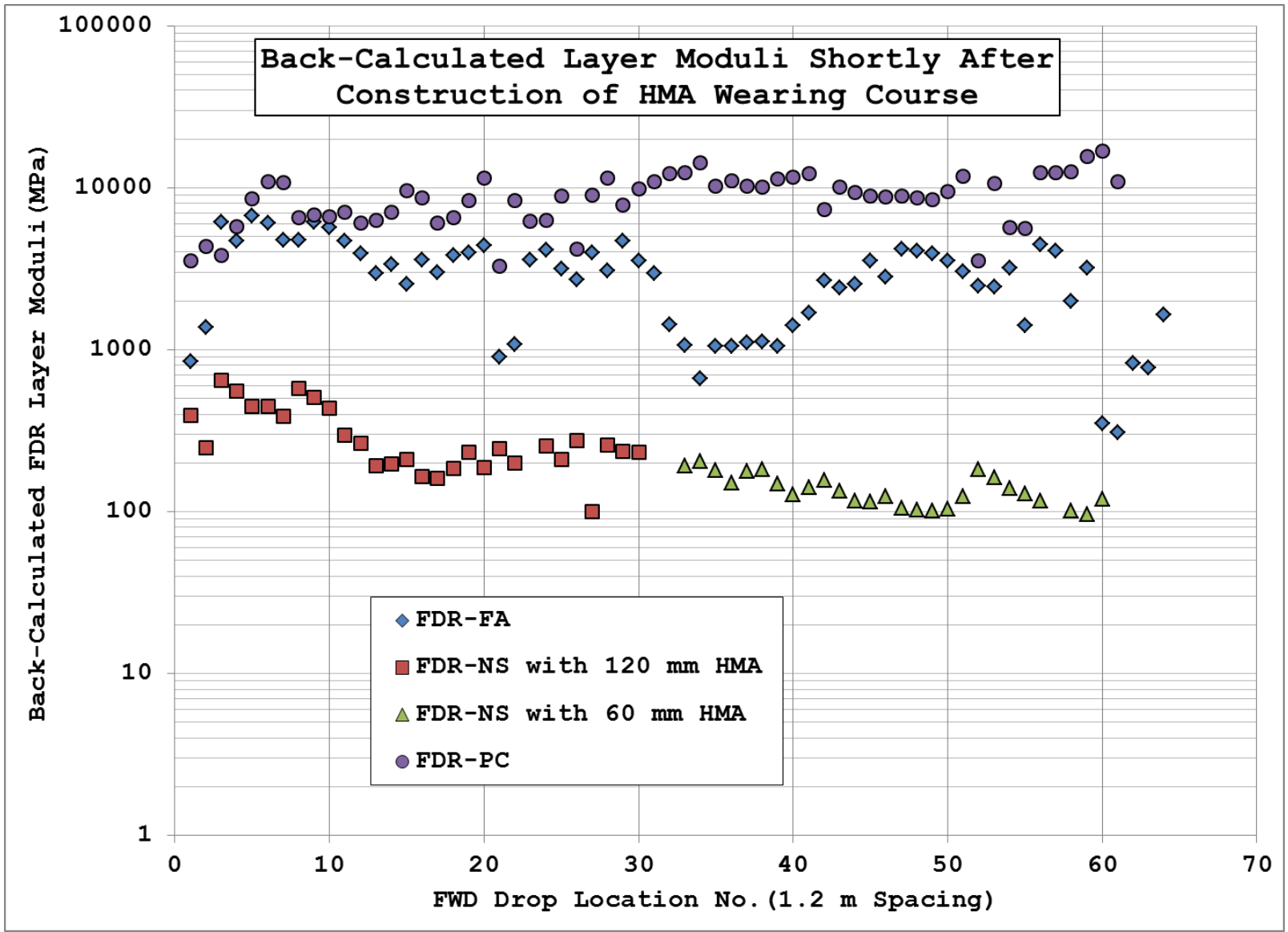
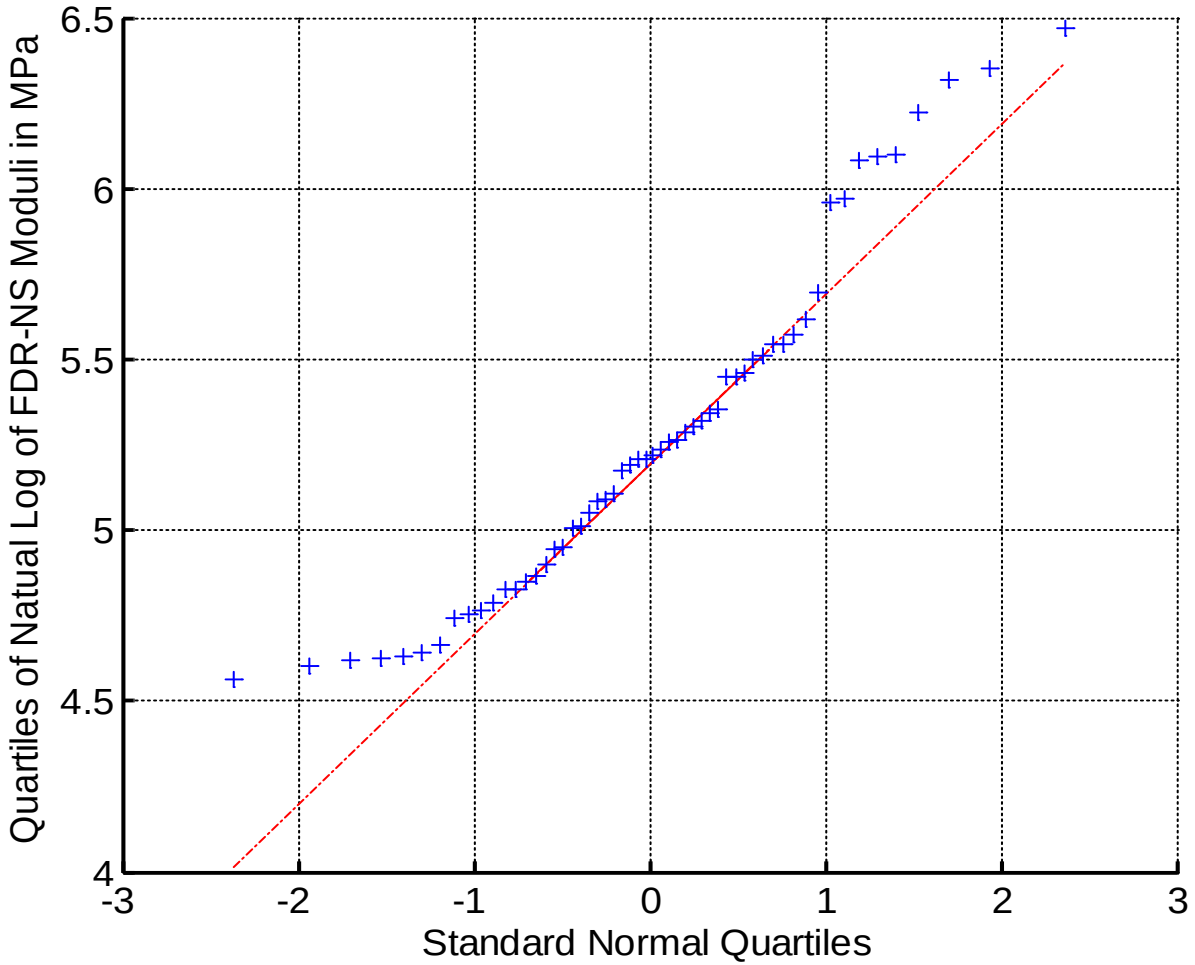
Initial Stiffness @19 days



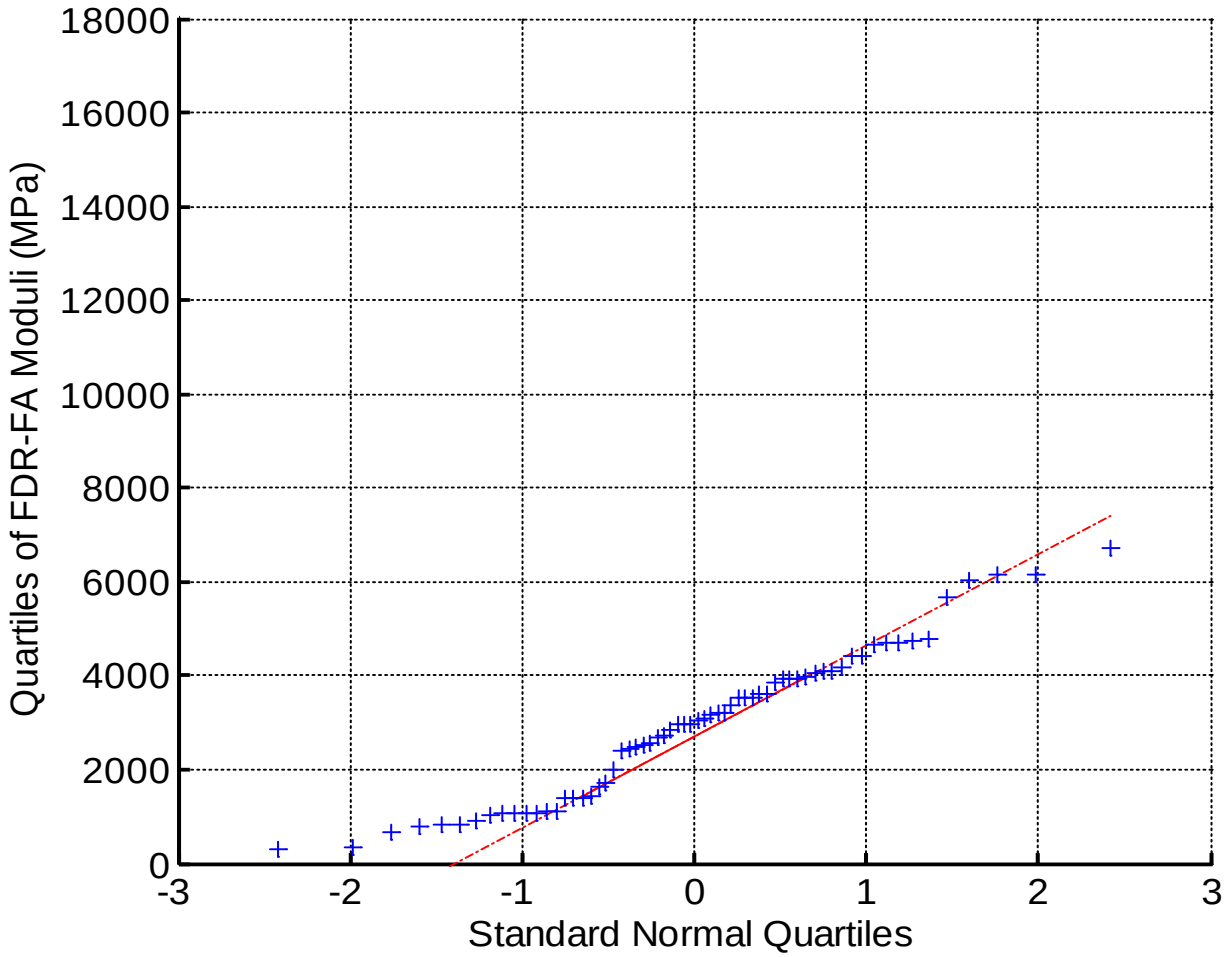
Initial Stiffness @ 19 days

- **FDR-NS QQ-Plot for Normal Distribution of Natural Log**



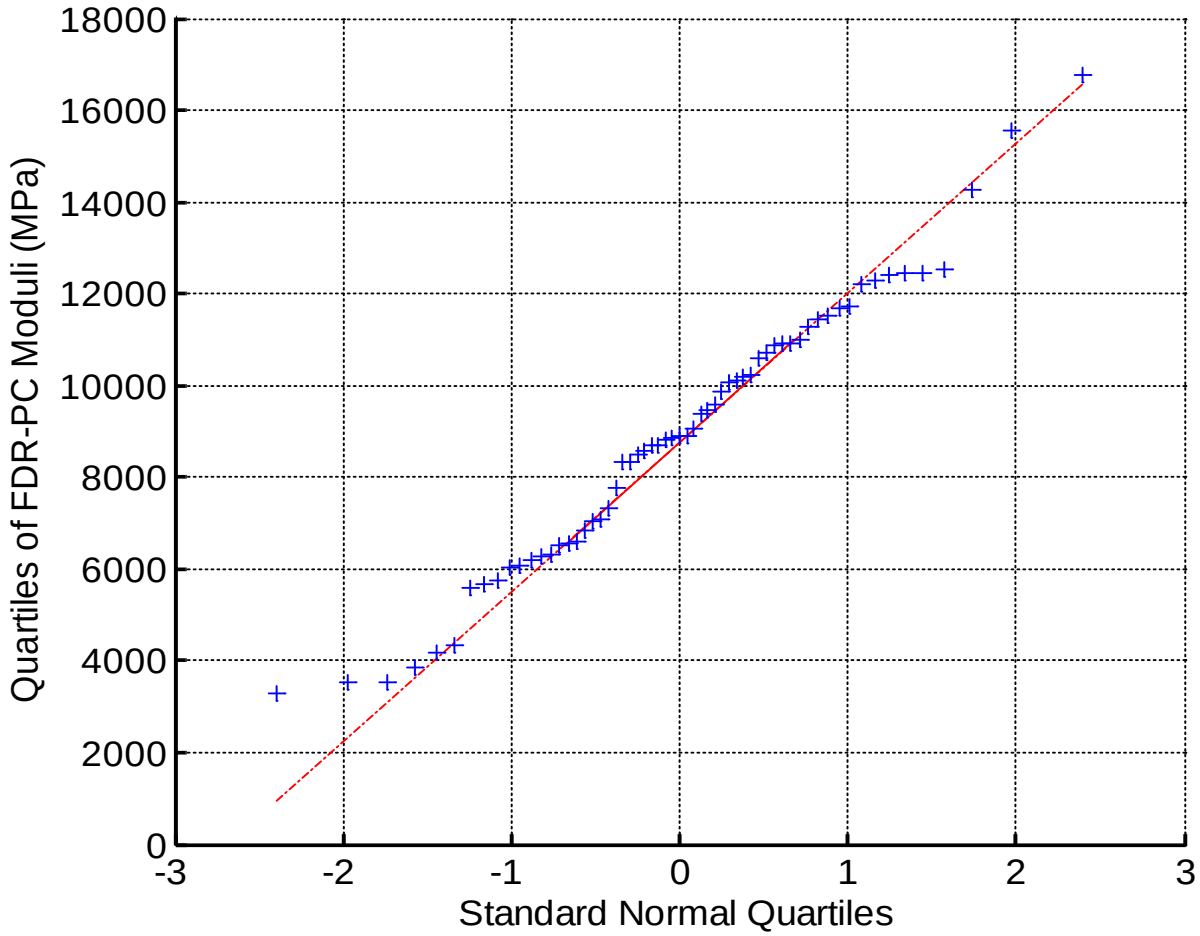
Initial Stiffness @ 19 days

- **FDR-FA QQ-Plot for Normal Distribution**



Initial Stiffness @ 19 days

- **FDR-PC QQ-Plot for Normal Distribution**



Initial Stiffness @ 19 days

Material Type	Approximate Distribution	Average Pavement Temperature	Mean (MPa)	Standard Deviation (MPa)	Coefficient of Variance
FDR-NS	Log-normal	15°C	220	117	0.53
FDR-FA	Normal	20°C	2,959	1,595	0.54
FDR-PC	Normal	19°C	8,925	2,978	0.33

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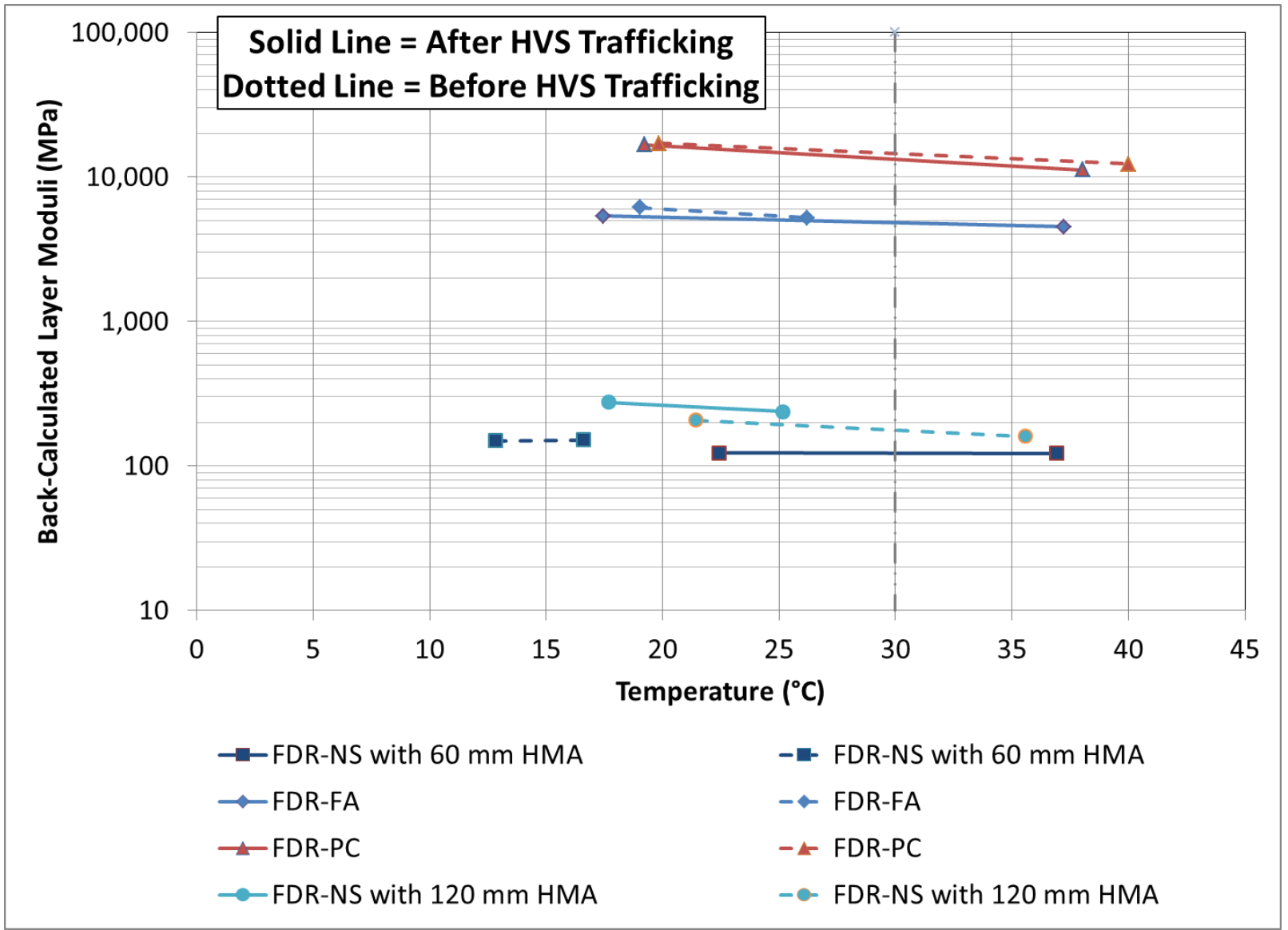
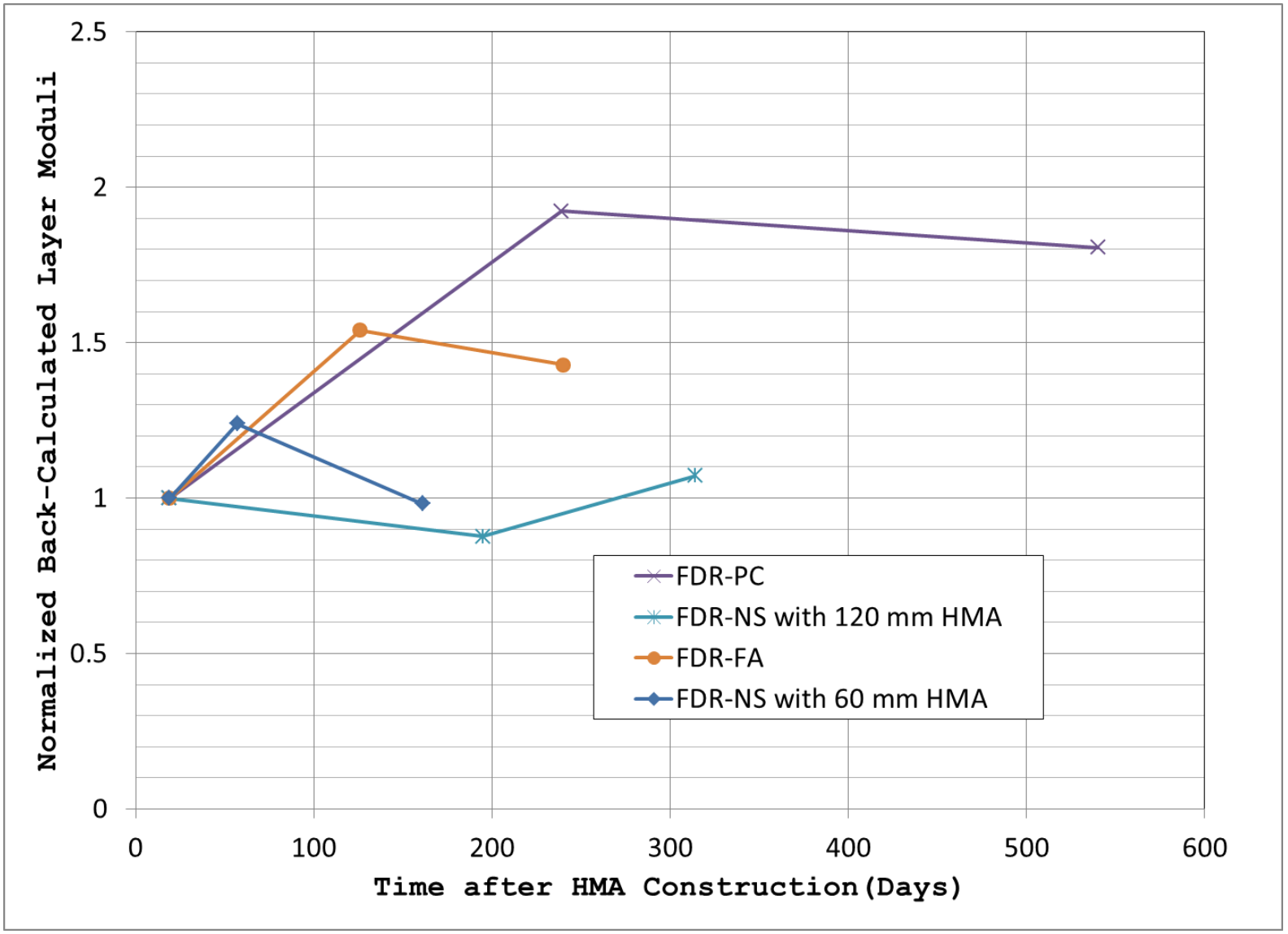
Effect of Pavement Temperature



Effect of Curing Time



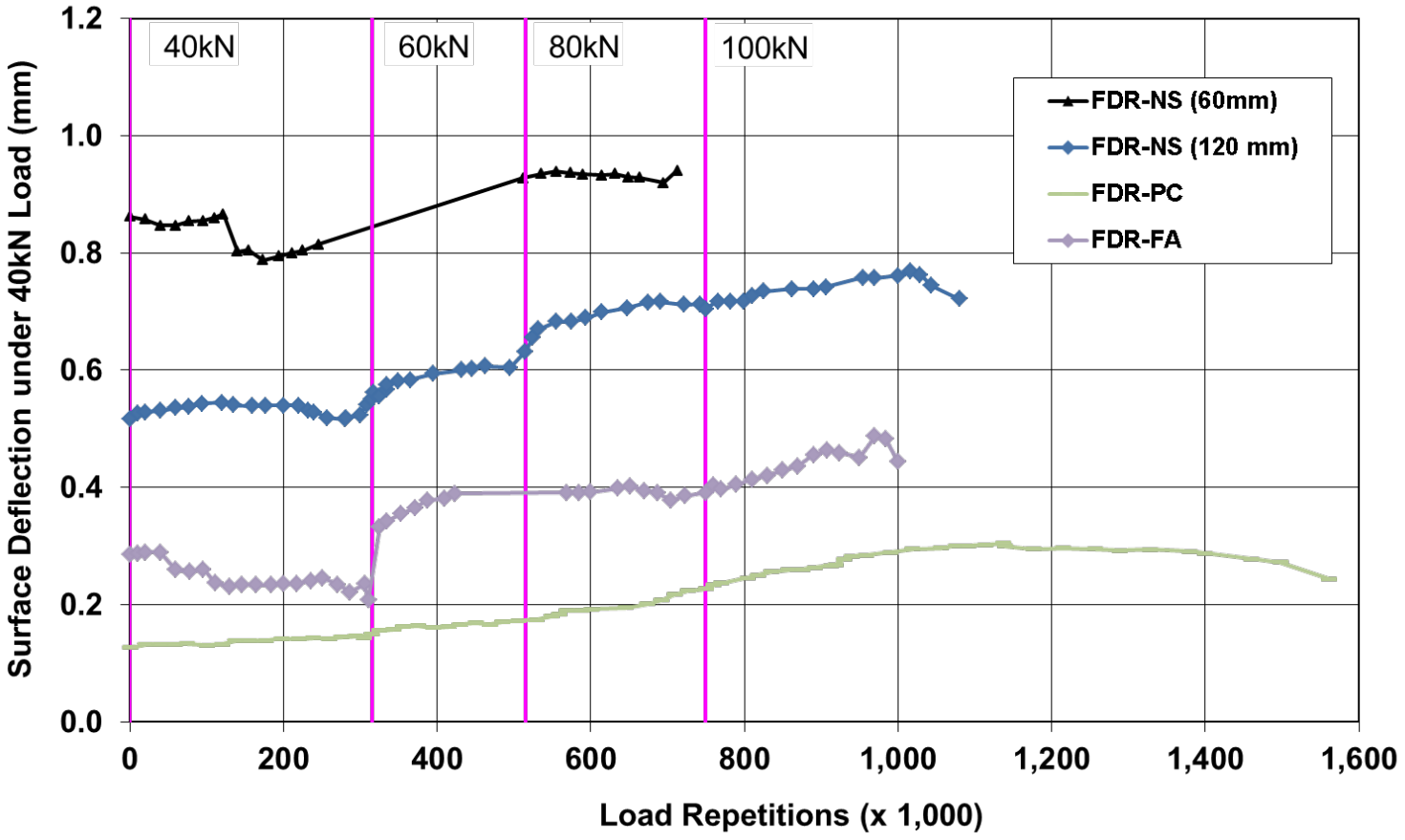
Effect of Trafficking + Curing

Matreial	When	Average (MPa)	C.O.V.	ESALs Applied (Mn)	Residual Stiffnes Ratio
FDR-NS with 60 mm HMA	Before	156	0.16	0	1.00
	After	137	0.19	5.1	0.88
FDR-NS with 120 mm HMA	Before	186	0.17	0	1.00
	After	103	0.50	20.8	0.55
FDR-FA	Before	5,100	0.23	0	1.00
	After	1,490	0.19	17.0	0.29
FDR-PC	Before	14,316	0.16	0	1.00
	After	6,064	0.70	43.3	0.42

Effect of Trafficking Alone

Matreial	When	Ratio of (Trafficked) /(Non Trafficked)	Relative Ratio
FDR-NS with 60 mm HMA	Before HVS	1.09	
	After HVS	1.18	1.08
FDR-NS with 120 mm HMA	Before HVS	1.09	
	After HVS	0.47	0.43
	Long After HVS	0.73	0.67
FDR-FA	Before	0.90	
	After	0.32	0.36
FDR-PC	Before	0.90	
	After	0.35	0.39

Effect of Traffic Verification



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Conclusions

- **Initial stiffness @ 19 days**
  - FDR-NS: 200 MPa with c.o.v of 55%
  - FDR-FA: 3000 MPa with c.o.v of 55%
  - FDR-PC: 9000 MPa with c.o.v of 35%
- **All FDR materials show slight sensitivity to temperature for their stiffness**
- **Effects of curing**
  - 50% increase for FDR-FA
  - 80% increase for FDR-PC
  - Roughly unchanged for FDR-NS

Conclusions (continued)

- **Effect of Trafficking**
  - About 60% drop in stiffness
  - Likely caused by damage in the FDR layer
  - FDR-NS shows re-stiffening after trafficking stopped, not sure whether is permanent
- **Implication for design**
  - Need to account for damage in the FDR layer
  - Curing is also critical.

QUESTIONS?

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