Rigid Airfield Pavement Research at Rowan University

Presented by:

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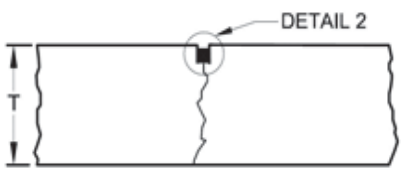
- Rowan University
  - **PI**: Dr. Yusuf Mehta
  - **Co-PI**: Dr. Douglas Cleary
  - **Research assistants:** Felipe Blotta, Charles Calimer, Nicole Giannelli, William McNally, Steve Corcoran
- Federal Aviation Administration
  - Dr. David Brill

OVERVIEW

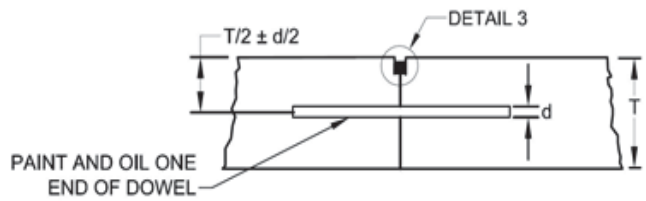
- Part 1: CC6 Field Data Analysis
- Part 2: CC6 Pavement Backcalculation (BAKFAA)
- Part 3: CC6 Curling Analysis (FEAFAA)
- Part 4: CC6 Dynamic Modeling (ABAQUS)

BACKGROUND

- Load Transfer Efficiency
  - Stresses, strains and deflections in loaded slab may be reduced
  - LTE (S) can be determined from embedded strain gages
  - LTE (δ) can be determined from HWD testing



TYPE D DUMMY



TYPE E DOWELED

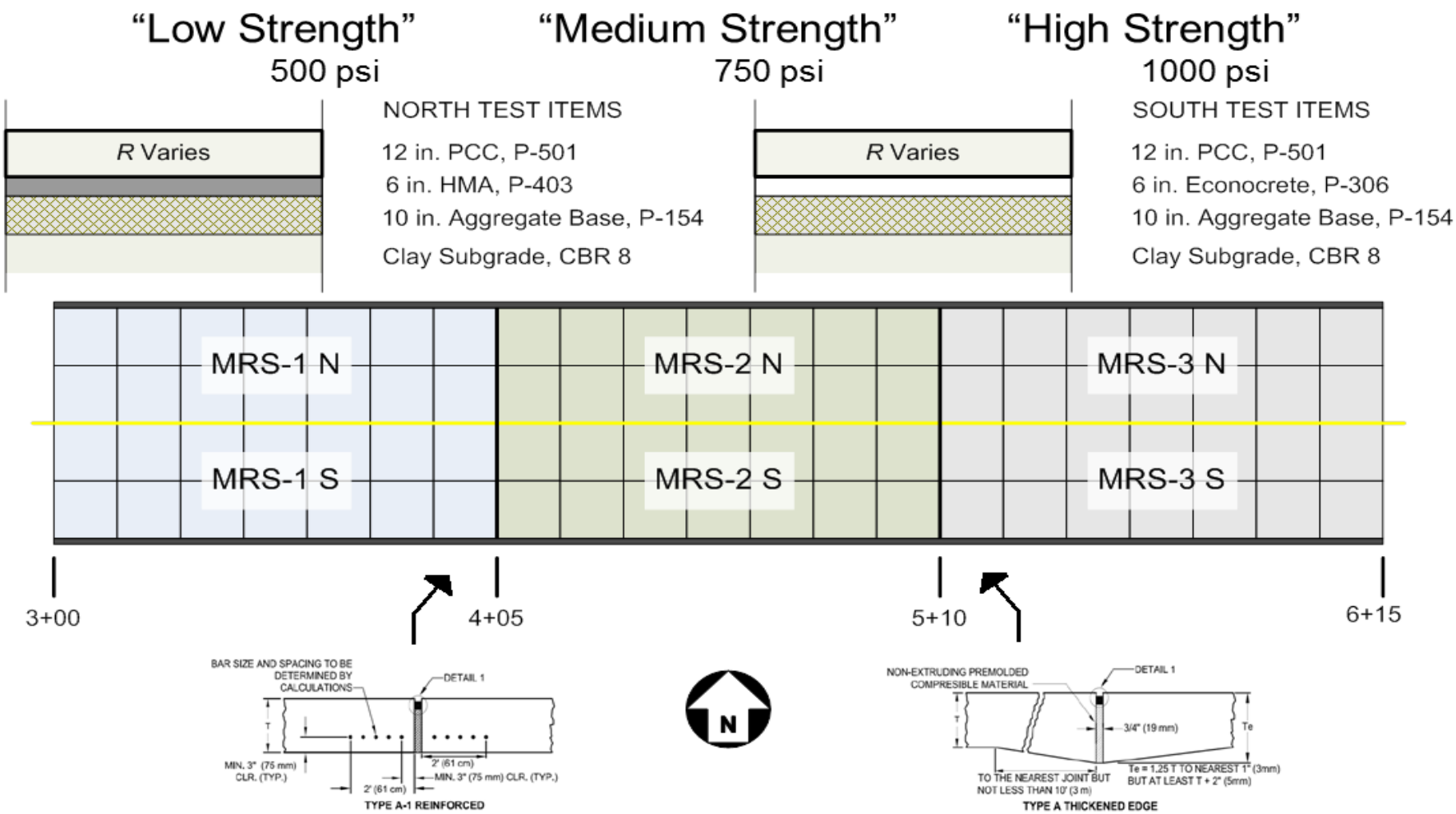
$$LTE(S) = \frac{\sigma_{unloaded}}{(\sigma_{loaded} + \sigma_{unloaded})} = \frac{\varepsilon_{unloaded}}{(\varepsilon_{loaded} + \varepsilon_{unloaded})}$$

$$LTE(\delta) = \frac{\delta_{unloaded}}{\delta_{loaded}}$$

PART 1: CC6 FIELD DATA

- Objectives
  - Validate single gage determination of LTE (S) for dual tandem gear type loading
  - Determine impact of traffic on joint LTE (S)
    - Doweled Joints
    - Isolation Joints (Reinforced & Thickened Edge)
  - Determine joint LTE (δ) from HWD

NAPTF CC6 LAYOUT

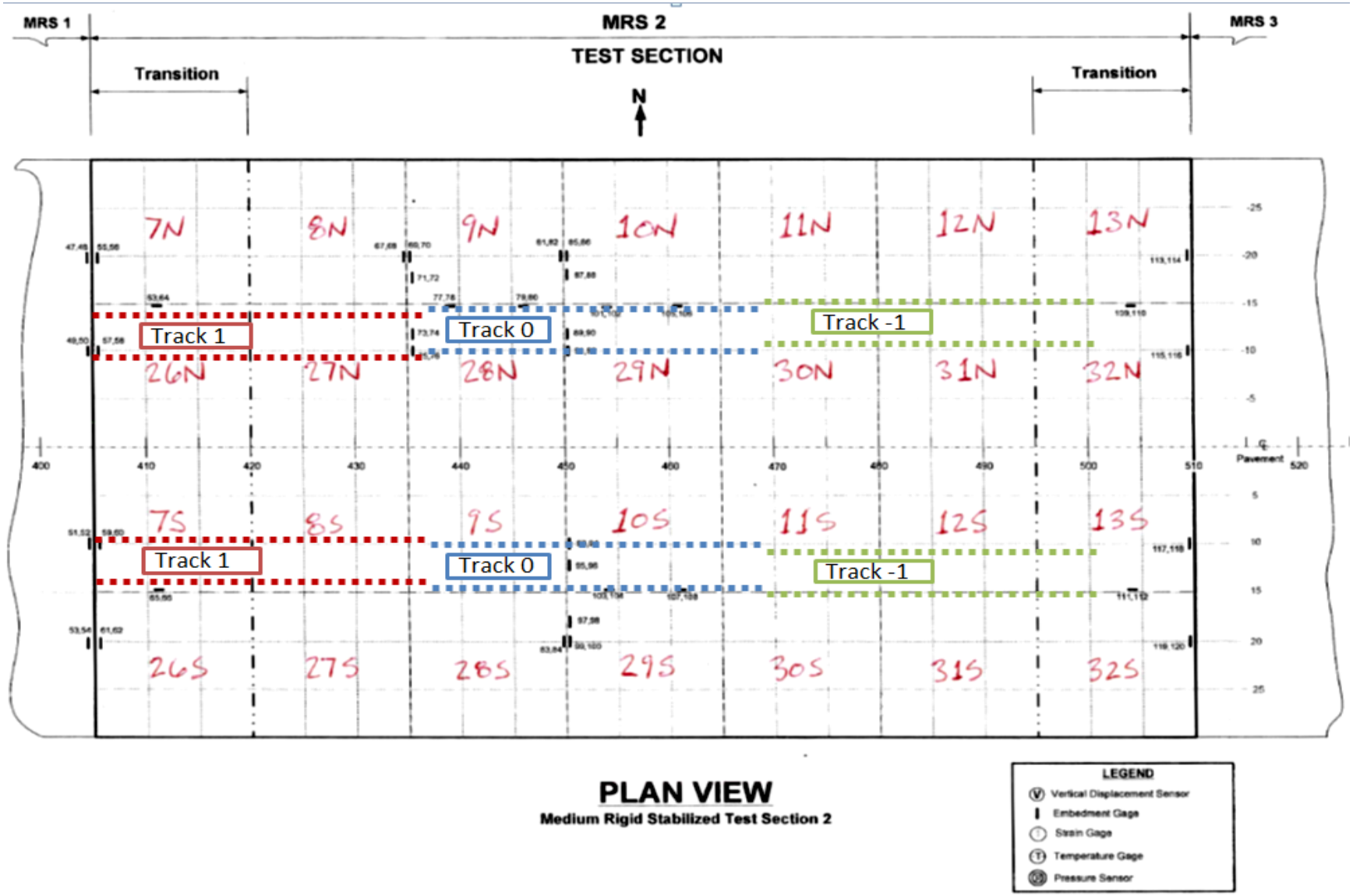


CC6 TRAFFIC HISTORY

Dates	Wander Pattern	Wheel Load, lbs.	Passes		
			MRS-1	MRS-2	MRS-3
7/8/11-8/15/11	*	44,000	6,790	0	0
8/30/11-12/20/11	1-238	45,000	15,708	15,708	15,708
12/27/11-1/12/12	239-286	52,000	0	3168	3168
No Pass Data Analyzed After This Point in Trafficking					
1/13/12-2/29/12	287-405	52,000	0	7854	7854
2/29/12-3/30/12	406-508	52,000	0	6,798	0
		70,000	0	0	6,798
3/30/12-4/16/12	509-558	70,000	0	3,300	3,300
Total Passes:			22,498	36,828	36,828

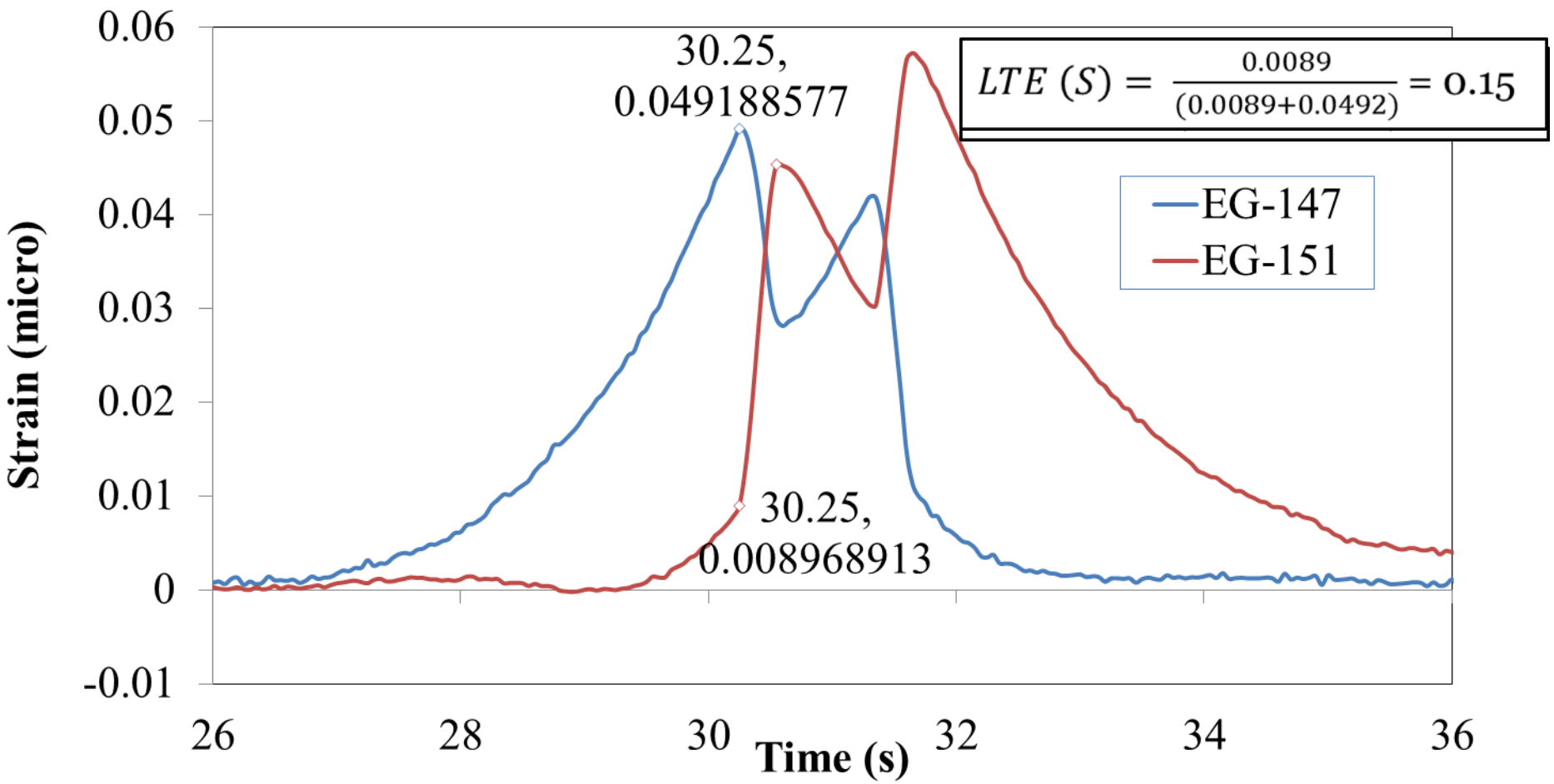
*Preliminary traffic tests (zero wander) on MRS-1N only

CC6 GAGE LAYOUT

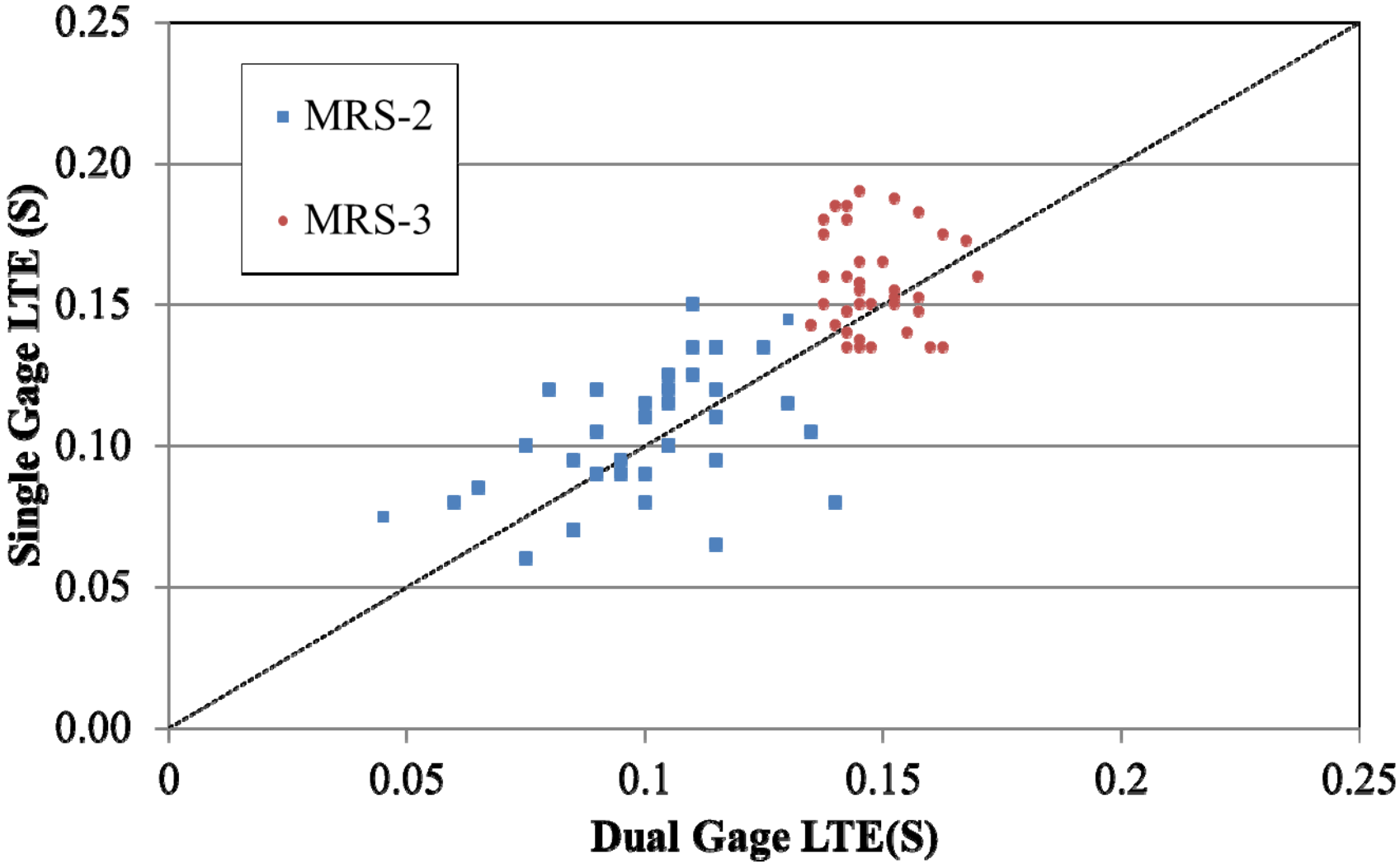


SINGLE GAGE VALIDATION

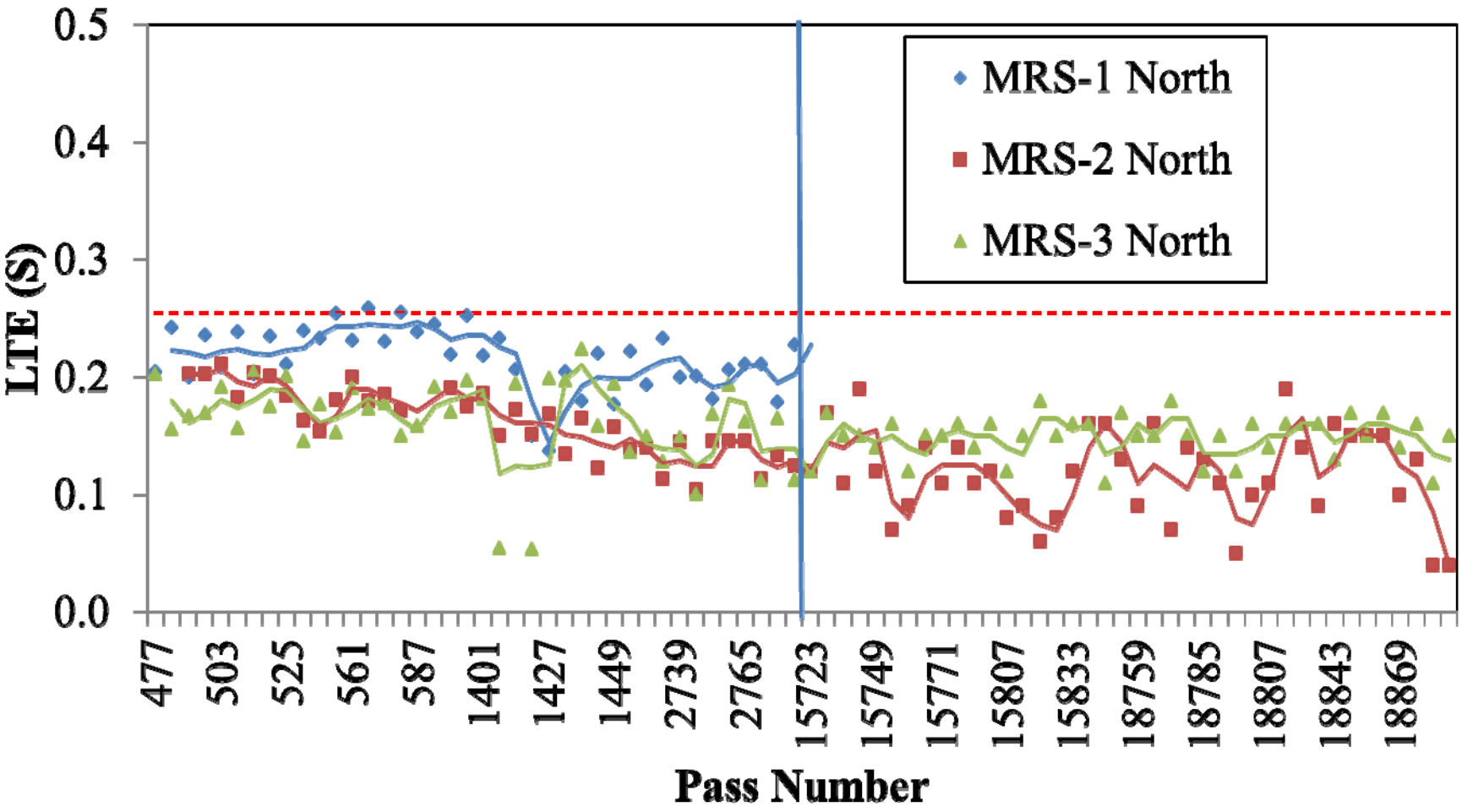
- Single vs. Dual gage analysis



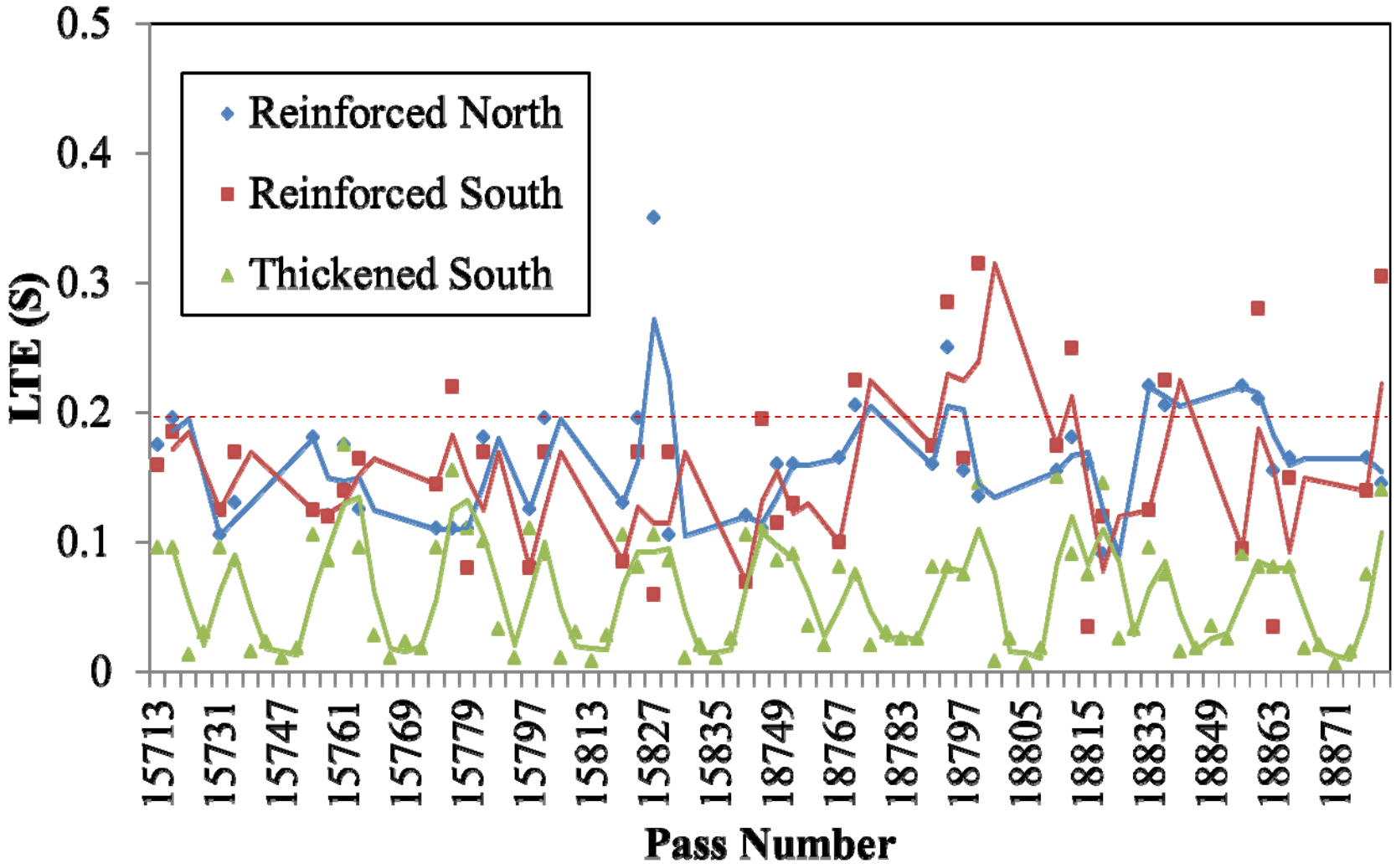
CC6 SINGLE VS. DUAL GAGE



CC6 DOWELED JOINT LTE(S)



CC6 ISOLATION JOINT LTE(S)

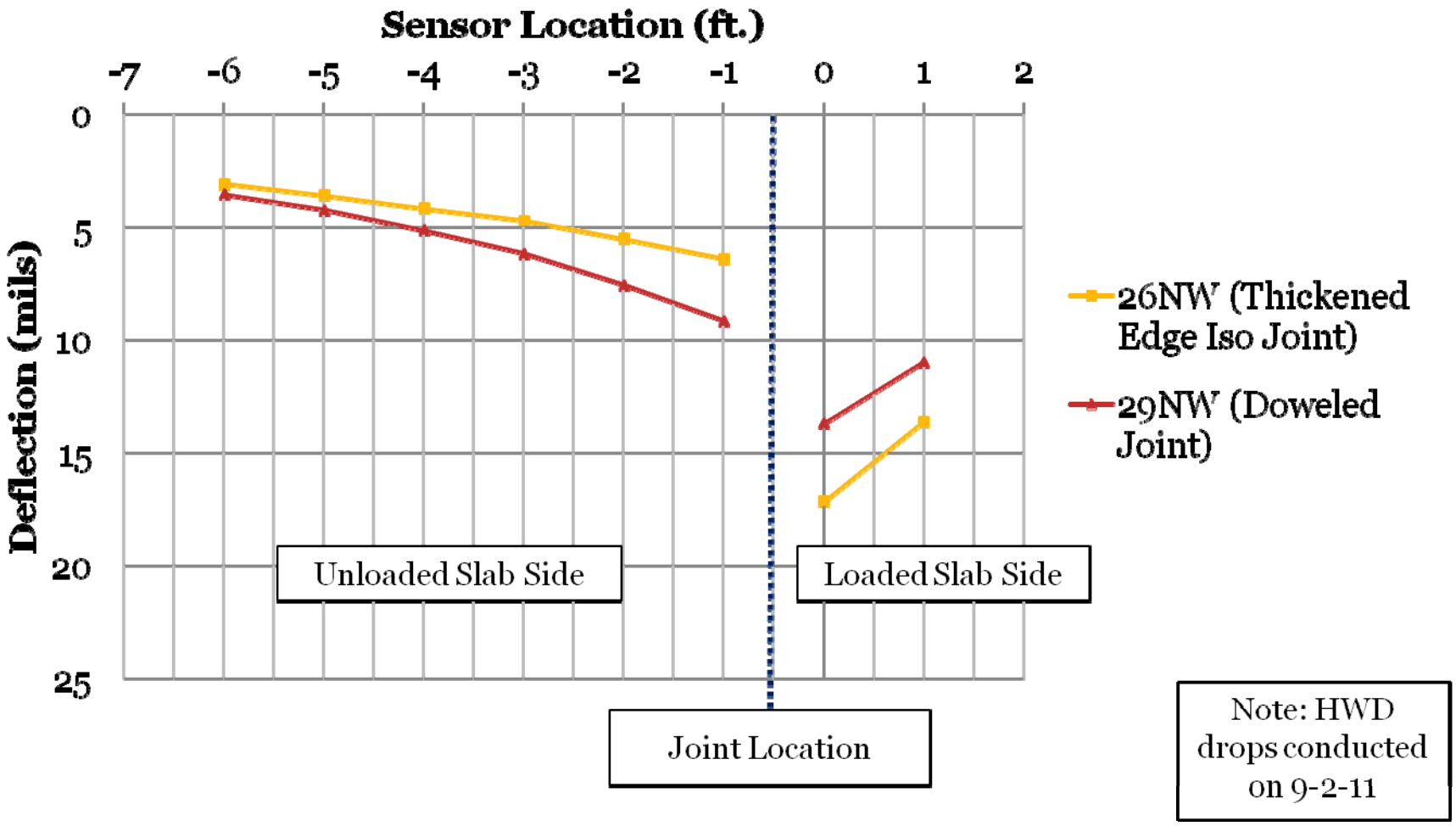


CC6 HWD LTE (δ)

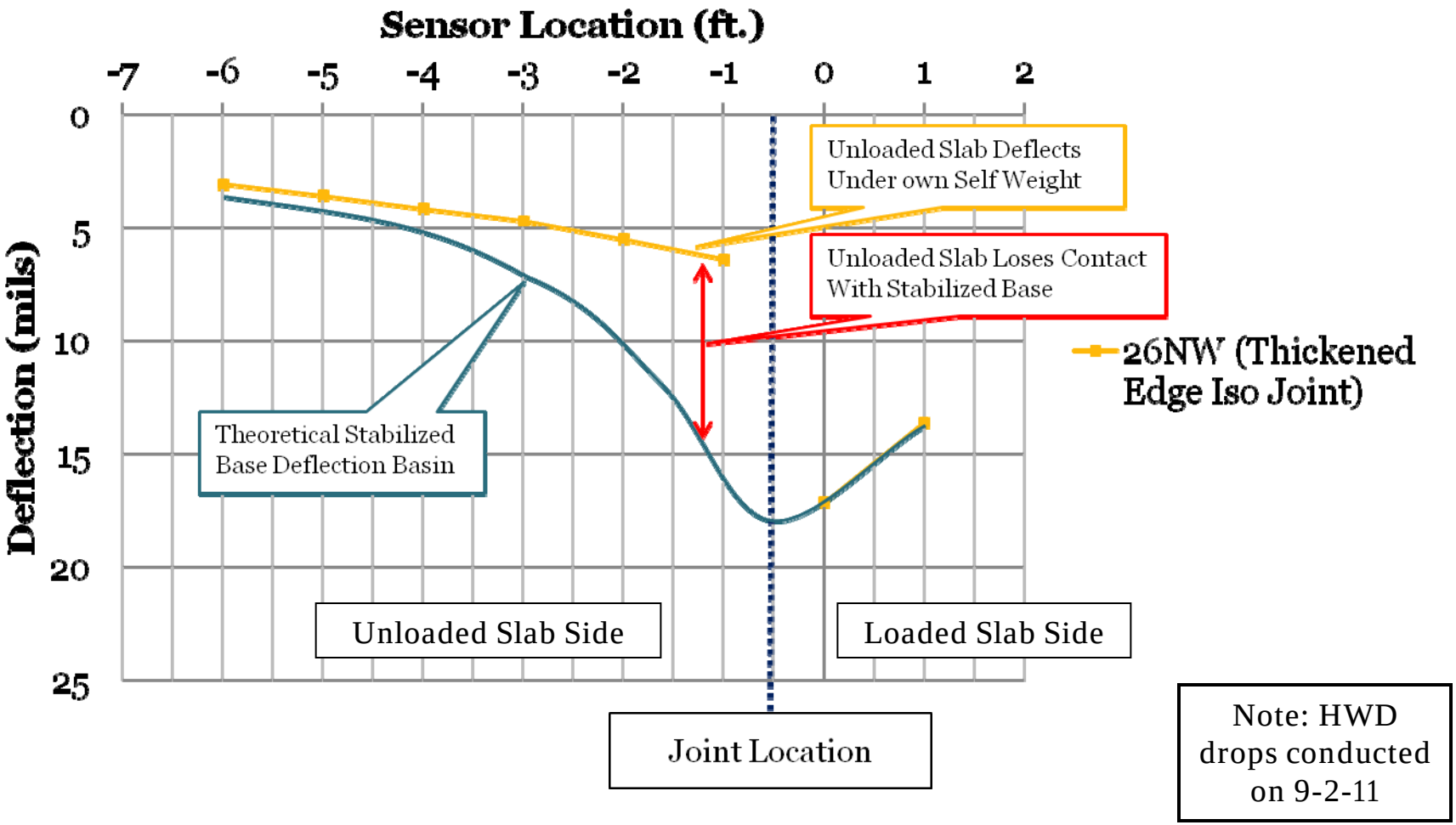
Doweled		
Section	**22-Jun**	**2-Sep**
MRS-1N	0.74	0.53
MRS-2N	0.76	0.65
MRS-3N	0.79	0.69

Isolation				
Joint Type	**22-Jun**		**2-Sep**	
	N-Asphalt	**S-Econocrete**	**N-Asphalt**	**S-Econocrete**
Reinforced	0.49	0.54	0.30	0.25
Thickened Edge	0.57	0.44	0.37	0.28

ISOLATION VS DOWEL JOINT HWD



ISOLATION VS DOWEL JOINT HWD



Note: HWD drops conducted on 9-2-11

CONCLUSIONS

- Single gage method is validated for determination of LTE (S) for dual tandem gear type
- LTE (S) of doweled joints are lower than 0.25 used for design
- LTE (S) was slightly higher for CC6 doweled joints on asphalt base compared to Econocrete base
- LTE (S) of isolation joints are lower than 0.25 but more variable compared to doweled
- LTE (δ) higher for doweled compared to isolation
- Isolation joints show an “apparent” load transfer which goes against conventional thought of no load transfer

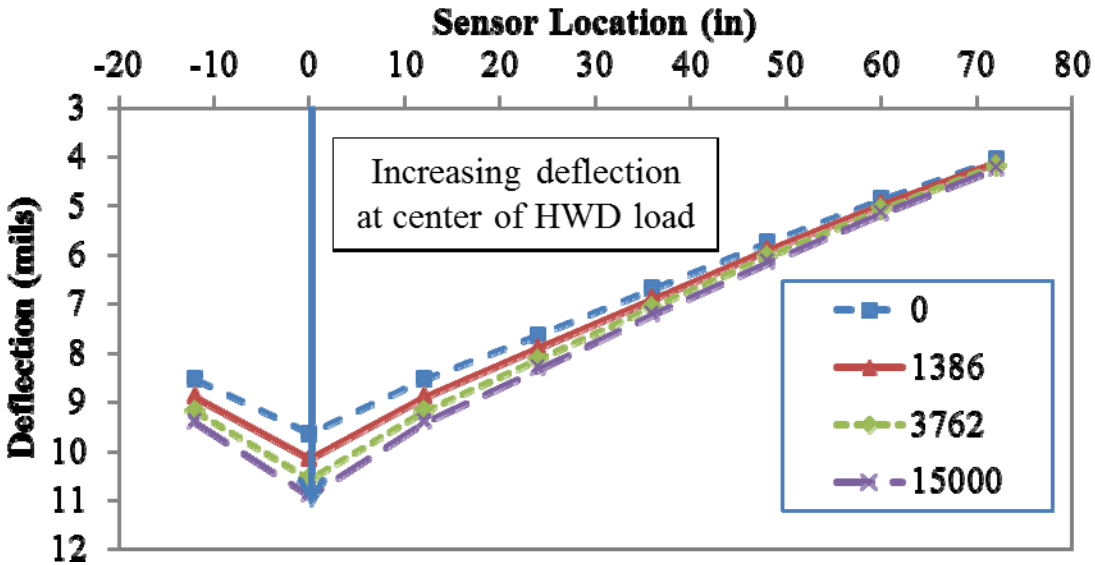
PART 2: CC6 PAVEMENT BACKCALCULATION

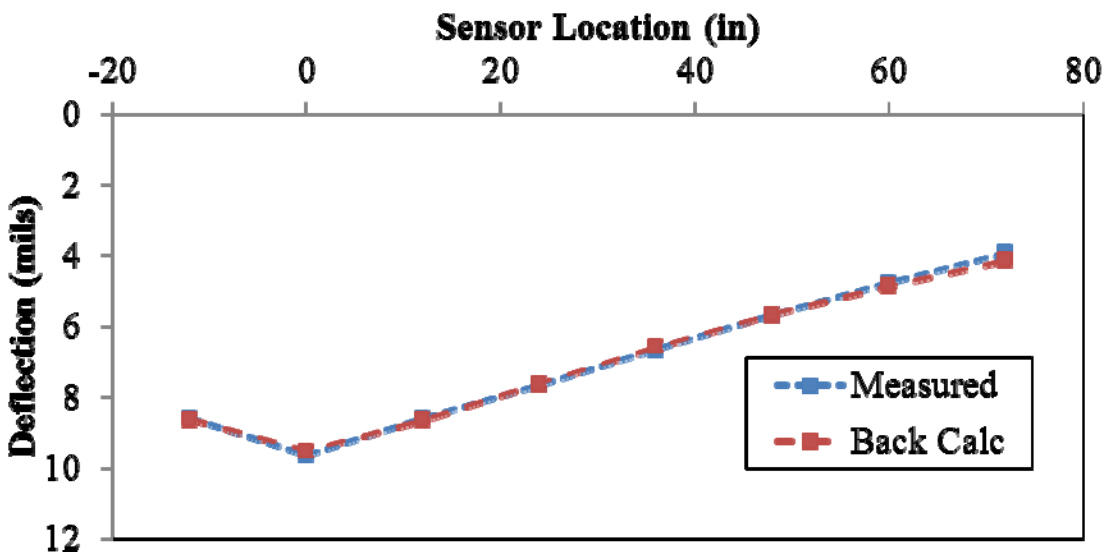
- Objectives
  - Determine baseline pavement layer stiffness's prior to trafficking of the test items using BAKFAA
  - Backcalculate PCC pavement layer stiffness's at various stages in trafficking to evaluate extent of deterioration
  - Evaluate PCC layer backcalculation results for multiple slabs along the entire length of each MRS test section

CC6 PAVEMENT STRUCTURE INPUTS

Layer	Expected Modulus of Elasticity (psi)	Design (Lab Tested) MOR (psi)	Poisson Ratio	Interface Parameter	Thickness (inches)
PCC Slab (MRS-1)	4,000,000	500 (662)	0.20	1.0	12
PCC Slab (MRS-2)	6,300,000	750 (763)	0.20	1.0	12
PCC Slab (MRS-3)	9,000,000	1000 (1007)	0.20	1.0	12
Subbase 1N (Asphalt)	500,000	—	0.40	1.0	6
Subbase 1S (Econocrete)	750,000	—	0.25	1.0	6
Subbase 2 (P-154)	51,400	—	0.40	1.0	10
Subgrade (Clay CBR 7)	10,300	—	0.40	1.0	144
Bedrock	1,000,000	—	0.5	1.0	Infinite

HWD CENTER SLAB DROPS





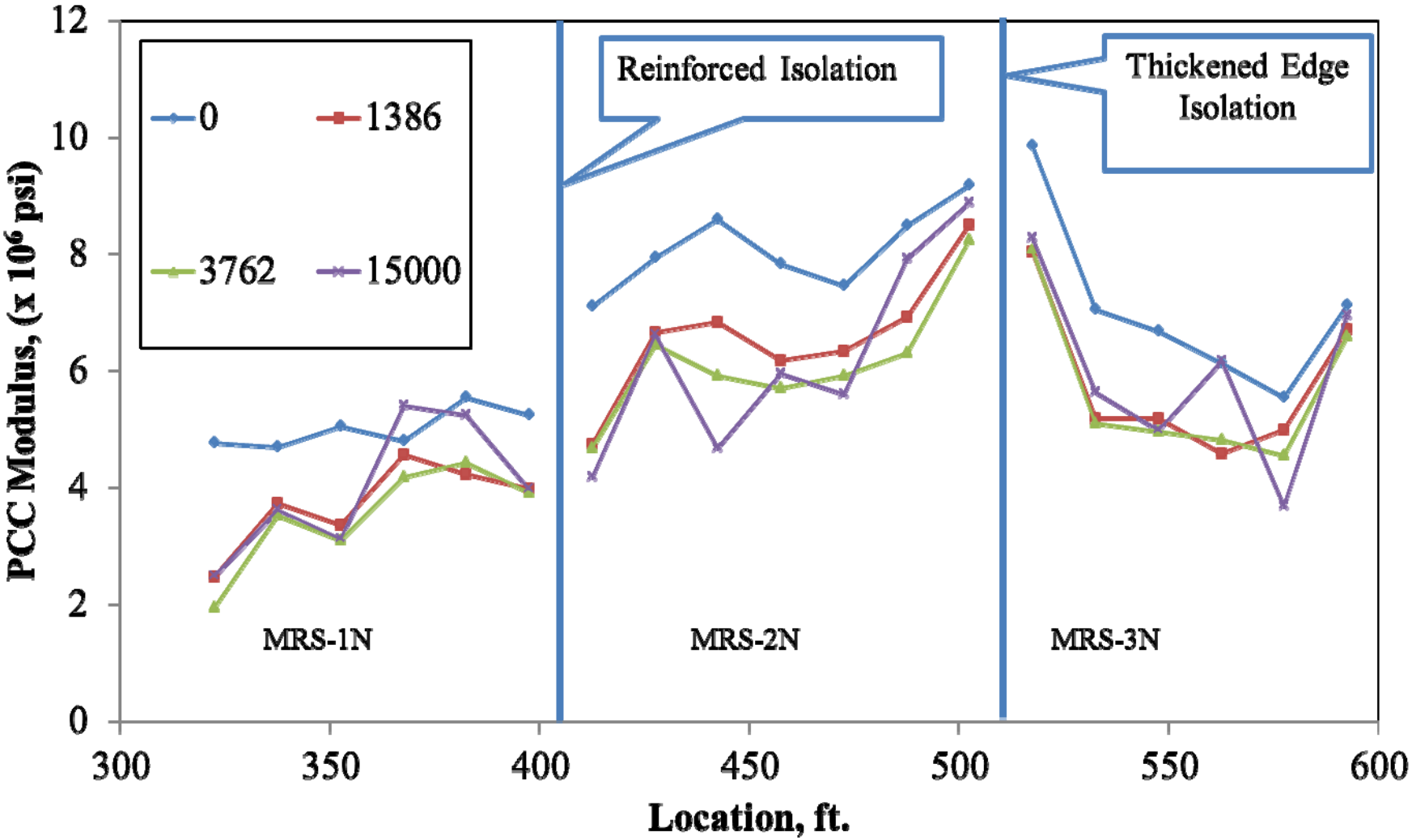
INITIAL BACK CALCULATION

Layer	MRS-1		MRS-2		MRS-3	
	North (psi)	South (psi)	North (psi)	South (psi)	North (psi)	South (psi)
PCC	5,017,000	5,400,000	8,082,000	8,300,000	7,067,000	9,400,000
Stabilized base	524,000	1,013,000	472,000	820,000	504,000	827,000
P-154 Subbase	120,000	133,000	116,000	139,000	120,000	132,000
Clay Subgrade	15,000	14,000	17,000	16,000	16,000	15,000

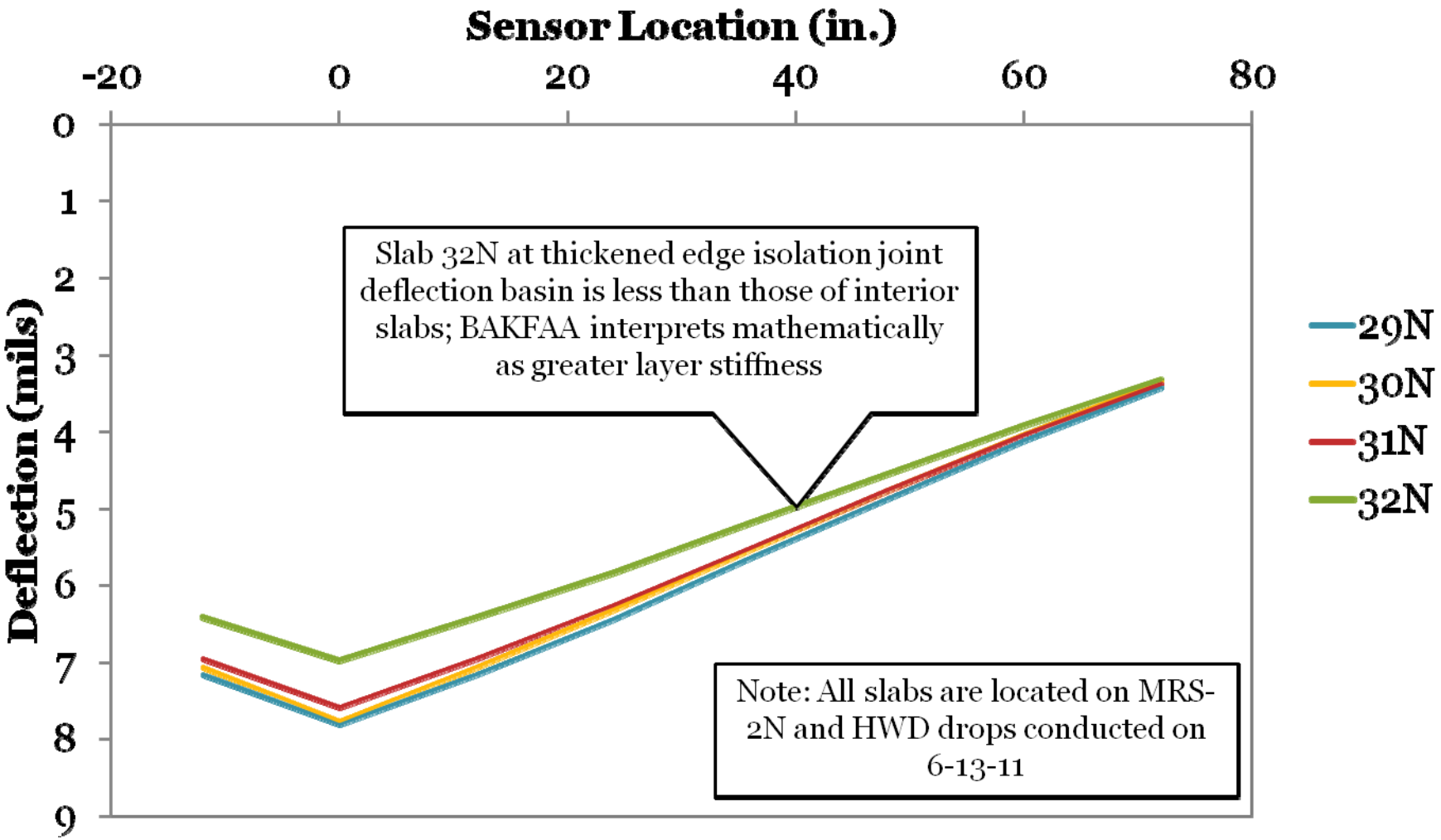
CC6 PLACEMENT CONCRETE MIX

Material	MOR 500psi	MOR 750 psi	MOR 1000 psi
Harmony No. 57 Stone, Round, lbs	1550	—	—
No. 57 Coarse Aggregate, lbs	—	1475	1535
No. 8 Intermediate Coarse Aggregate, lbs	—	490	535
Harmony Concrete Sand lbs	1414	—	—
Concrete Sand, lbs	—	1225	1070
Water, lbs	325	230	236
Type 1 Portland Cement, lbs	460	500	680
Air, %	6.5	7	4.5
Slump, in.	6	5.5	3.5
SIKA air, oz. (Air Entrainer)	4.5	5	4.5
W/C Ratio	0.71	0.46	0.35

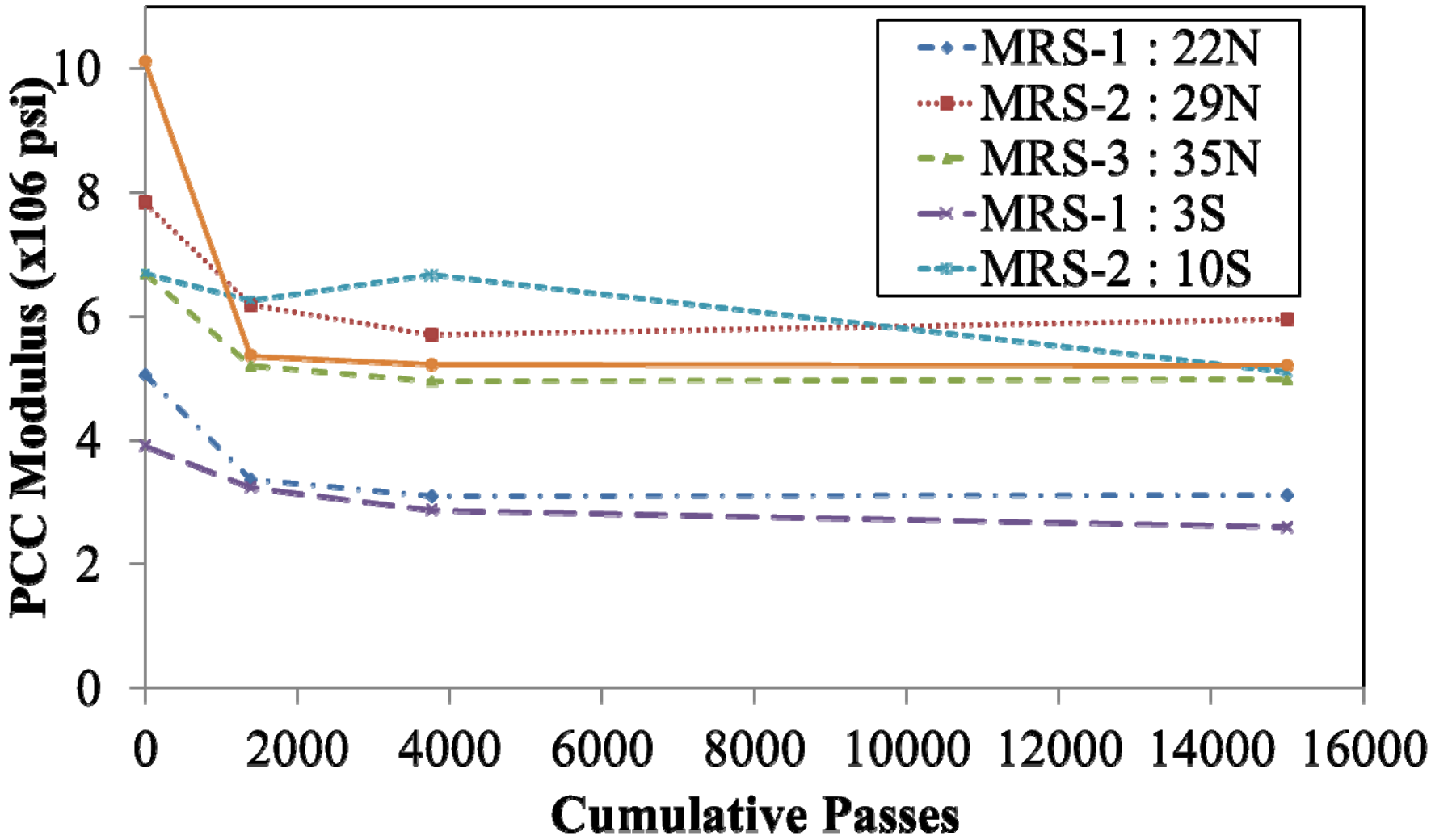
PCC LAYER MODULUS CC6 NORTH



EFFECT OF ISOLATION JOINT



PCC MODULUS VS. PASSES



CONCLUSIONS

- On average, MRS-1 PCC modulus decreased from 5.0−5.4x10^6 psi to 4.0−4.3x10^6 psi whereas the PCC modulus of MRS-2 and MRS-3 did not drop below 5x10^6 psi after 15,000 passes on the test sections
- Majority of decrease in PCC elastic modulus occurs during the first 2000-3000 passes
- Backcalculation results were best for slabs at the interior of each MRS section, away from the isolation joints
- MRS-2 and MRS-3 were found to have similar elastic modulus despite different flexural strength; this is attributed to same aggregate source

PART 3: CC6 CURLING ANALYSIS

- Objectives
  - Determine impact of temperature slab curling on edge stresses and joint LTE (S) with respect to:
    - Load magnitude
    - CC6 Pavement structure
    - Temperature gradient

CC6 STRUCTURAL INPUTS

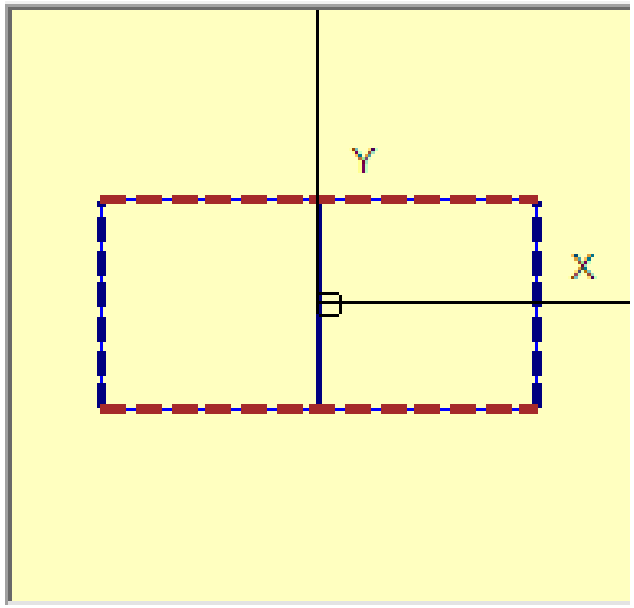
- ACI Relationships between E and MOR

Layer	Modulus of Elasticity, psi	MOR, psi	Poisson Ratio	Thickness, in.
PCC Slab (MRS-1)	3,800,000	500	0.15	12
PCC Slab (MRS-2)	5,700,000	750	0.15	12
PCC Slab (MRS-3)	7,600,000	1000	0.15	12
Sub-base (Asphalt)	400,000	—	0.35	6
Sub-base (Econocrete)	700,000	—	0.20	6
2nd Sub-base	51,400	—	0.35	10
Subgrade	10,400	—	0.40	Infinite

FEAFAA MODEL PARAMETERS

Number of Slabs	2
Slab Size	15 ft. X 15 ft.
Mesh Size	3 in. X 3in. (slab)
	6 in. X 6in. (foundation)
Thermal Coefficient	$5x10^{-6}/°F$
Slab Curling Shape	Circular
Dowel Bar Diameter	1.0 in.
Dowel Bar Spacing	12 in.
Joint Opening	0.375 in.
Method of Bar Placement	Placed in fresh concrete
Joint Simulation	Equivalent Joint Stiffness (vertical springs)
Equivalent Joint & Boundary Stiffness	120,803 psi.

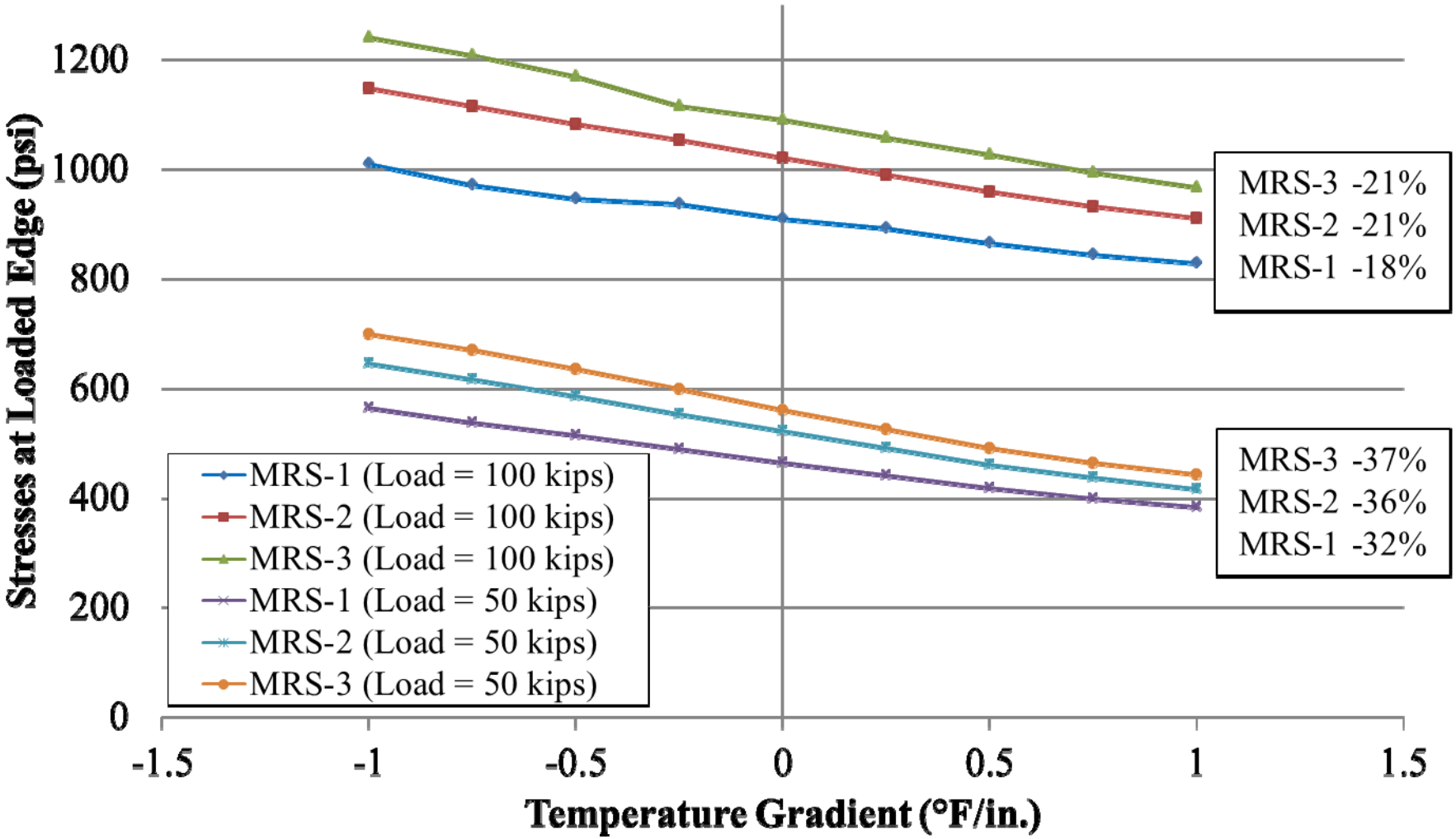
FEAFAA MODEL PARAMETERS



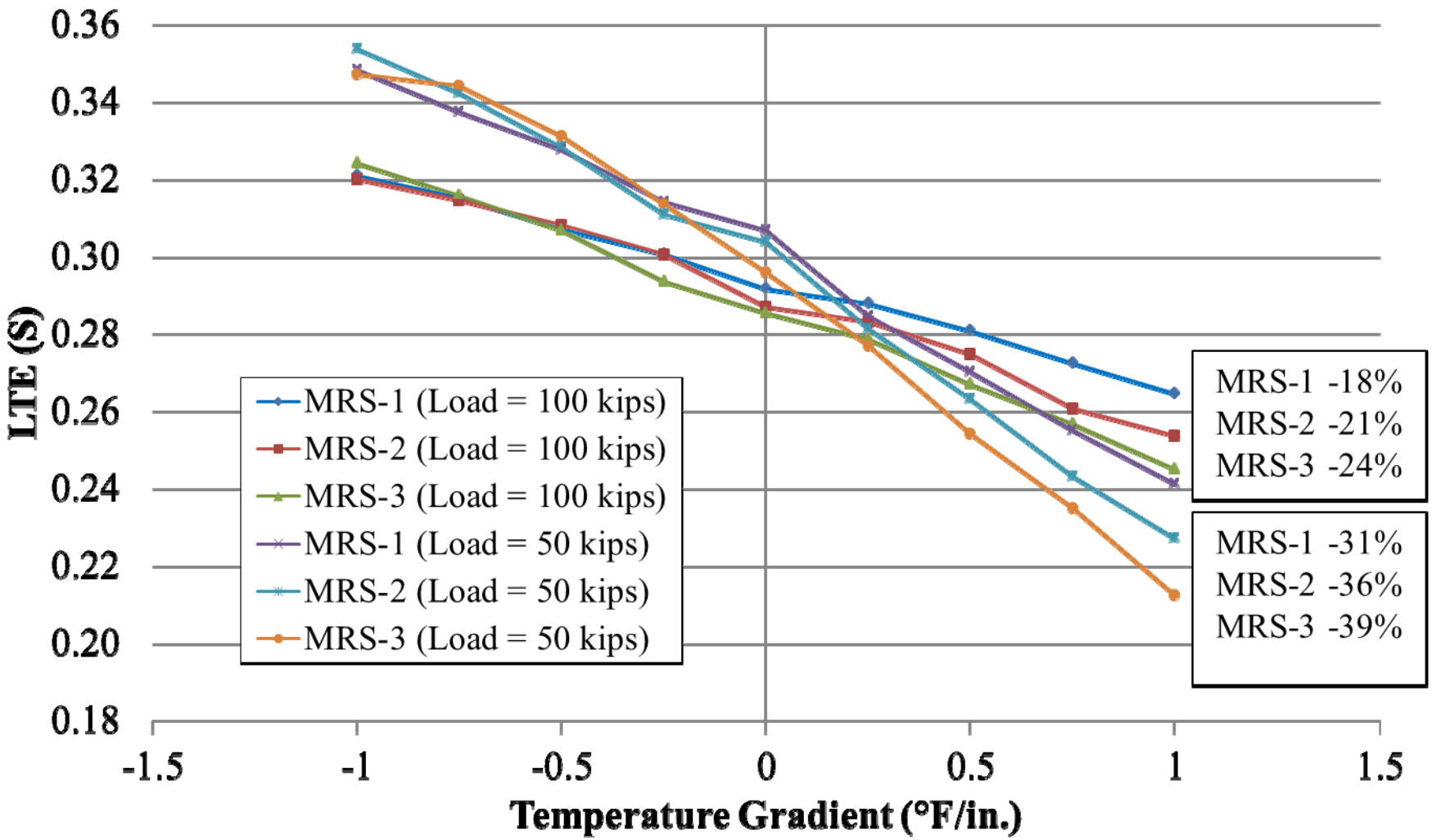
Gear Position

Parameter	Dimension
Number of Wheels	1
Length/Width of Each Wheel	16.7 in
Gross Weight	50 & 100 kips
Tire Pressure	180 & 360 psi
Number of Main Gears	1
Percent of Weight on Main Gear	100%

EDGE STRESSES CC6 NORTH



LTE (S) CC6 NORTH



CONCLUSIONS

- Stabilized base type had a negligible effect on edge stresses and joint LTE (S) regardless of temperature gradient
- Temperature gradient has a more significant effect on edge stresses and joint LTE (S) as the load decreases
- Higher MOR pavements seem to be more sensitive to temperature curling effects caused by temperature gradients
- LTE (S) is more sensitive to temperature curling effects as temperature gradient increases from negative to positive

PART 4: CC6 DYNAMIC MODELING

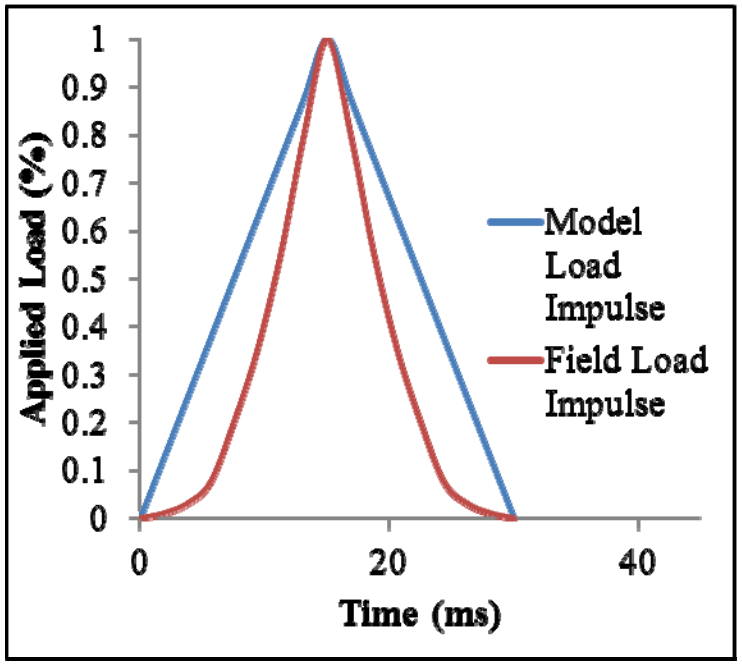
- Objectives
  - Model NAPTF loads for CC6 test items using ABAQUS
  - Calibrate model with HWD field data
  - Validate model with NAPTF strain gage data

3D FE MODEL USING ABAQUS

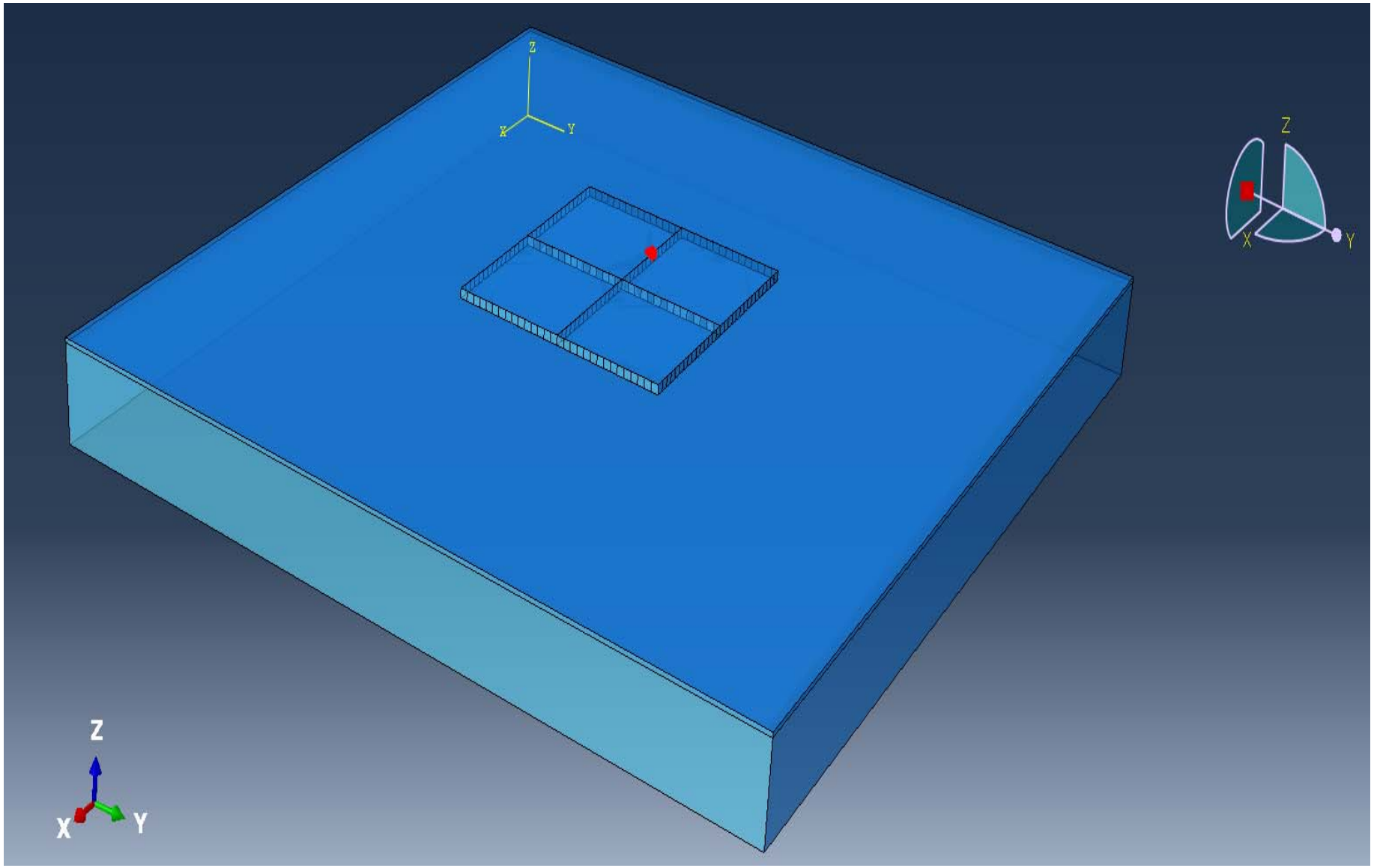
Model Properties

Concrete and Foundation Model	Linear Elastic
Elements	C3D8I - 8-node linear brick, Incompatible modes
Mesh Size	6in. X 6in. (slab); 12 in. X 12in. (foundation)
Interactions	Surface to Surface Hard Contact
Joint Simulation	Spring elements are used and spring constant is defined
Pavement damping	Stiffness proportional, 'β'
Foundation damping	Neglected
Loading	HWD / Dynamic
Boundary Conditions	Displacements U_1 and U_2 in base layer is constrained in the plane of direction. Sub-grade layer is constrained in all directions at the bottom

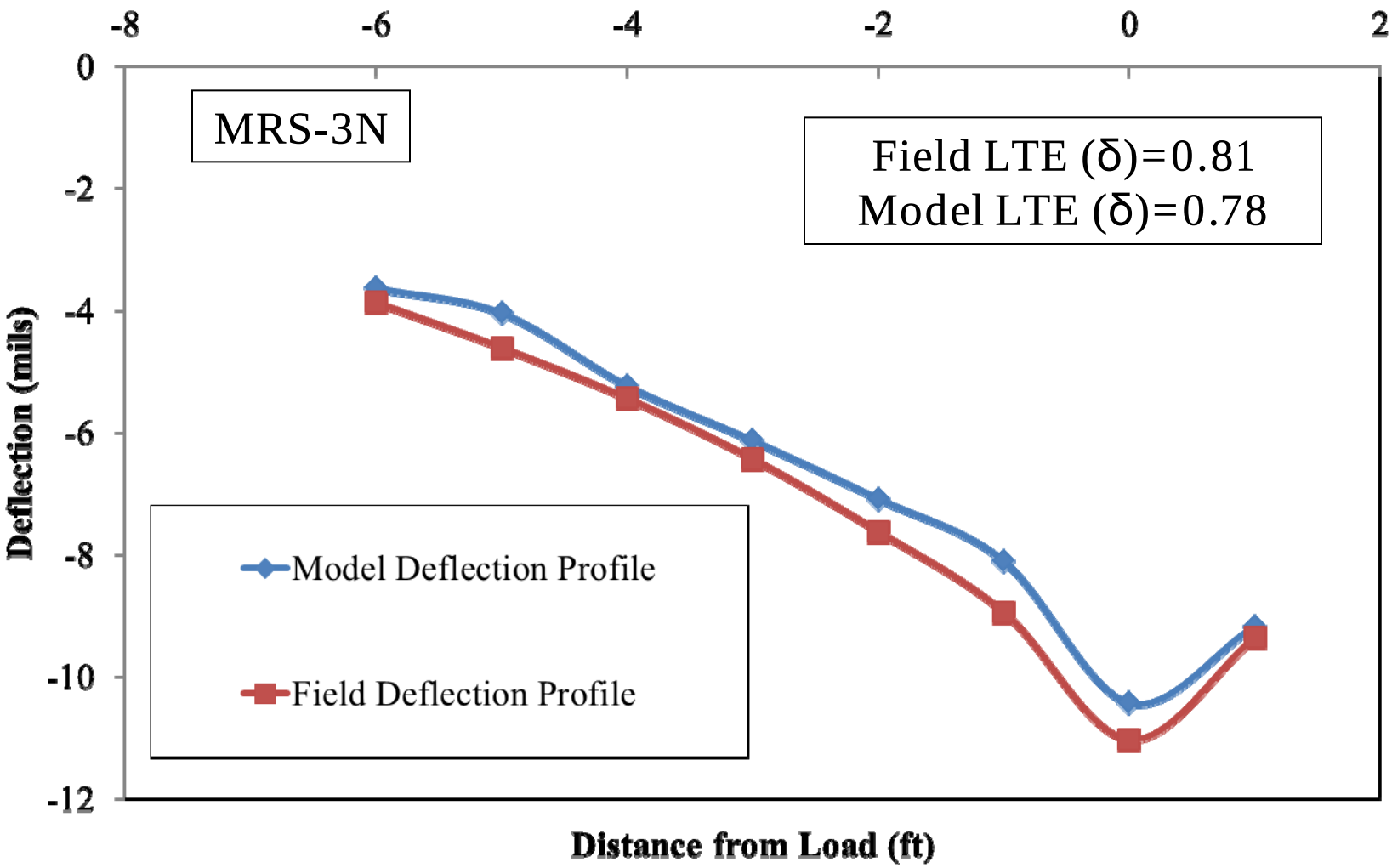
HWD Impulse



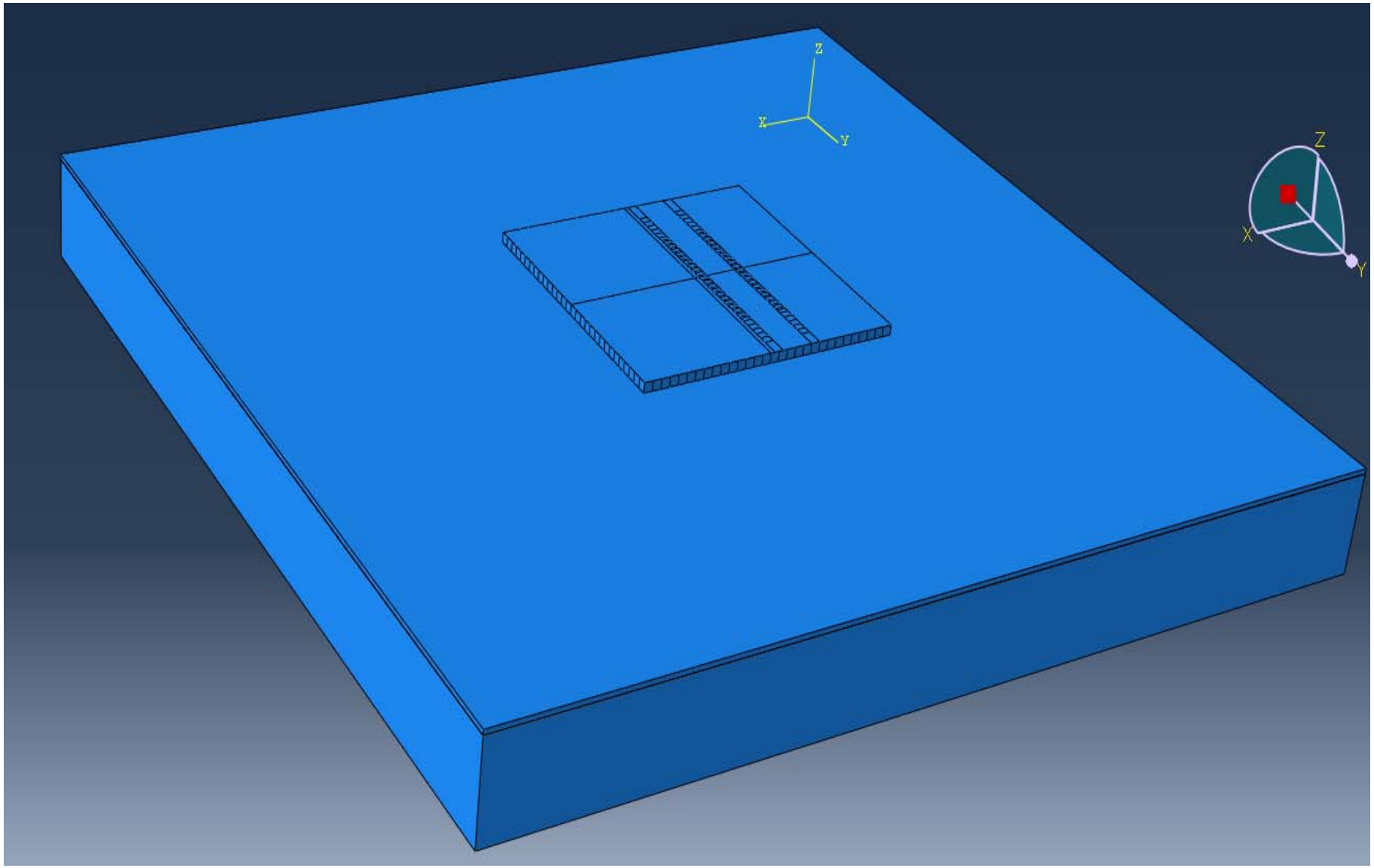
ABAQUS MODEL: HWD LOAD



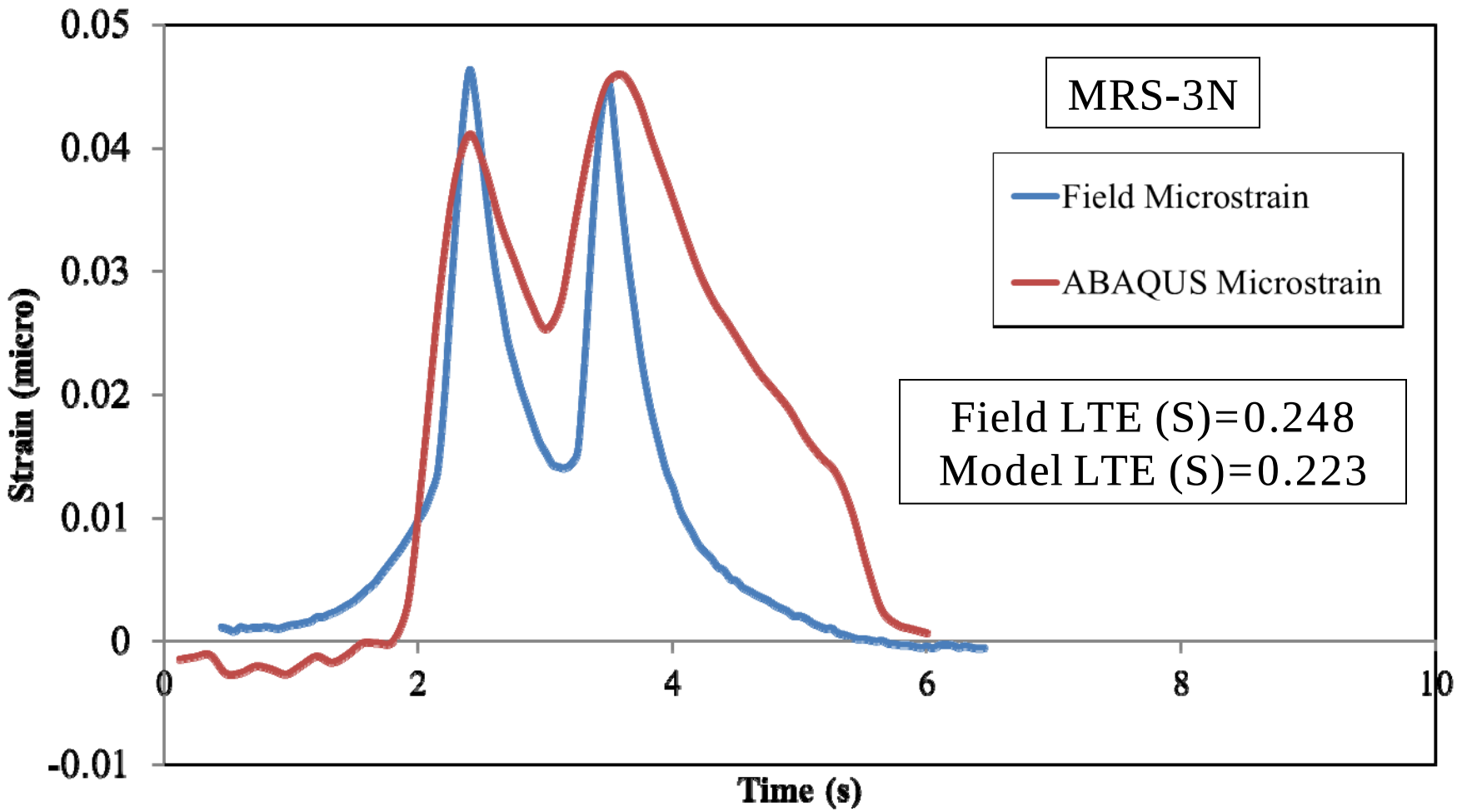
HWD: FIELD VS MODEL



ABAQUS MODEL: DYNAMIC LOAD



DYNAMIC: FIELD VS MODEL



CONCLUSIONS

- Model joint stiffness (k_j) used in model in the range of 35-40,000psi, which is similar to that determined from HWD field data

- HWD and dynamic wheel load has been successfully modeled for almost all MRS test sections (North and South)

- Further calibration (joint stiffness, pavement damping, etc.) required to further improve accuracy of model results for each test section

Questions & Discussion

Thank you