SHRP Test Road Research at Ohio University

SPS-2 Tech Day, May 22, 2019
ODOT District 6 Headquarters, Delaware

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Russ College of Engineering and Technology
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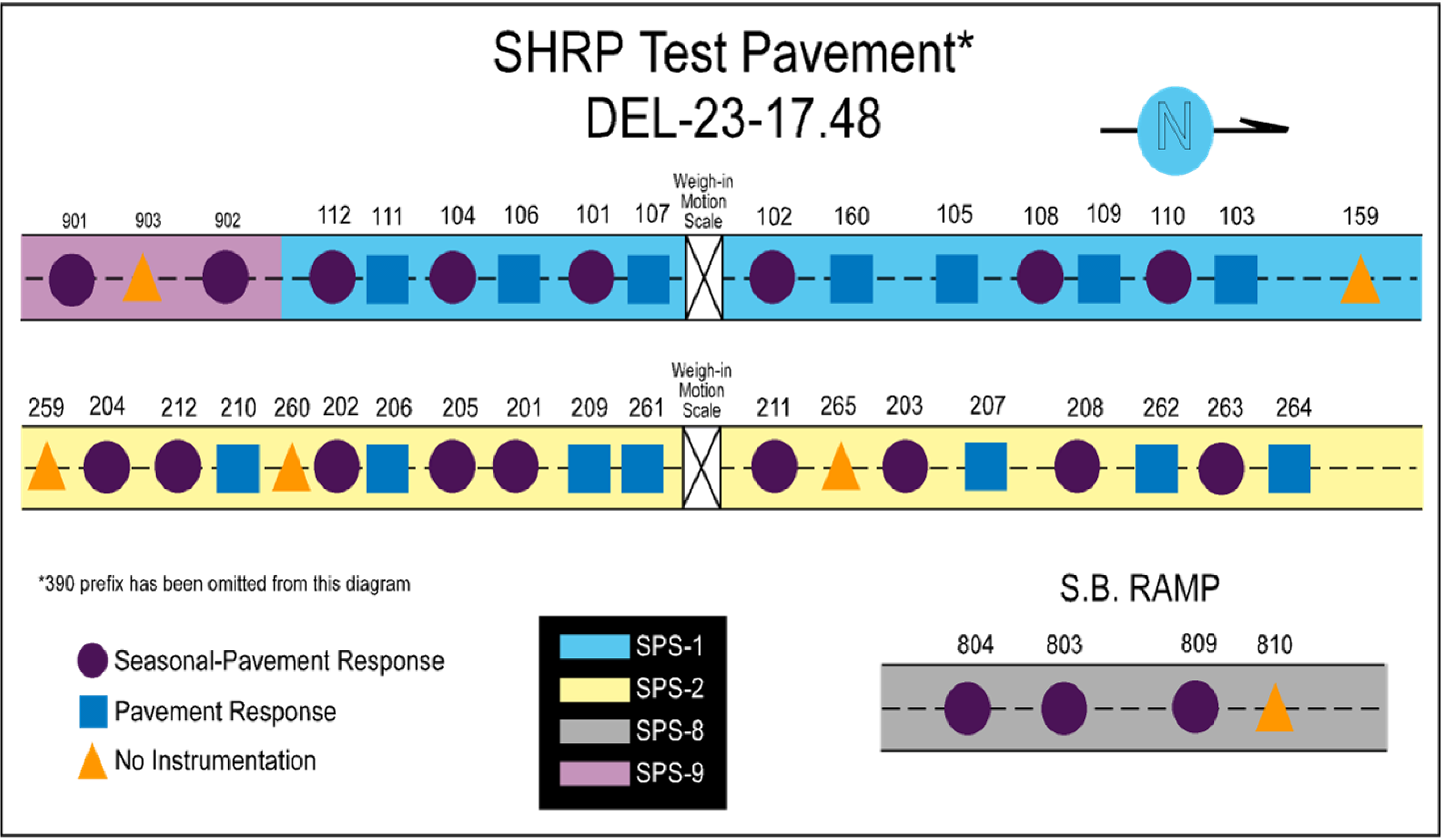
Outline

SPS-2 Studies on SHRP Test Road

- Project Instrumentation
- Controlled Load Vehicle Tests
- Monitoring and Performance
- TPI Pooled Fund Study
- Base Type Selection

Project Instrumentation

SHRP Test Road Overview



Test Pavement Instrumentation

ODOT Projects to develop and install instrumentation

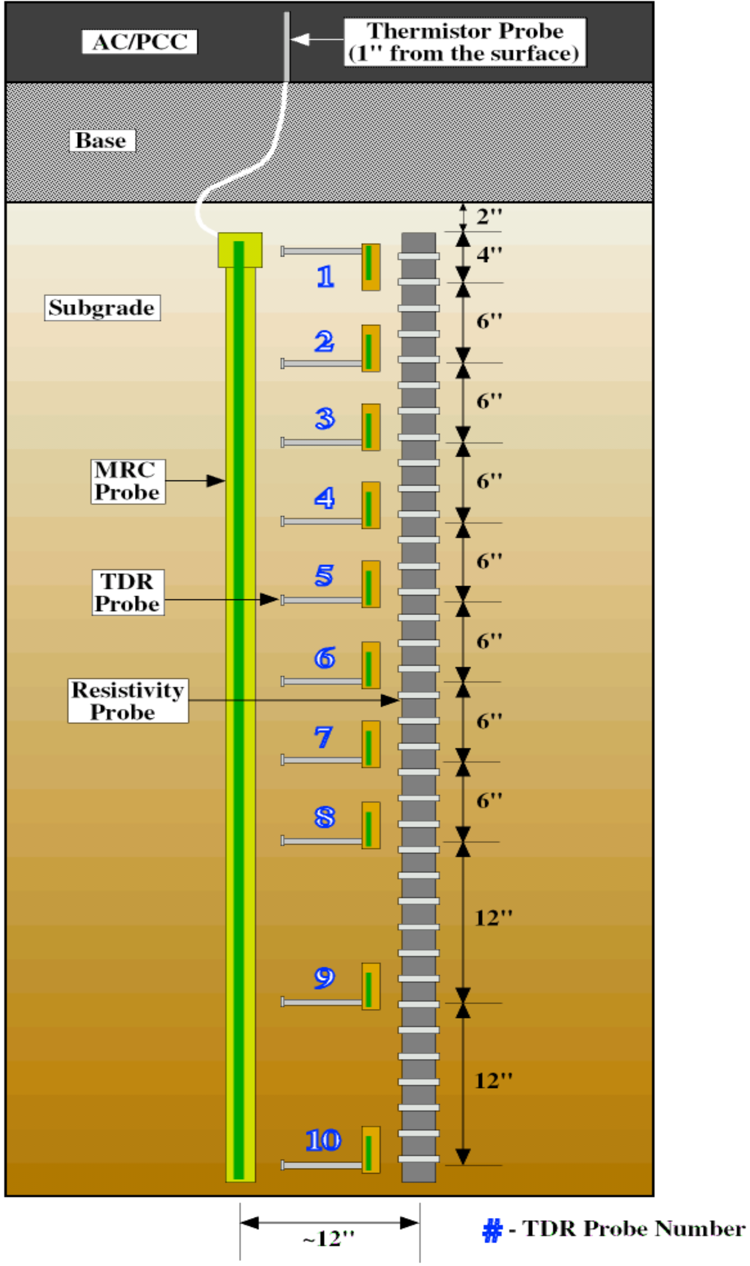
- *Development of an Instrumentation Plan for the Ohio SPS Test Pavement. FHWA/OH-94/019 July, 1994*
  - Type of sensors
  - Installation methodology
  - Calibration procedures
  - Wiring schematics
- *Coordination of Load Response Instrumentation of SHRP Pavement. FHWA/OH-00/009. May, 1999*
  - Coordination of instrumentation installation by six universities (OU, OSU, UT, UC, CWRU, and UA)
  - Controlled load vehicle tests

Environmental Instrumentation

- 20 Sections
  - Monitor soil moisture
  - Monitor soil and pavement temperature
  - Monitor frost depth
  - Monitor ambient weather with Weather Station

Typical Environmental Instrumentation for Ohio Test Road

- Campbell Scientific FHWA TDR Probes
  - Used to collect soil moisture content
- MRC Thermistor Probes
  - Use to measure pavement, base and subgrade temperature
- CRREL Resistivity Probe
  - Used to measure frost depth in base and subgrade



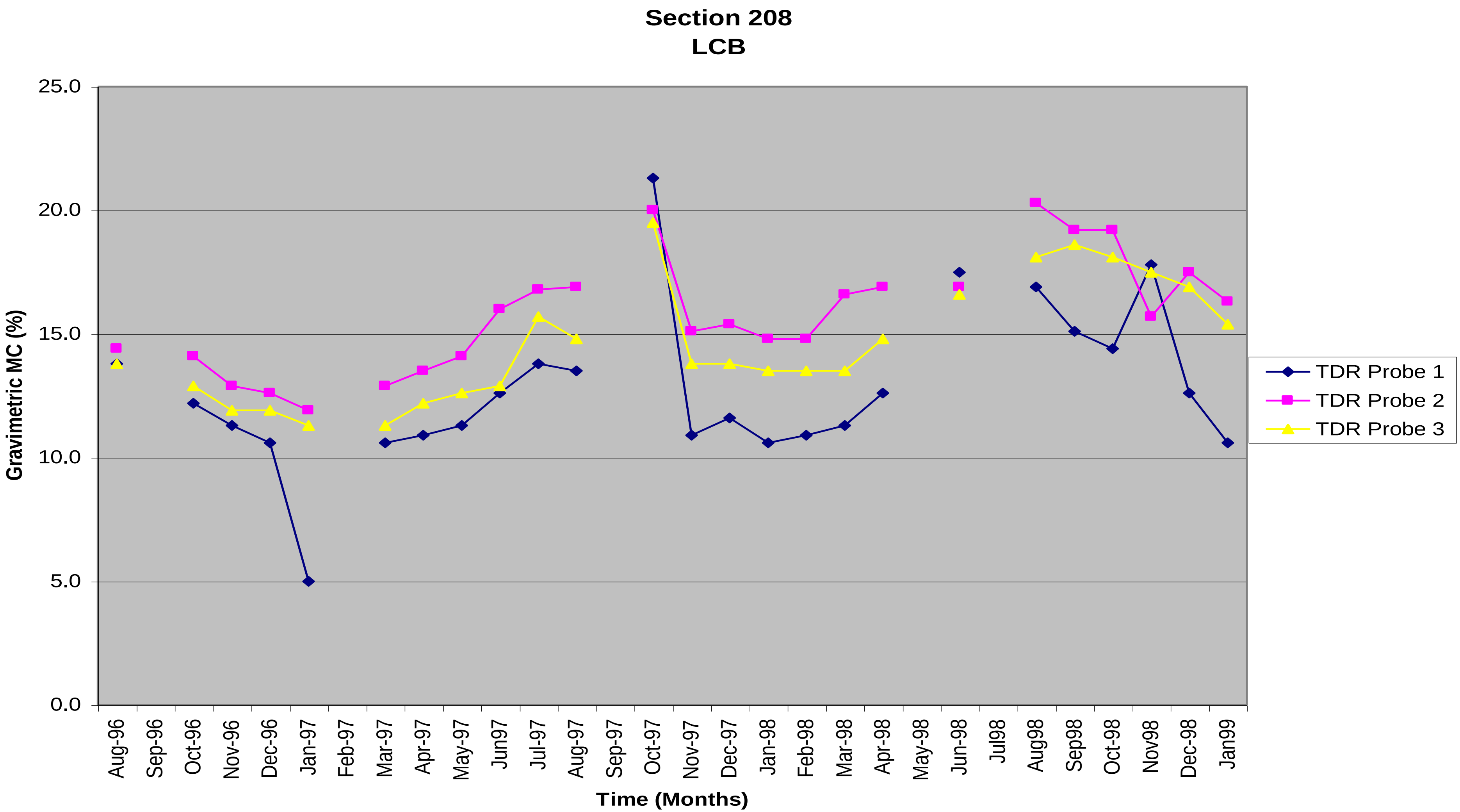
Environmental Instrumentation Installation

Environmental Instrumentation Installation

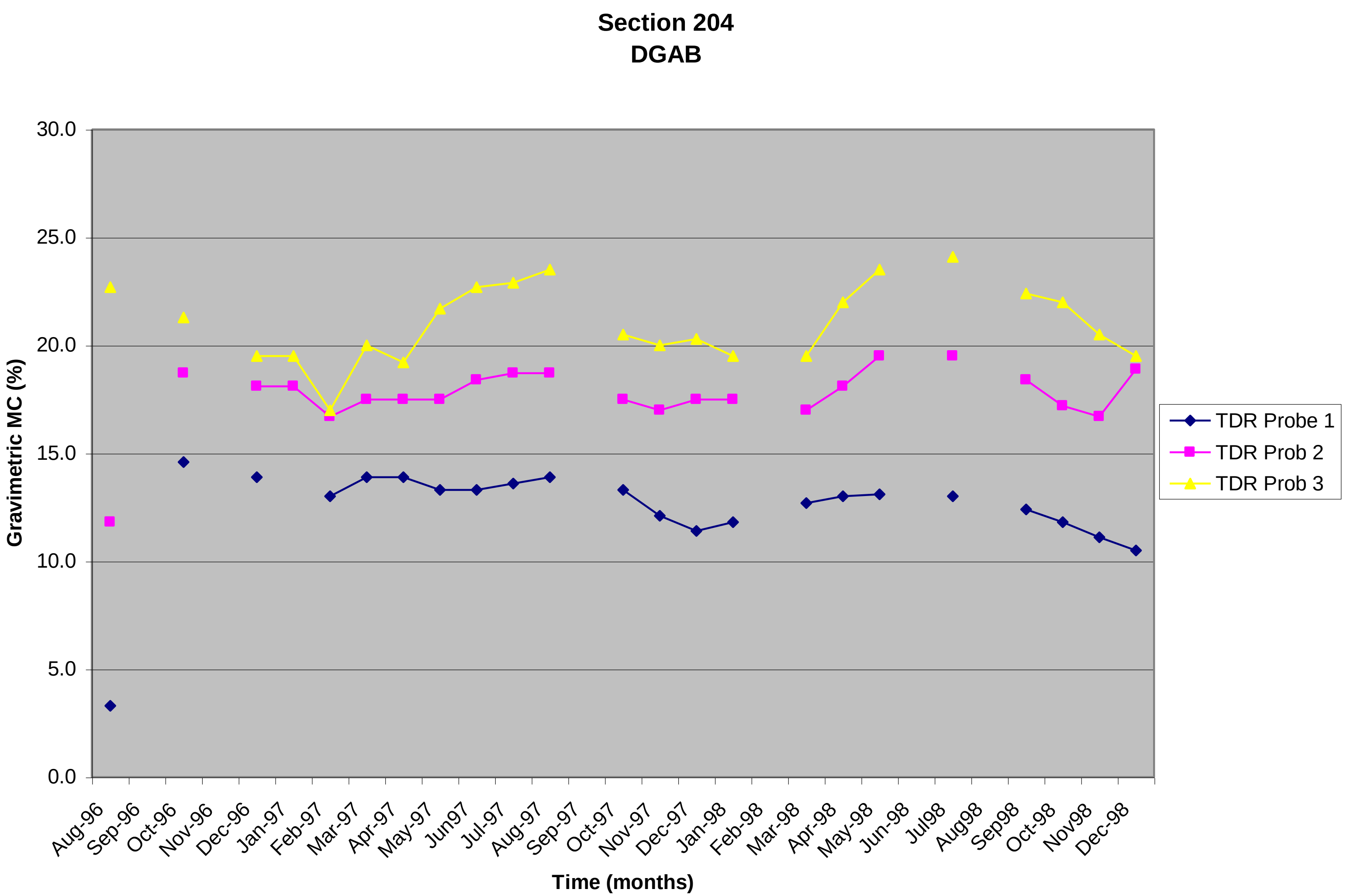
Time Domain Reflectometry (TDR) Probe

MRC Thermistor Probe

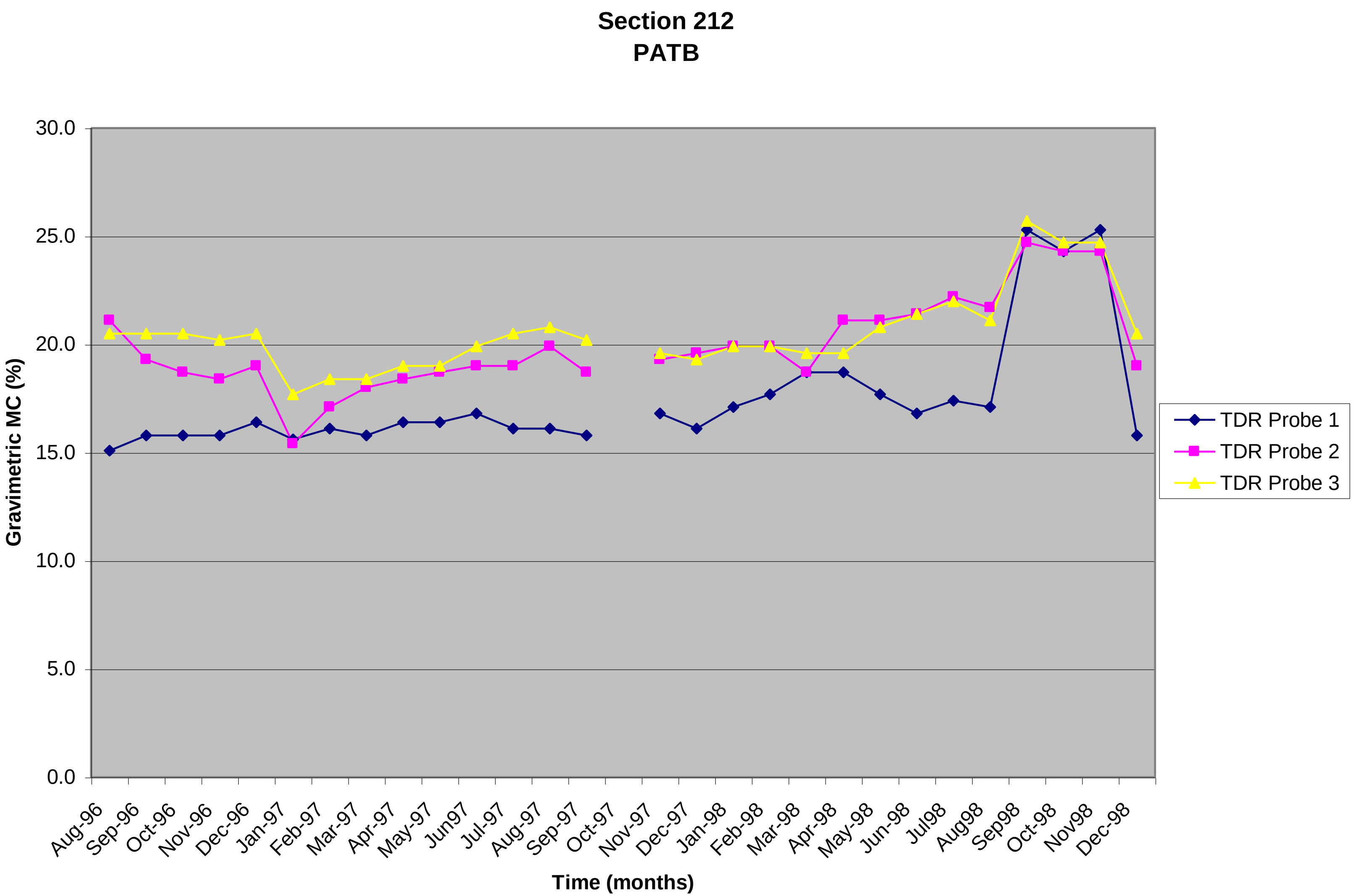
Typical TDR Data



Typical TDR Data



Typical TDR Data

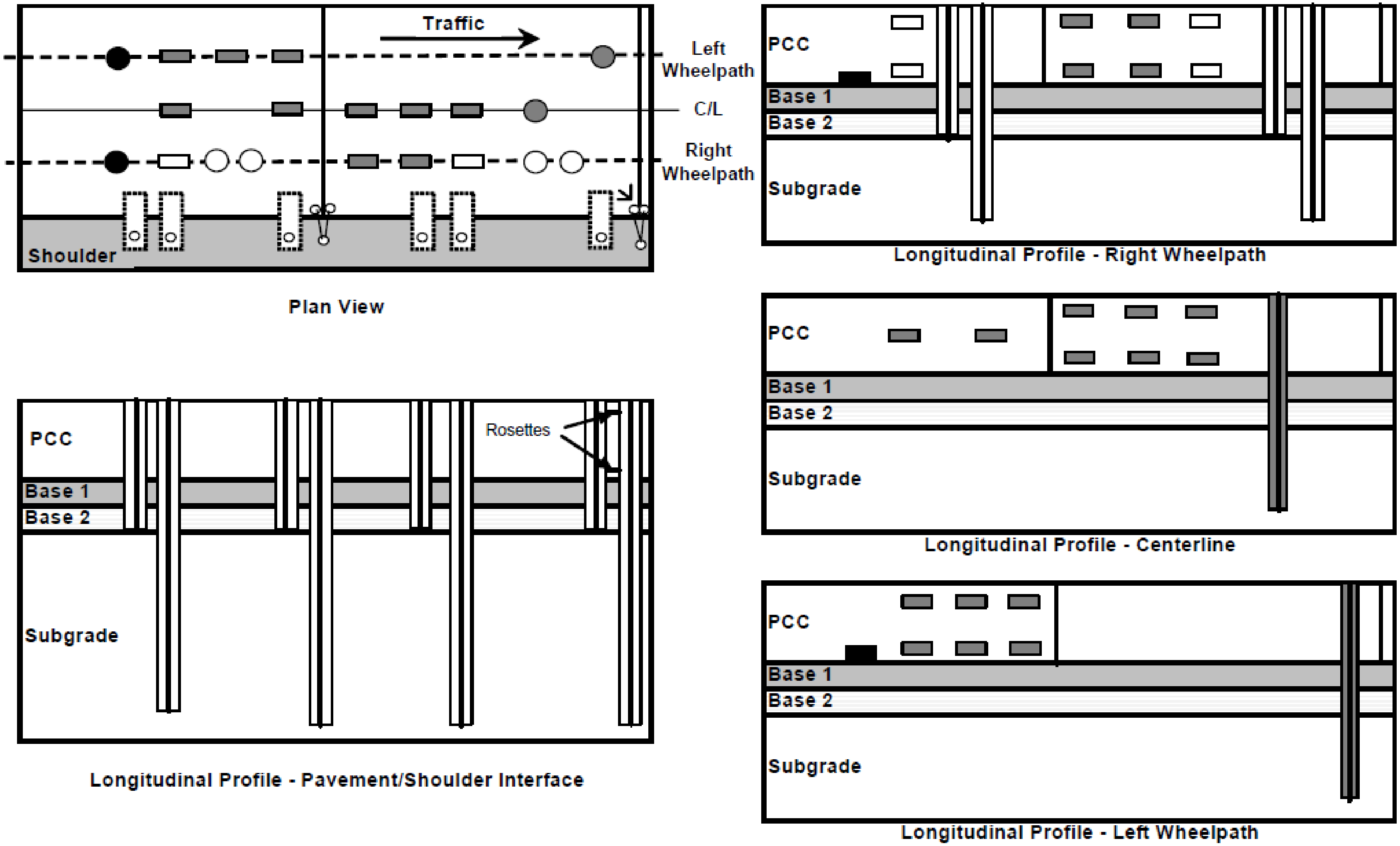


Pavement Response Sensors

- Dynatest Past II PCC / AC Strain Gauges
- Geokon 3500 Pressure Cells
- Lucas Schaevitz LVDTs
- VCE4200 Geokon vibrating wire strain gauges
- KM100B Tokyo Sokki Strain gauges
- Carlson A-8 Strain meter

Pavement Response Instrumentation

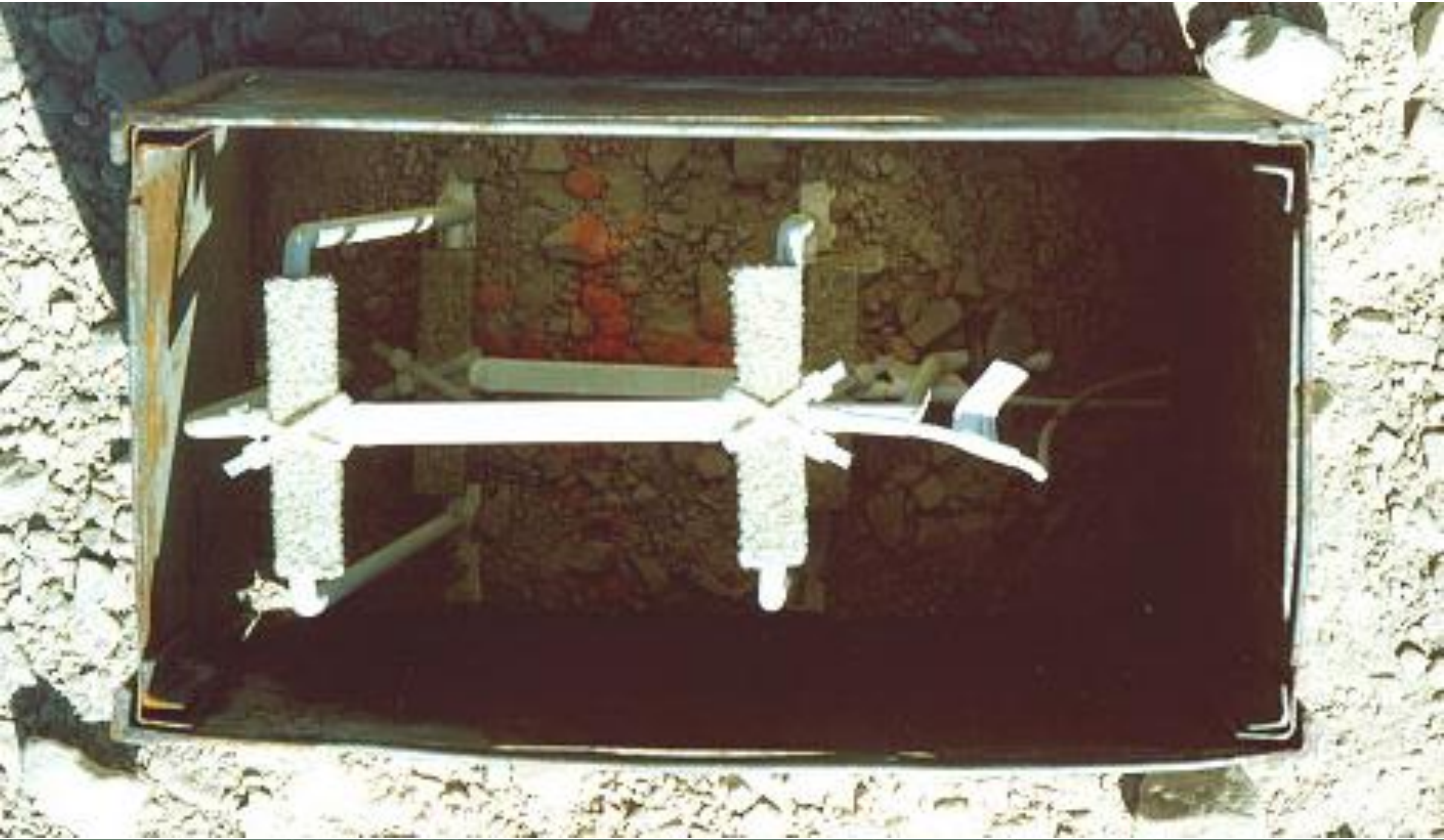
Dynamic Sensor Locations in PCC Pavement Sections



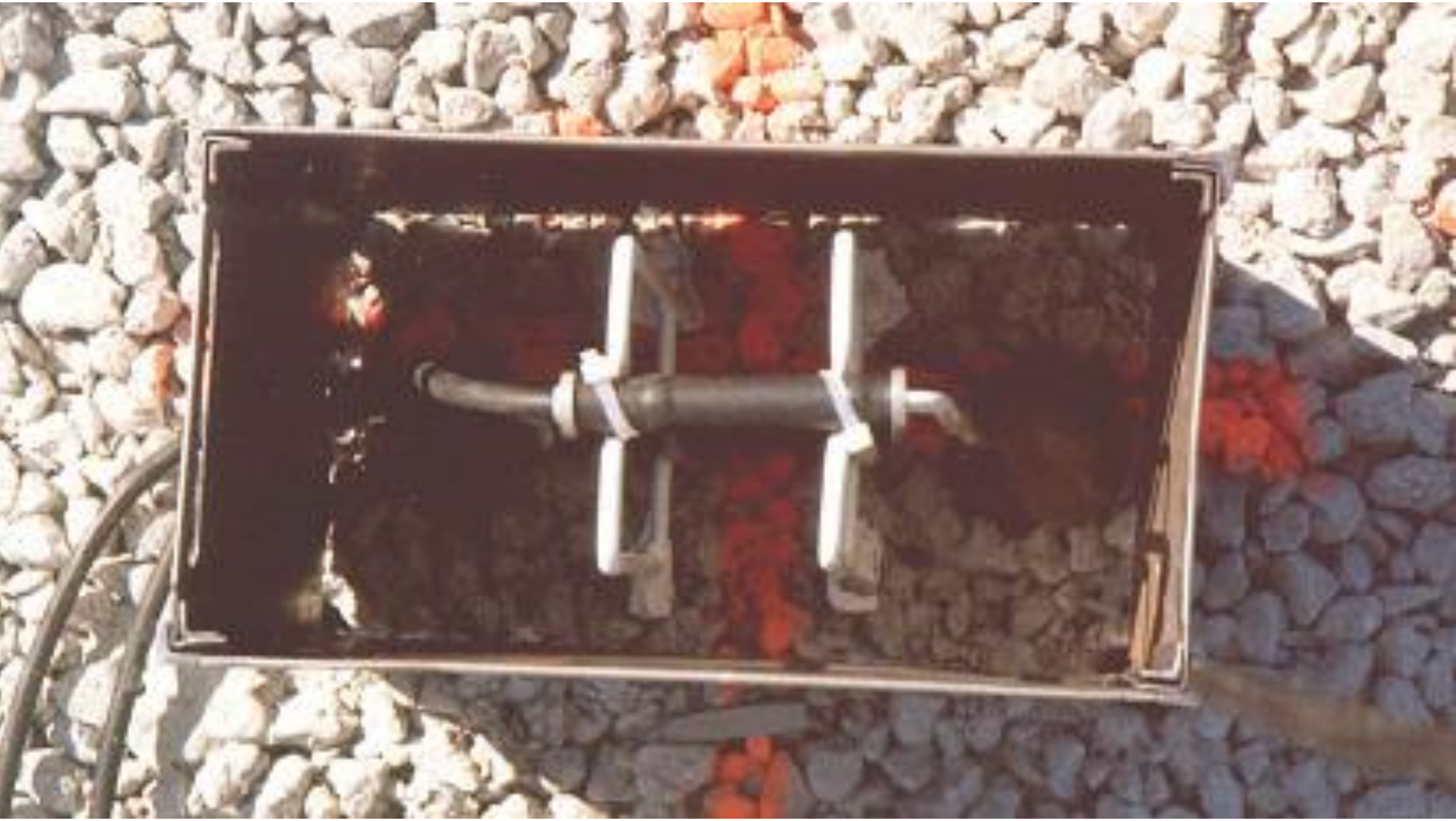
Pavement Response Sensor Installation

Pavement Response Sensor Installation

Dynatest Past II PCC

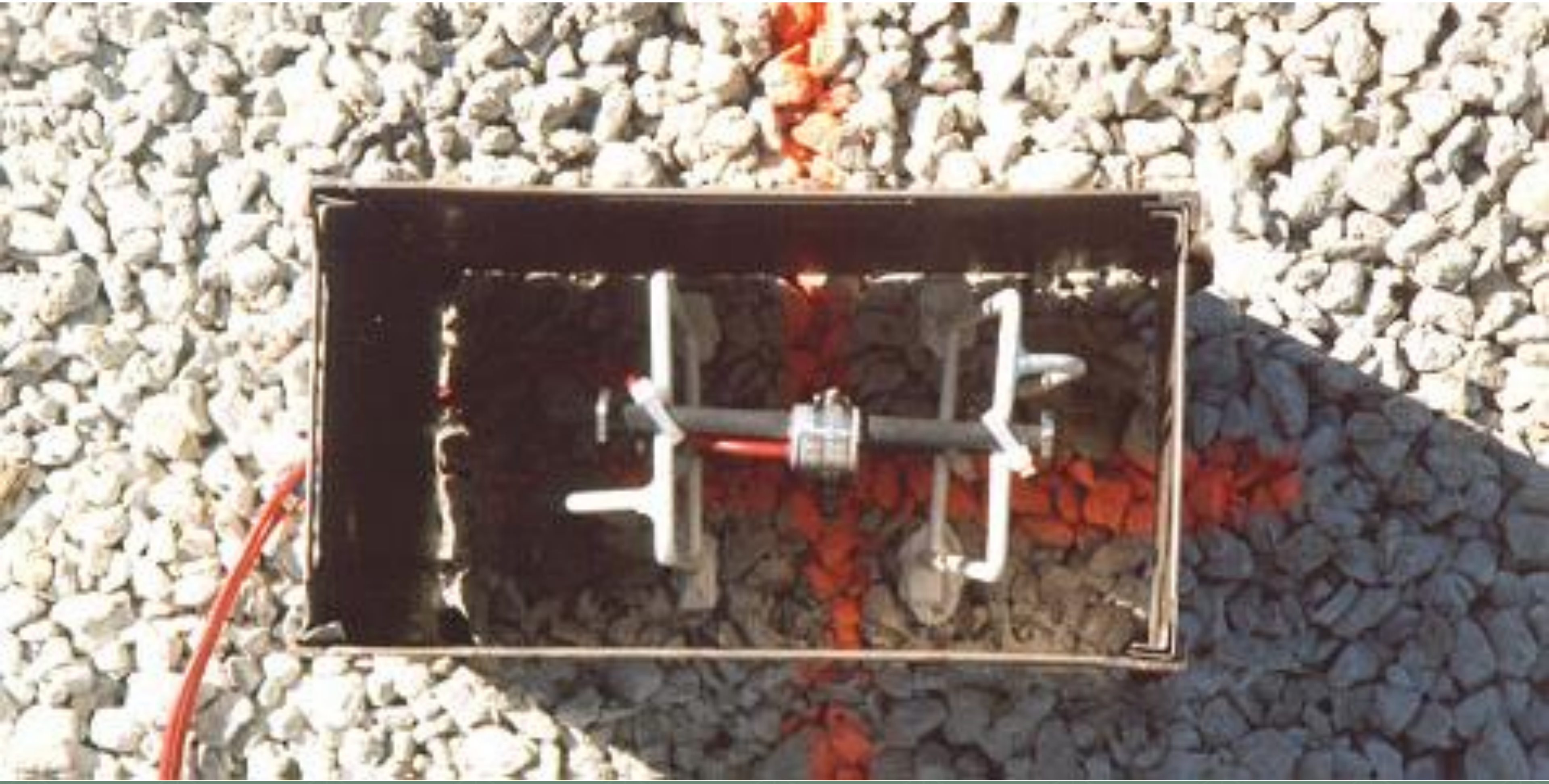


KM100B

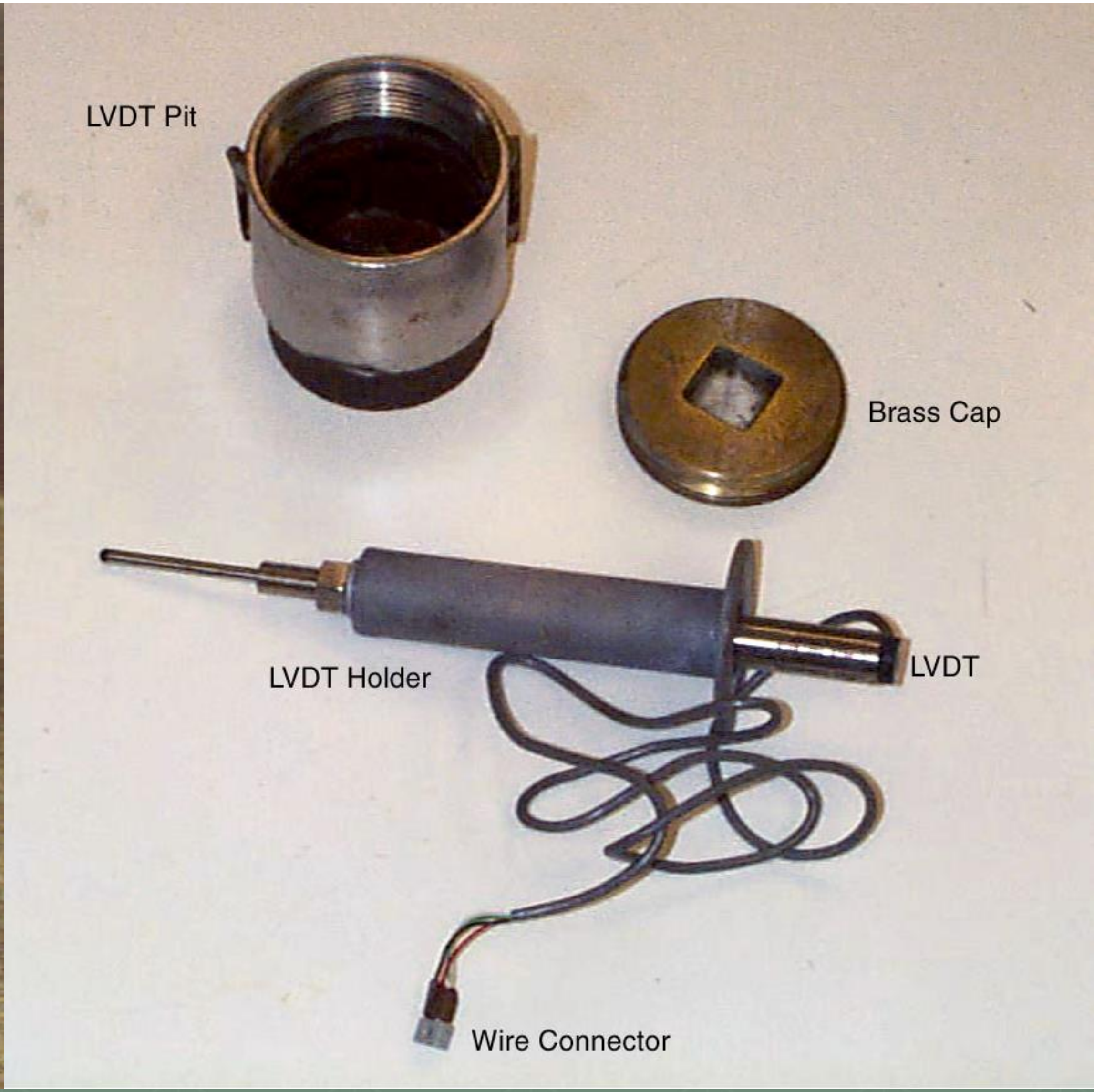


Carlson A8 Strain Meter

Geokon VCE 4200 Vibrating Wire Strain Gauges



LVDTs used in PCC and AC sections



Soil Pressure Cells

Geokon Model 3500

Controlled Load Vehicle Tests

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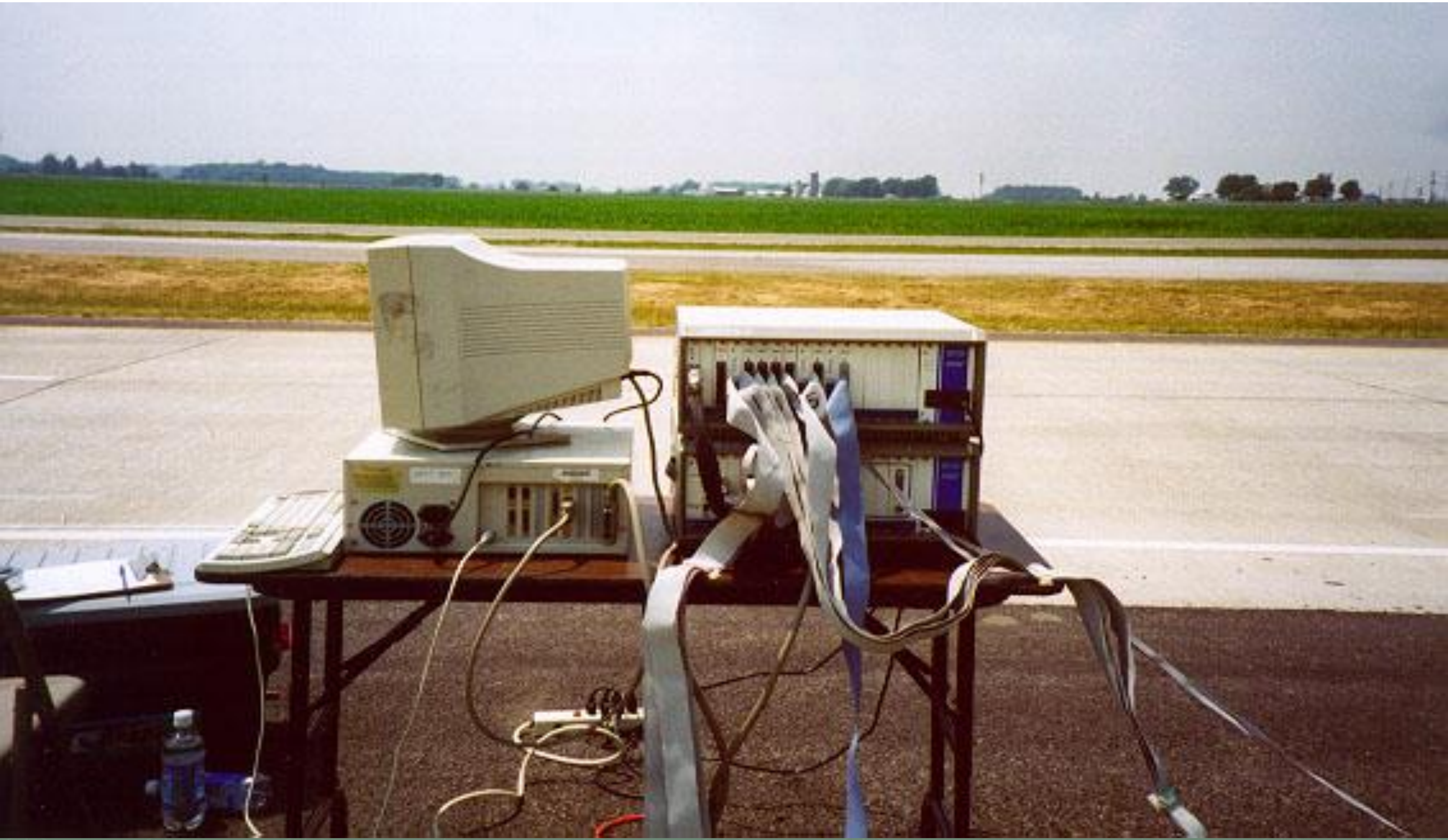
Controlled Load Vehicle Test Series Design

- Select the Sections to be tested
- Select trucks to be used in the tests
- Establish test matrix
- Check strain gauges
- Install and balance LVDTs

Setup

- Adjust air pressure in truck tires
- Load trucks to achieve desired axle weight
- Weigh trucks
  - Individual tires or set of duals
- Measure all tires for print width and geometric positioning on pavement
- Connect data acquisition systems to sensors

Data Acquisition System



Test Procedure

- Spread a thin layer of fine, damp sand in wheel path to measure lateral offset of truck
- Trigger data acquisition system as truck approaches
- Collect 500 samples per second minimum from each sensor
- Measure lateral offset distance in spread sand patch

Tire Marks on Sand Patches

Test Vehicles

Canadian National Research Council Test Truck

ODOT Tandem Axle Dump Truck

Controlled Load Vehicle Test Parameters

Test Date	Test Series	Truck	No. of Truck Passes		No. Sections Monitored		Dynamic Parameters*					
			AC Sections	PCC Sections	AC	PCC	Load	Speed	No. Axles	Axle Spacing	Tires	Vehicle Dynamics
12/5/95 to 3/16/96	I**	CNRC-Tan-Dual	79		1	1	X	X	X	X	X	
		CNRC-Tri-Dual	33									
		CNRC-Tri-SS	32									
8/96	II	Single Dump	41	44	6	5	X	X	X			
		Tandem Dump	59	29								
6/97	III	CNRC-Tan-SS	5		3		Sand Calibration					
		CNRC-Tan-Dual	47	34	7	8	X	X	X	X	X	X**
		CNRC-Tan-SS	55	55								
		CNRC-Tri-SS	20	20								
		Tandem Dump	122	109								
7,8/97	IV	Single Dump	38	39	12	14	X	X	X			
		Tandem Dump	38	39								
10/98	V	Single Dump	24	48	8	9	X	X	X			
		Tandem Dump	12	48								
9/99	VI	Single Dump	43	43	8	8	X	X	X			
		Tandem Dump	43	43								
10/99	VII	Single Dump	30-60 runs/section		7	7	X	X	X			
		Tandem Dump	30-60 runs/section									
		FWD	50 drops/section		7	7						
		Dynaflect	20 readings/section		7	7						
4,5/01	VIII	Single Dump	40	40	10	12	X	X	X			
		Tandem Dump	40	40								
10/03	IX	Single Dump	45	0	3	0	X	X	X			
		Tandem Dump	45	0								

* Pavement temperature, soil moisture and lateral truck position were monitored during each series of tests
**Funded by FHWA

Summary of Concrete Sections in Controlled Load Vehicle Test

	Controlled Vehicle Test Series								
	I	II	III	IV	V	VI	VII	VIII	IX
Date	12/95, 3/96	8/96	6/97	7/97	10/98	9-10/99	Oct-99	4-5/01	10/03
Section	SPS-2								
201		X	X	X	X	X		X	
202			X	X		X		X	
203				X			X		
204			X	X	X		X	X	
205		X	X	X	X	X		X	
206				X		X		X	
207				X			X		
208		X		X	X	X		X	
209		X	X		X				
210			X	X	X	X		X	
211				X			X		
212		X	X	X	X	X		X	
261			X		X		X		
262				X	X	X		X	
263				X			X	X	
264				X			X	X	
	SPS-8								
809	X								

Dynamic Load Response

- Approximately 11,000 axle passes during controlled truck runs
- Over 931,000 sensor readings
- Over 1200 sensors monitored
- Nine test series since 1995

Analysis of Results (example)

Section 390201

- Undrained Section
- 200 mm (8 in) of PCC
- 150 mm (6 in) of ODOT Item 304 Dense Graded Aggregate Base (DGAB)
- 3.66 m (12 ft) wide
- 4.57 m (15 ft) joint spacing

Locations of Relevant Sensors

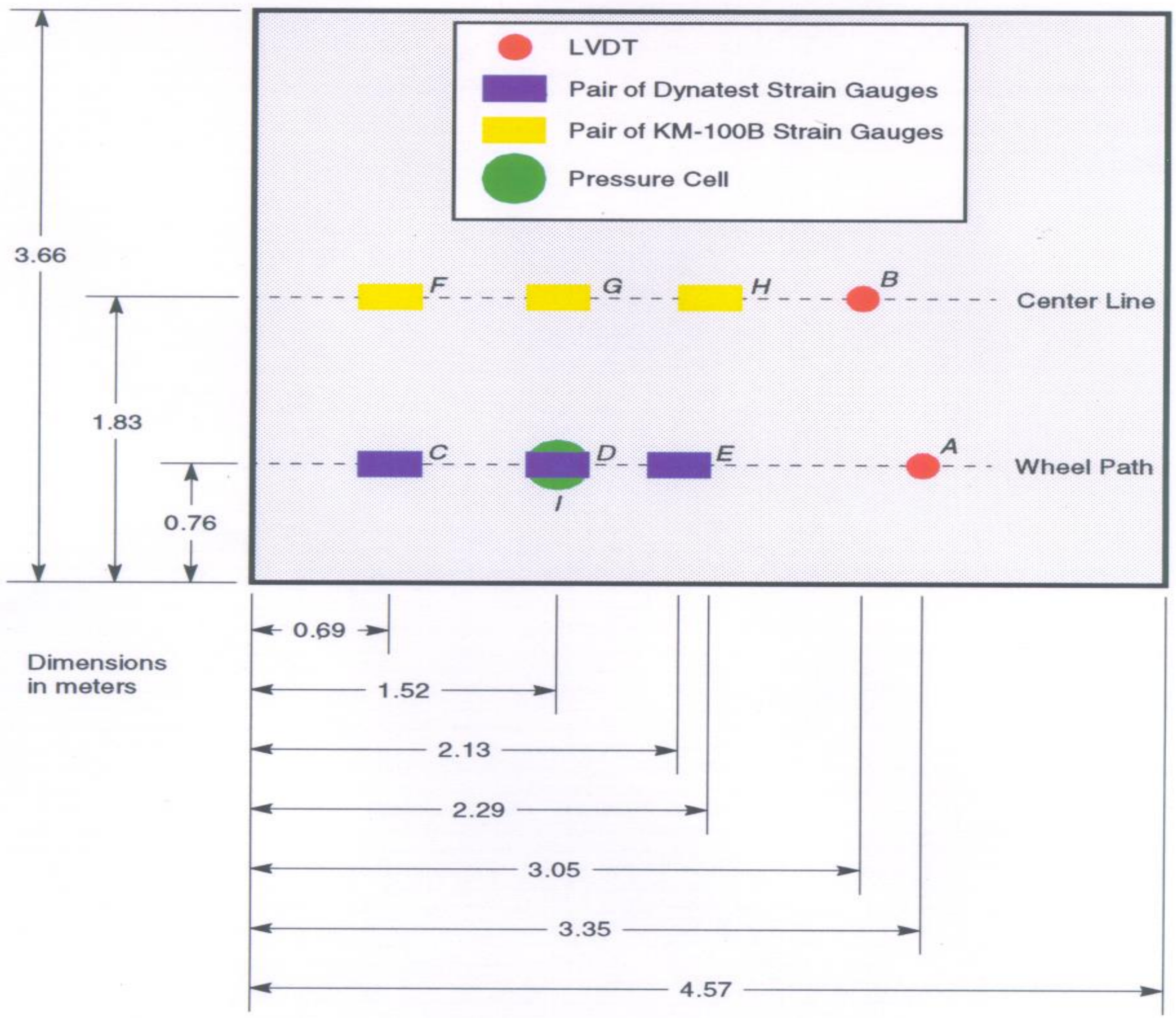
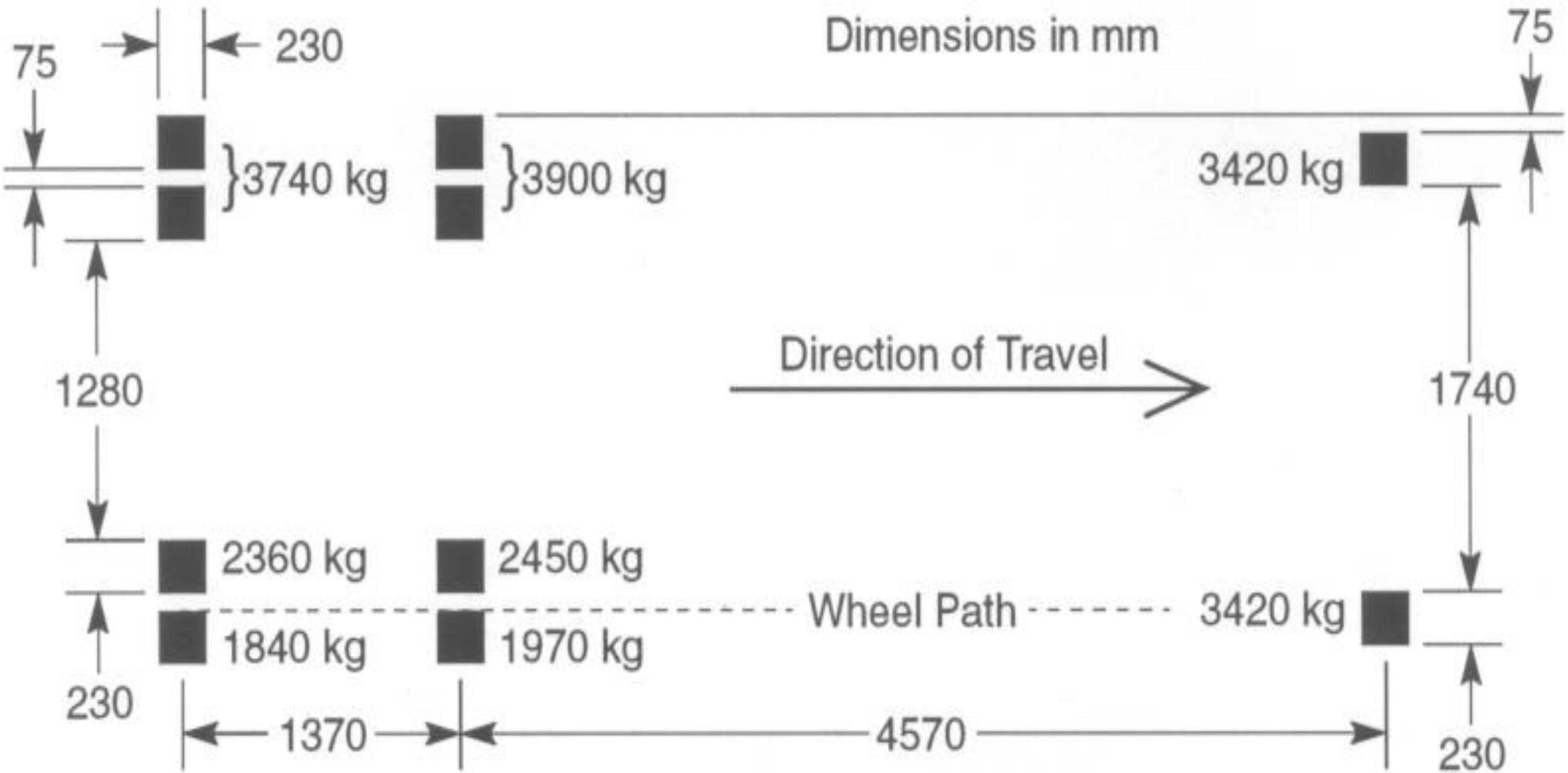


Figure 1: Locations of Sensors in PCC Section 201

Tire Loads for Example



Example Parameters

- Date: July 30, 1997
- Speed: 21.8 m/s (50 mph)
- Total load: 23,000 kg (50,700 lbs)
- Load distribution area: 230 mm (9 in) square
- ODOT tandem axle truck

Finite Element Model (FEM) Parameters

- FEM mesh modeled right half of the lane
- Enforced symmetry along longitudinal center line
- No shoulder was modeled.
  - Untied AC shoulder at the site
- Steel dowels at 305 mm (12 in) intervals
  - Dowel length: 460 mm (18 in)
  - Dowel diameter: 38 mm (1.5 in)

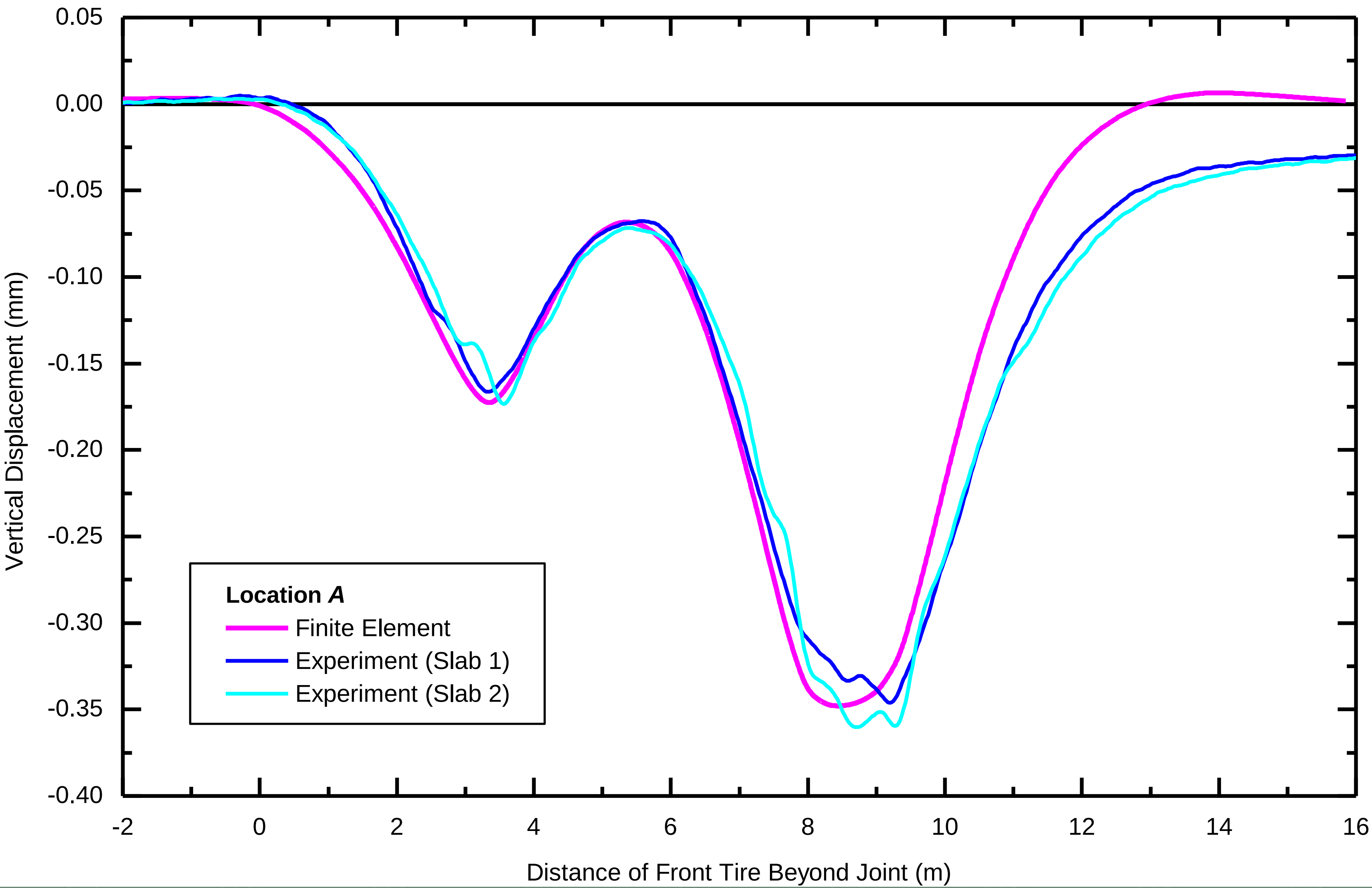
Finite Element Model (FEM) Mesh Parameters

- Mesh extended 2.44 m (8 ft) to the right and 2.44 m (8 ft) below the surface
- Mesh representing jointed pavement extended 6.86 m (22.5 ft) before and after instrumented slab
- Displacement was not permitted at bottom and right boundaries

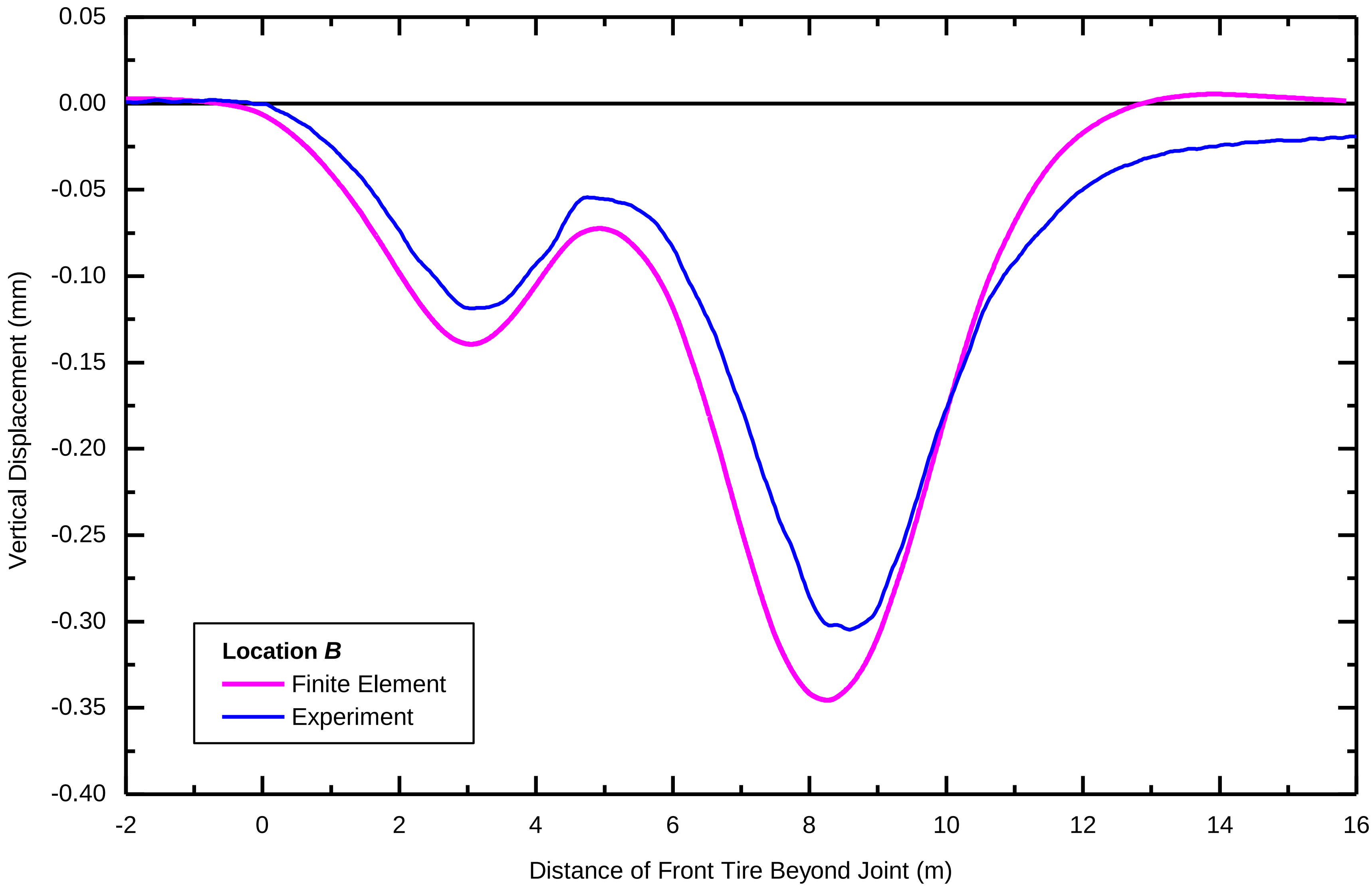
Pavement Parameters
Modulus of Elasticity Used

- Subgrade: 62 MPa (9000 psi)
- Base: 172 MPa (25,000 psi)
- PCC: 34,000 MPa (4,930,000 psi)

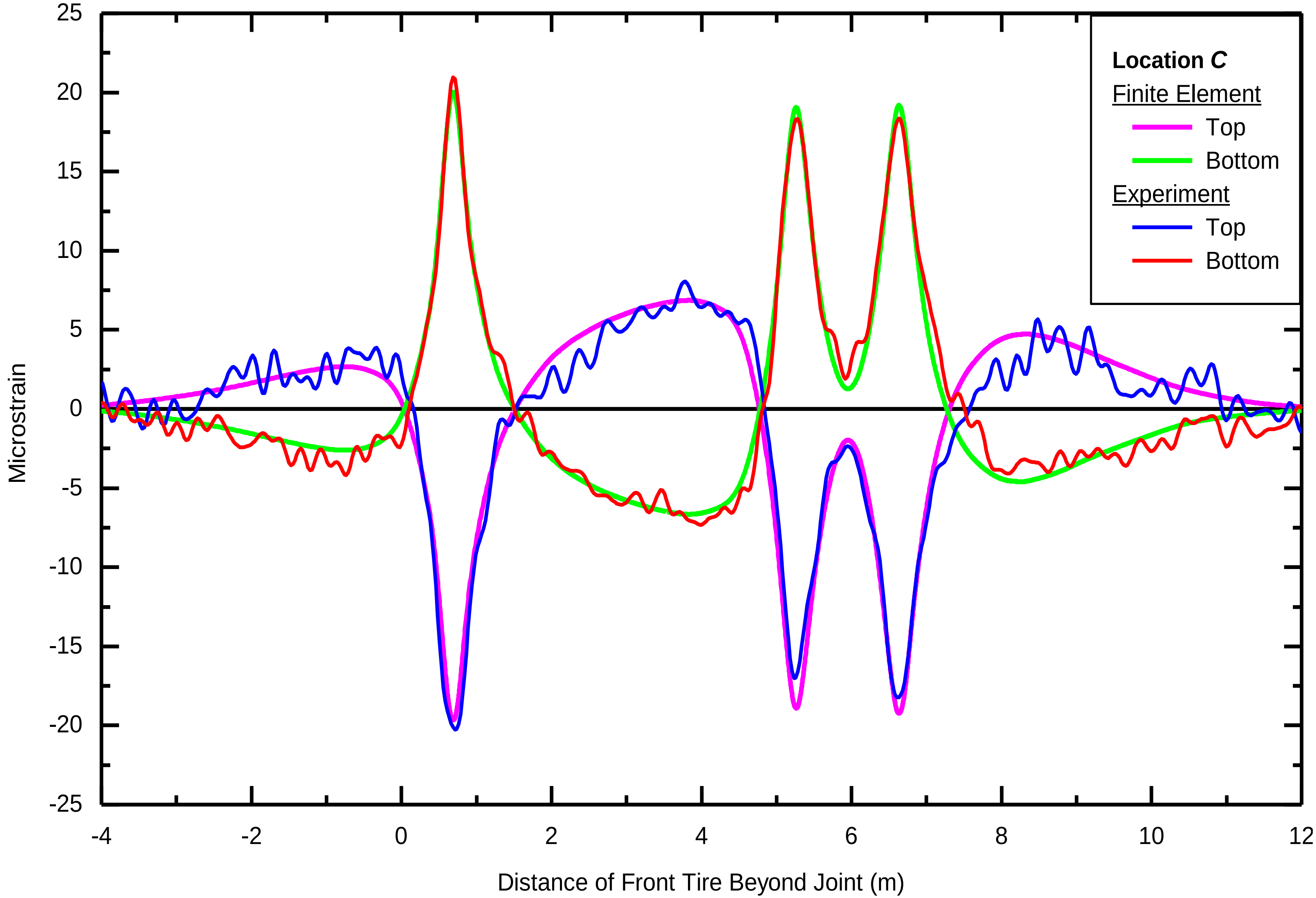
Displacement at Location A



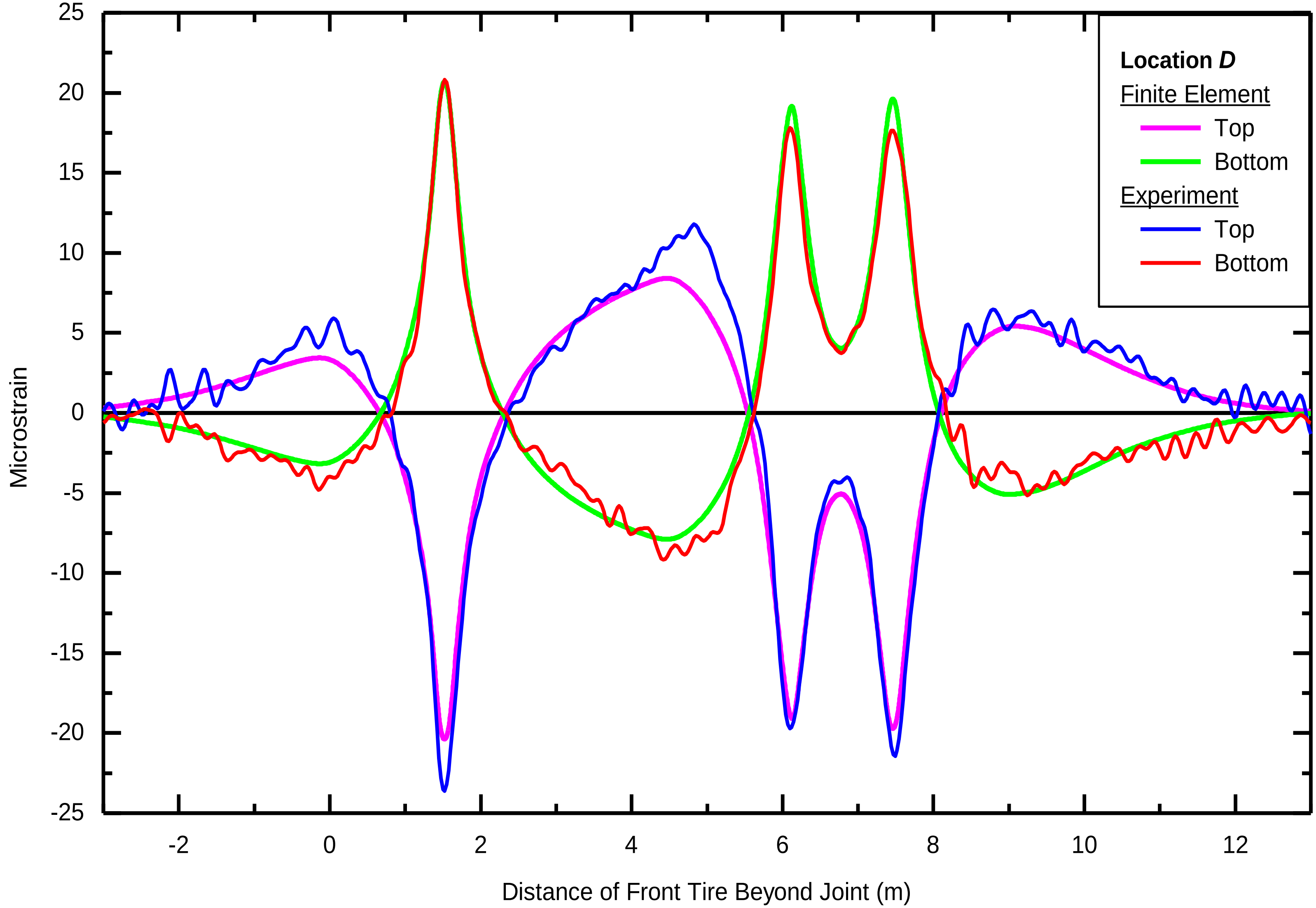
Displacement at Location B



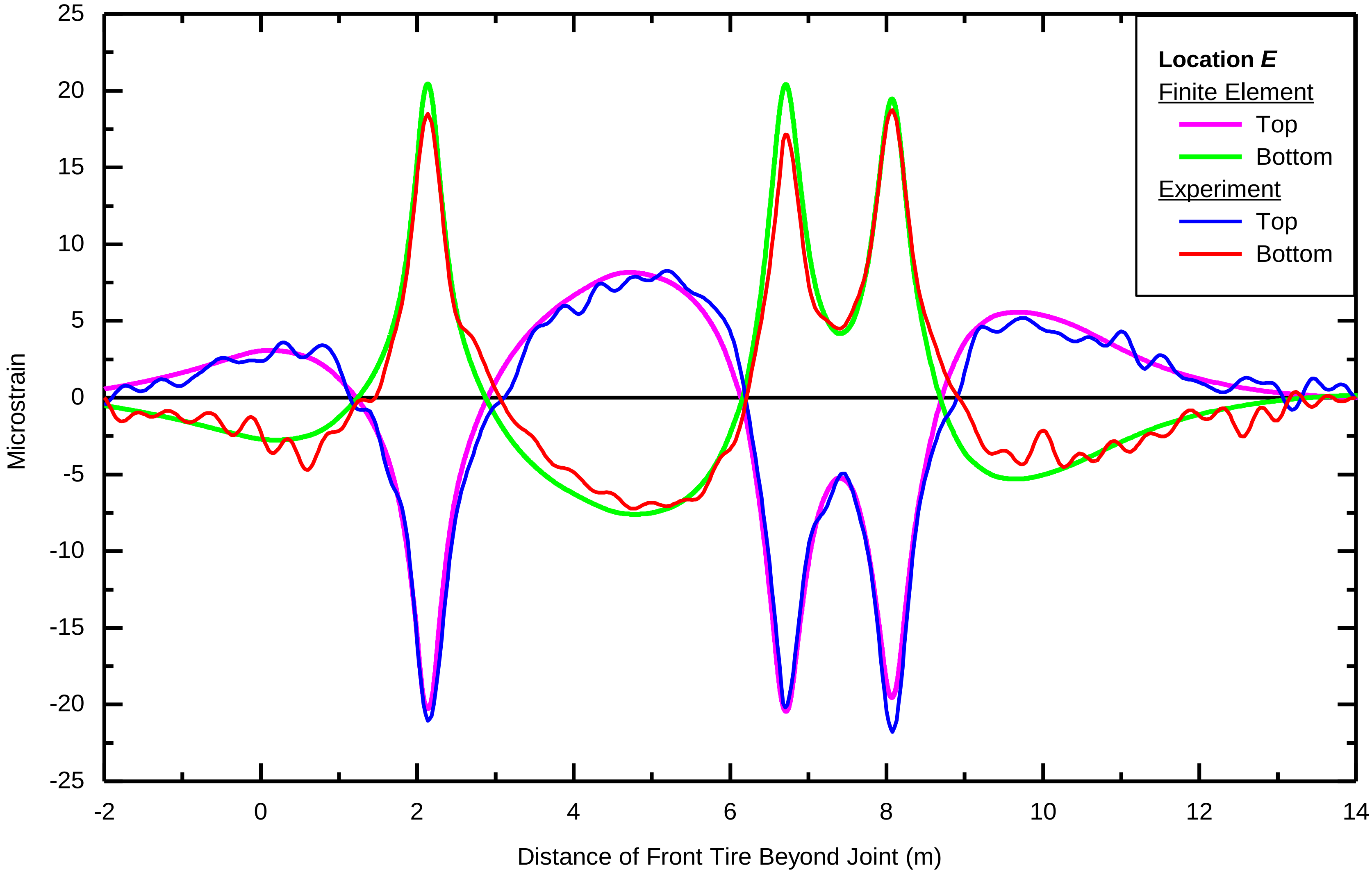
Strains at Location C



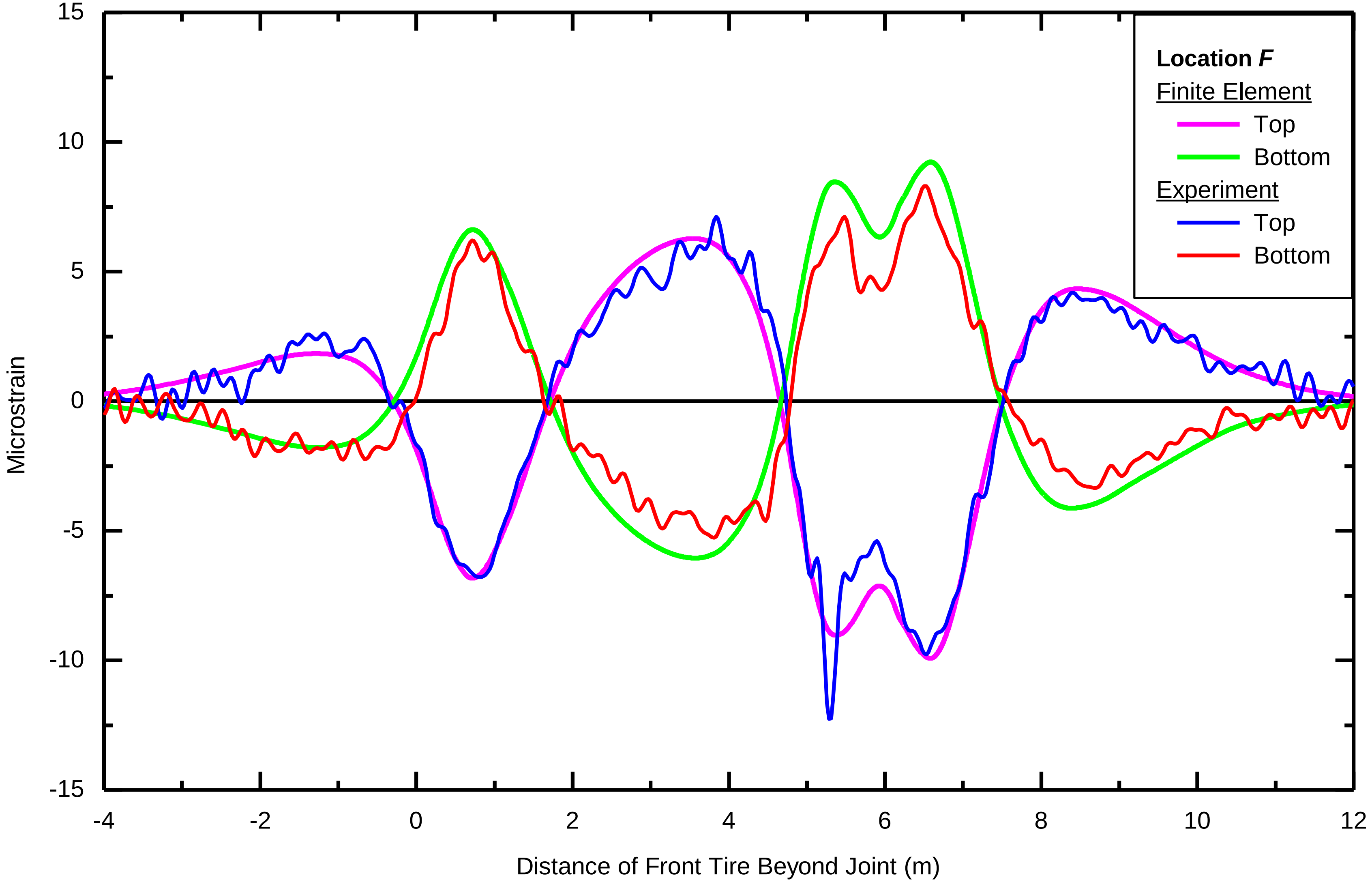
Strains at Location D



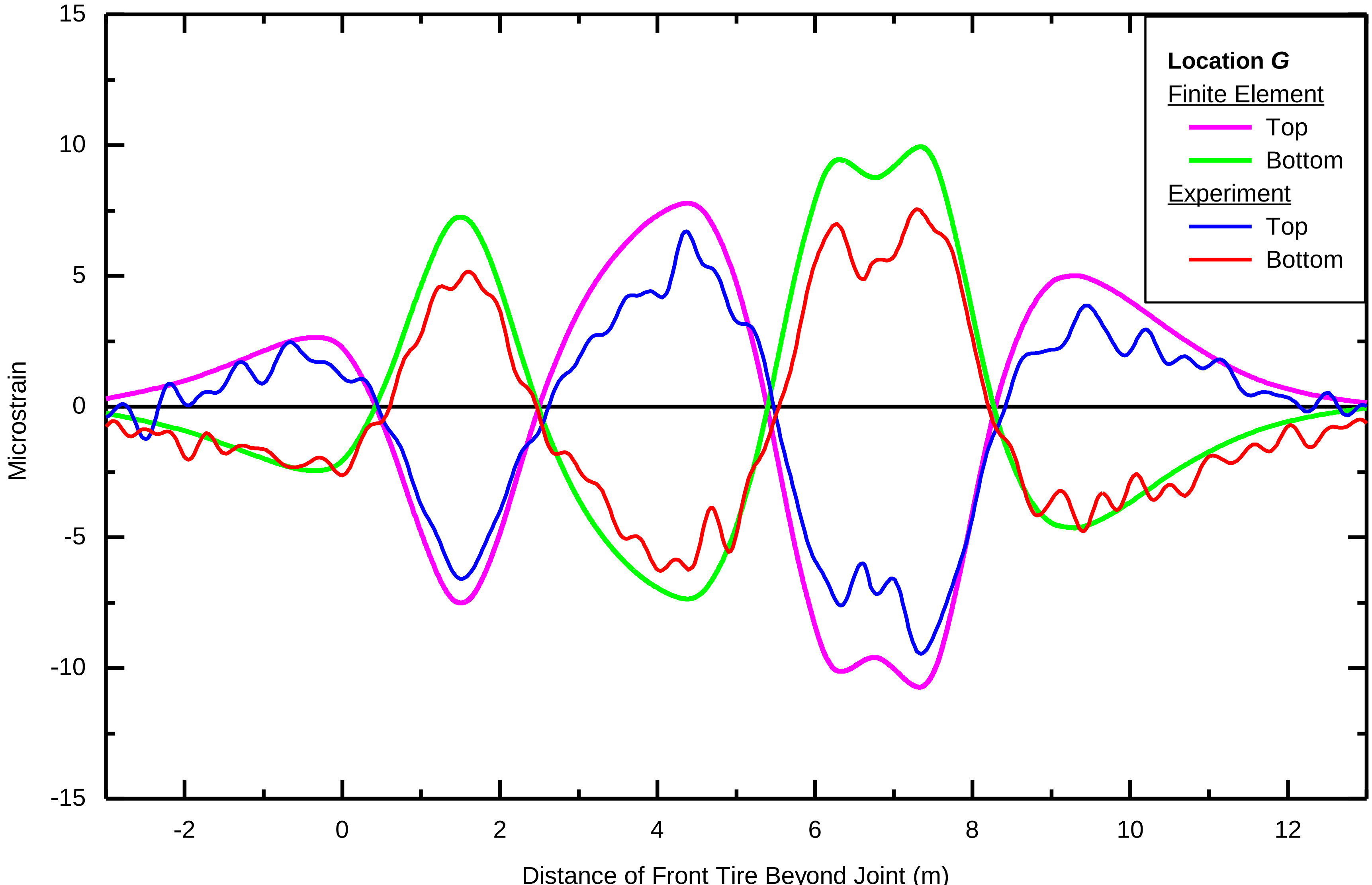
Strains at Location E



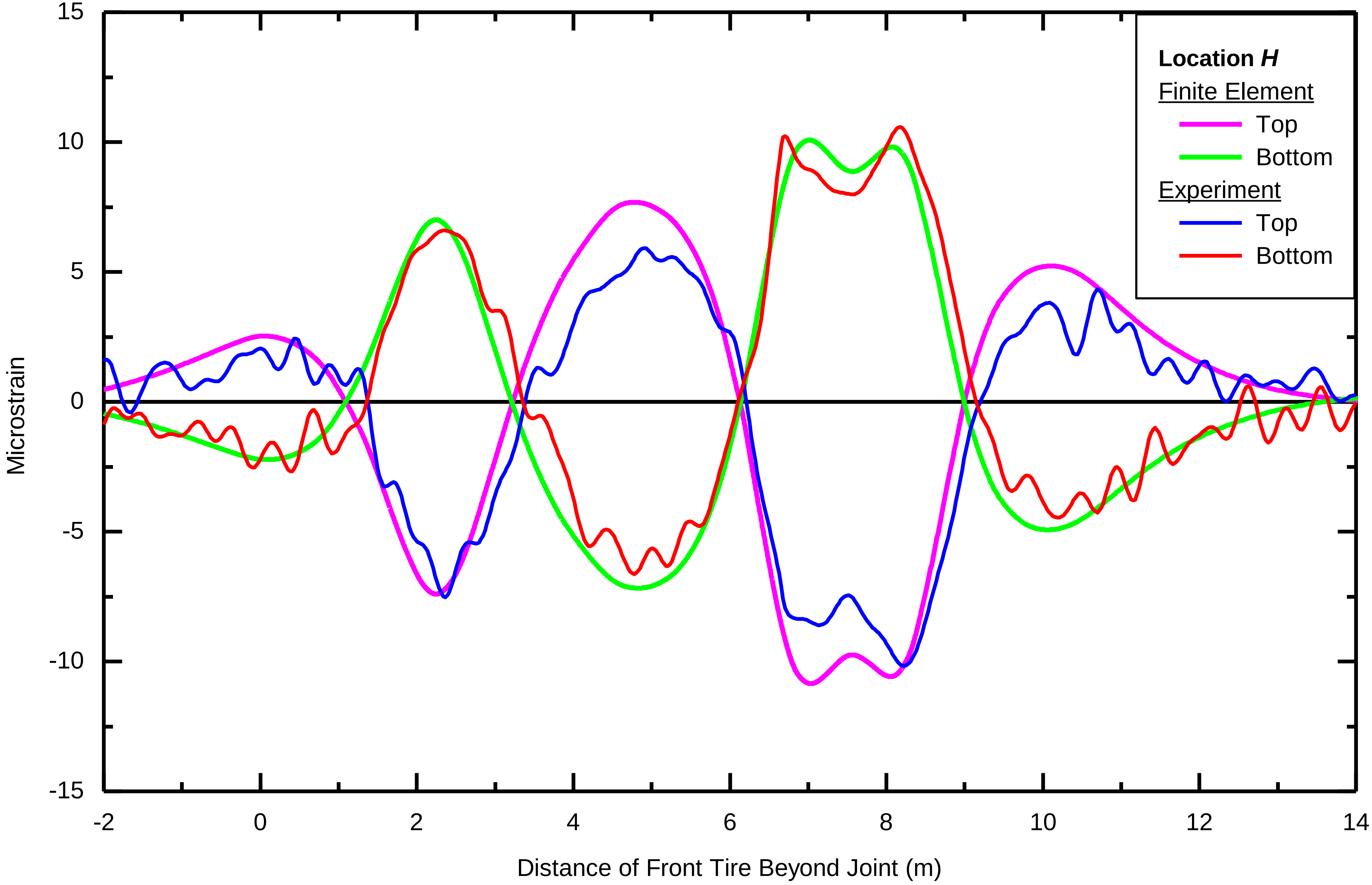
Strains at Location F



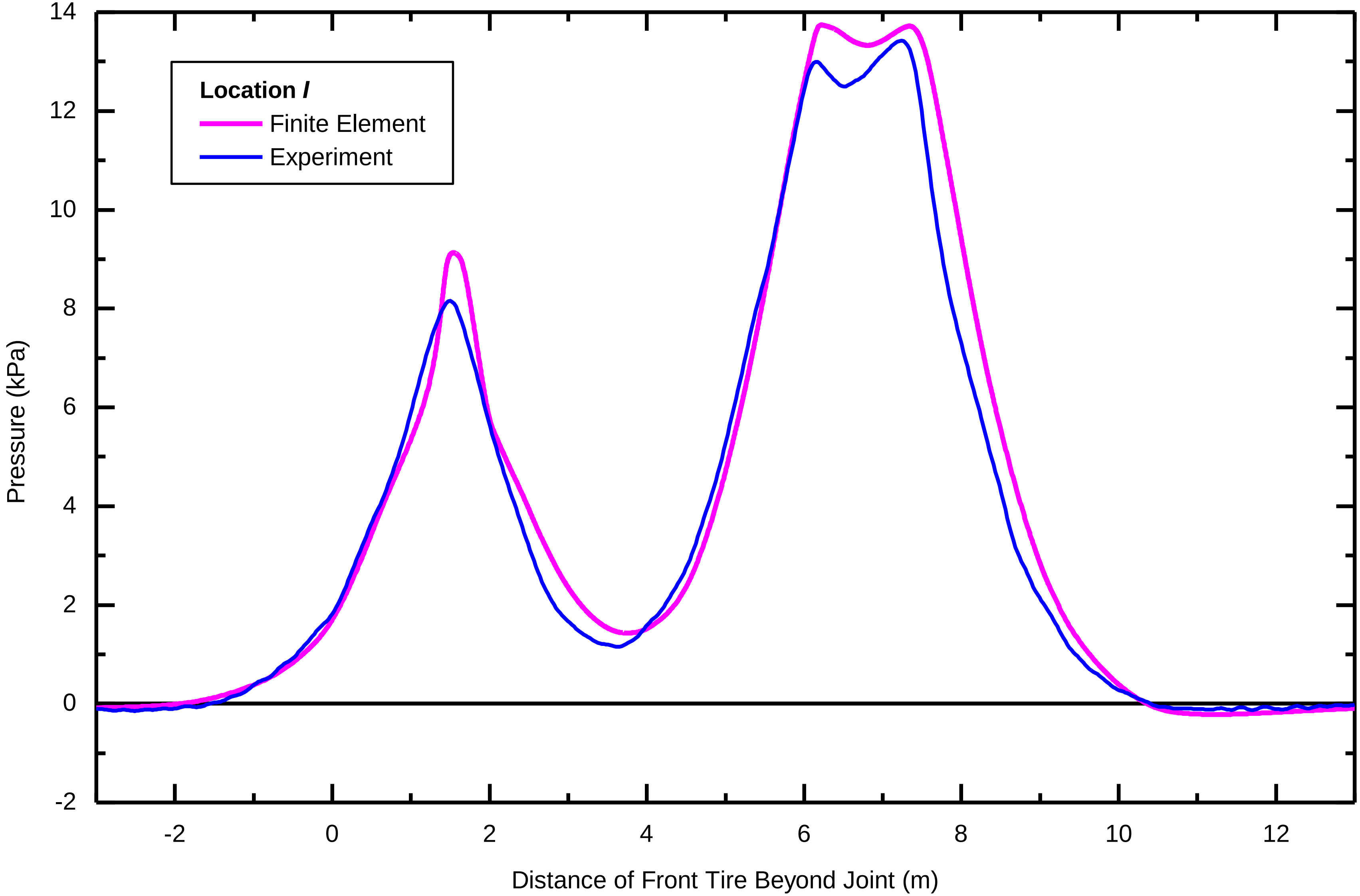
Strains at Location G



Strains at Location H



Pressure at Location I



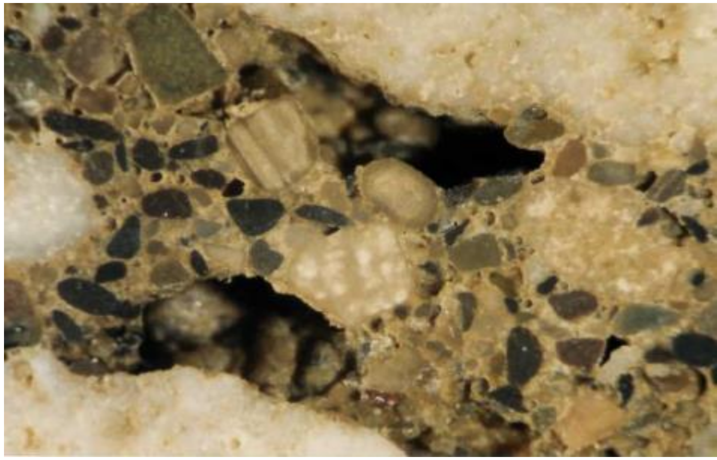
Monitoring and Performance

Monitoring and Performance Analysis Research Projects

- *Continued Monitoring of Instrumented Pavements in Ohio*
  - Report FHWA/OH-2002/035, December 2002
- *Evaluation of Pavement Performance on DEL-23*
  - Report FHWA/OH-2007/05, March 2007
  - Collected data from 2000 – 2005
  - Petrographic analysis of three mixes and lean concrete base
    - Sections 205, 206, 809, and 810

LCB Petrographic Analysis

Approximately half the total air void content in cores LCB-1, LCB-2, and LCB-3 (Section 205) is entrapped air. 70% of the total air void content in LCB-4 (Section 205) represents entrapped air



Characterization Data from LCB Cores LCB-1, 2, 3, and 4

Core	Air Content (%)			Cement Paste Content (%)	Density (lb./ft.^{3})	Depth of Carbonation (mm)
	< 1 mm	> 1 mm	Total			
LCB-1	3.9	3.7	7.6	18.8	141.8	Complete carbonation except for the geometric center of the core
LCB-2	4.9	4.5	9.4	19.0	139.7	Complete carbonation except for the geometric center of the core
LCB-3	4.8	6.2	11.0	16.3	139.3	Complete carbonation except for the geometric center of the core
LCB-4	2.2	5.1	7.3	19.2	143.8	Complete carbonation except for the geometric center of the core

[A] ASTM C 457

Analysis of Cores from DEL23

- 550 PSI Mix: Sections 809 & 810
- ODOT Mix: Section 206
- 900 PSI Mix: Section 205

ODOT Data on Pavement Concrete in Sections 205, 206, 809, and 810

Test Section	Compressive Strength (psi)		Split Tensile or Flexural Strength (psi)		Modulus of Elasticity (10^6 psi)
	28-day	1-year	28-day	1-year	
205	5930 (a)	7915 (a)	545	750	7.3 (b)
206	8165 (c)	8120 (a)	425	620	---
809, 810	2910 (d)	4880 (d)	755 (c)	795 (c)	3.4 to 3.8

(a) Average for three cores (b) 1-year (c) Flexural strength (d) Average for six cores and cylinders

Characterization Data Obtained on Cores PCC-1, 2, 3, and 4

Core	Estimated Water To Cementitious Material Ratio	Air [a] Content (%)	Saturated Density (lb./ft^3)	Cement Paste Content (%)	Depth of Carbonation On Wearing Surface (mm)
PCC-1	0.30	2.5	146.7	35.5	0
PCC-2	0.30	2.2	147.8	35.1	0
PCC-3	0.30	6.6	140.4	35.0	0
PCC-4	0.40	2.5	147.3	27.0	0

(a) ASTM C 457

Sections 809 and 810: 550 PSI Mix

Characterization Data for Cores 809 and 810

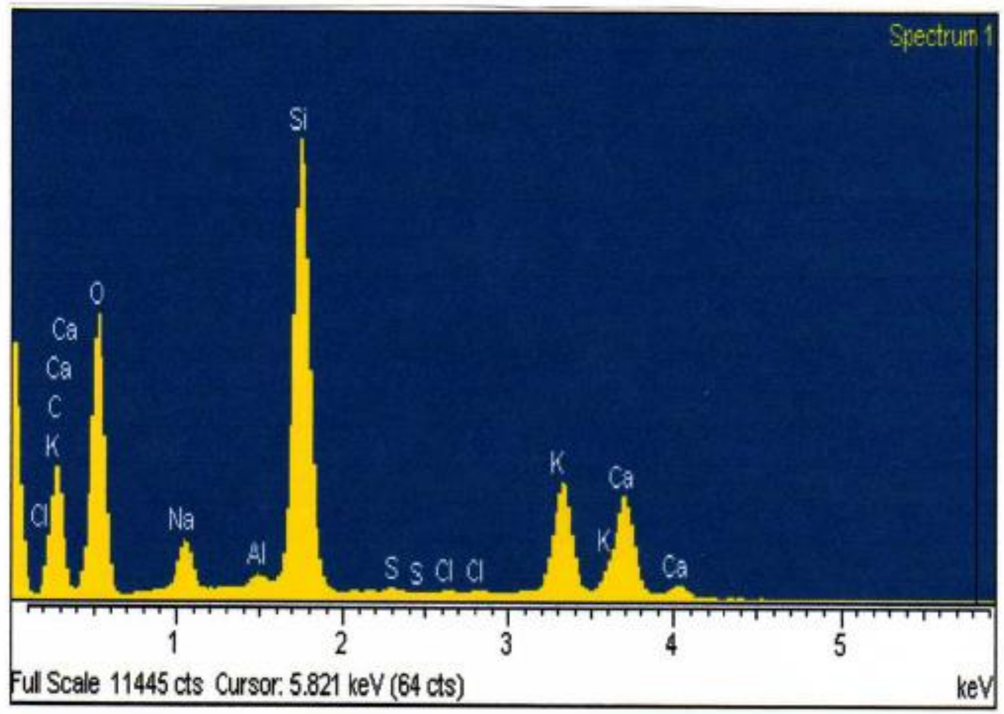
Core	Estimated Water To Cementitious Material Ratio (%)	Air Content (%)			Cement Paste Content	Density (lb./ft^3)	Depth of Carbonation (mm)
		<1 mm	> 1 mm	Total			
809	0.55 - 0.58	4.6	2.8	7.4	20.4	140.5	3 - 6
810	0.45 - 0.52	4.5	2.5	7.0	20.7	140.8	3 - 5

[a] ASTM C 457

Class C Mix, Core PCC-4

900 PSI Mix

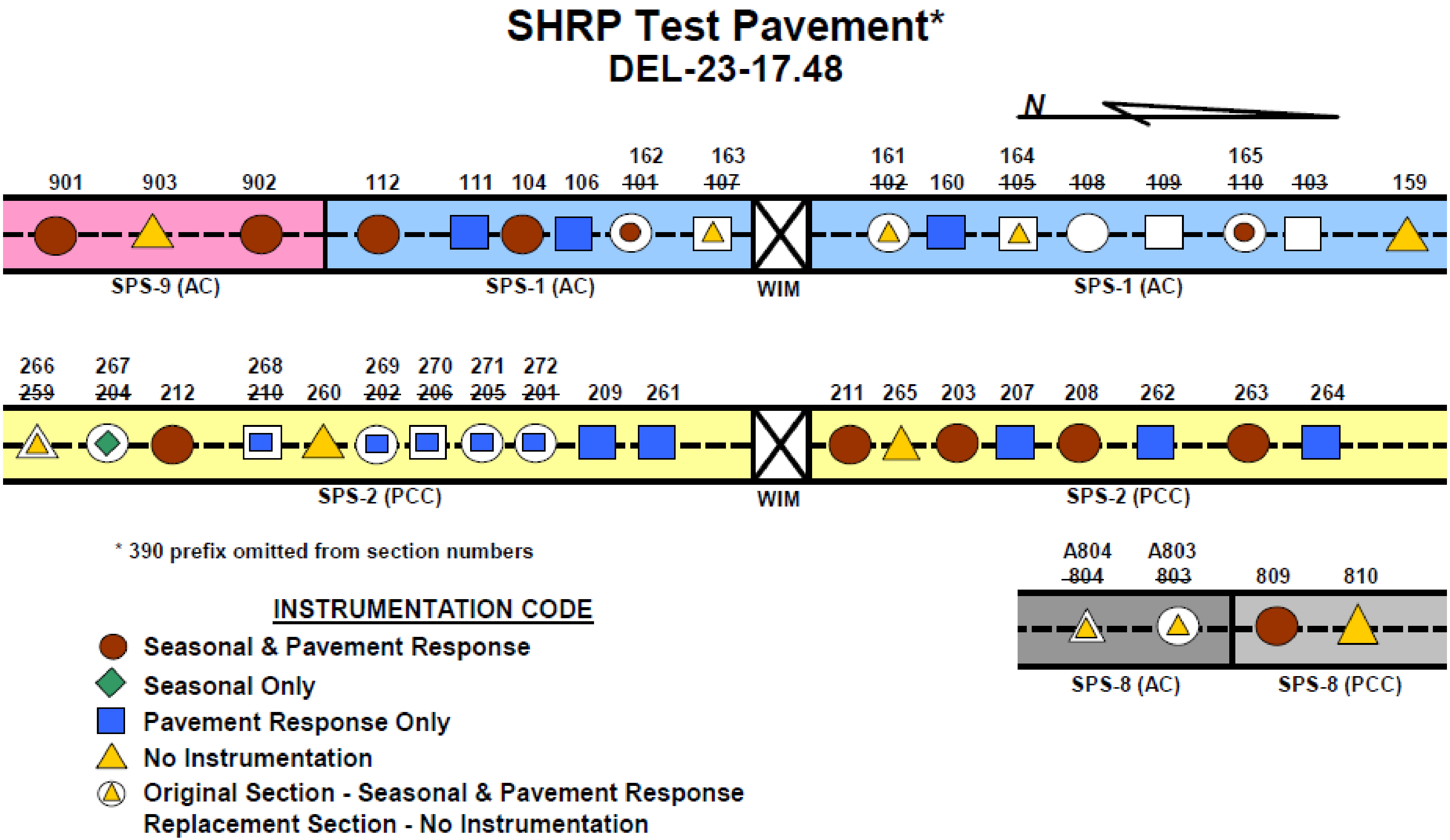
- Energy dispersive X-Ray Spectrum from PCC 1, 2, 3 showed evidence of very mild ASR activity (rims on chert) (Ca, K, and Na in figure)



Element	Weight%	Atomic%	Compd%	Formula	Number of ions
Na K	4.56	4.48	6.15	Na2O	0.61
Al K	0.64	0.53	1.21	Al2O3	0.07
Si K	26.96	21.65	57.68	SiO2	2.97
S K	0.31	0.22	0.77	SO3	0.03
Cl K	0.17	0.11	0.00		0.01
K K	13.04	7.52	15.70	K2O	1.03
Ca K	13.09	7.37	18.31	CaO	1.01
O	41.23	58.13			7.99
Totals	100.00				
				Cation sum	5.74

Figure 6.11 - Energy Dispersive X-ray Spectroscopy (EDS) Spectrum of Material Deposited as Efflorescence - Section 206

Replaced Sections



Tech Note No. 3

- Subgrade moisture was higher at the southern end of the project.

Ohio Research Institute for Transportation and the Environment

ORITE

Subgrade Variability on the Ohio SHRP Test Road

ORITE–3 (ODOT)

Depth of water table below top of pavement 12/17/96 – 1/22/99, meters (feet)

Section No.	Average Depth	Average Elevation	Maximum Depth	Maximum Elevation	Minimum Depth	Minimum Elevation
390103	2.60 (8.52)	(946.85)	3.71 (12.17)	(943.20)	1.96 (6.43)	(948.94)
390108	2.00 (6.56)	(946.79)	2.87 (9.42)	(943.93)	1.57 (5.15)	(948.20)
390102*	1.58 (5.18)	(948.51)	1.90 (6.23)	(947.46)	1.26 (4.13)	(949.56)
390104	1.20 (3.94)	(952.06)	1.71 (5.61)	(950.39)	0.80 (2.62)	(953.38)
390901	2.53 (8.30)	(947.22)	3.48 (11.42)	(944.10)	1.70 (5.58)	(949.94)
390204	2.77 (9.09)	(946.47)	3.30 (10.83)	(944.73)	2.39 (7.84)	(947.72)
390212	1.73 (5.68)	(951.47)	2.12 (6.96)	(950.19)	1.47 (4.82)	(952.33)
390201	1.60 (5.25)	(949.62)	1.77 (5.81)	(949.06)	1.38 (4.53)	(950.34)
390208	2.56 (8.40)	(945.96)	3.60 (11.81)	(942.55)	2.02 (6.63)	(947.73)

*Sensor destroyed after the 3/12/97 reading

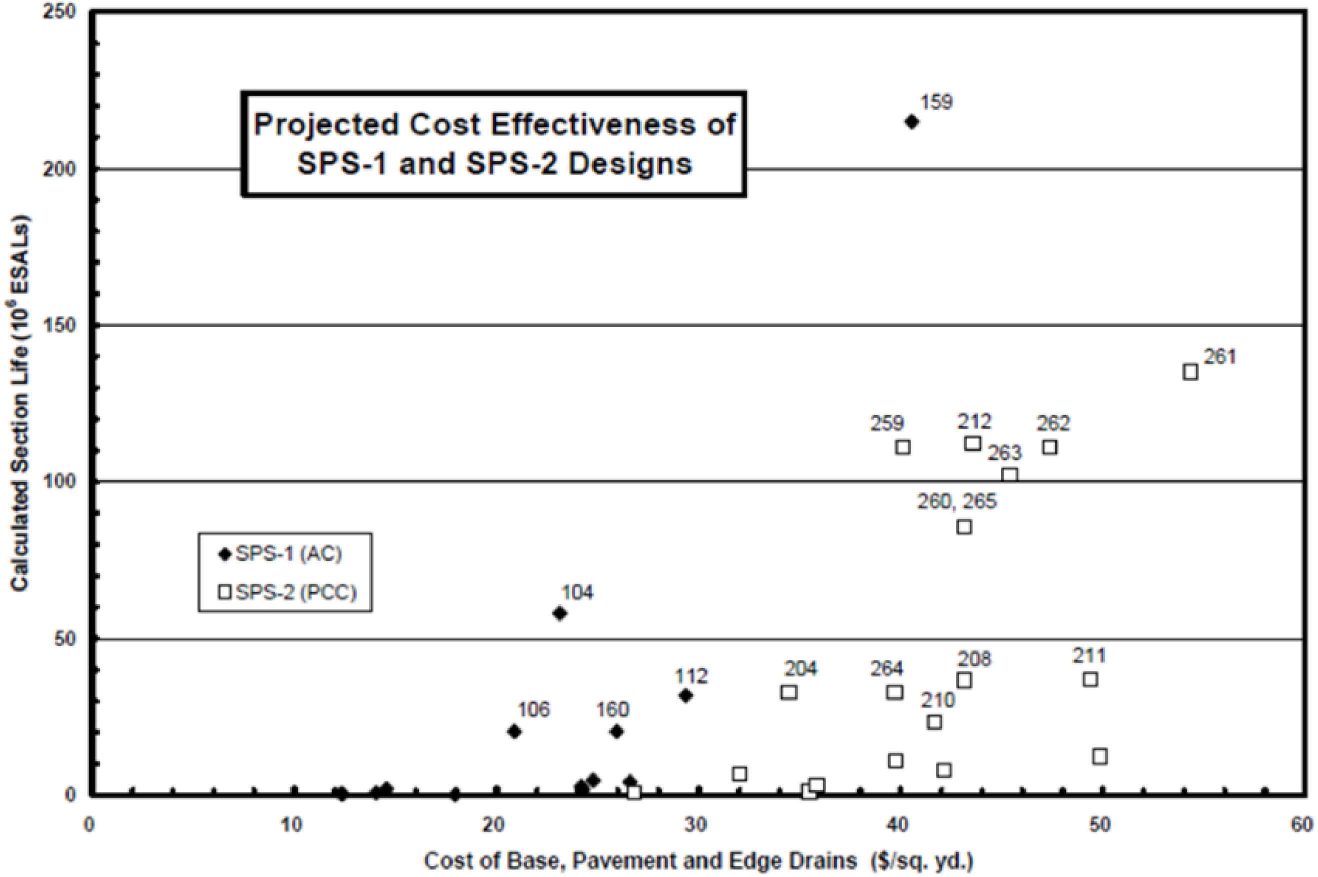
Tech Note No.3

- Average subgrade moduli in the 36 mainline test sections, as determined by the FWD and Boussinesq equation varied from 4.97 to 29.77 ksi with an average of 15.18 ksi.
- The standard deviation was 8.24 ksi and the coefficient of variation was 54%
- This six fold difference in average modulus can have a dramatic effect on performance, especially those designed for limited service.

Section No.	Soil Classification	Nuclear Density Readings			In-Situ Modulus - FWD				
		Dry Unit Weight		Moisture Content (%)	Average		Std. Deviation		CV
		pcf	kg/m3		Mpa	ksi	Mpa	ksi	
SPS-1									
390101		116.8	1870.4	8.9	80.6	11.69	40.1	5.81	0.50
390102		124.6	1995.9	8.3	140.5	20.37	58.3	8.45	0.41
390103		119.8	1919.0	7.7	108.2	15.69	30.2	4.38	0.28
390104		119.7	1918.0	9.2	116.2	16.85	48.7	7.06	0.42
390105		117.6	1883.8	9.7	107.2	15.54	22.8	3.31	0.21
390106		123.4	1976.2	10.0	123.3	17.88	40.9	5.93	0.33
390107	A-7-6	121.3	1942.5	6.8	115.6	16.76	39.4	5.71	0.34
390108		117.4	1881.1	8.5	130.7	18.95	44.0	6.38	0.34
390109		119.7	1917.9	9.7	79.4	11.51	39.2	5.68	0.49
390110	A-4/A-4a	118.0	1889.7	9.7	89.3	12.95	37.5	5.44	0.42
390111	A-6	121.3	1943.6	9.7	124.7	18.08	62.0	8.99	0.50
390112		121.9	1953.2	8.7	95.3	13.82	43.3	6.28	0.45
390159		118.9	1905.1	11.3	39.8	5.77	22.0	3.19	0.55
390160	A-4/A-4a	123.1	1971.8	8.5	128.5	18.63	38.6	5.60	0.30
SPS-9									
390901		126.2	2021.5	9.7	186.0	26.97	99.6	14.44	0.54
390902	A-4/A-4a	122.2	1958.0	10.7	106.9	15.50	47.8	6.93	0.45
390903		126.1	2020.4	8.8	98.8	14.33	41.1	5.96	0.42
SPS-2									
390201		119.6	1916.3	11.1	62.4	9.05	28.6	4.15	0.46
390202	A-6	124.6	1995.4	10.4	123.4	17.89	70.0	10.15	0.57
390203		120.4	1928.6	8.4	103.0	14.94	28.2	4.09	0.27
390204		124.5	1994.3	9.8	205.3	29.77	95.4	13.83	0.46
390205	A-6	118.6	1899.3	11.0	64.3	9.32	37.1	5.38	0.58
390206		120.0	1921.7	10.1	87.8	12.73	46.1	6.68	0.53
390207	A-6	120.9	1936.1	8.2	117.8	17.08	36.2	5.25	0.31
390208		115.2	1845.3	9.3	112.7	16.34	39.0	5.66	0.35
390209		118.1	1891.8	11.7	71.6	10.38	54.1	7.84	0.76
390210		116.0	1858.7	8.8	71.1	10.31	31.4	4.55	0.44
390211	A-6	119.7	1917.4	9.4	109.3	15.85	21.2	3.07	0.19
390212		126.0	2017.8	9.2	140.9	20.43	49.0	7.11	0.35
390259		115.0	1842.1	8.7	79.0	11.46	33.9	4.92	0.43
390260		121.4	1945.2	11.6	101.5	14.72	41.6	6.03	0.41
390261		120.7	1933.9	9.0	124.1	17.99	43.9	6.37	0.35
390262	A-6	120.4	1929.7	8.9	107.8	15.63	42.6	6.18	0.40
390263		119.4	1912.6	11.3	93.7	13.59	42.7	6.19	0.46
390264		112.4	1799.9	13.4	34.3	4.97	15.8	2.29	0.46
390265		121.9.	1953.2	8.6	88.7	12.86	18.3	2.65	0.21
	Average	120.7	1930.8	9.6	104.7	45.18	42.5	6.16	0.41
	Std. Dev.	4.3	68.6	1.8	56.8	8.24			
	Coef. Of Var.	0.04	0.04	0.18	0.54	0.54			

Evaluation of Pavement Performance

- Estimates of construction costs and predicted service life show Section 259 to be the most cost effective PCC section.



- PCC sections containing high strength concrete had skid numbers in the low thirties, while sections with standard concrete had skid numbers in the low forties. This ten point difference can be an important safety consideration

Evaluation of Pavement Performance

- Fracture planes in the PCC cores were oriented perpendicular to the plane of the wearing surface. There was actually more than one crack involved, and these cracks exhibited a significant amount of branching. The cracks passed through, rather than around, coarse aggregate particles. The nature of this cracking indicated that it was a fatigue failure which occurred as a result of repeated stress applications over a period of time. These cracks were initiated at the slab surface and propagated down into the slab

Evaluation of Pavement Performance

- Top-down slab cracking requires either a failure of the base material, and/or curling of the PCC slab. Observations made in the laboratory, as well as data generated at the project site, suggested that slab curling caused by differential temperatures and/or moisture through the slab was the most likely cause of the cracking
- The 8 inch and 11 inch thick PCC slabs on lean concrete base (LCB) were the first to exhibit longitudinal cracking.

TPI Pooled Fund Study

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TPI Pooled Fund Study

- *Truck/Pavement/Economic Modeling and In-Situ Field Data Analysis Applications*
  - Report FHWA/OH-2006/3A, March 2007
  - Volume 1: Influence of Drainage on the Selection of Base

TPI Pooled Fund Study: Subgrade Moisture

- GB variation 2 to 4 % (Ohio data)
- GB variation 1% (NC data)
- PATB and LCB 2 to 4% (all data)
- LCB magnitude of variation is site dependent (2% to 9%)

TPI Pooled Fund Study: Subgrade Moisture Conclusions

- GB, ATB, PATB same (Ohio & NC data)
- LCB is highly variable (Ohio & NC data)
- Unable to establish effect of base from LTPP database (DataPave)
- LTPP data (Ohio & NC) did not support the hypothesis that base type affects subgrade moisture contents

Subgrade Moisture – Tech Note No. 9

- Pavement type does not appear to have an appreciable effect on the volumetric moisture content (VMC) of the subgrade
- VMC data shows, in most cases, a slight reduction in moisture close to the subgrade surface when longitudinal drains are present


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Pavement Design Feature Effects on Subgrade Volumetric Moisture Content

ORITE–9 (ODOT)

Subgrade Moisture – Tech Note No. 9

- VMC data show, in most cases, a slight reduction in moisture close to the subgrade surface when longitudinal drains are present

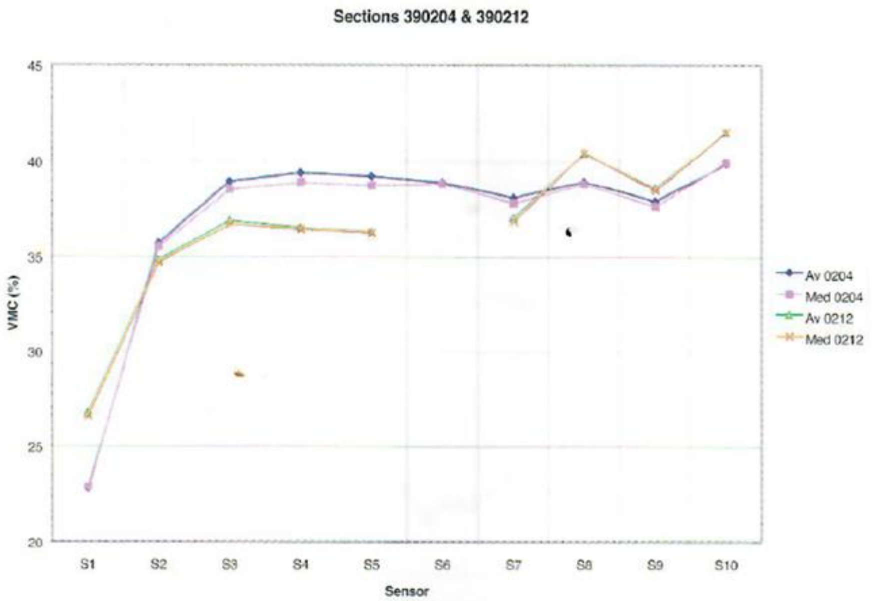


Figure 5. Average and Median VMC (Sections 390204 & 390212)

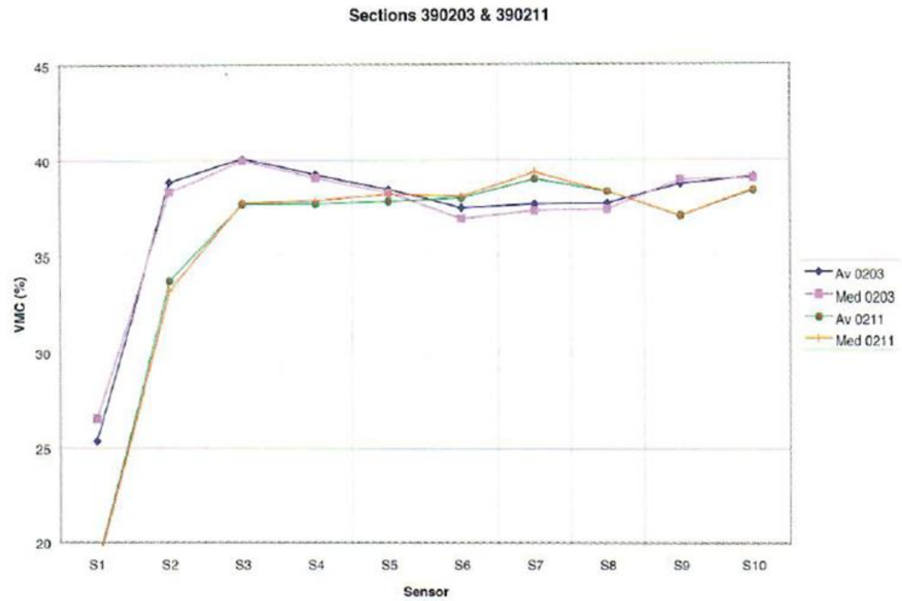


Figure 6. Average and Median VMC (Sections 390203 & 390211)

Subgrade Moisture – Tech Note No. 9

- Sections with DGAB tended to have a higher VMC through the subgrade when other factors were removed from the comparison

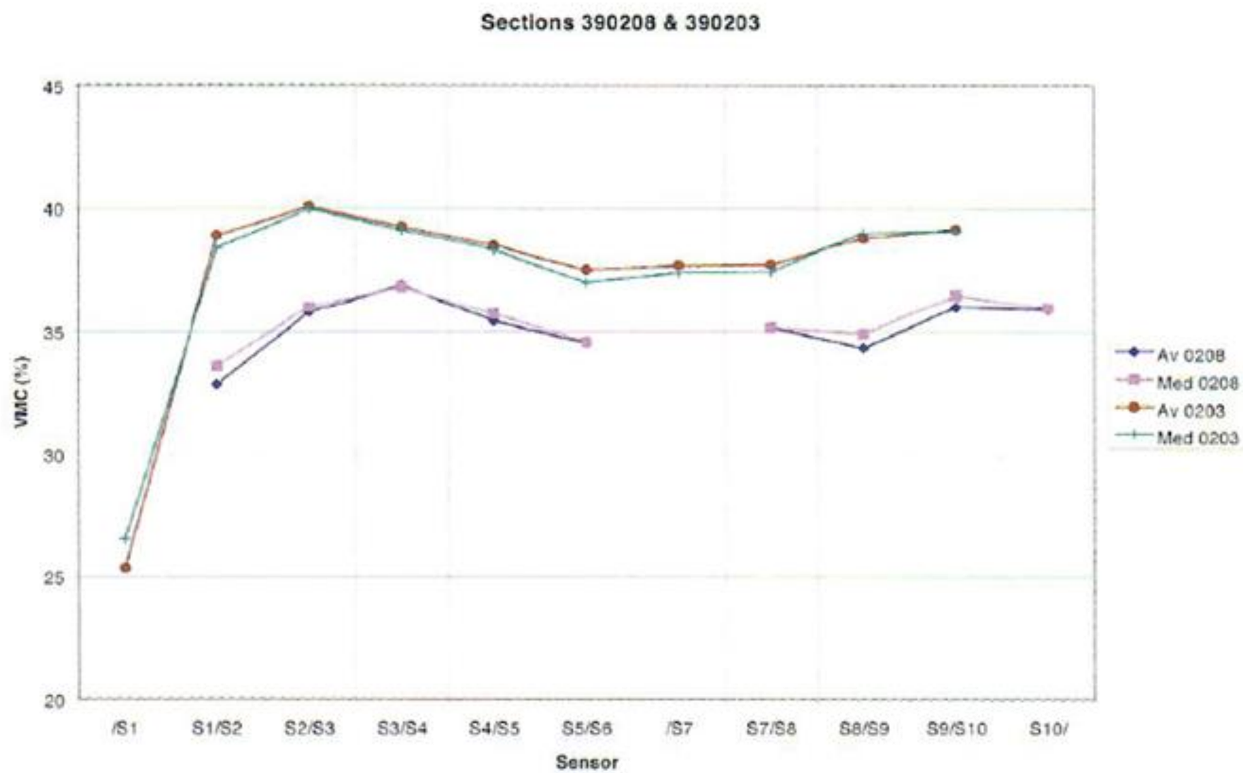


Figure 7. Average and Median VMC (Sections 390208 & 390203)

Subgrade Moisture – Tech Note No. 9

- Subgrade moisture experiences annual cycles
  - Maximum values in July-August
  - Minimum values occurring in January-February

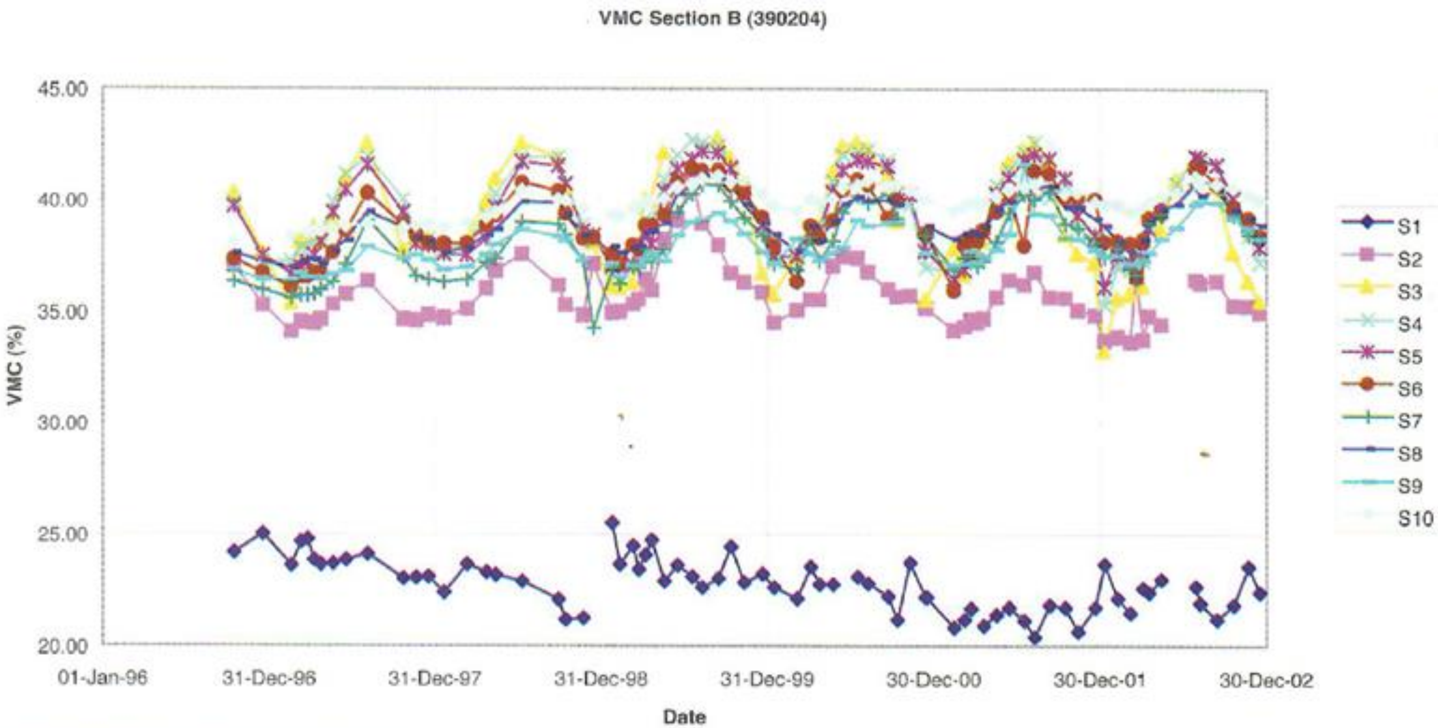
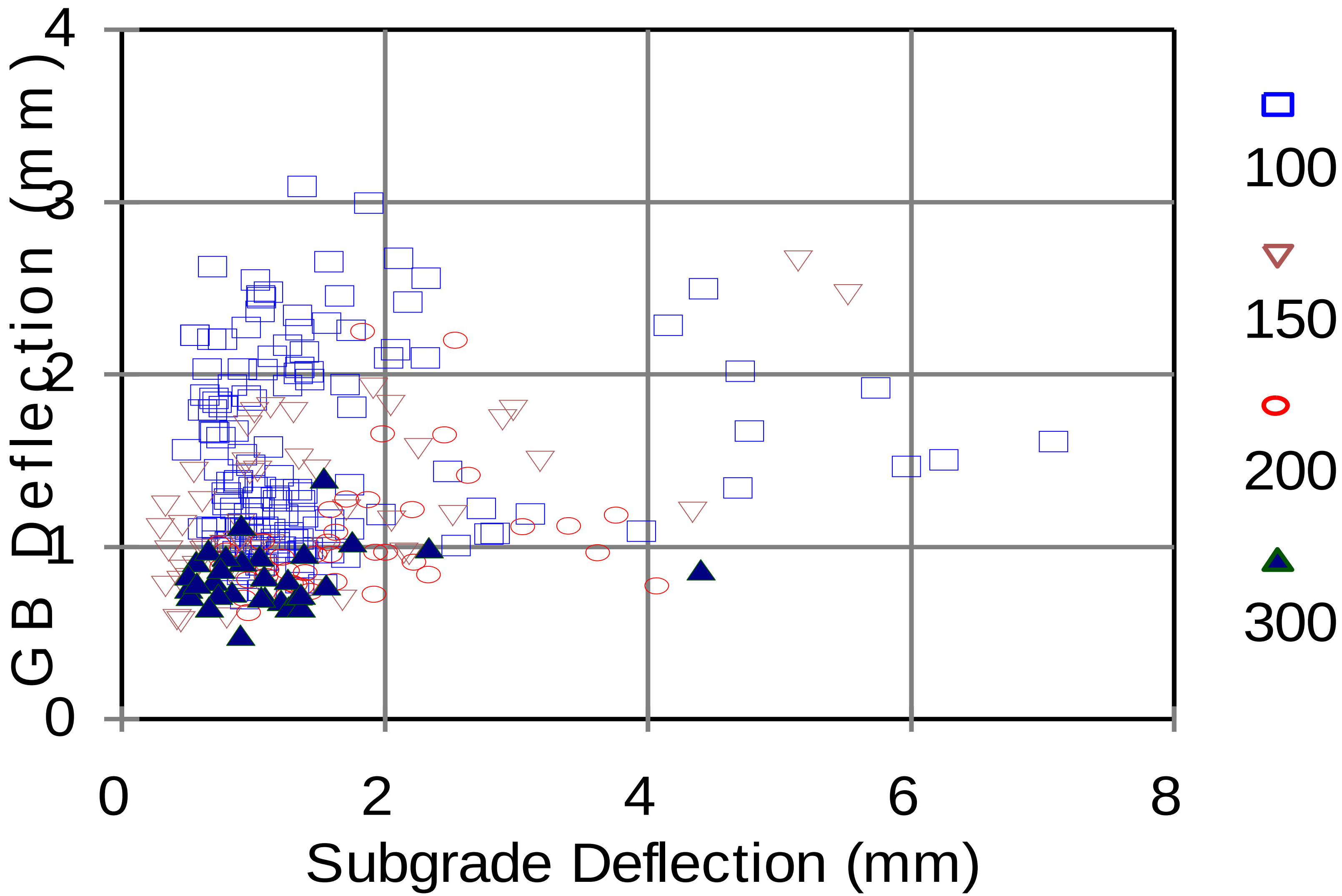
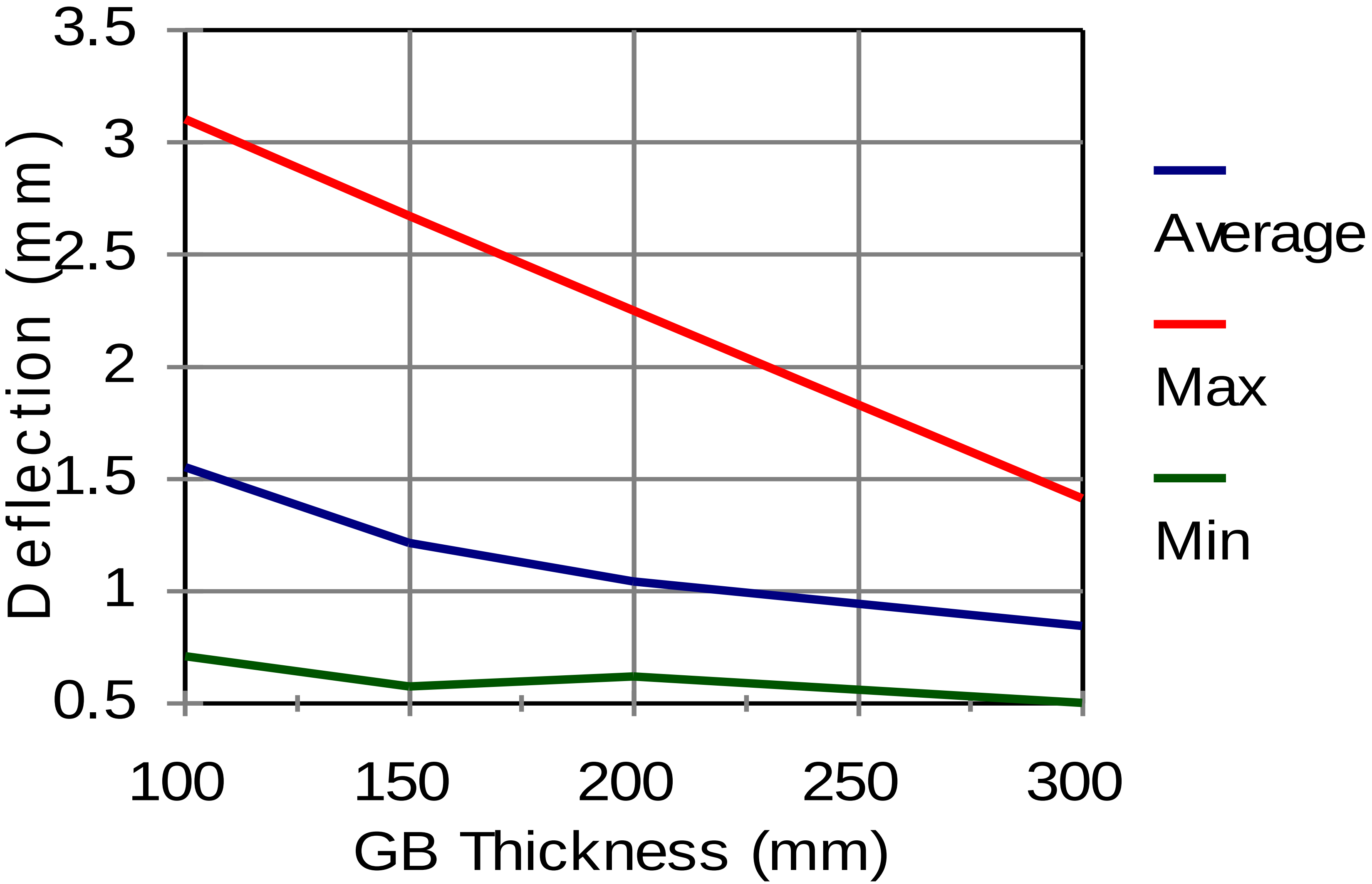


Figure 1. VMC Time Series for Section 390204

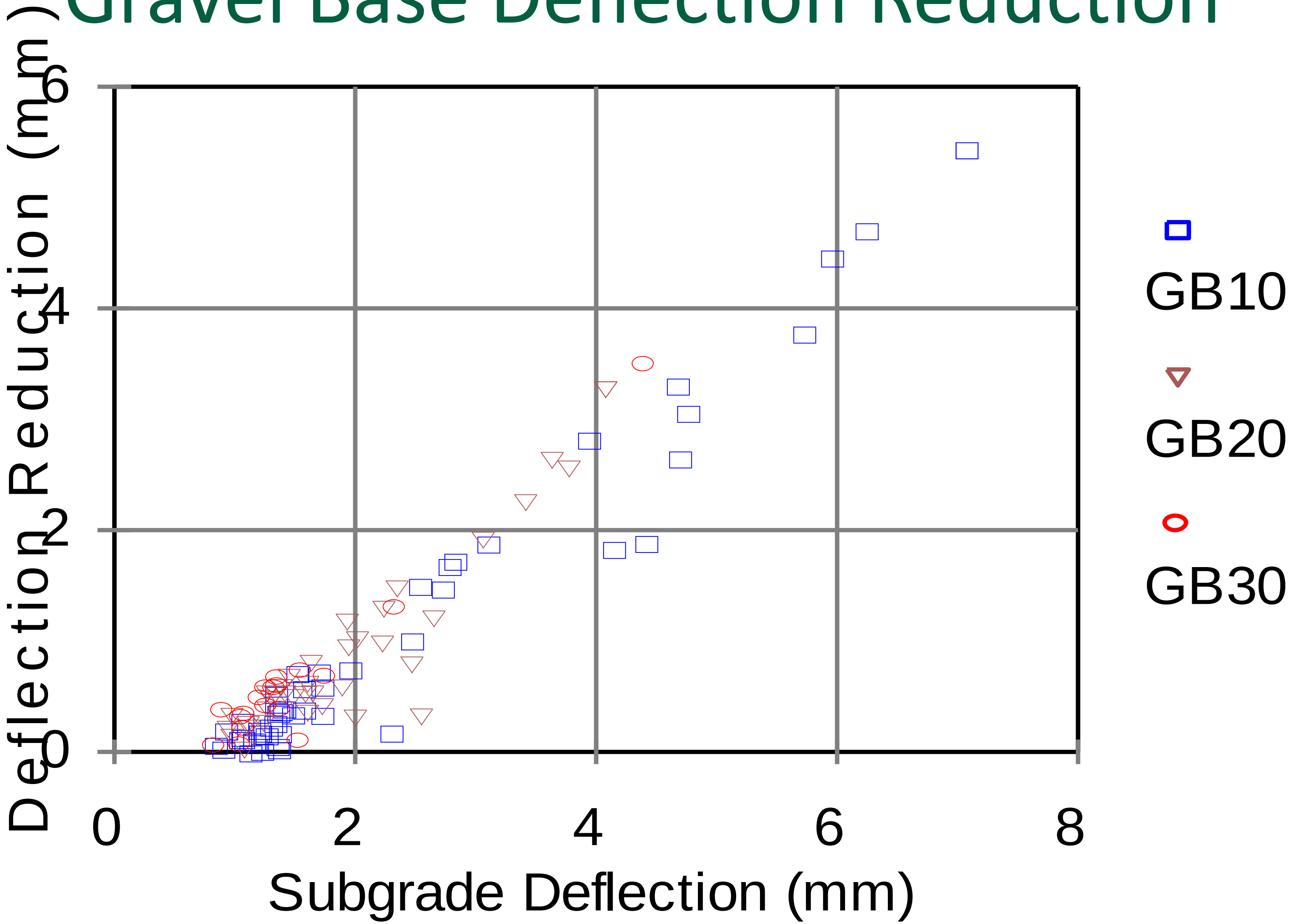
Gravel Base Deflection



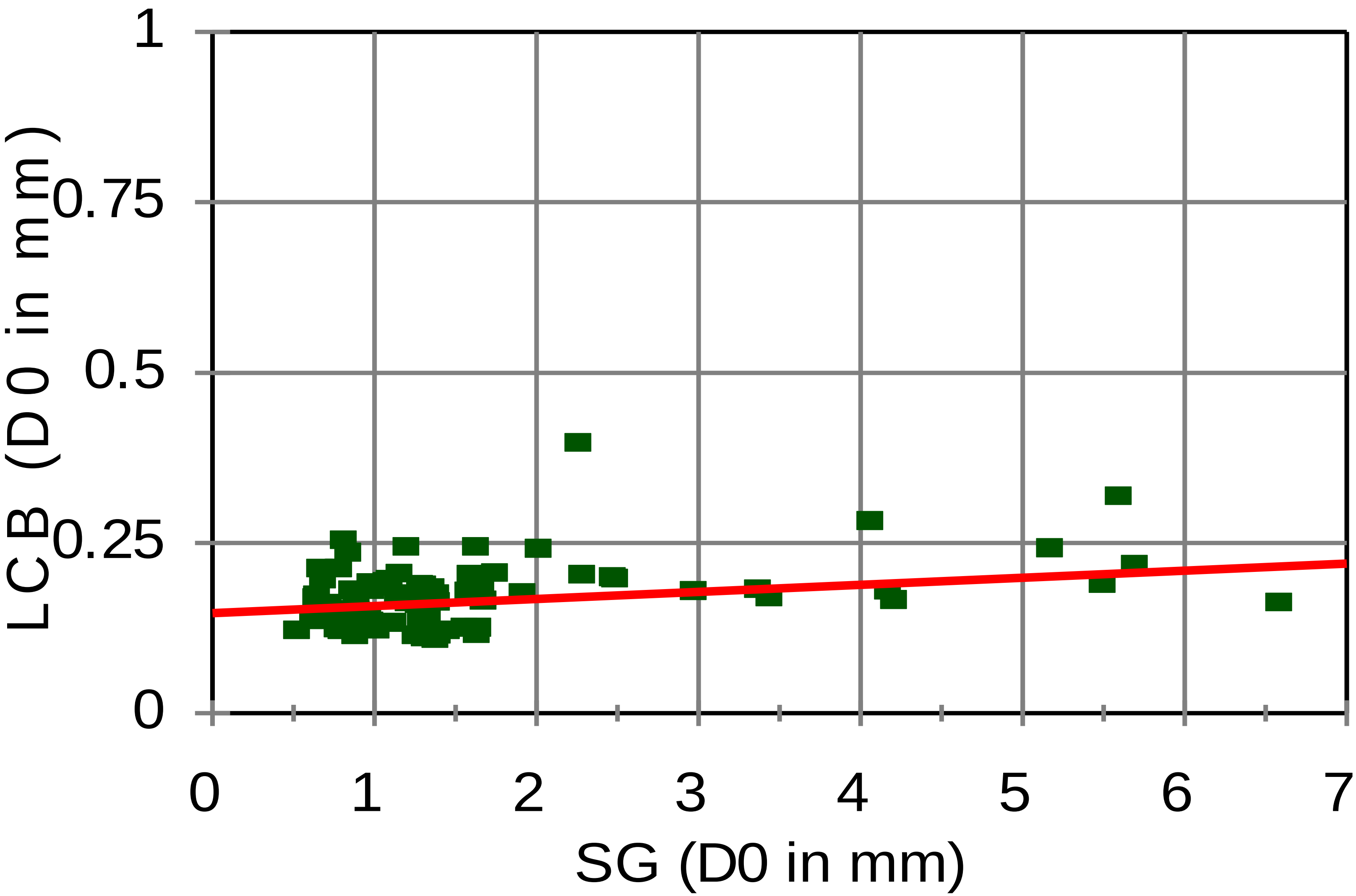
Gravel Base Deflection



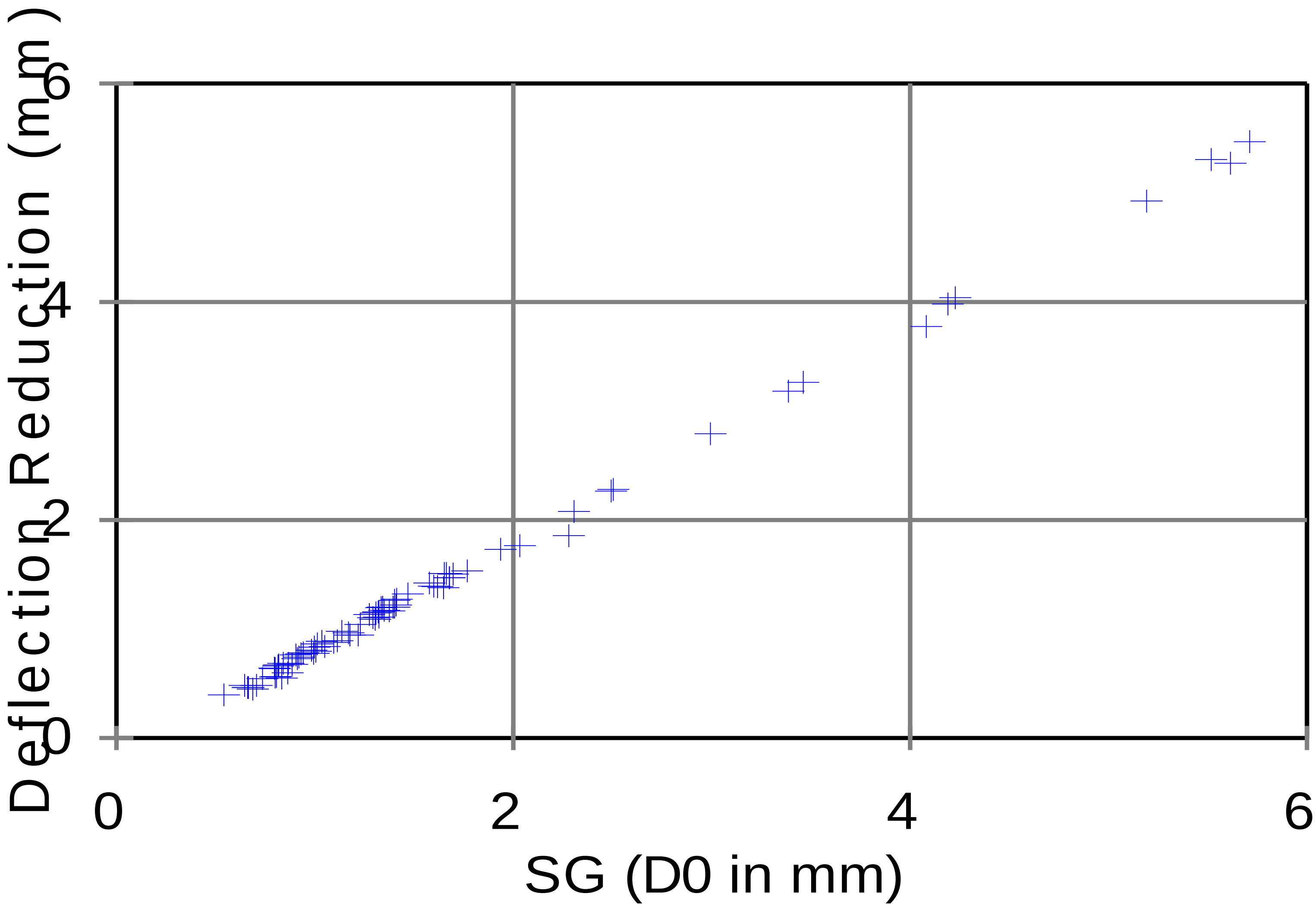
Gravel Base Deflection Reduction



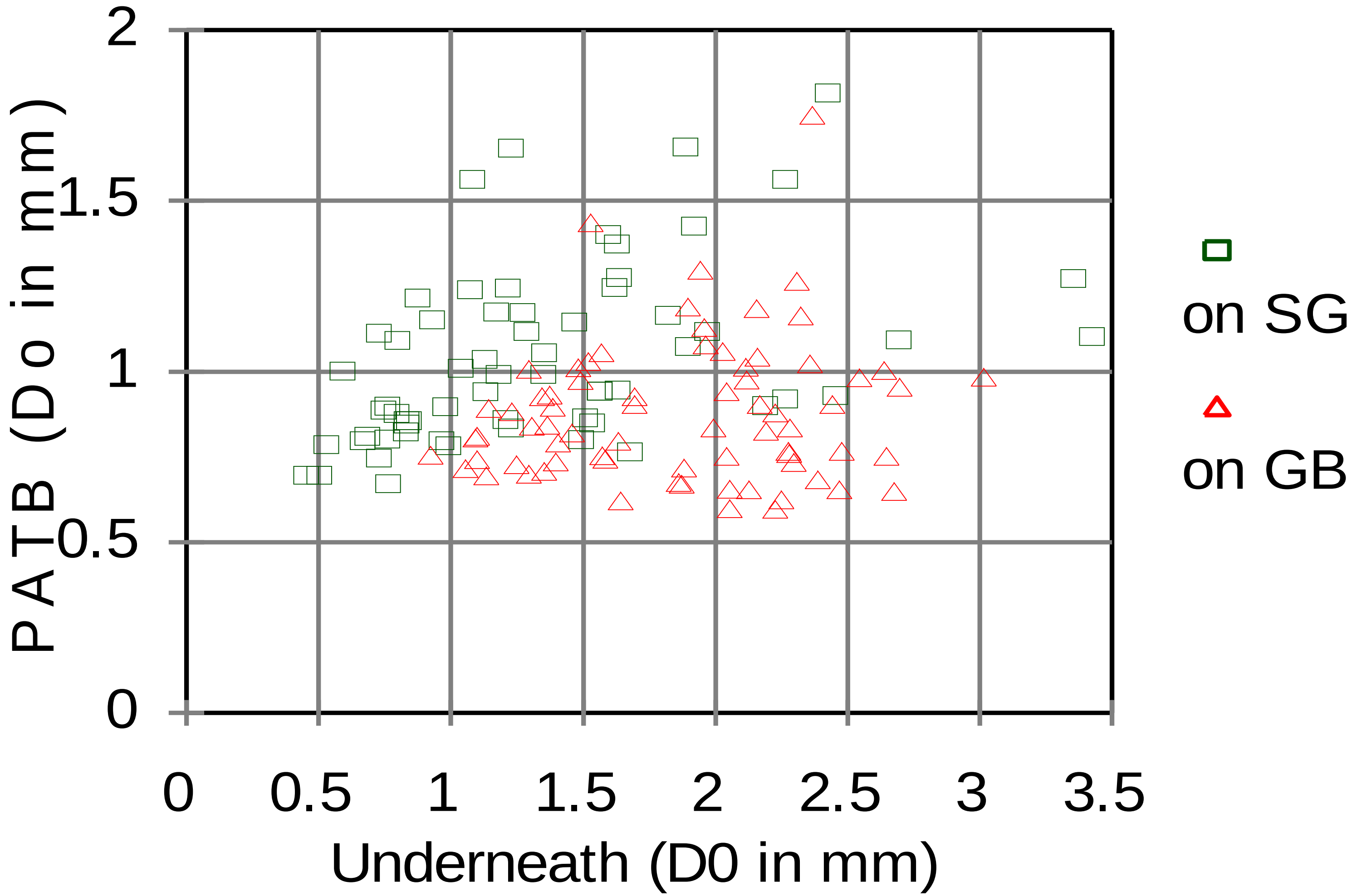
LCB Deflection



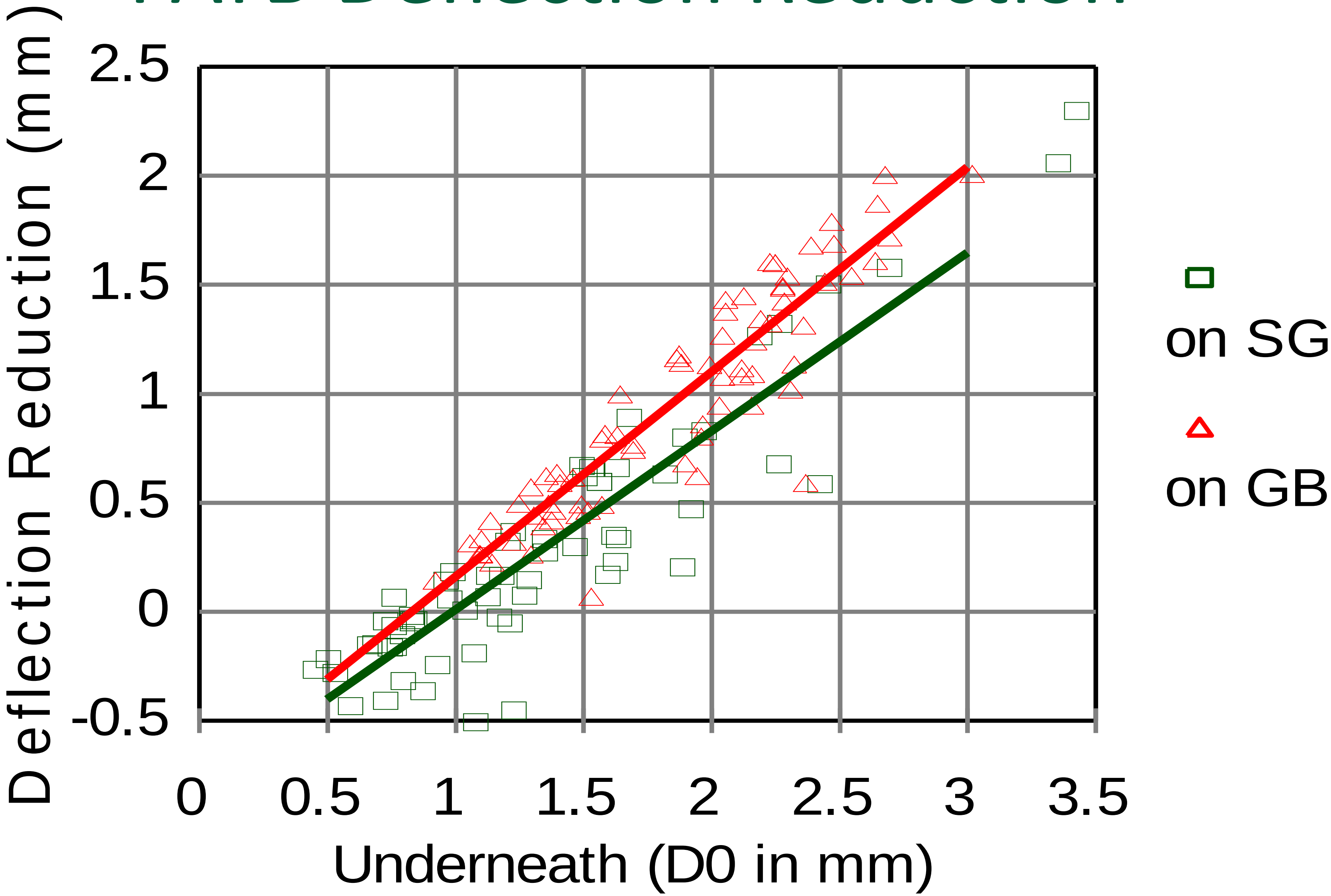
LCB Deflection Reduction



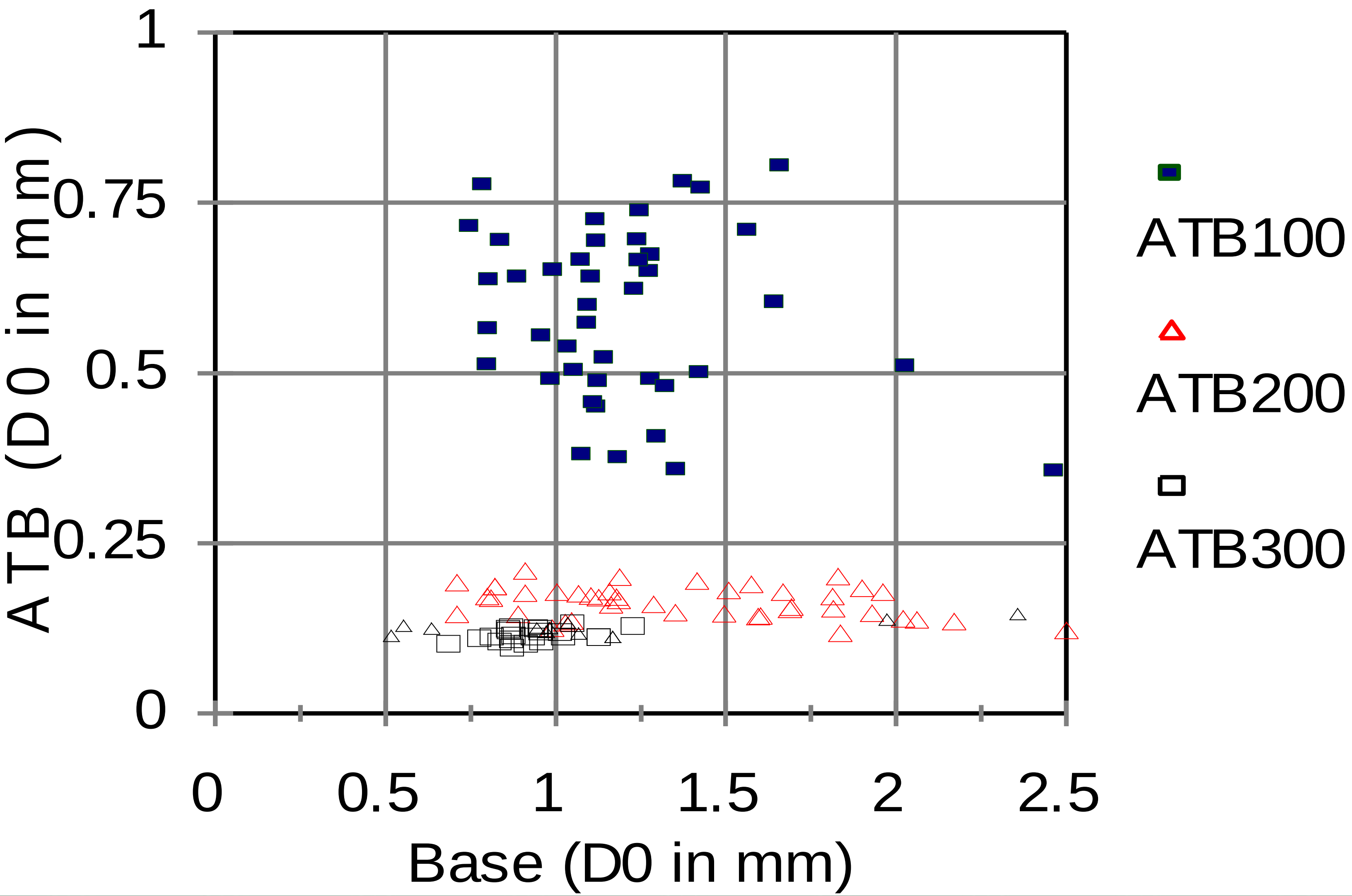
PATB Deflection (100mm)



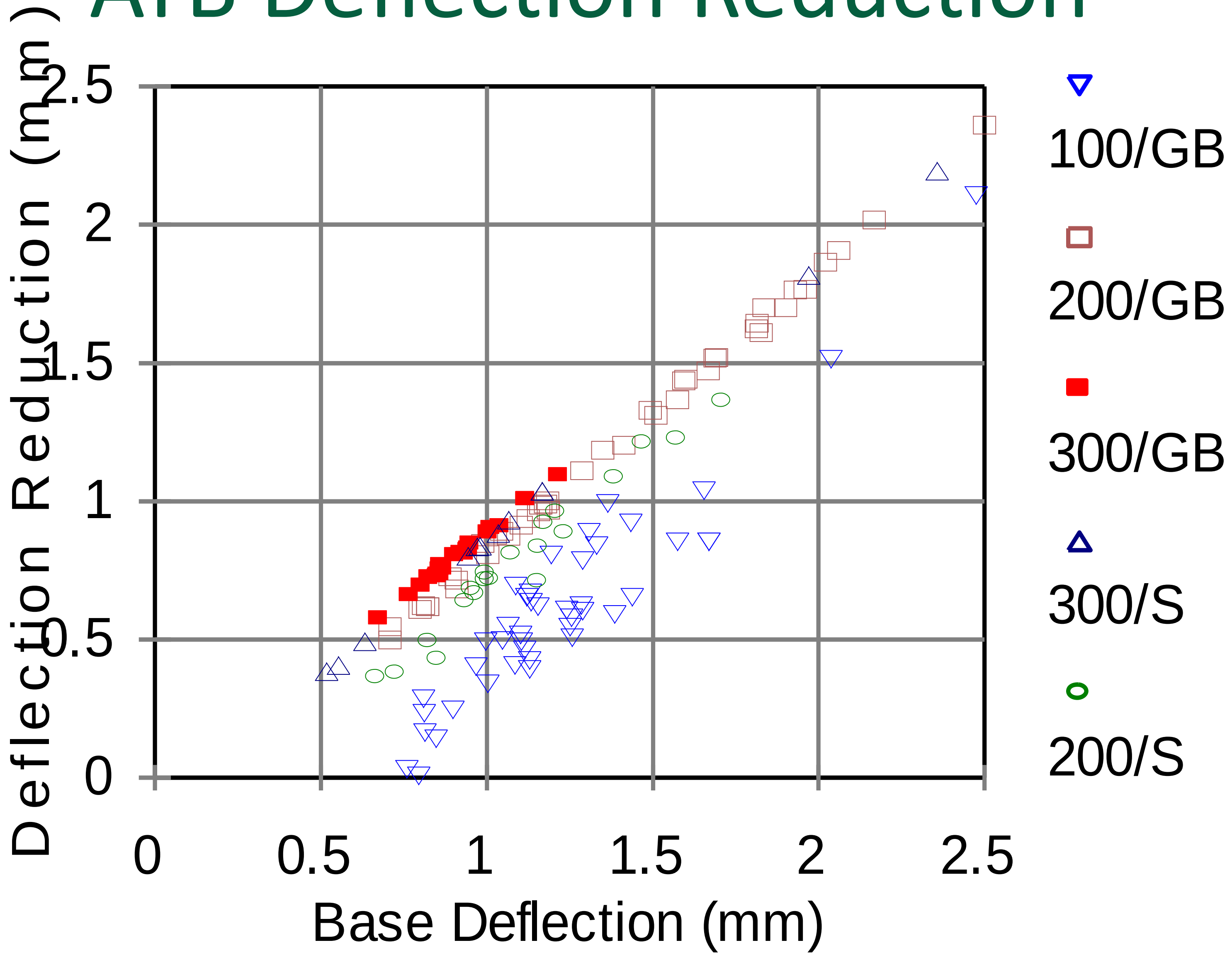
PATB Deflection Reduction



ATB Deflection



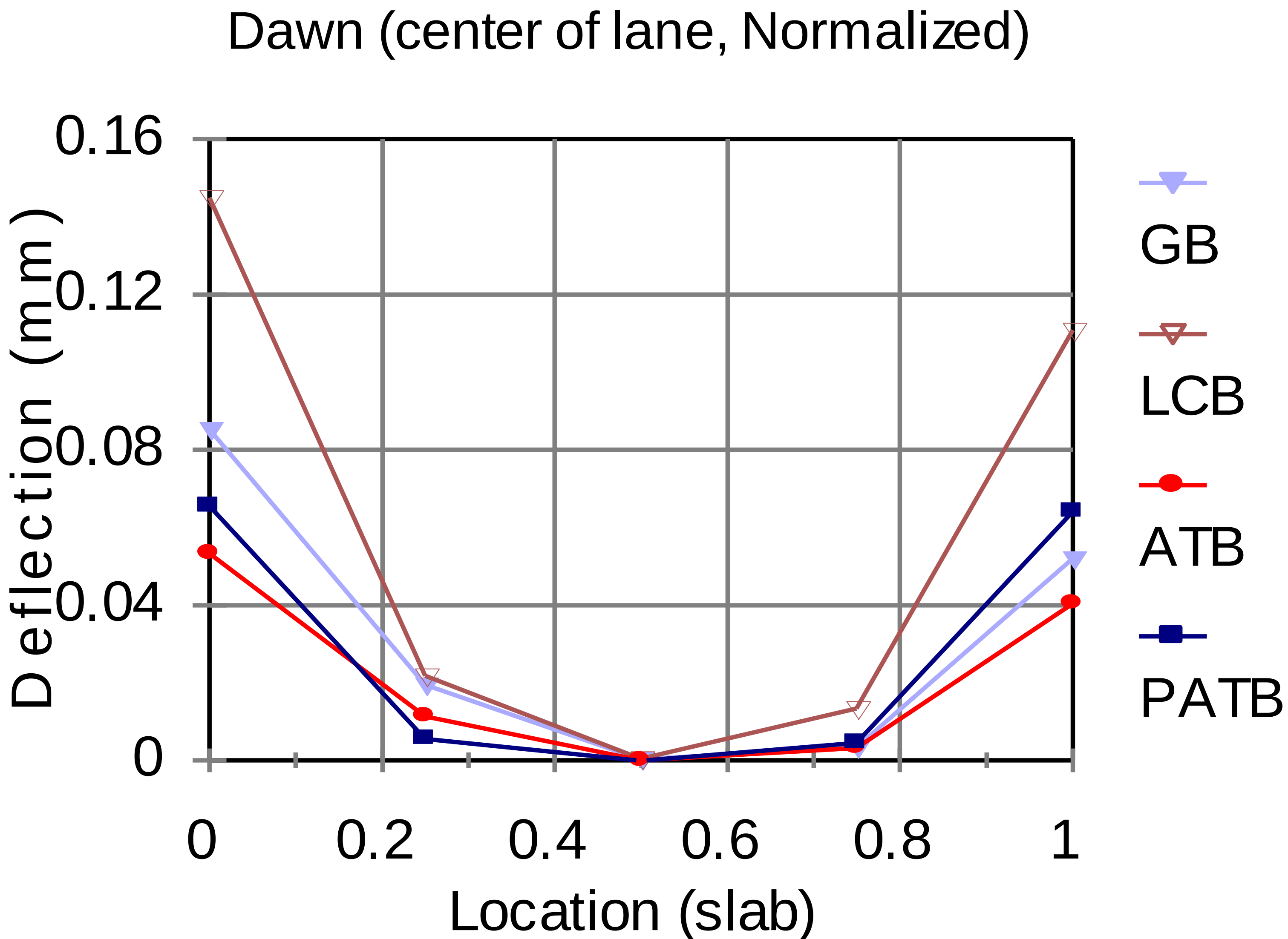
ATB Deflection Reduction



Findings from Base Deflection

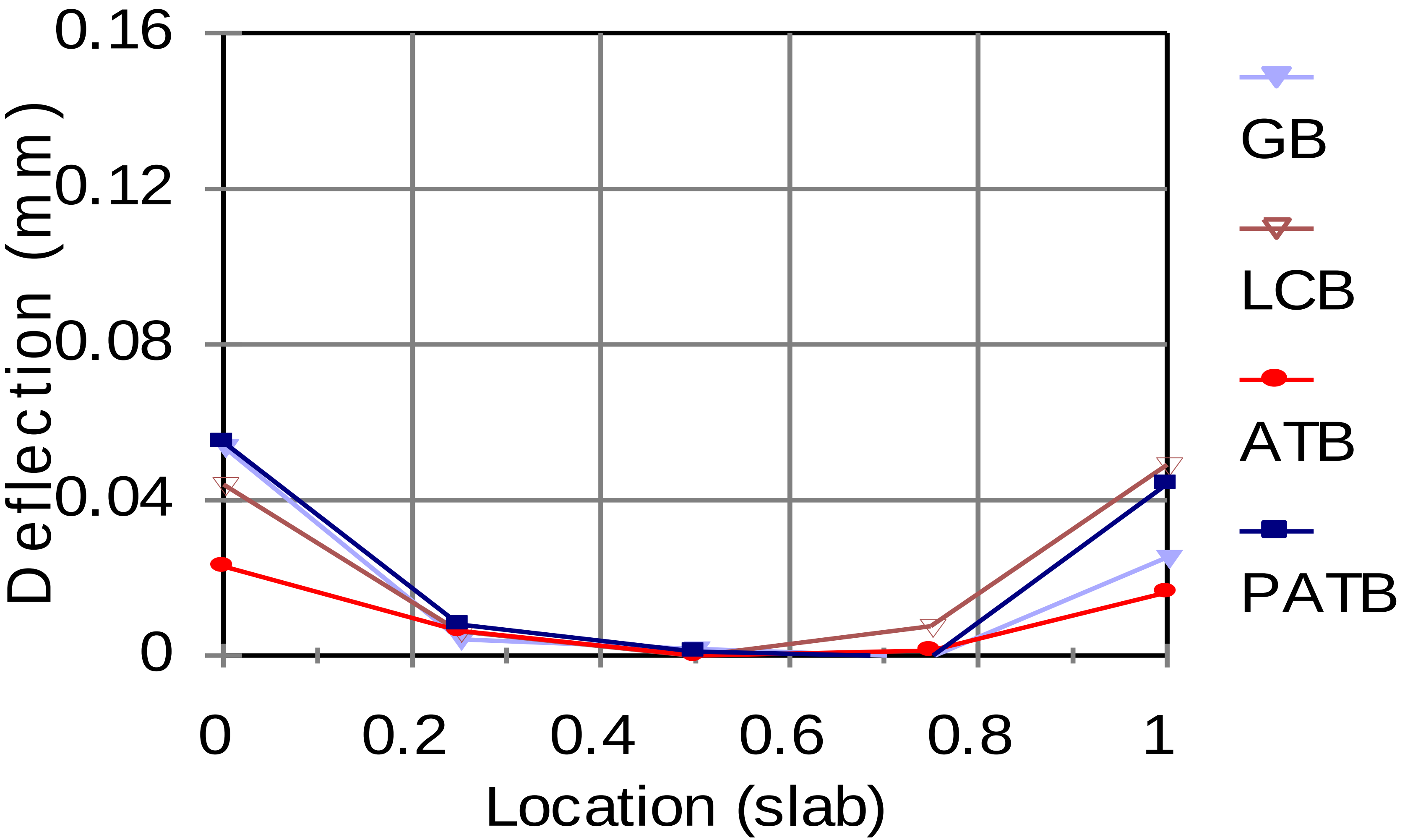
- GB: > 200mm (stiffness, uniformity)
- ATB: > 150mm (uniformity)
- 150mm LCB = 200mm ATB
- 150mm PATB = 200mm GB

Curling Effect Analysis

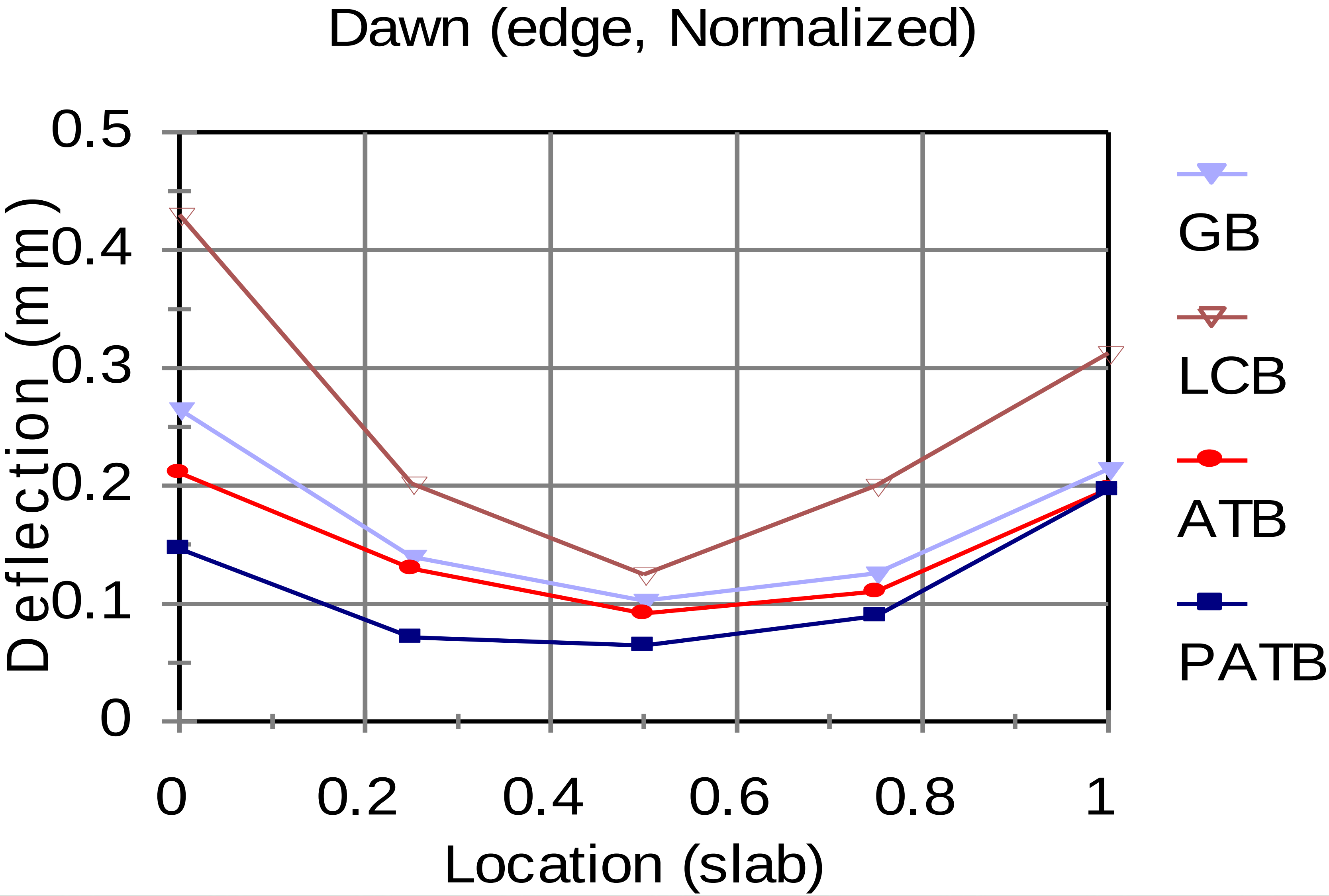


Curling Effect Analysis

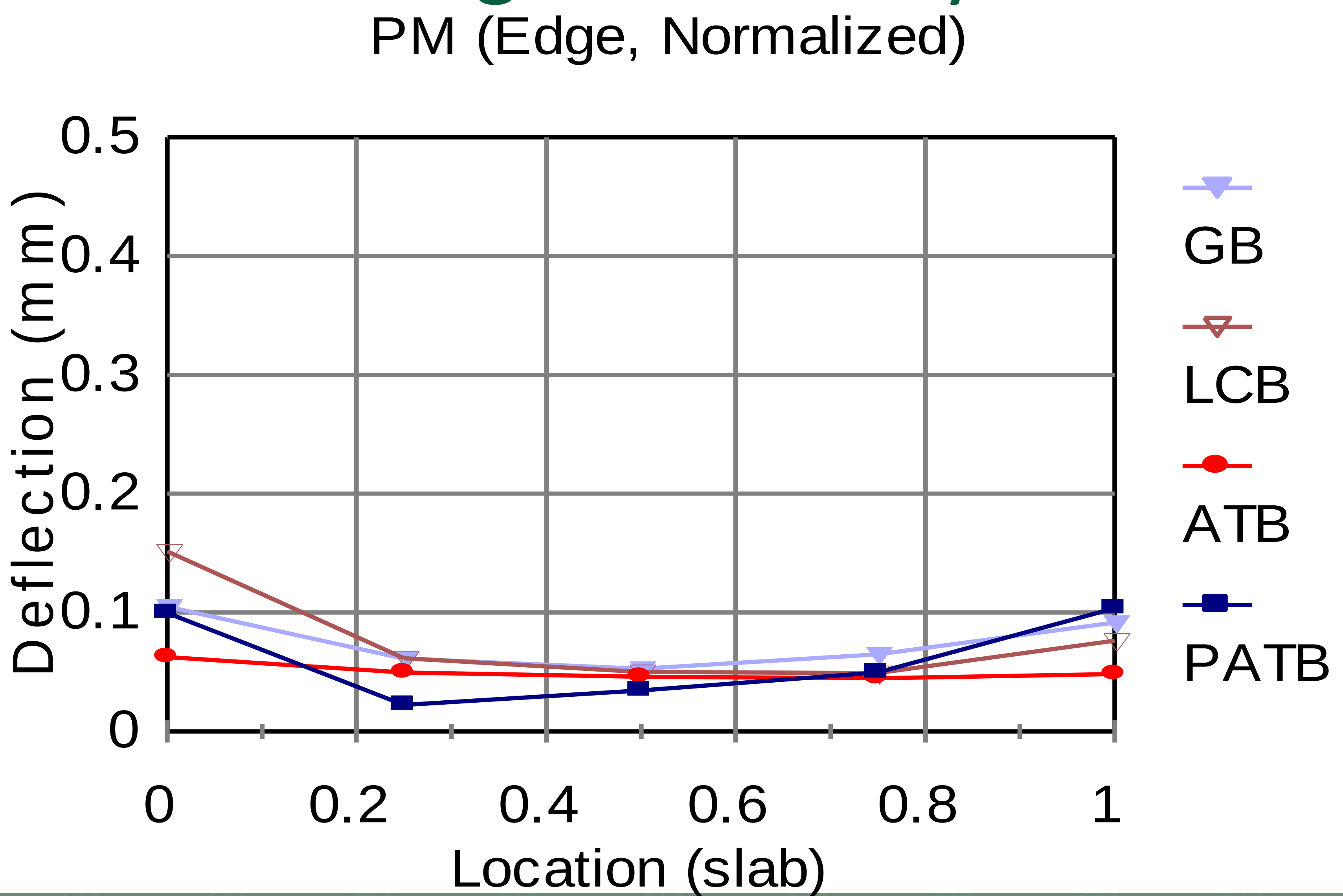
PM (Center of Lane, Normalized)



Curling Effect Analysis



Curling Effect Analysis



Findings from Curling Effect Analysis

- LCB has greatest variation (fatigue life)
- ATB has least variation
- GB and PATB are in between

Base Type Selection

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Instrumented Test Pavements in Ohio

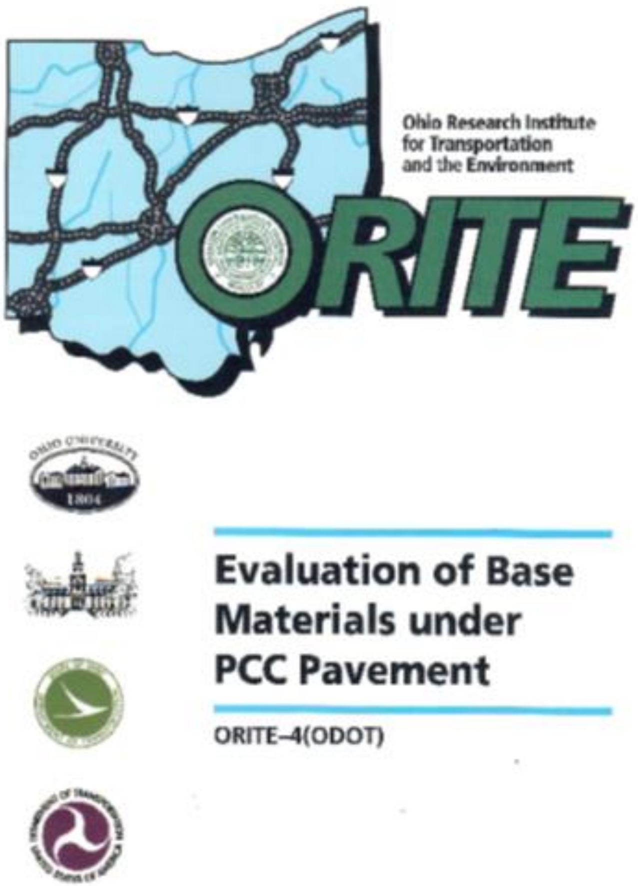
- Ohio SHRP Test Road US23 in Delaware
- SR 2 Vermillion
  - Instrumentation of a Rigid Pavement System
- US33 Bellefontaine
  - A Demonstration Project on Instrumentation of a Flexible Pavement
- US35 Rio Grande
  - Pavement Joint Performance

Rigid Pavement

- Uniform support to the slab at all times and all locations (base stiffness)
- Non-erosive (pumping)
- Construction platform (support paver)

Rigid Pavement

- ATB is the best base
- LCB is sensitive to curling effect, poor performance
- GB performed fairly (lower volume facilities)
- PATB performed better than GB and LCB
- ATB is denser and more stable than PATB
- ORITE Tech Note No. 4
- ASCE *Journal of Transportation Engineering*
  - Vol 132, No. 10 p. 753, Oct. 2006



Rational Approach for Base Type Selection

Shad M. Sargand, M.ASCE[1]; Shin Wu, M.ASCE[2]; and J. Ludwig Figueroa, F.ASCE[3]

Abstract: The objective of this study was to investigate how base materials should be properly selected for specific types of pavement, considering not only the performance of individual layers but also how they interact in the completed pavement structure. Base types considered included: granular (GB), lean concrete (LCB), asphalt treated (ATB), cement treated (CTB), and permeable asphalt treated (PATB) bases, constructed under both hot mix asphalt (HMA) and Portland cement concrete (PCC) pavements. The Long Term Pavement Performance (LTPP) Seasonal Monitoring Program (SMP) sites investigated included four SMP sections in the North Carolina SPS-2 experiment on US52 (wet-no-freeze zone) and 13 SMP sections in the SPS-1 and SPS-2 experiments on the Ohio SHRP Test Road (wet-freeze zone). The NC site contained two GB and two LCB sections, and the OH site contained eight GB, one ATB, two PATB, and two LCB sections. Environmental data were collected via seasonal monitors and time domain reflectometry. Pavement performance was monitored by obtaining periodic condition surveys and falling weight deflectometer measurements. Major findings of the study included the fact that base type had little impact on subgrade moisture and that the choice of base depends chiefly on three requirements: (1) appropriate stiffness; (2) sufficient permeability; and (3) good constructability. Guidelines for the selection of bases under flexible and rigid pavements are given.

DOI: 10.1061/(ASCE)0733-947X(2006)132:10(753)

CE Database subject headings: Rigid pavements; Flexible pavements; Drainage; Moisture; Subgrades; Base course.

Questions?

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