



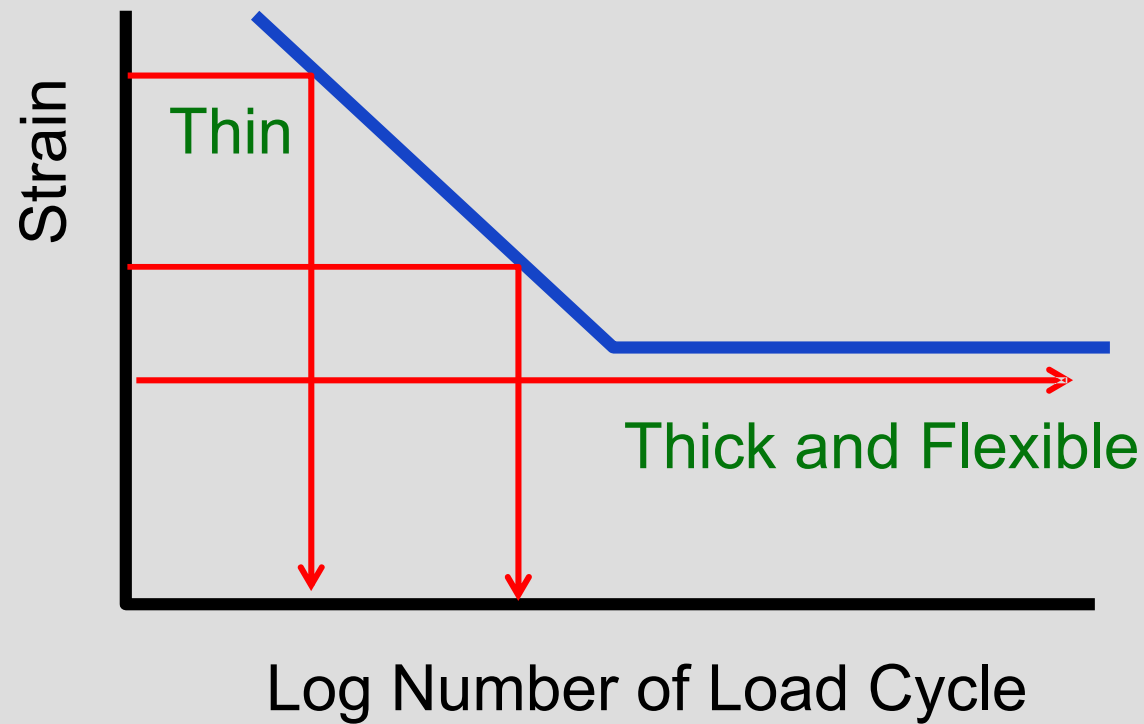
## **Perpetual Pavement Asphalt Concrete on WAY-30 Test Road and APLF**

**Ohio Asphalt Paving Conference  
February 4, 2009**

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Ohio Dept. of Transportation**

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Department of Civil Engineering  
Ohio University**

# Fatigue Behavior (S-N Diagram)



# Perpetual Pavement

• No (Fatigue) Cracking → **Structural Design**

• No Rutting

• No Thermal Cracking

• No Stripping

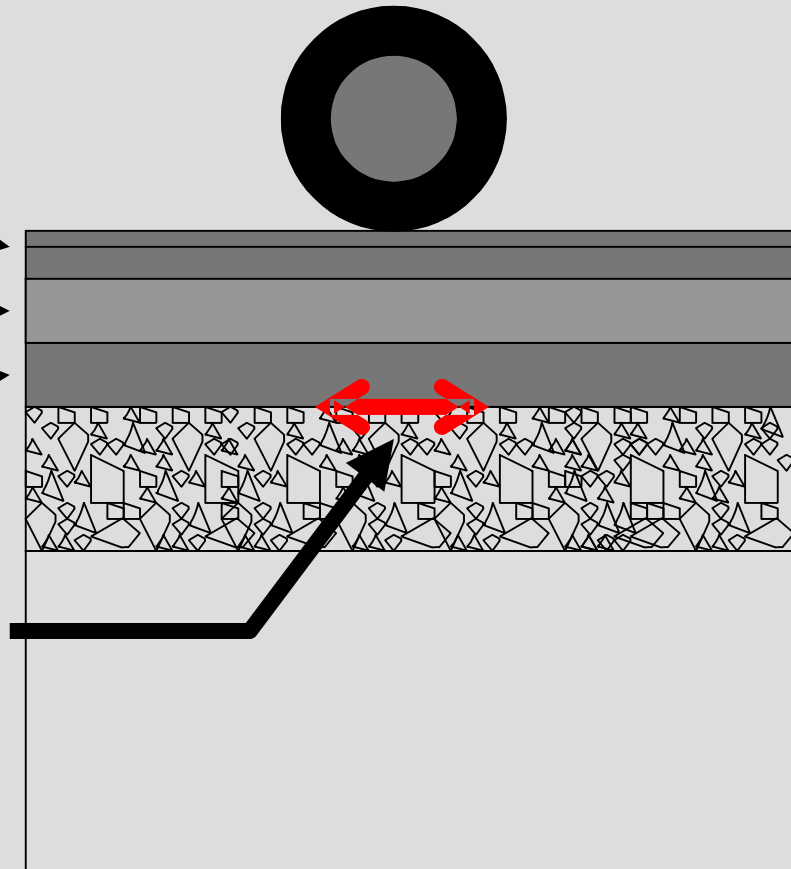


**Mix Design**

# Perpetual Design Criteria

Surface: High Performance →  
Base: Economical & Durable →  
Fatigue Resistant Layer →

Maximum Tensile Strain  
for **Fatigue Control**



# US 30 Asphalt Pavement Materials

Thickness (inches)	Material	Design Air Voids (%)	PG Binder	Properties
<b>1.25</b>	(856) Stone Matrix Asphalt Concr, 12.5mm	3.5	76-22M	Durable Rut Resistant
<b>1.75</b>	(442) Asphalt Concrete Inter. Course, 19mm Type A	4.0	76-22M	Durable Rut Resistant
<b>9</b>	(302) Asphalt Concrete Base	4.5	64-22	Economical Stable
<b>4</b>	(302) Special Fatigue Resistant Base Layer	3.0	64-22	Fatigue Resistant
<b>6</b>	(304) Aggregate Base			Stable

# Project Information

- Project 44(2004)
- Project Length: 7.97 miles
- Letting Date: 2/20/2004
- Contractor: Beaver Excavating Company
- Total Cost: \$47.2 million
- Work Started: 3/15/2004
- Open to Traffic: 12/19/2005

# WAY-30 ODOT Work Plan

## ODOT

- Costs & User Delay

- Safety

- Ride and Condition

## OU

- Dynamic Pavement Reponse

- Determine Mechanical Properties

- Verify Design Procedure

# WAY-30 ODOT Work Plan

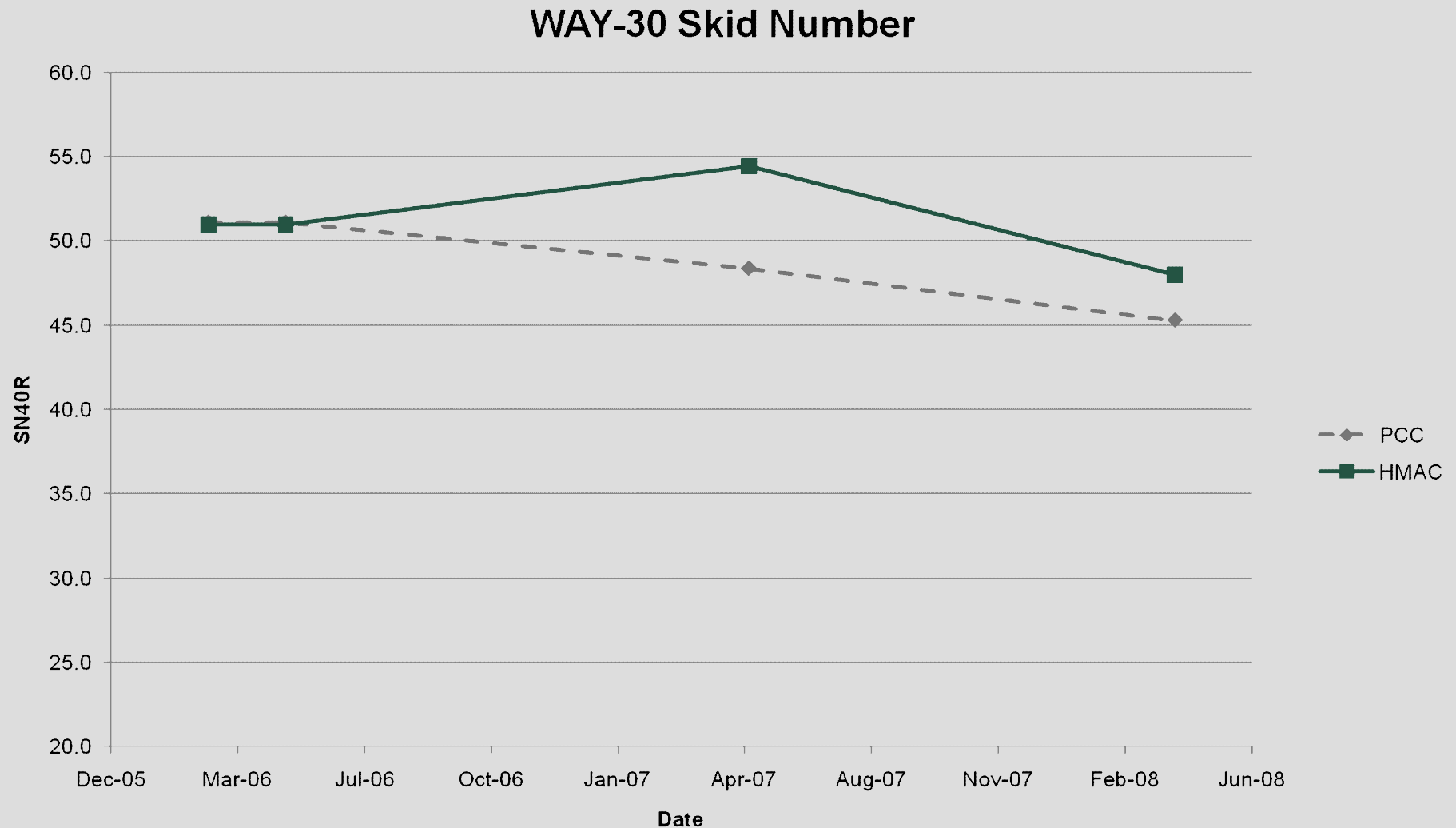
- Economic Analysis
  - Initial Construction Cost
  - Rehabilitation Cost
  - Force Account Maintenance
  - Salt Usage
  - Pavement Marking Costs



# WAY-30 ODOT Work Plan

- Safety
  - Fatal Accidents
  - Nonfatal Accidents
  - Property Damage Accidents
  - Pavement Skid

# WAY-30 skid number



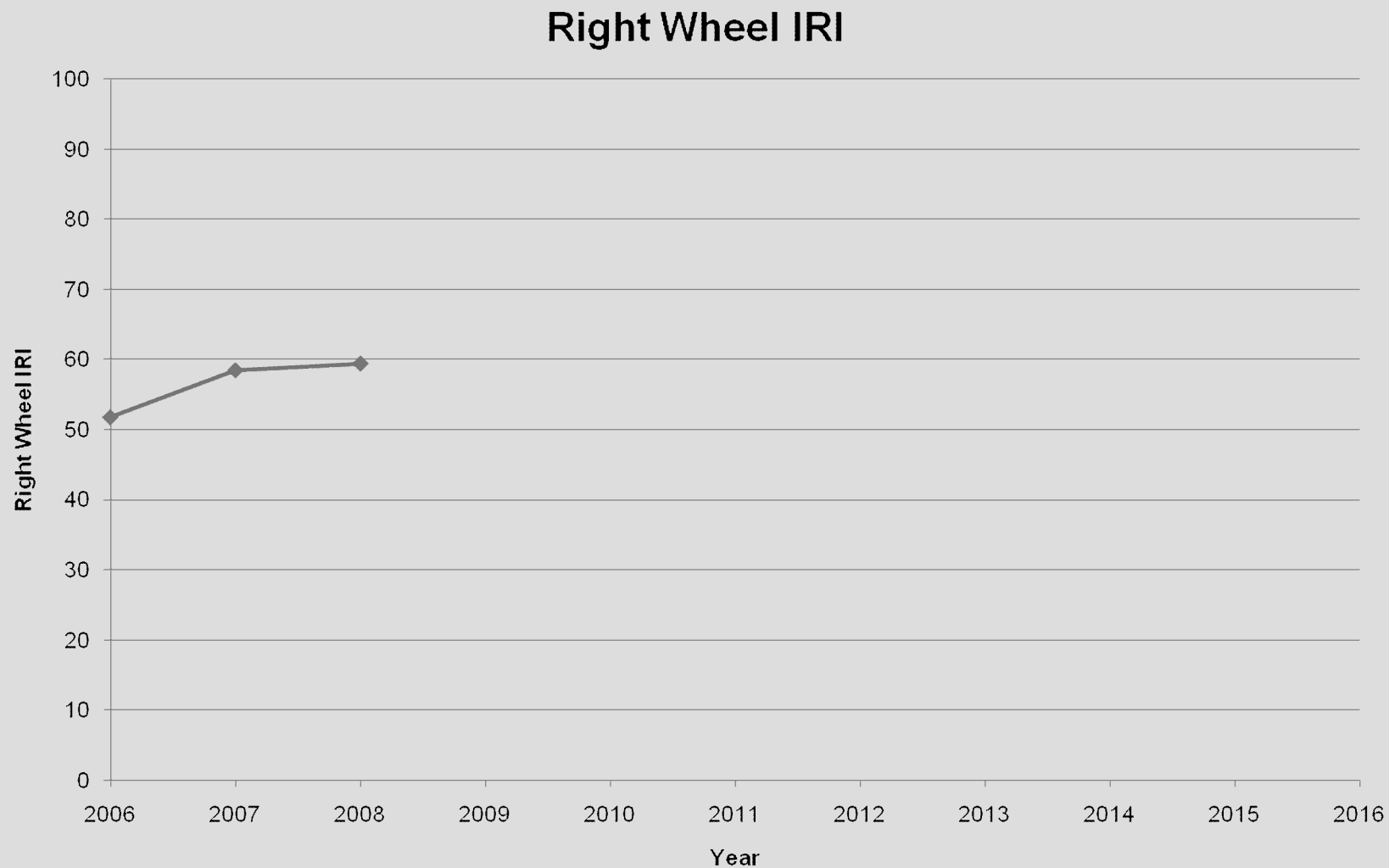
# WAY-30 ODOT Work Plan

- User Delay
  - Pavement Construction Duration
  - Rehabilitation Duration
  - Queues During Rehabilitation

# WAY-30 ODOT Work Plan

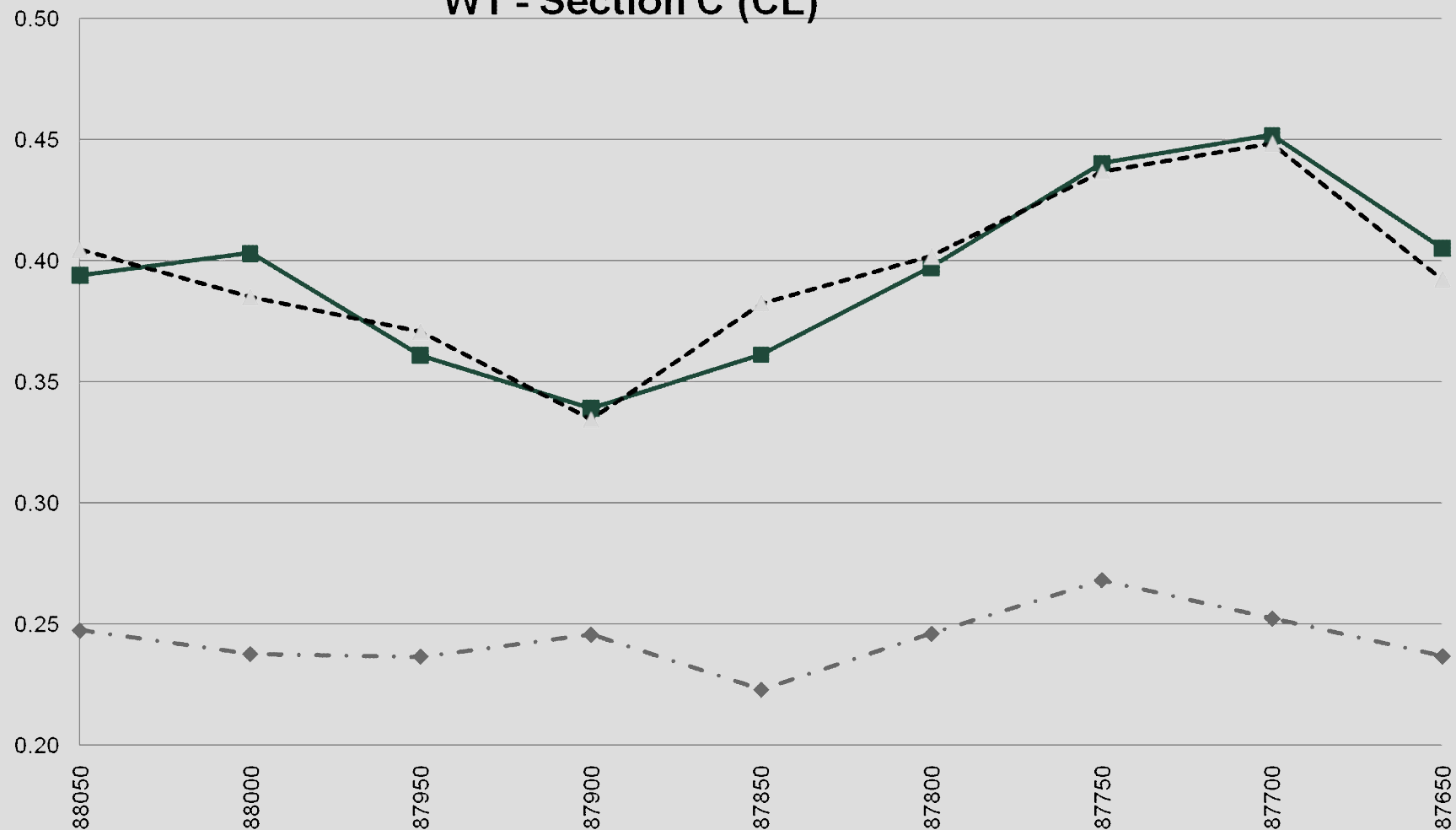
- Ride and Condition
  - Pavement Ride Quality
  - Pavement Condition Rating
  - Pavement Damage (deflection)
  - Subgrade Moisture & Water Table
  - Climatic Data
  - Noise

# WAY-30 Ride Quality



# WAY-30 FWD W1

W1 - Section C (CL)



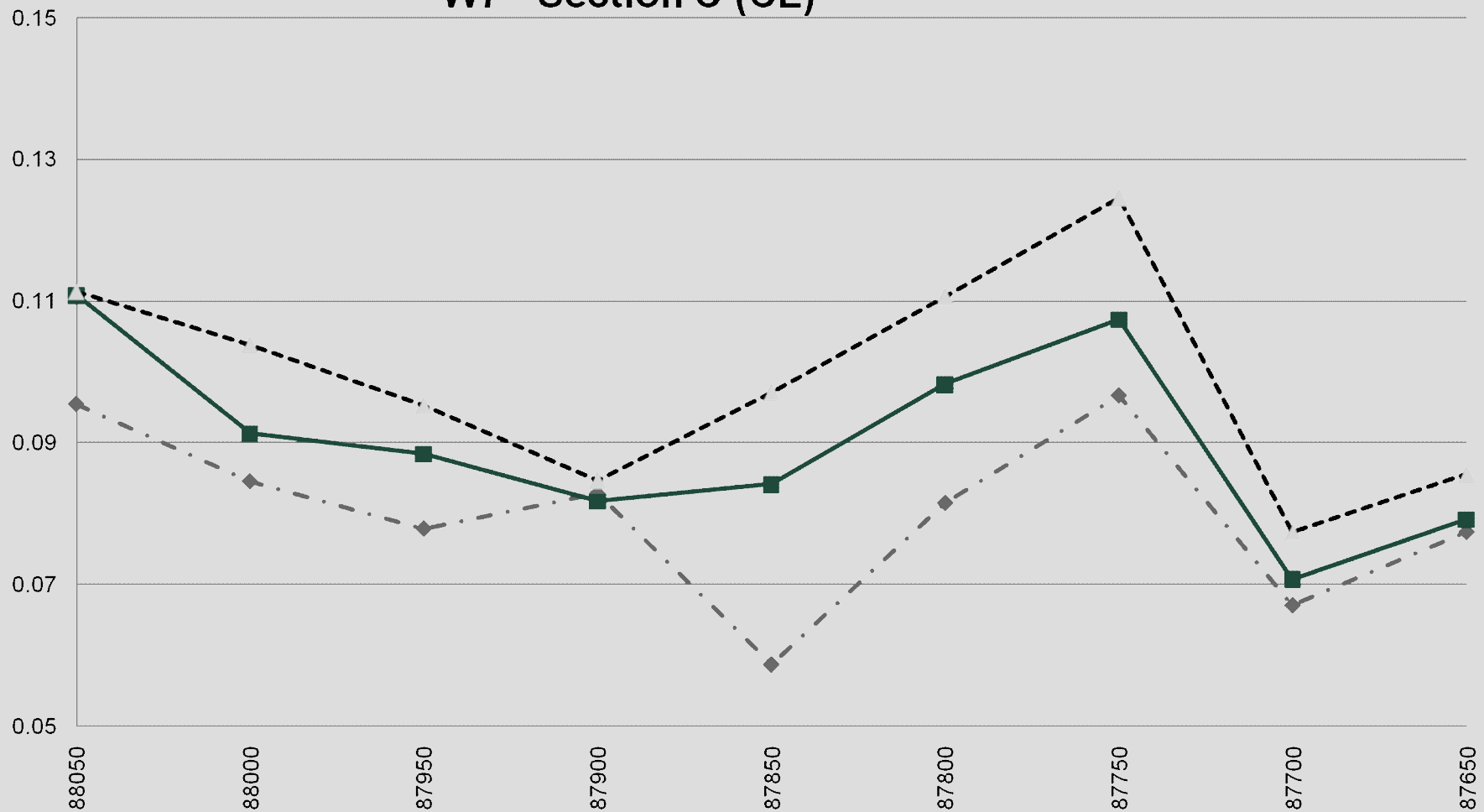
# WAY-30 FWD W5

W5 - Section C (CL)



# WAY-30 FWD W7

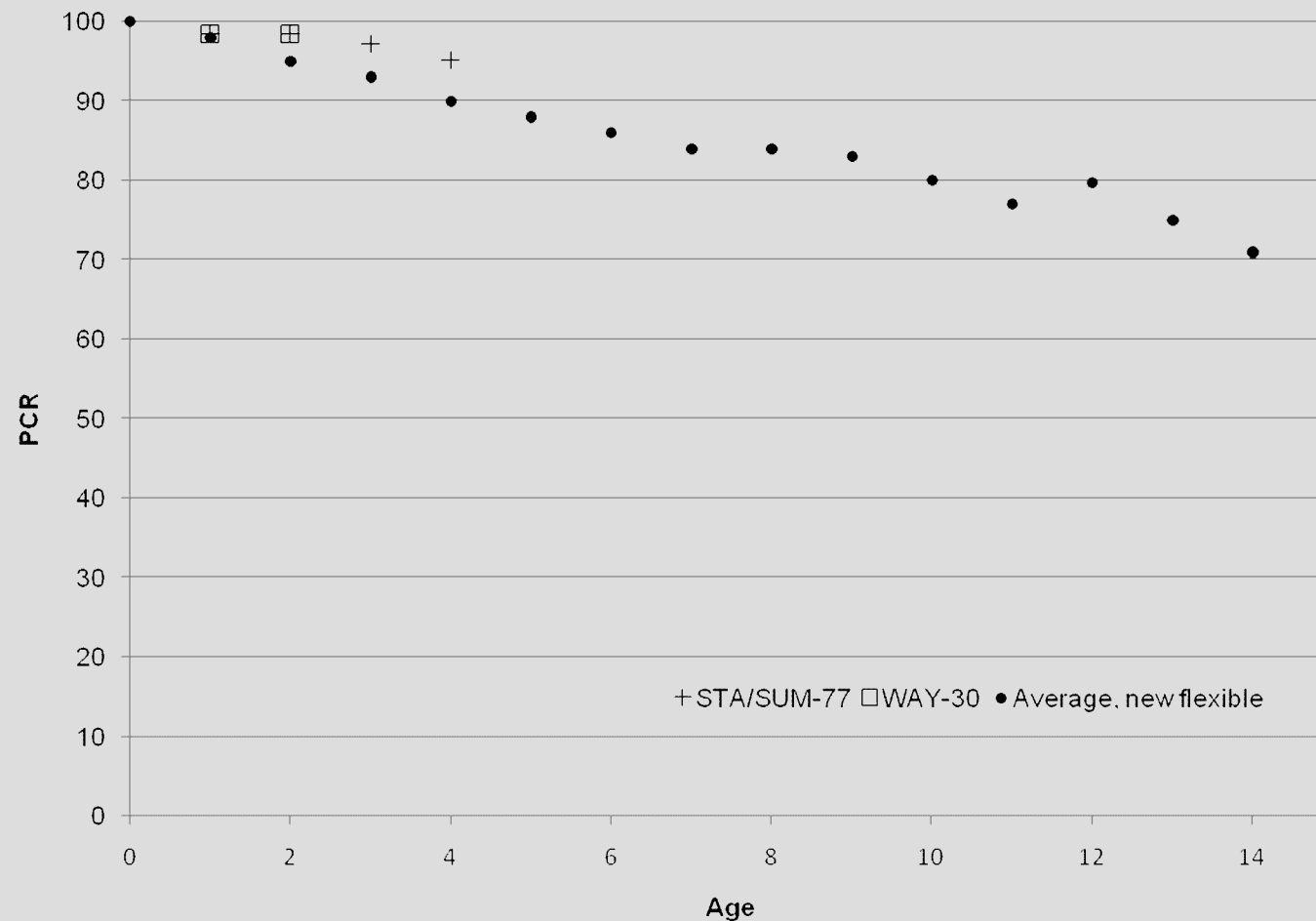
W7 - Section C (CL)





# WAY-30 PCR

## Perpetual Pavement



# WAY-30 Project Background

## Research Objectives for ORITE and OPE

- The WAY-30 bypass consists of 3 research projects:
  - Climatic and Dynamic Load Response Instrumentation
  - Determination of mechanical properties of materials used.
  - Assessment of the perpetual pavement concept for asphalt concrete.
- These projects, designed by ODOT, will incorporate new and innovative design procedures, specifications, test procedures, and construction techniques.

# Project Objectives

- Review design procedures used by ODOT.
- Develop comprehensive instrumentation plans to monitor environmental and load response parameters.
- Monitor dynamic responses of the pavement structure during non-destructive testing and controlled vehicle load testing.
- Determine mechanical properties of the pavement materials used during construction and in service
- When the project is completed, the Office of Pavement Engineering (OPE), with information provided by ORITE, will be able to achieve the strategic goal of developing design procedures for these long life pavements.

# Instrumentation Plan

- ORITE's instrumentation plan will monitor environmental and response parameters in each pavement type.
- Environmental parameters to be monitored in only one section of each pavement type.
- Dynamic load responses will be collected.

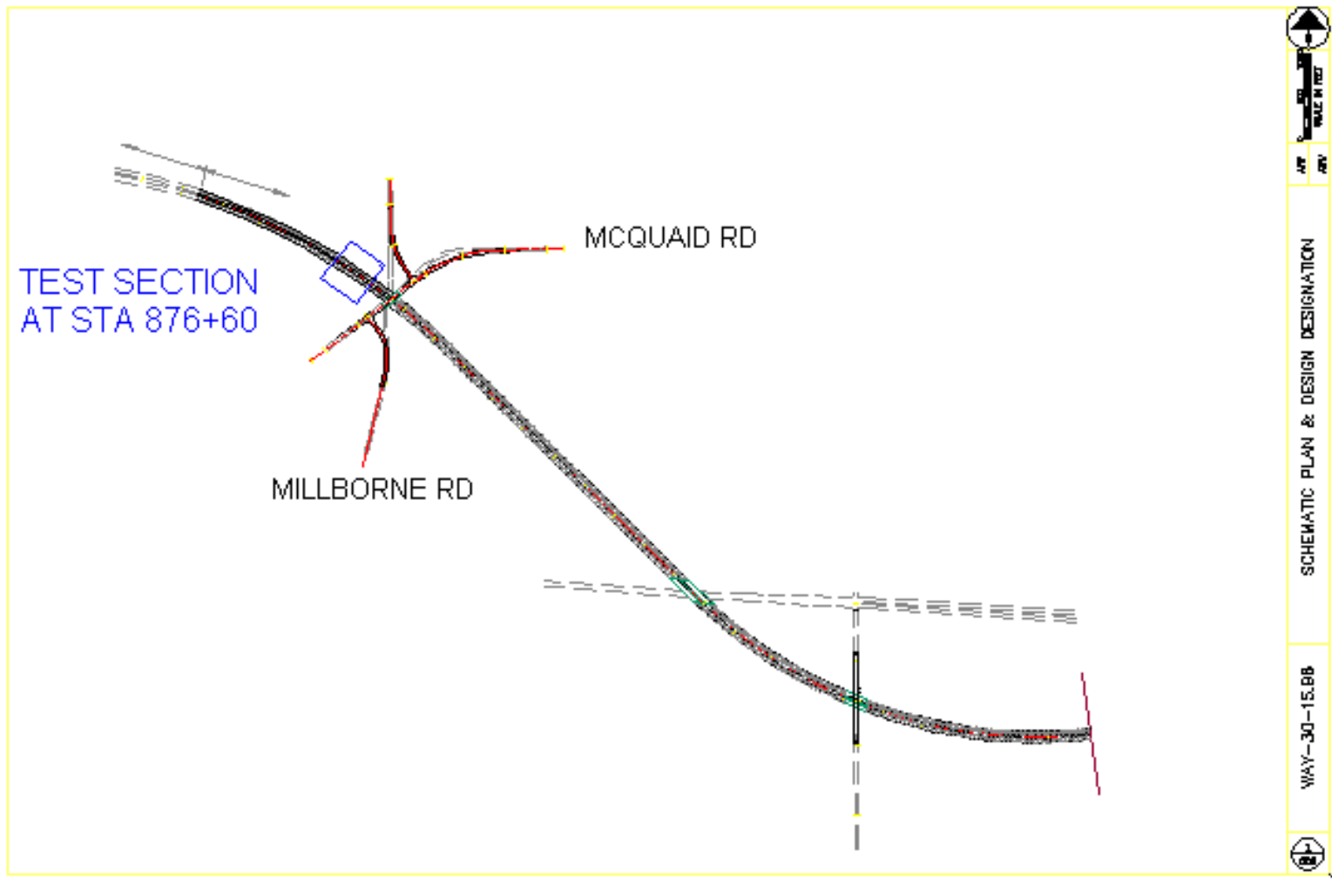
# US 30 Bypass of Wooster, Ohio



# Test Section at Geyer's Chapel

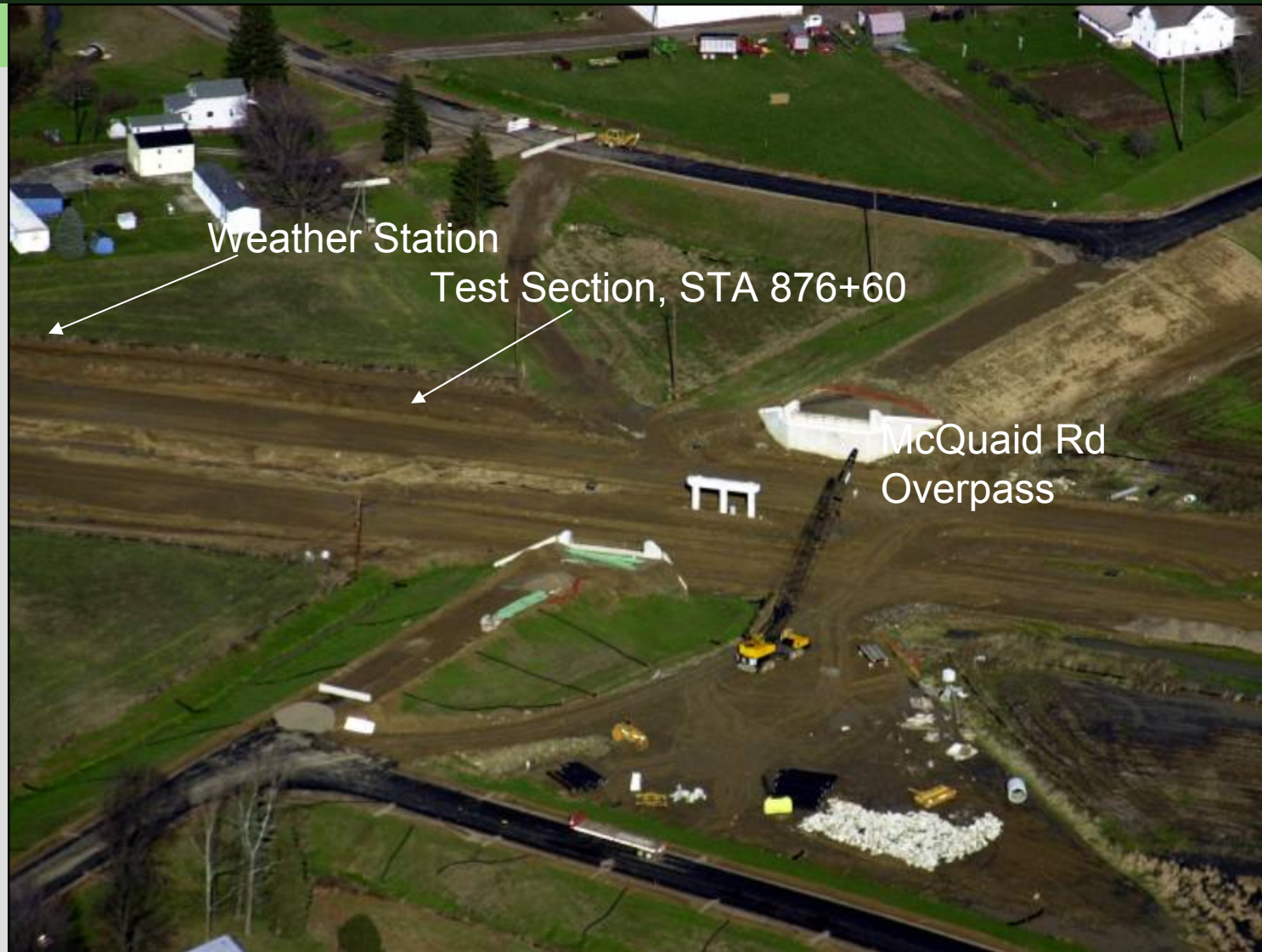


# Test Section at McQuaid Road





# Test Section at McQuaid Road





# Instrumentation Schedule

## Asphalt Concrete Test Sections

### Environmental Parameters

<u>MEASUREMENT</u>	<u>LAYERS</u>	<u>MANUFACTURER</u>	<u>SENSOR</u>
Temperature	Pavement, Base and Subgrade	Measurement Research Corp.	MRC Thermistor
Moisture	Base and Subgrade	Campbell Scientific, Inc.	TDR Probes

Automatic weather station installed to collect data related to air temperature, precipitation (rain and snow), wind speed and direction, relative humidity, and incoming solar radiation.

# Instrumentation Schedule

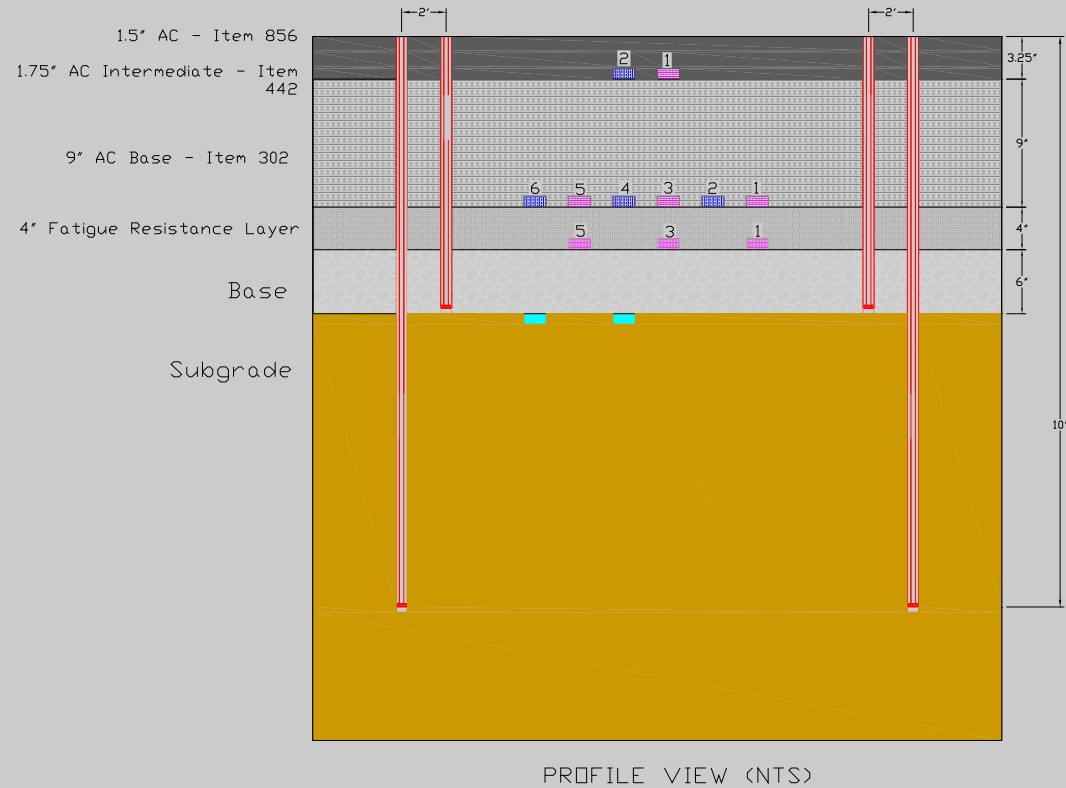
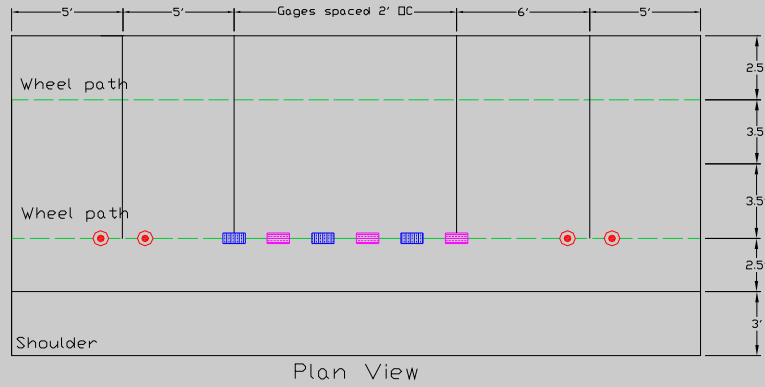
## Asphalt Concrete Test Sections

### Response Parameters

<u>MEASUREMENT</u>	<u>PARAMETERS</u>	<u>MANUFACTURER</u>	<u>SENSOR</u>
Displacement	Load Response and Seasonal Response	Macro Sensors	Macro Sensors LVDTs (Linear Variable Displacement Transducer)
Pressure	Load Response and Seasonal Response	Geokon Inc.	Geokon 3500 Pressure Cell
Strain	Longitudinal and Transverse Strain	Dynatest	Dynatest PAST II Strain Transducer

# A C S E C T I O N

AC Section A

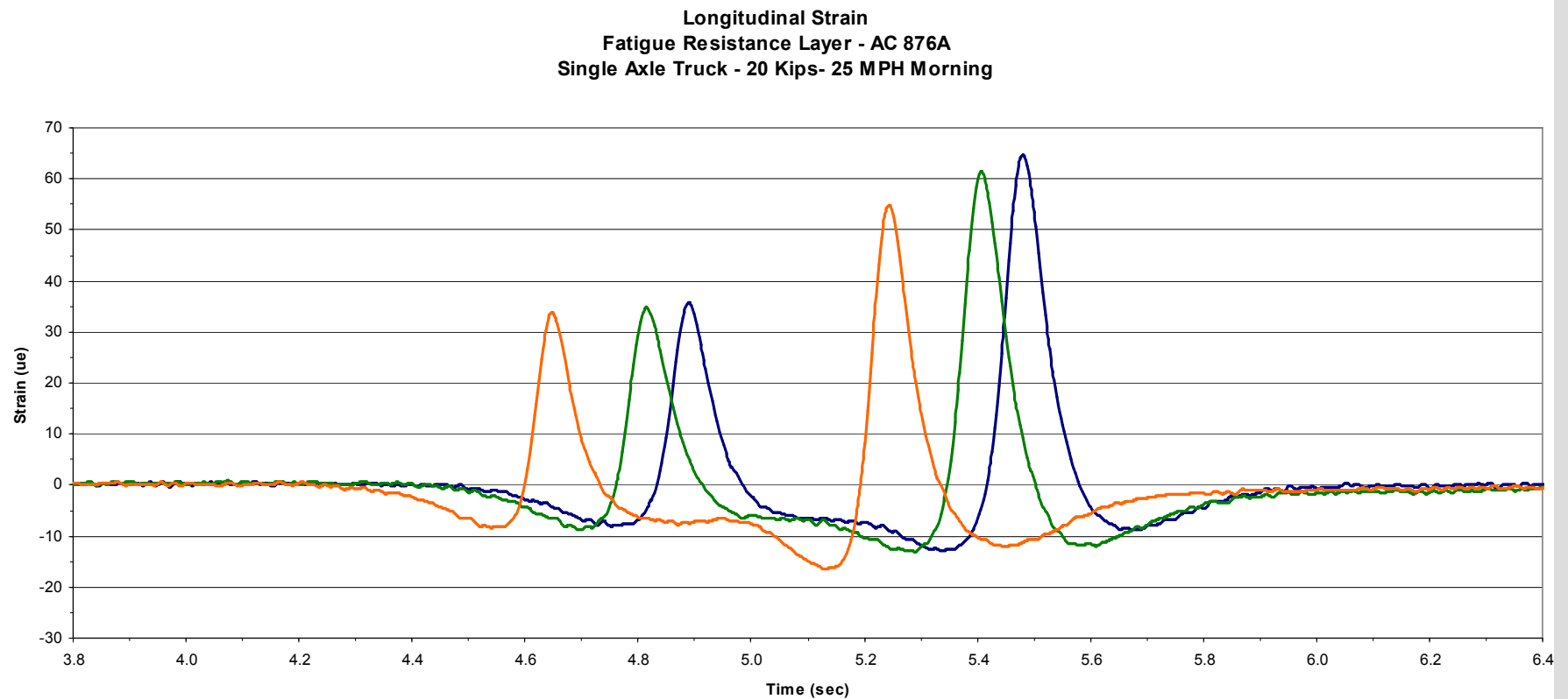


- Single Layer Deflectometer
- Longitudinal Gage
- Transverse Gage
- Pressure Cell

AC STN 876 SECTION A LABELING

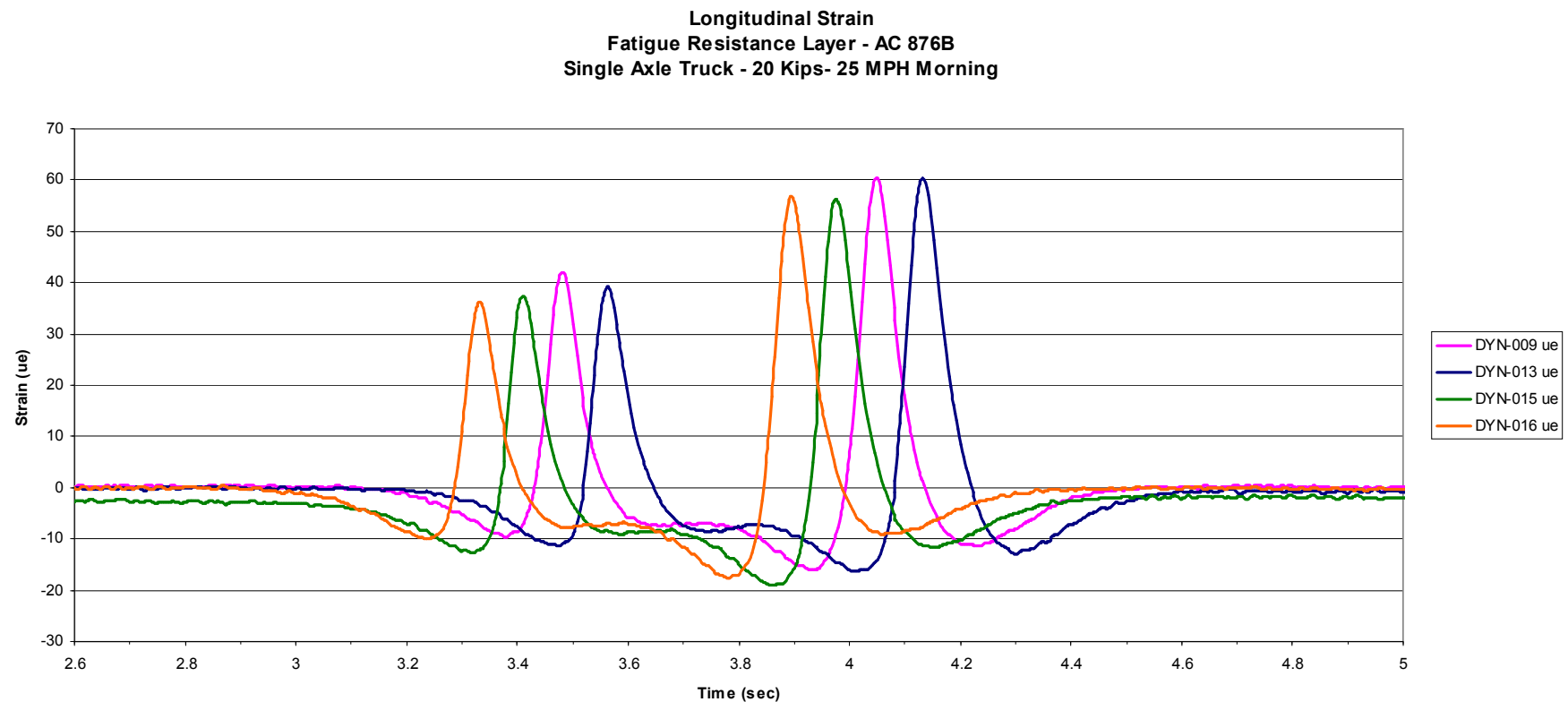
# WAY-30 FRL Longitudinal Strain Response

25 mph Test: ODOT 20 Kip Single Axle Truck Run 1-I



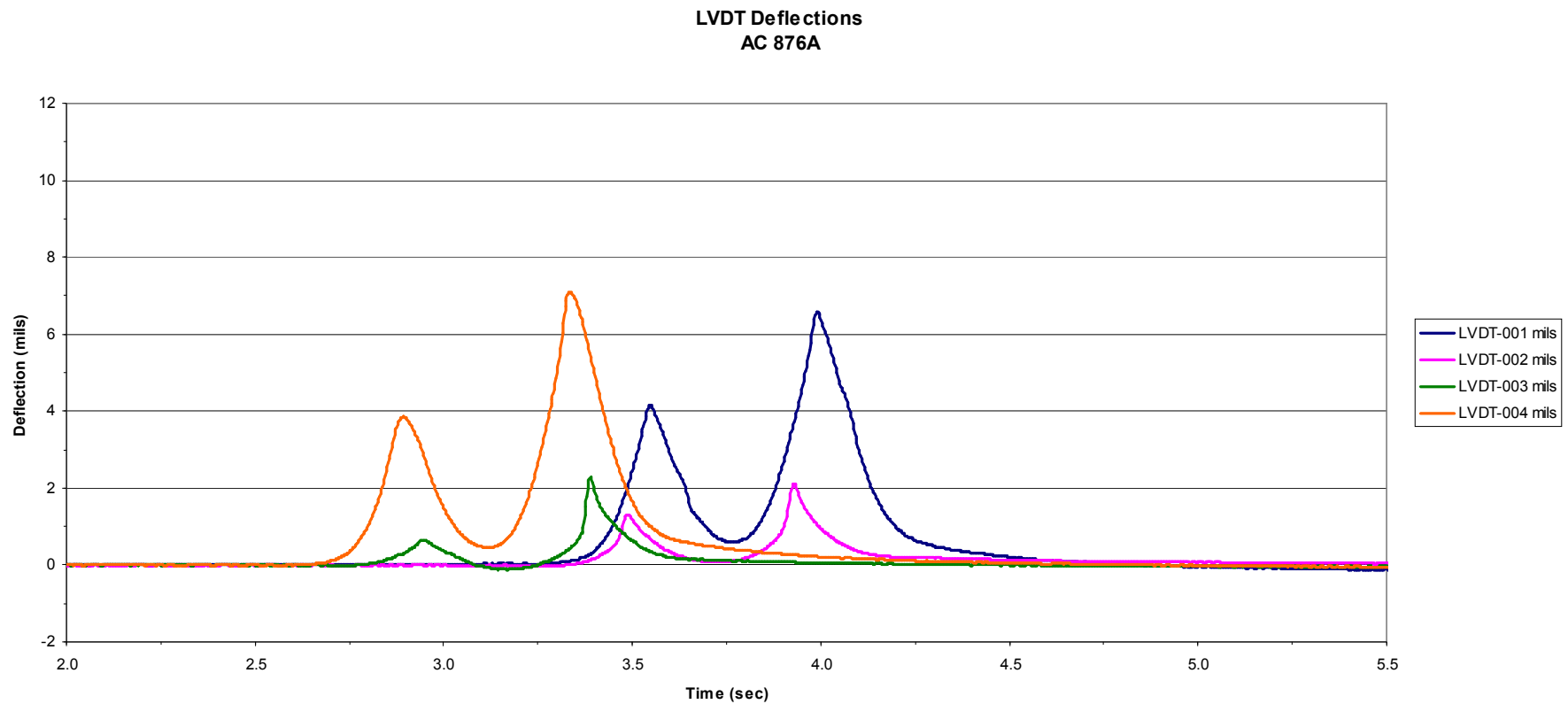
# WAY-30 FRL Longitudinal Strain Response

25 mph Test: ODOT 20 Kip Single Axle Truck Run 1-I



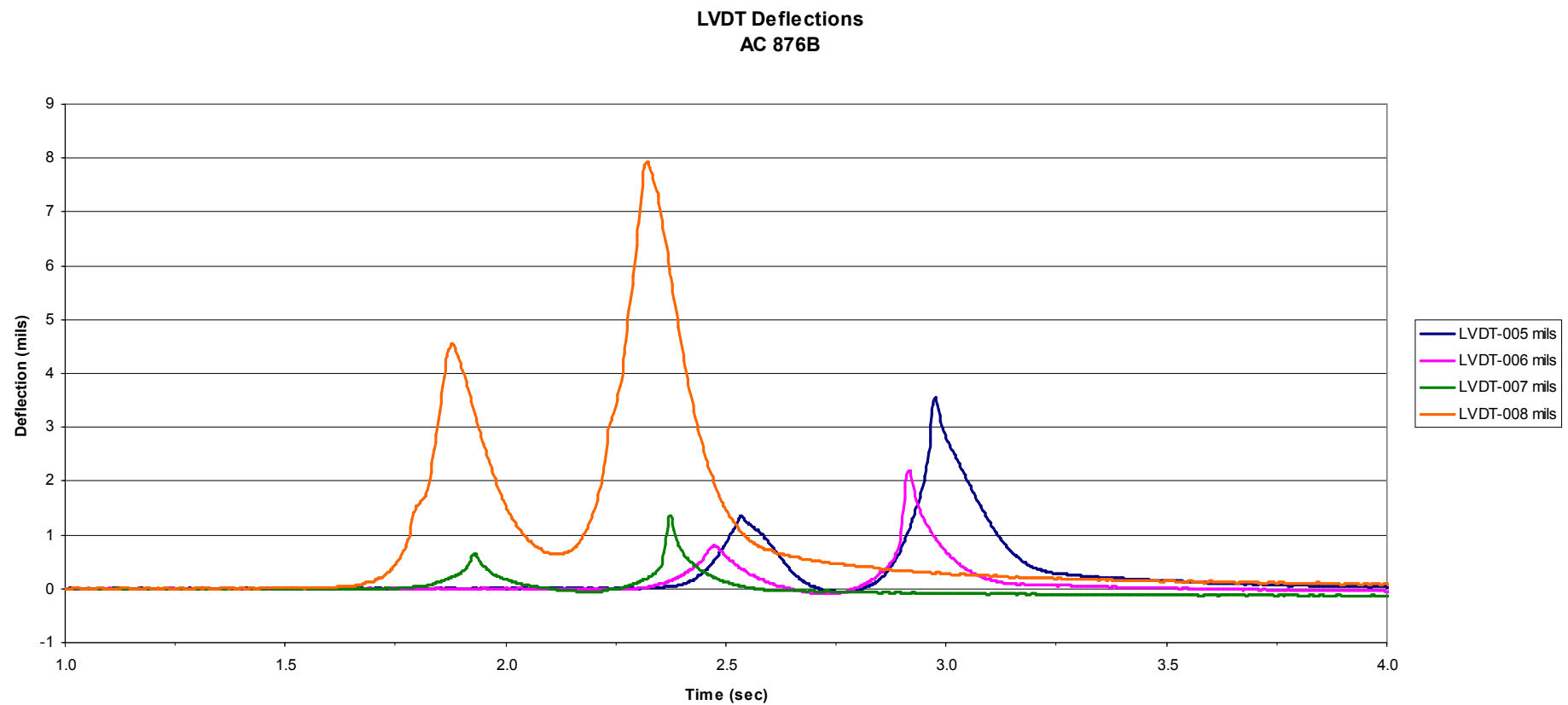
# WAY-30 LVDT Response

25 mph Test: ODOT 20 Kip Single Axle Truck Run 1-II



# WAY-30 LVDT Response

25 mph Test: ODOT 20 Kip Single Axle Truck Run 1-II



# Conclusions

- In the December 2005 CVL test, at low temperature, the longitudinal strain in the FRL was under  $35 \mu\epsilon$ , even at the slowest speeds.
- In general, observed strains under FRL remained below design strains, even under hot summer conditions for CVL truck loads at near highway speeds (45 mph (72 km/h) and higher). CVL loads are heavier than most truck loads.
- Loads at slower speeds (e.g. 5 mph (8 km/h)) were higher, but would only be experienced rarely, e.g. when traffic is stalled. The perpetual pavement FRL is designed to withstand a limited number (dozens or perhaps hundreds) of these loads with no ill effect.



# Conclusions

- Strains developed at the bottom of the ATB layer are lower than the strains developed at the bottom of the fatigue layer, as expected. Overall, the maximum longitudinal strains in the ATB layer are slightly higher than the maximum transverse strain in all axle configurations and loading conditions during the December tests, and for the single axle loads during the July tests.
- Maximum longitudinal strains are slightly higher than maximum transverse strains for all December runs and all single axle runs in July.
- The maximum pressure observed in the subgrade during CVL tests on the AC sections was 6.5 psi (44.8 kPa) at 45 mph (72 km/h) under a 40 kip (178 kN) tandem axle load.



Warm Mix Asphalt Perpetual Pavement

# ORITE Warm Mix Asphalt Research Project


- Detailed field, controlled environment, and laboratory evaluation of Aspha-min, Evotherm, and Sasobit and Conventional mixes
  - Field study in Guernsey County, OH
  - Controlled load and environment test at ORITE's Accelerated Pavement Load Facility (APLF) in Lancaster, OH
  - Laboratory studies of materials
- Project sponsored by the Ohio Department of Transportation (ODOT) and the the US Federal Highway Administration (FHWA)

# Controlled Load and Environment Testing at the Accelerated Pavement Load Facility (APLF)

- WMA and HMA surface layers have been built and will be tested at the Accelerated Pavement Load Facility (APLF)
  - Same types as those used on GUE-541 (Aspha-min, Evotherm, Sasobit, and HMA)
  - Built on perpetual pavement sections at two thicknesses
    - Perpetual Pavement similar to WAY-30 construction
- Testing under load at three temperatures:

high	(105°F (40.6°C)),
medium	(70°F (21.1°C)),
low	(40°F (4.4°C))
- FWD
- Collect Pavement Response data
- Infrared camera (during construction)

# Accelerated Pavement Load Facility (APLF)

- Complete, full-scale two-lane pavement, base, and subgrade construction.
  - Testing of Asphaltic Materials and PCC.
  - Full environmental control to regulate humidity and temperature from 10°F (-12°C) to 130°F (54°C).
  - Multiple test paths across the 32-ft (9.75 m) wide pavement.
- 
- A rolling tire load of 9000 lb (40 kN) to 30,000 lb (133 kN) can be applied to simulate a slowly passing truck ( $\leq 5$  mph ( $\leq 8$  km/h)) with standard single or dual tires or wide single tires, up to 500 times per hour

# Installation at the APLF



← Paving in the APLF

Sensor placement →





# APLF Equipment



Load Wheel behind beam

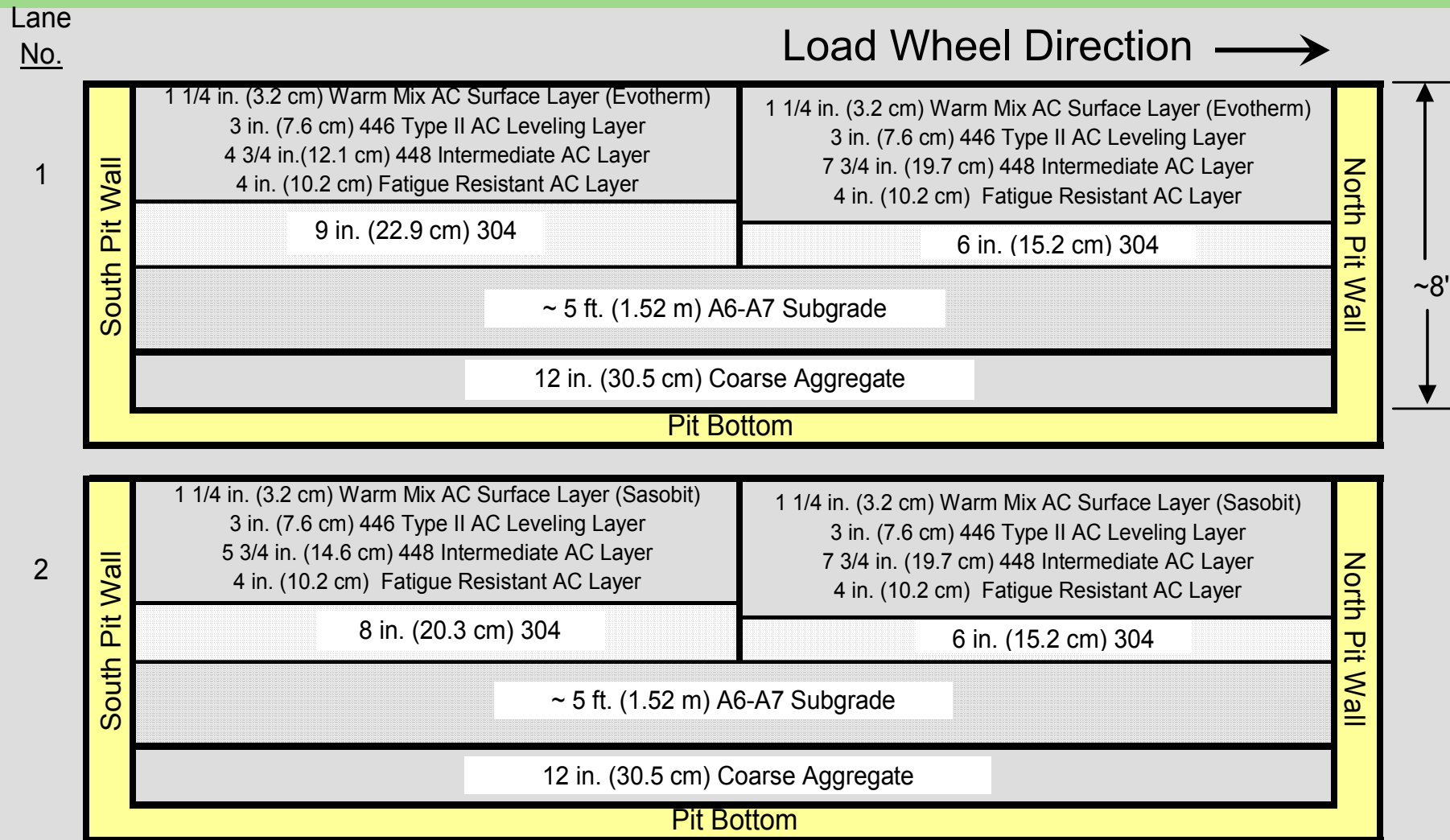
← Profilometer placed  
under load wheel beam

# Abbreviations used

- AC=Asphalt Concrete
- WMA=Warm Mix Asphalt
- HMA=conventional Hot Mix Asphalt
- ODOT=Ohio Department of Transportation
- 304 or DGAB=Dense Graded Aggregate Base (ODOT item 304)
- 448 Intermediate Layer=ODOT Item 448
- ATB=Asphalt Treated Base: Modified ODOT Item 302
- FRL=Fatigue Resistant Layer



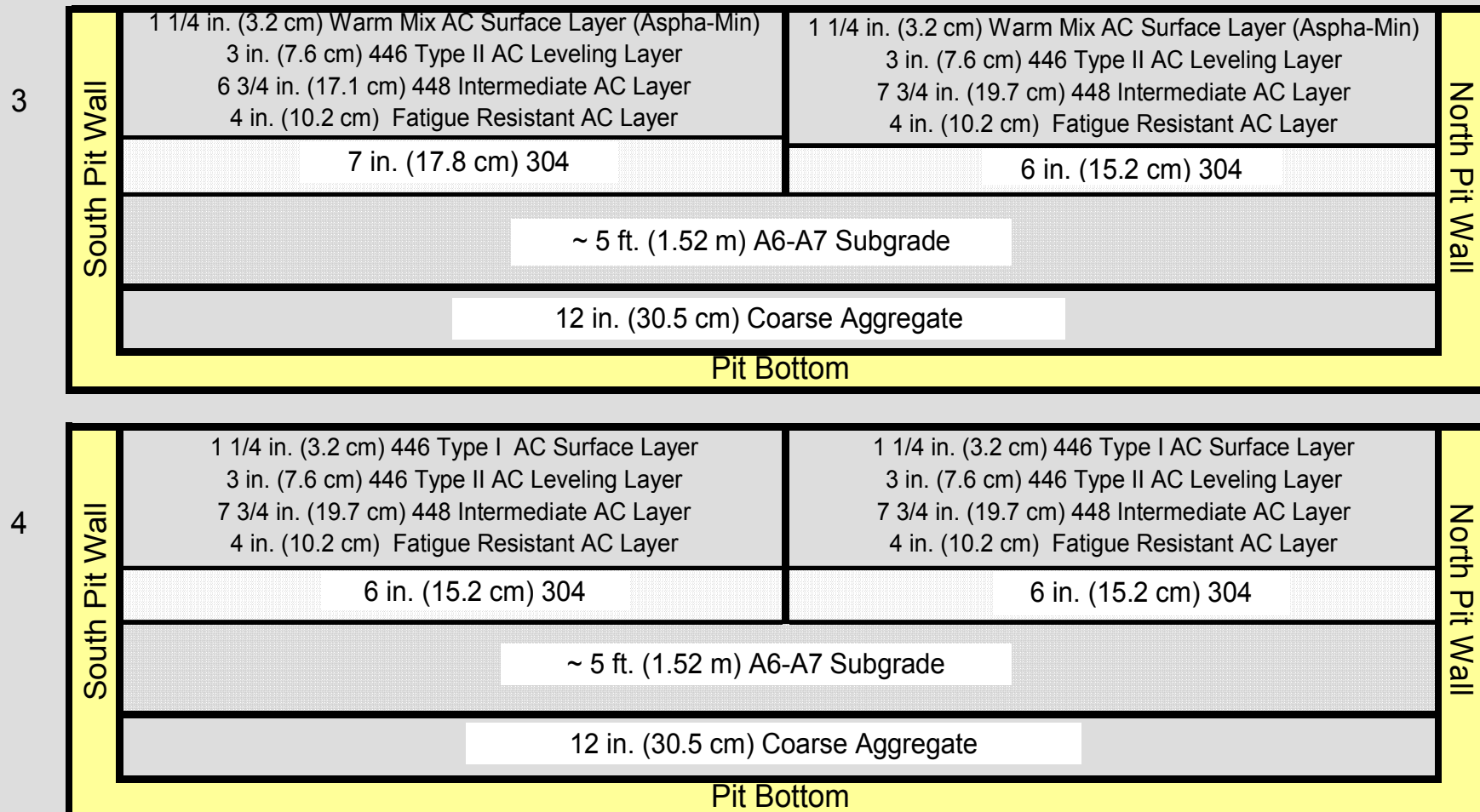
# Layers of WMA pavements constructed in APLF profile view of Lanes 1 and 2



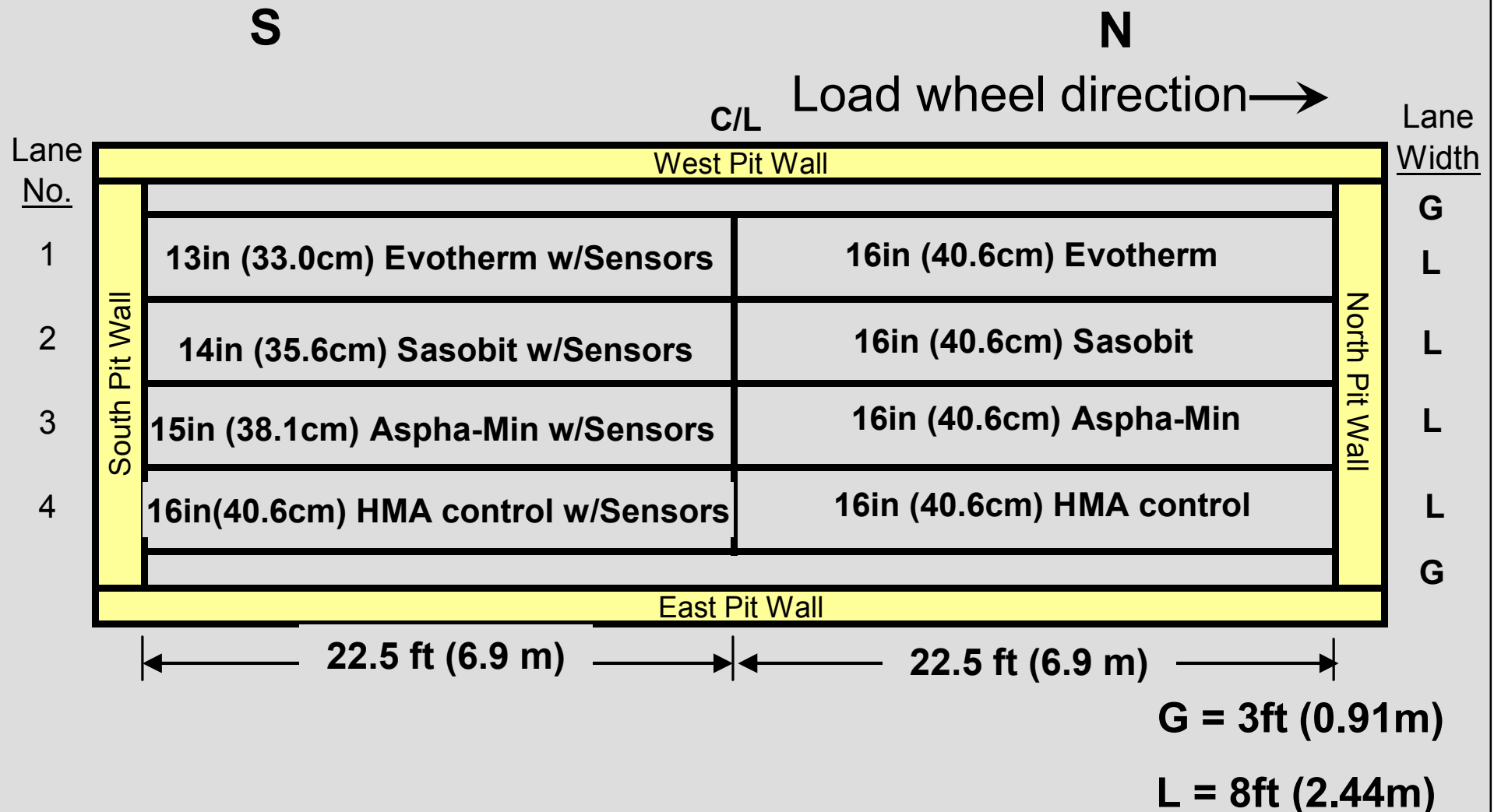
# Layers of WMA pavements constructed in APLF profile view Lanes 3 and 4

Lane

Load Wheel Direction →



# Layout of WMA pavements constructed in APLF plan view



# APLF Monitoring

- Environmental parameters
  - pavement layer temperature
  - Base temperature and moisture
  - Subgrade temperature and moisture
- Load response
  - Displacement
  - Strain
  - Pressure

# Instrumentation in APLF

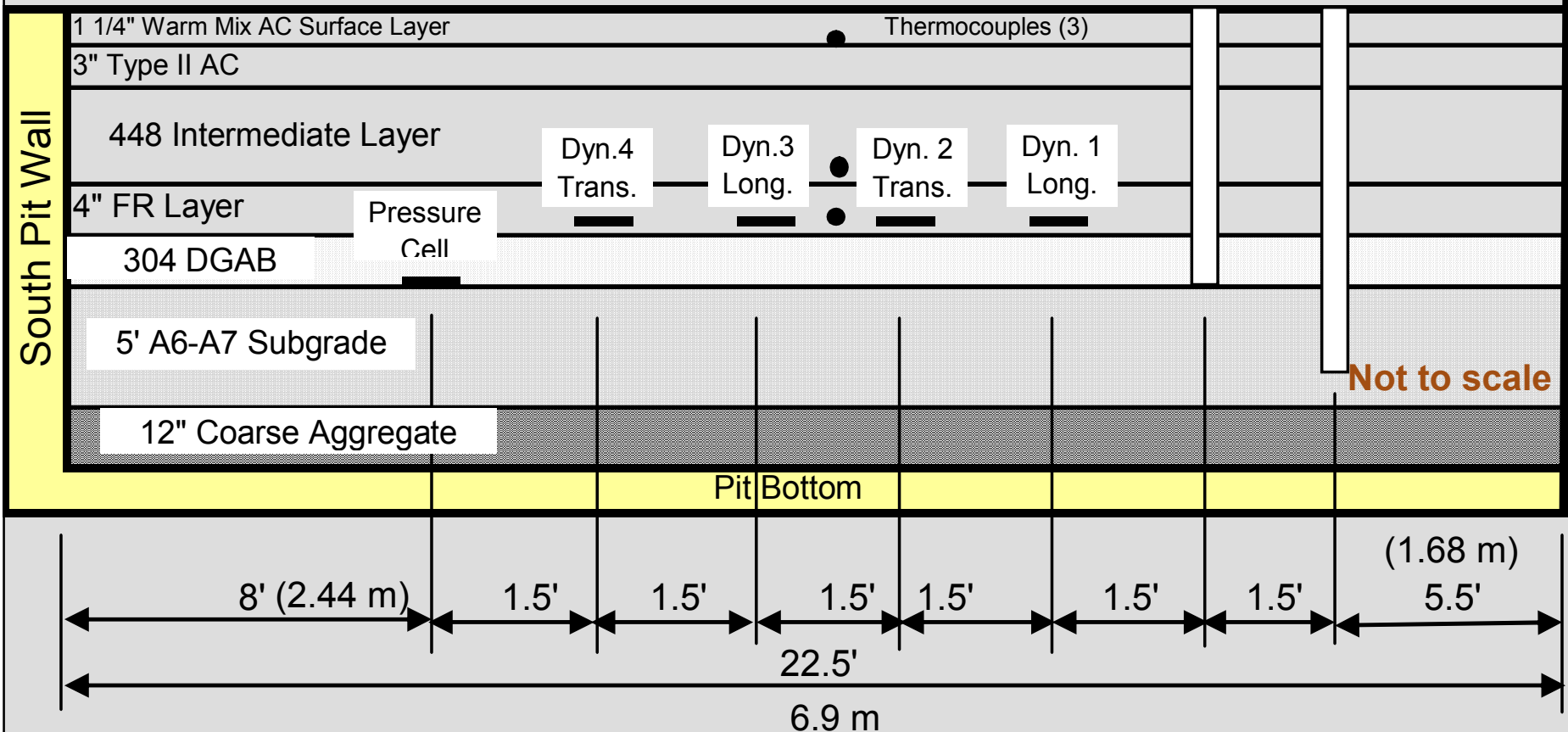
1"=2.54 cm; 1'=0.305 m, 1.5'=0.46 m

Load wheel direction →

LVDT 2 - Ref. Top  
of Subgrade

LVDT 1  
Ref. ~ 5'

C/L

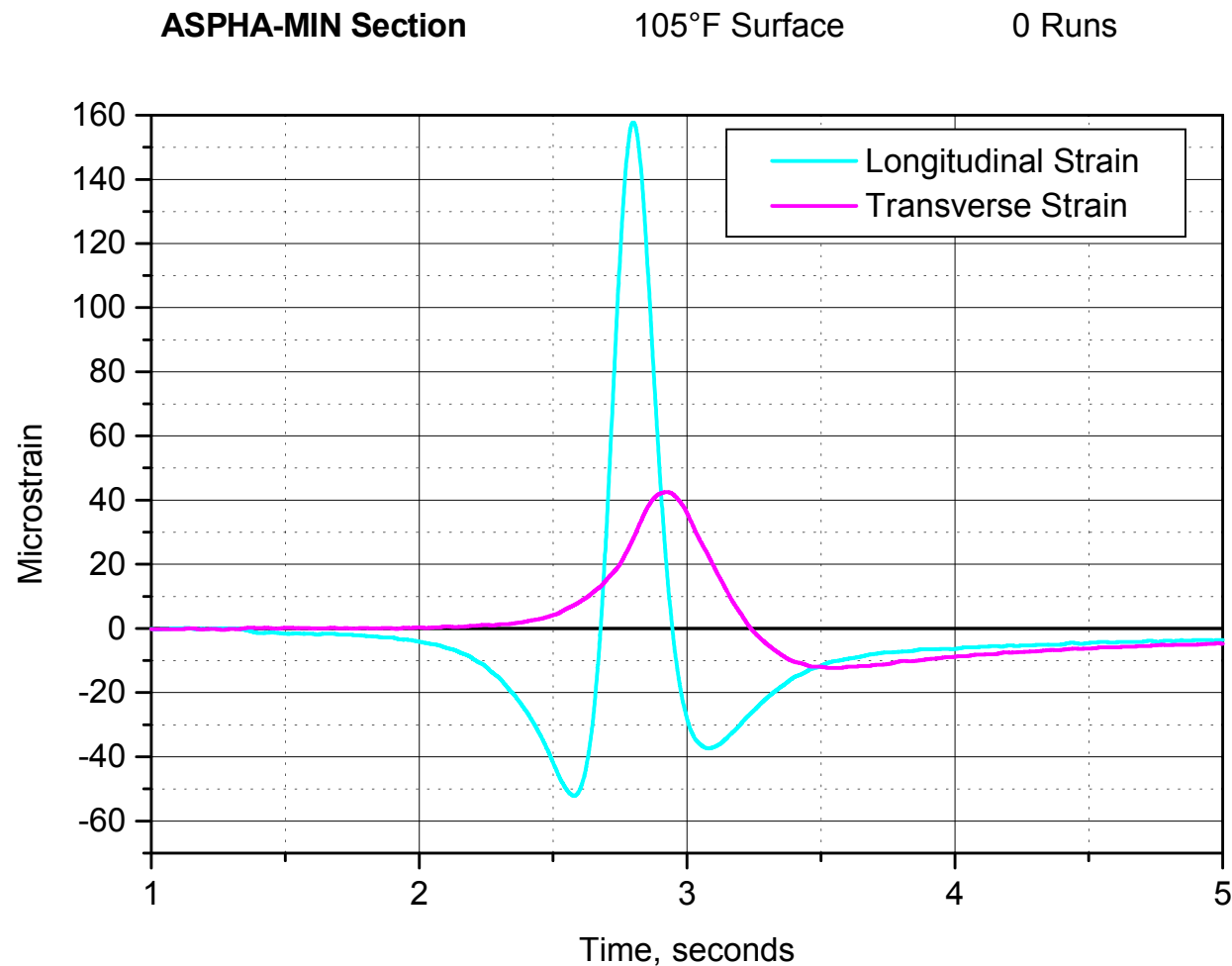


# APLF Test Method

- Tests were conducted in this order:
  - Low temperature (40°F (4.4°C)) -- Completed
  - Medium temperature (70°F (21.1°C)) -- Completed
  - High temperature (105°F (40.6°C)) – HMA completed. Will complete WMA sections by end of January
- At each temperature and for each pavement:
  - Collect data from instruments at beginning with tire loads of 6 kip (27 kN), 9 kip (40 kN), and 12 kip (53 kN)
  - 10,000 passes of 9 kip (40 kN) dual tire load at 5 mph (8 km/h)
  - Collect data from instruments at end with same loads as at beginning
  - Each type of pavement is tested in sequence
  - Periodically measure profile with profilometer to check for rutting

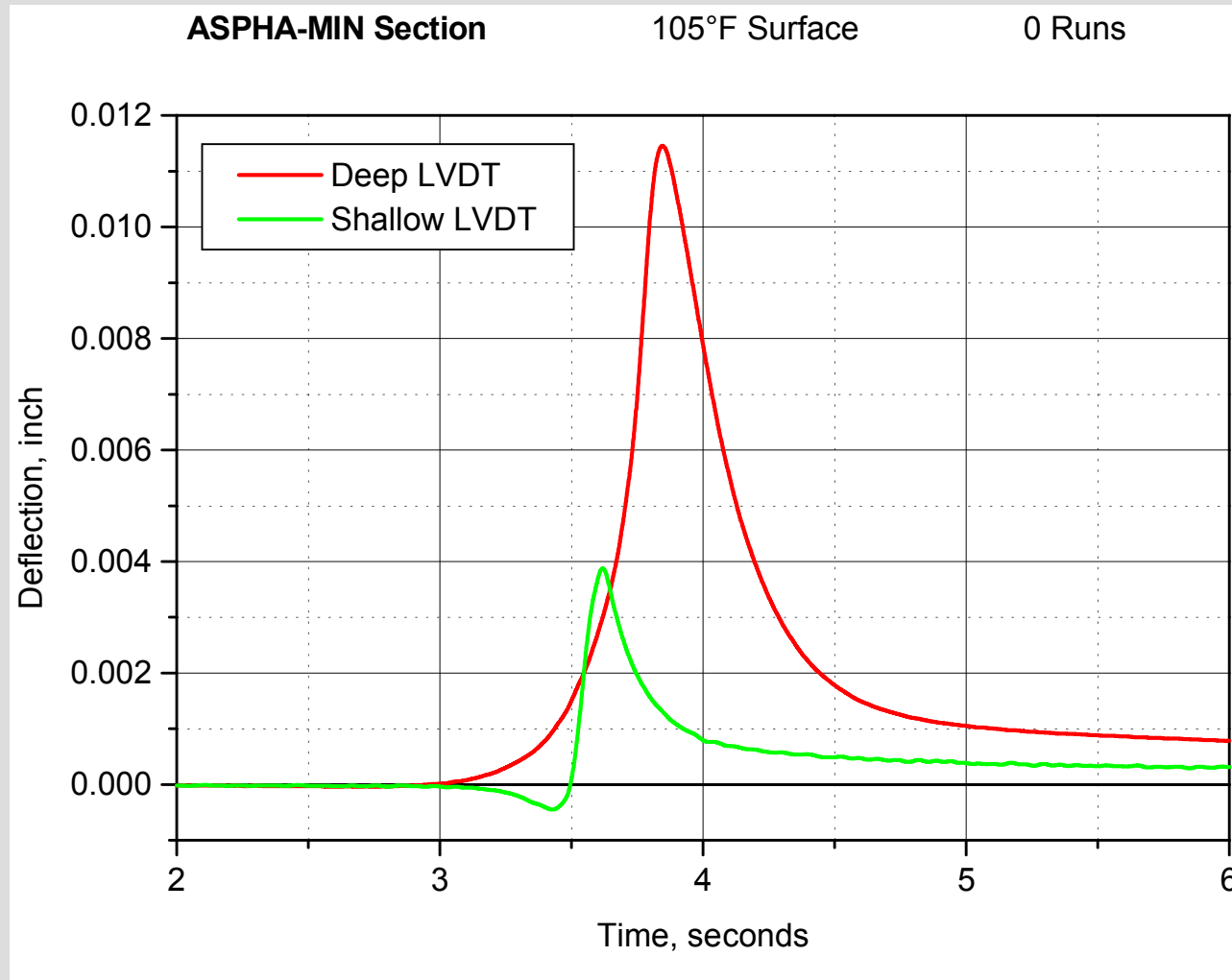
# Asapha-min S Section Initial Results from APLF

0 Runs at high temperature. Load = 12 kip.



# Asapha-min S Section Initial Results from APLF

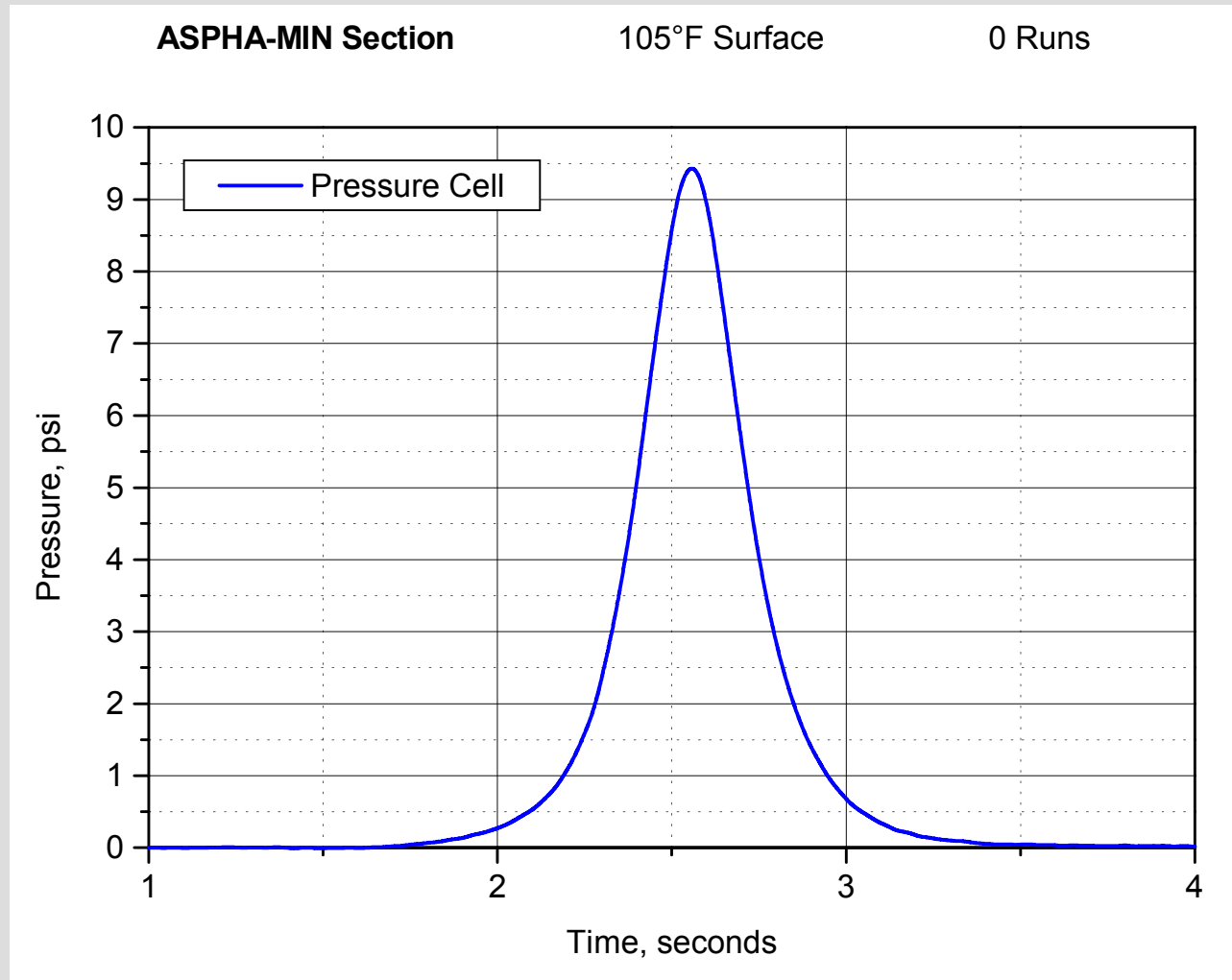
0 Runs at high temperature. Load = 12 kip.





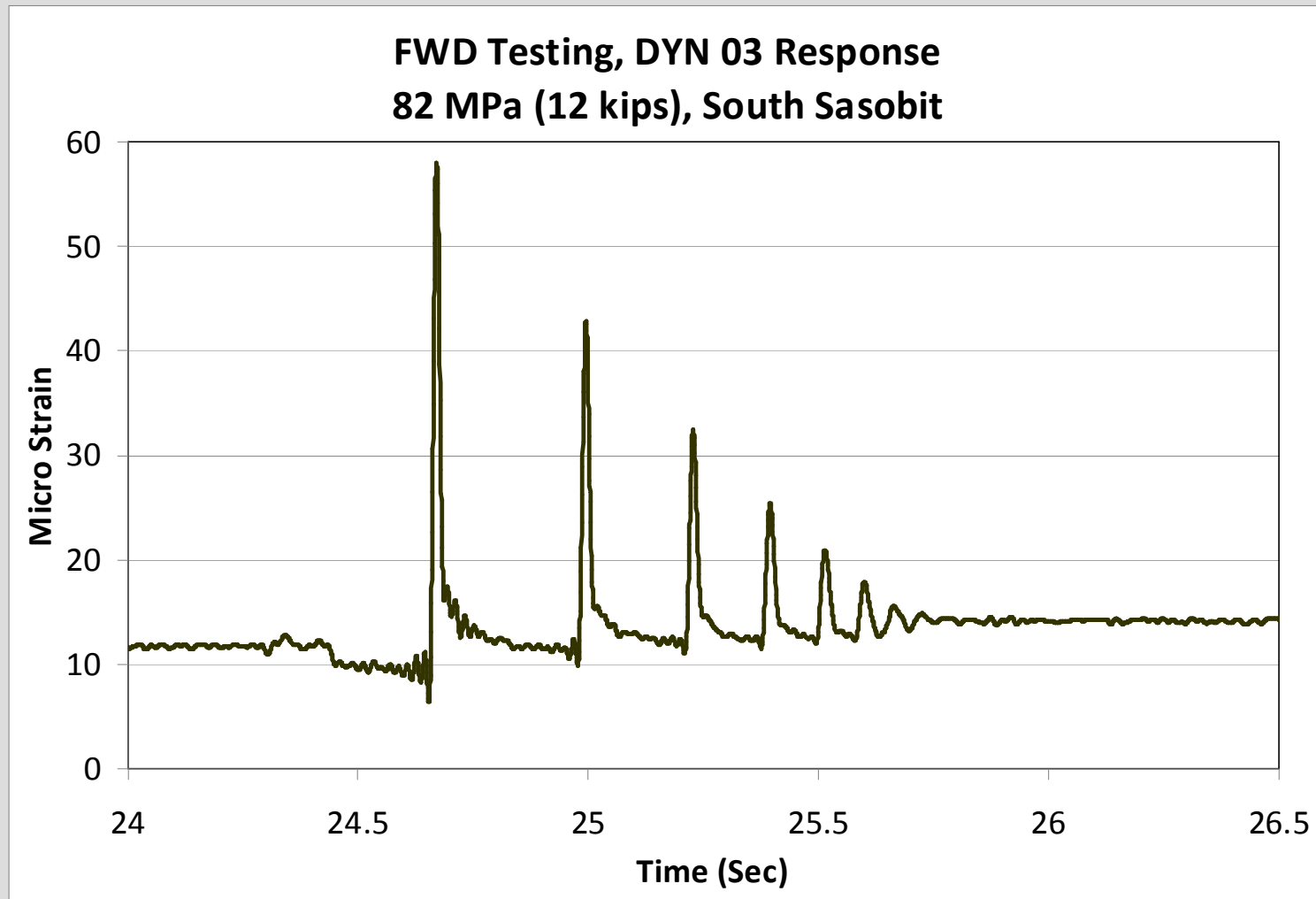
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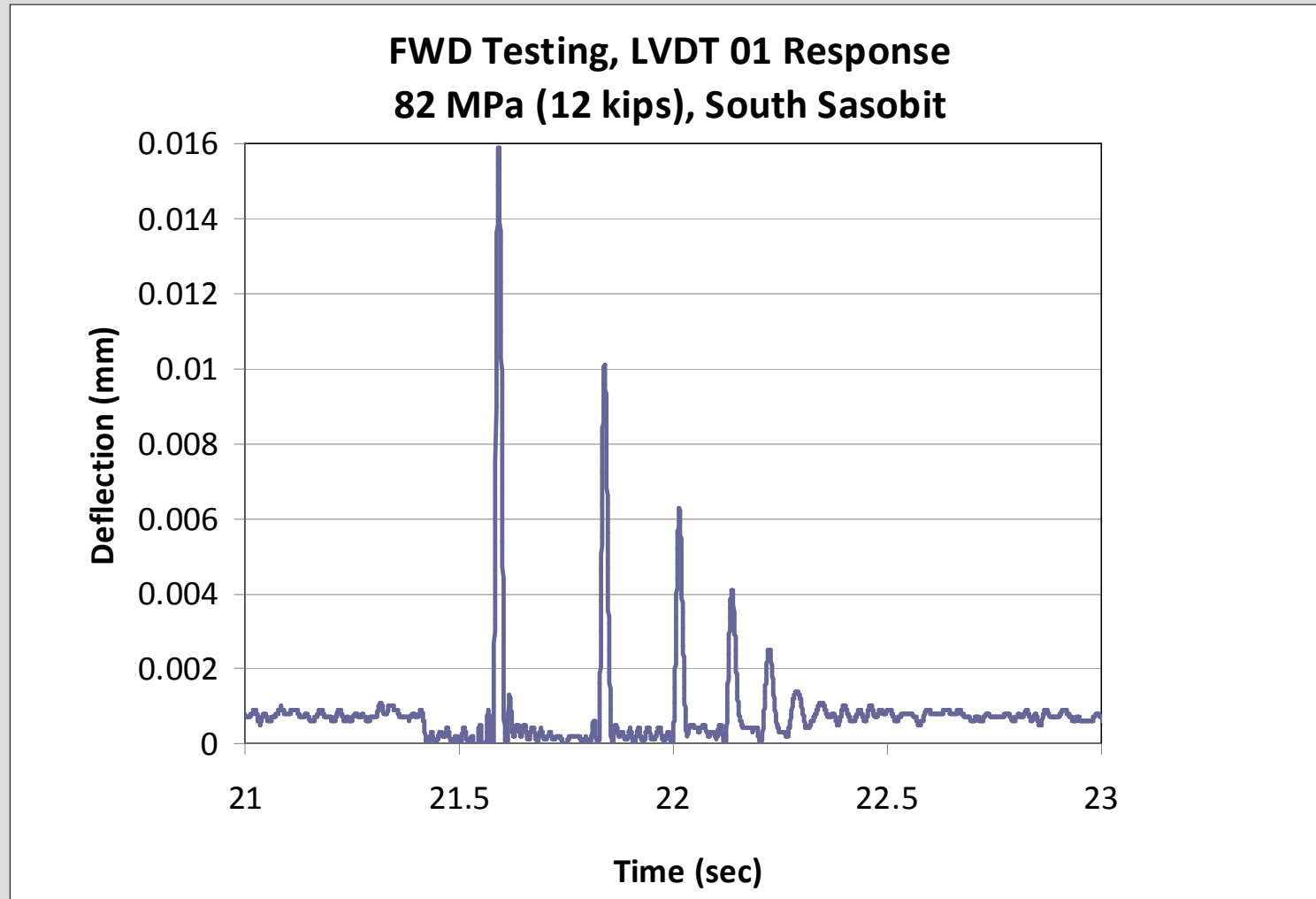
# FWD Strain Response

## Longitudinal strain in FRL



# FWD Deflection Response

## Deep LVDT



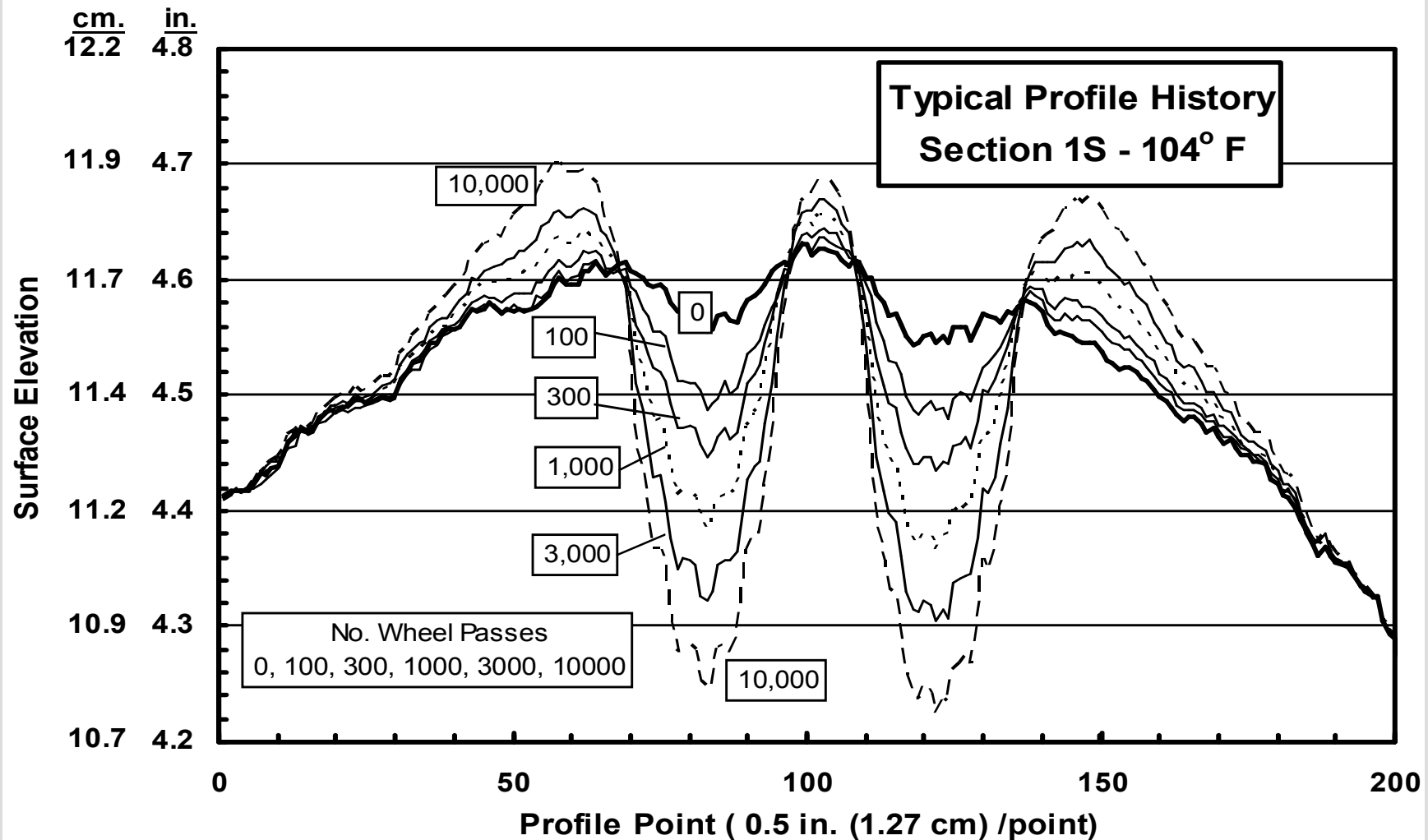
# Measured sensor responses under FWD load plate

Measured Responses from Embedded Sensors under FWD Load Normalized to 9,000 lbs.f. (40.0 kN)				
Nominal Air Temperature	1S (Evotherm)	2S (Sasobit)	3S (Asphamin)	4S (Control)
AC Thickness	13" (33.0 cm)	14" (35.6 cm)	15" (38.1 cm)	16" (40.6 cm)
Average Longitudinal Micro-Strain (Tensile)				
40° F (4.4° C)	12.5	20.2	16.1	10.1
70° F (21.1° C)	30.4	42.7	16.7	36.3
104° F (40.0° C)	55.6	70.4	52.2	51.6
Average Transverse Micro-Strain (Tensile)				
40° F (4.4° C)	17.3	22.7	18.0	15.1
70° F (21.1° C)	39.6	40.0	22.3	32.3
104° F (40.0° C)	51.3	49.8	51.3	47.7
Vertical Pressure on Subgrade - psi (kPa)				
40° F (4.4° C)	1.21 (8.35)	0.77 (5.32)	1.06 (7.34)	0.63 (4.36)
70° F (21.1° C)	3.06 (21.2)	2.52 (17.4)	2.27 (15.6)	1.42 (9.79)
104° F (40.0° C)	4.34 (29.9)	3.19 (22.0)	3.97 (27.4)	4.25 (29.3)
Deflection at Deep LVDT - mils (microns)				
40° F (4.4° C)	1.91 (48.5)	2.03 (51.5)	1.82 (46.2)	1.48 (37.6)
70° F (21.1° C)	2.04 (51.8)	4.42 (112)	2.20 (55.9)	2.34 (59.4)
104° F (40.0° C)	6.43 (163)	4.84 (123)	4.30 (109)	3.86 (98.0)

# Measured sensor responses under rolling wheel load

Measured Responses from Embedded Sensors under Rolling Wheel Load = 9,000 Ibs.f. (40.0 kN)				
Nominal Air Temperature	1S (Evotherm)	2S (Sasobit)	3S (Asphamin)	4S (Control)
AC Thickness	13" (33.0 cm)	14" (35.6 cm)	15" (38.1 cm)	16" (40.6 cm)
Average Longitudinal Micro-Strain (Tensile)				
40° F (4.4° C)	17.6	17.1	15.8	17.6
70° F (21.1° C)	37.2	40.4	29.6	33.3
104° F (40.0° C)	30.6	33.7	30.3	56.9
Average Transverse Micro-Strain (Tensile)				
40° F (4.4° C)	22.5	21.2	19.5	18.8
70° F (21.1° C)	54.9	58.3	38.1	33.6
104° F (40.0° C)	174.8	165.7	159.1	116.2
Vertical Pressure on Subgrade - psi (kPa)				
40° F (4.4° C)	1.50 (10.3)	0.74 (5.1)	1.24 (8.6)	0.86 (6.0)
70° F (21.1° C)	3.75 (25.9)	3.03 (20.9)	2.84 (19.6)	2.51 (17.3)
104° F (40.0° C)	7.59 (52.3)	6.66 (46.0)	6.64 (45.8)	6.22 (42.9)
Deflection at Deep LVDT - mils (microns)				
40° F (4.4° C)	2.24 (56.7)	1.97 (50.0)	1.80 (45.7)	1.93 (49.0)
70° F (21.1° C)	4.00 (102)	4.62 (117)	2.99 (75.9)	2.97 (75.4)
104° F (40.0° C)	7.47 (190)	11.1 (282)	9.95 (253)	7.23 (184)

# Section 1S profile history showing rutting



# WMA Conclusions

- In this study, the main purpose of studying the different WMA sections was to determine the rutting behavior of the different mixes
- Early consolidation of warm AC mixes under rolling tires was more than the conventional mix, after which the rate of consolidation was slightly less for the warm AC mixes than that for the conventional mix. Of the three warm AC mixes, Evotherm showed more consolidation than Aspha-Min and Sasobit, which were about the same.

# Perpetual Pavement Conclusions

- The main purpose of looking at the different thicknesses of the perpetual pavement intermediate layers was to compare the strains in the FRLs.
- Reducing the thickness of the intermediate (ODOT Item 448) course from 7.75 in (19.7 cm) to as small as 4.75 in (12.1 cm) and increasing the thickness of the DGAB (ODOT Item 304) layer a corresponding amount did not significantly increase the strain at the base of the FRL.
- When examining FRL strain behavior, it should be noted that this testing was conducted with the pavement at a uniform high temperature; in the field there would typically be a temperature gradient that would moderate the effect.



# FWD Conclusions

- While trends of increasing response with increasing temperature and decreasing AC thickness generally prevailed under the rolling wheels, there were two major differences in responses measured with the FWD and the rolling wheels. First, transverse strains were much higher than longitudinal strains under the rolling wheels at higher temperatures, and higher than either strain under the FWD load plate. Second, the magnitudes of surface deflection and vertical pressure on the subgrade were much larger under the 5 mph (8.0 km/hr) rolling wheels than under the FWD load plate at higher temperatures. Both observations confirm that vehicles moving at creep speed induce higher responses than the FWD, which is designed to simulate vehicles traveling at normal highway speeds.

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