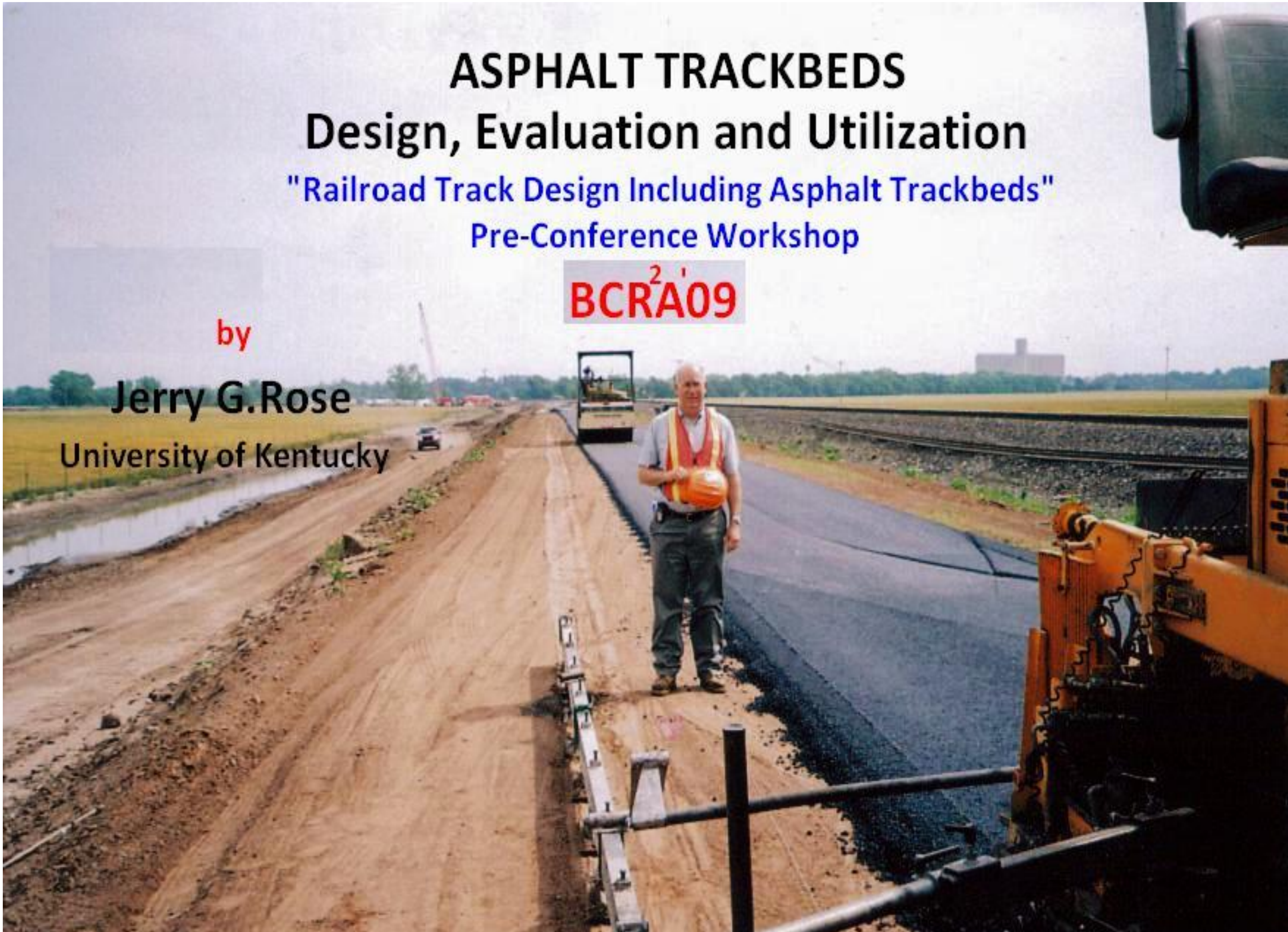

ASPHALT TRACKBEDS
Design, Evaluation and Utilization
"Railroad Track Design Including Asphalt Trackbeds"
Pre-Conference Workshop
BCR2A'09
by
Jerry G.Rose
University of Kentucky

ASPHALT TRACKBEDS
Design, Evaluation and Utilization

Introduction

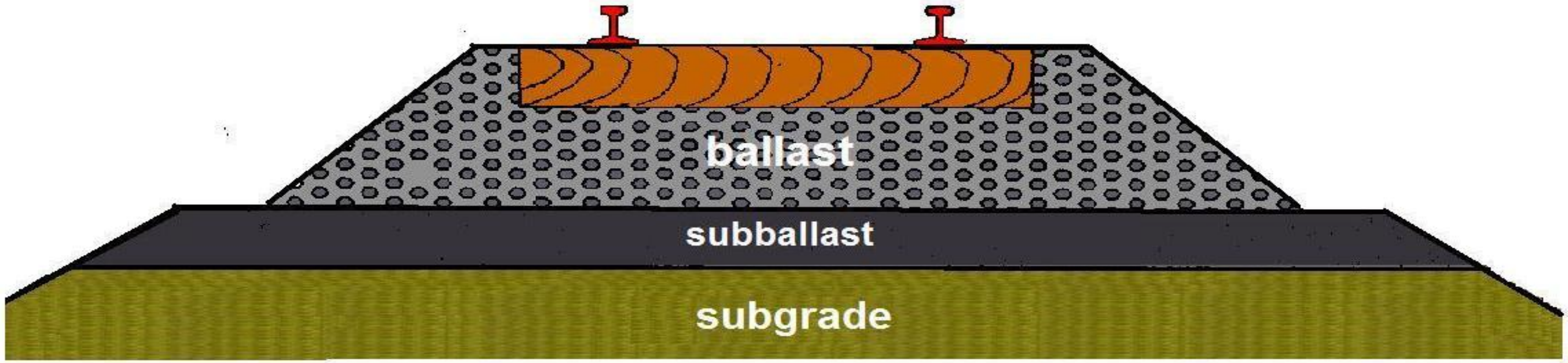
Trackbed Measurements & Evaluations

- Earth Pressure Cell
- Piezoelectric Film Sensor
- Track Deflection
- Track Stiffness
- Long-Term Track Settlement

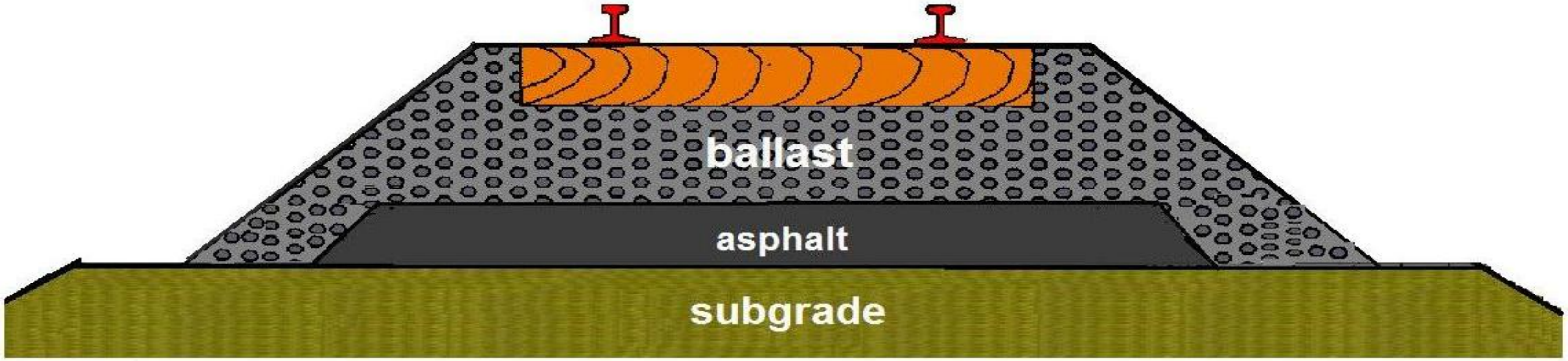
Trackbed Materials Classifications

Utilization Applications

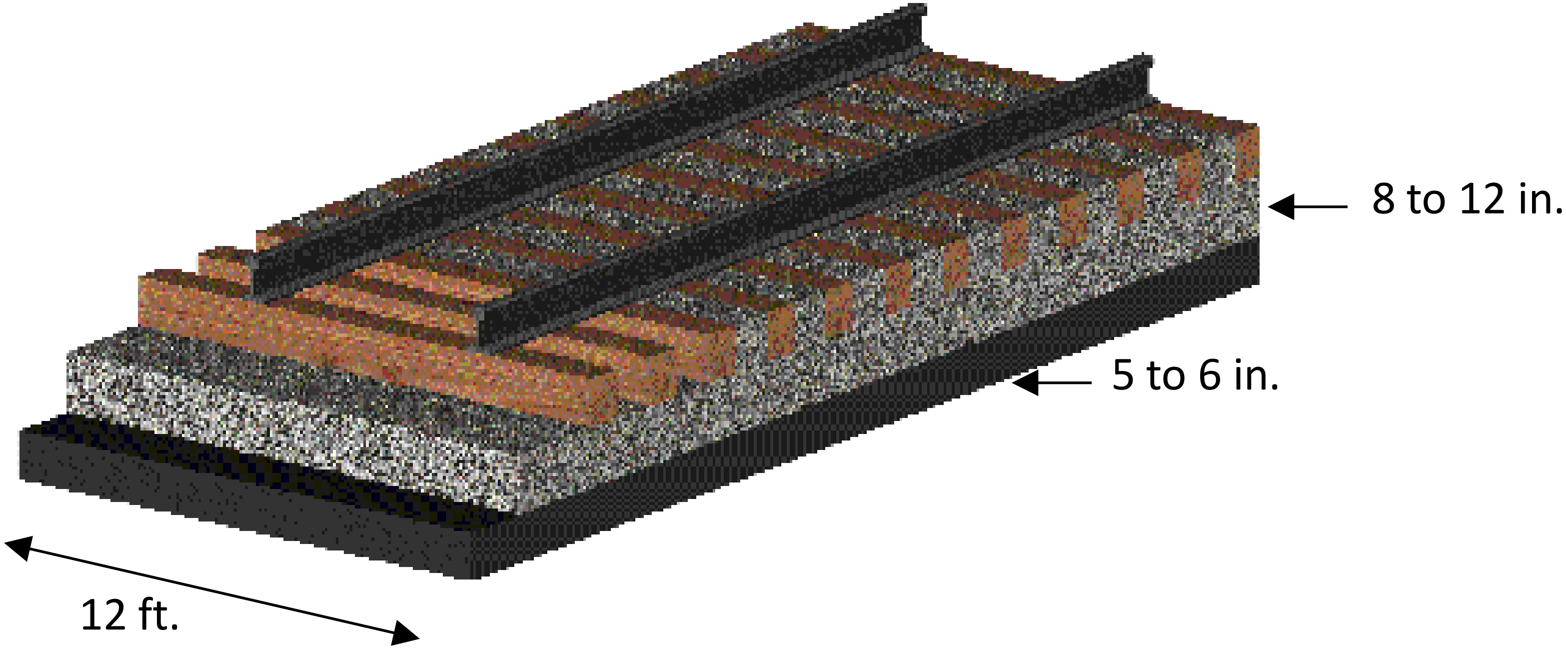
KENTRACK Structural Design



BALLASTED TRACKBED



ASPHALT TRACKBED

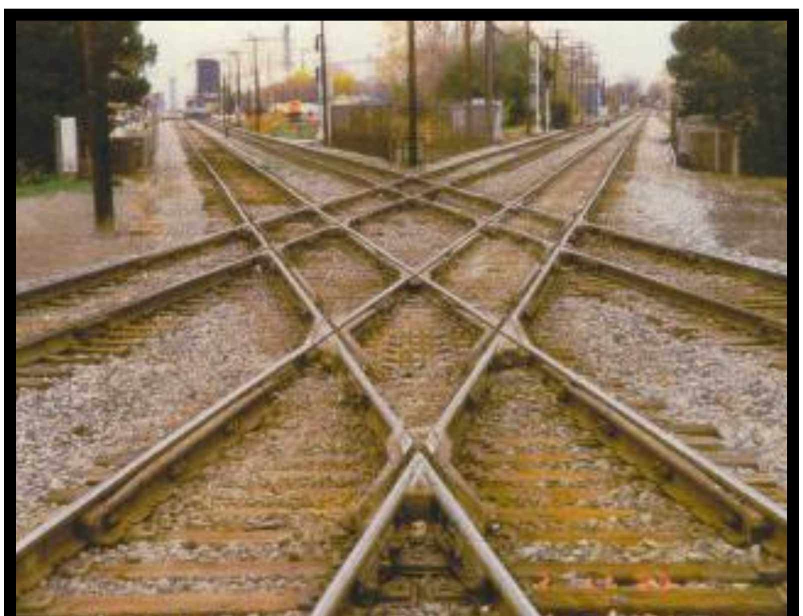


Strengthens Trackbed Support

Waterproofs Underlying Roadbed

Confines Ballast and Track






Dense-Graded Highway Base Mix
1 – 1 ½ in. Maximum Size Aggregate
Asphalt Binder +0.5% above Optimum
Low to Medium Modulus Mix, 1 - 3% Air Voids

Composition of Dense-Graded HMA Mix

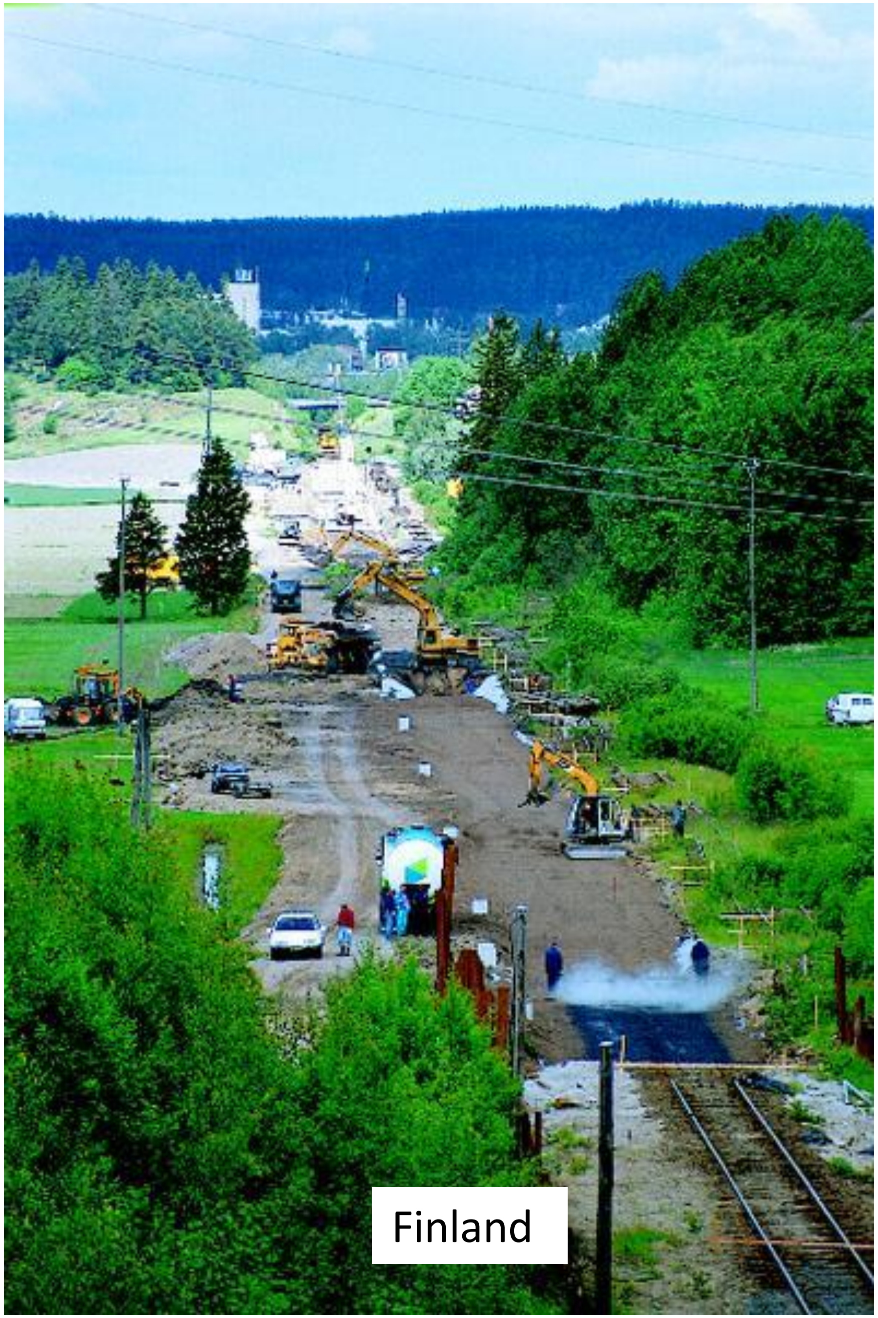
Sieve size	Amount finer, mass %	
	Recommended	Actual
1.5 inch	100	100
¾ inch	70 - 98	76
3/8 inch	44 - 76	52
No. 4	30 - 58	41
No. 8	21 - 45	30
No. 16	14 - 35	23
No. 30	8 - 25	17
No. 50	5 - 20	11
No. 200	2 - 6	4.5
Asphalt	3.5 - 6.5	6.4

Marshall Mix Design Criteria for HMA Underlayment

Property	Required Range	Actual Test Results
Compaction	50 blows	50 blows
Stability (lbs)	750 minimum	1730
Flow (inch)	0.15 – 0.25	0.24
Percent air voids	1 - 3%	2%
Voids filled w/asphalt	80 - 90%	86%
In-place density*	92 - 98%	94%**
*Maximum density = 151 ptc		
** Average nuclear density test results		


Italy


Germany


Finland


Ingersoll Rand

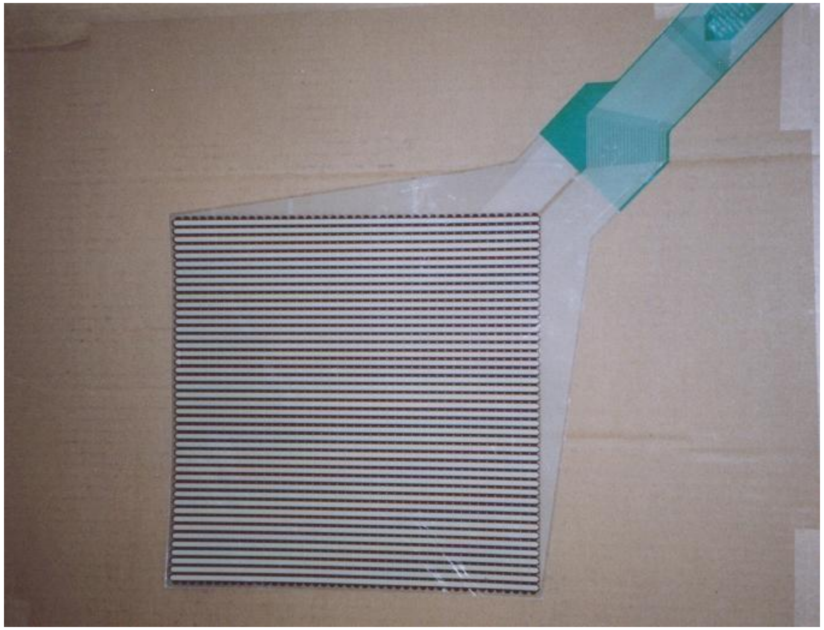

CHINA SHIPPING



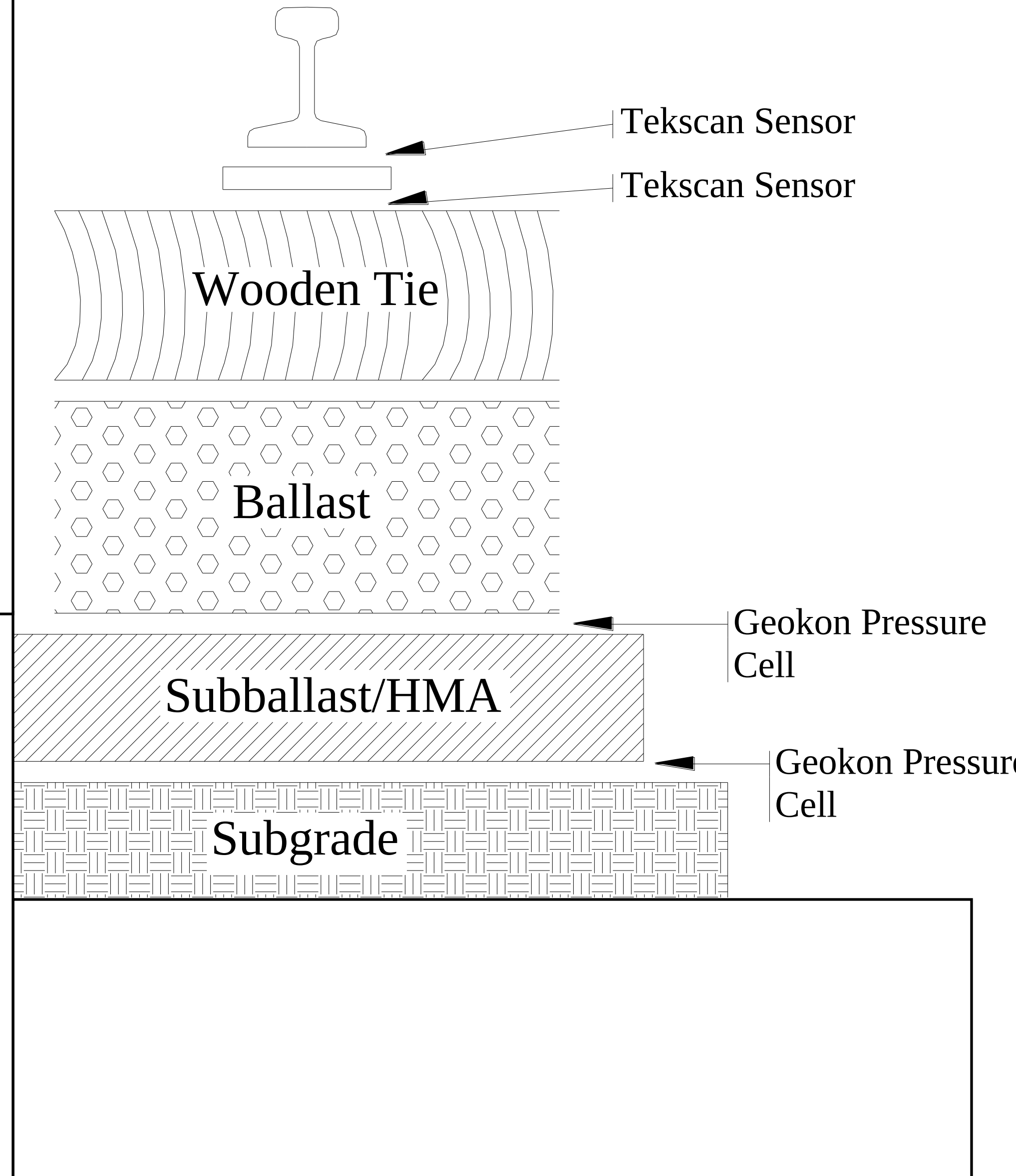

Trackbed Measurements & Evaluations

Earth Pressure Cell
Piezoelectric Film Sensor
Track Deflection
Track Stiffness
Long-Term Track Settlement

Tekscan Sensor



Geokon Pressure Cell Pressure



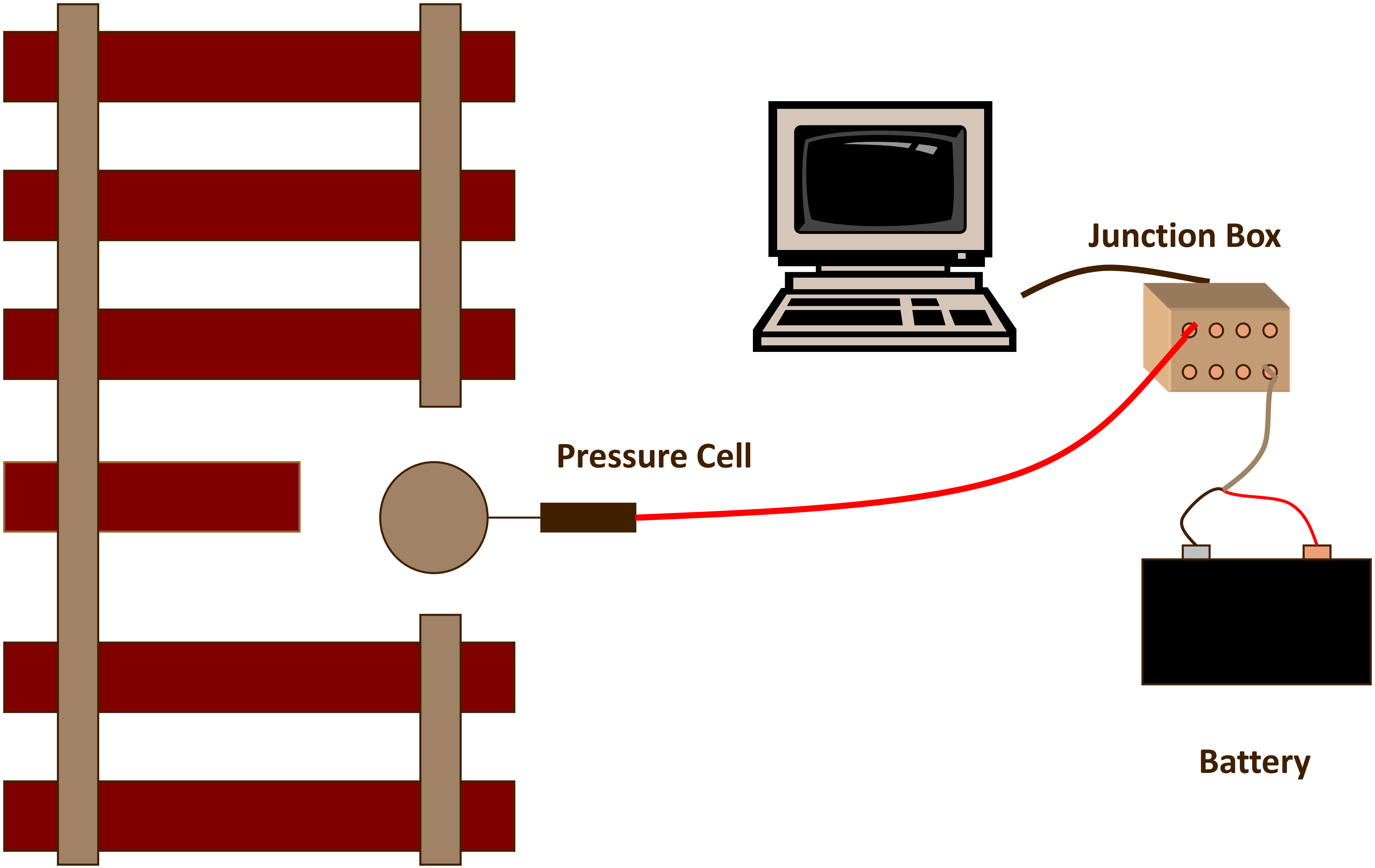
Pressure Cell

- Geokon Model 3500-2
- 9 in. Diameter
- Strain Gage
- Snap-Master
- Thermistor

Cell Placement on Asphalt

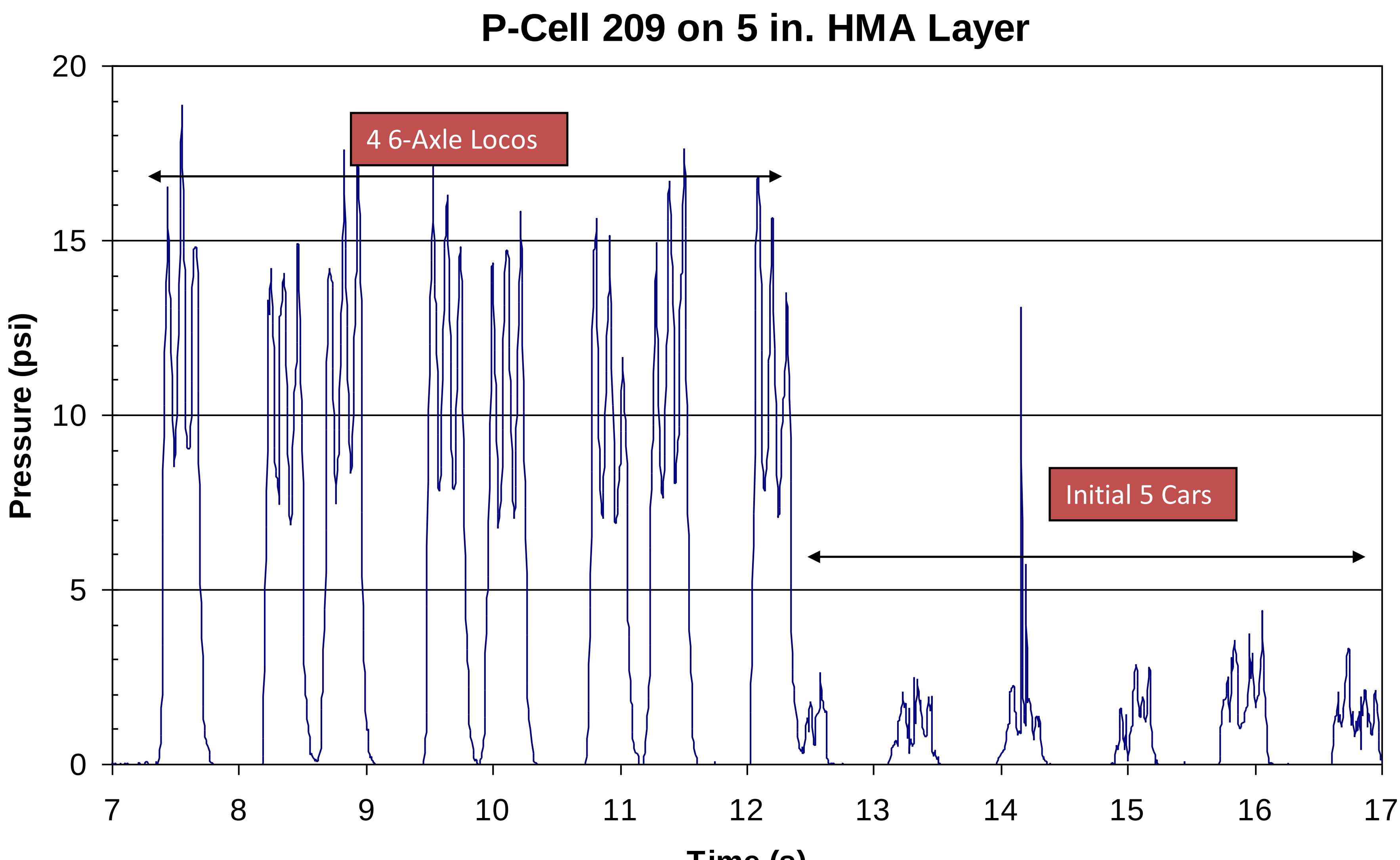
Geokon Hydraulic Earth Pressure Cells

9 in. Diameter

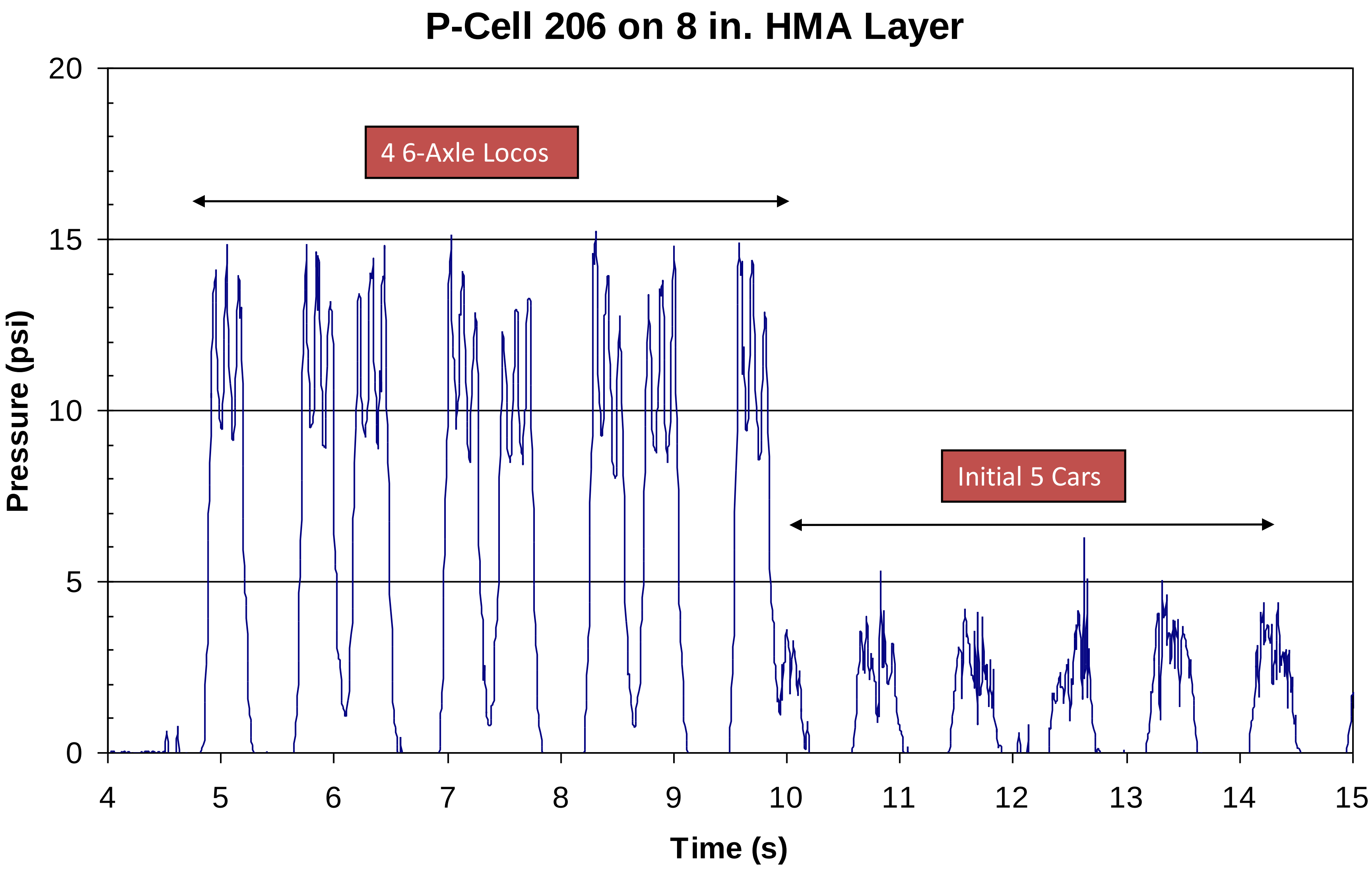


Pressure Cell Measurement Configuration

Empty Coal Train at Conway



Empty Coal Train at Conway



286,000 lb

62,000 lb

180 lb

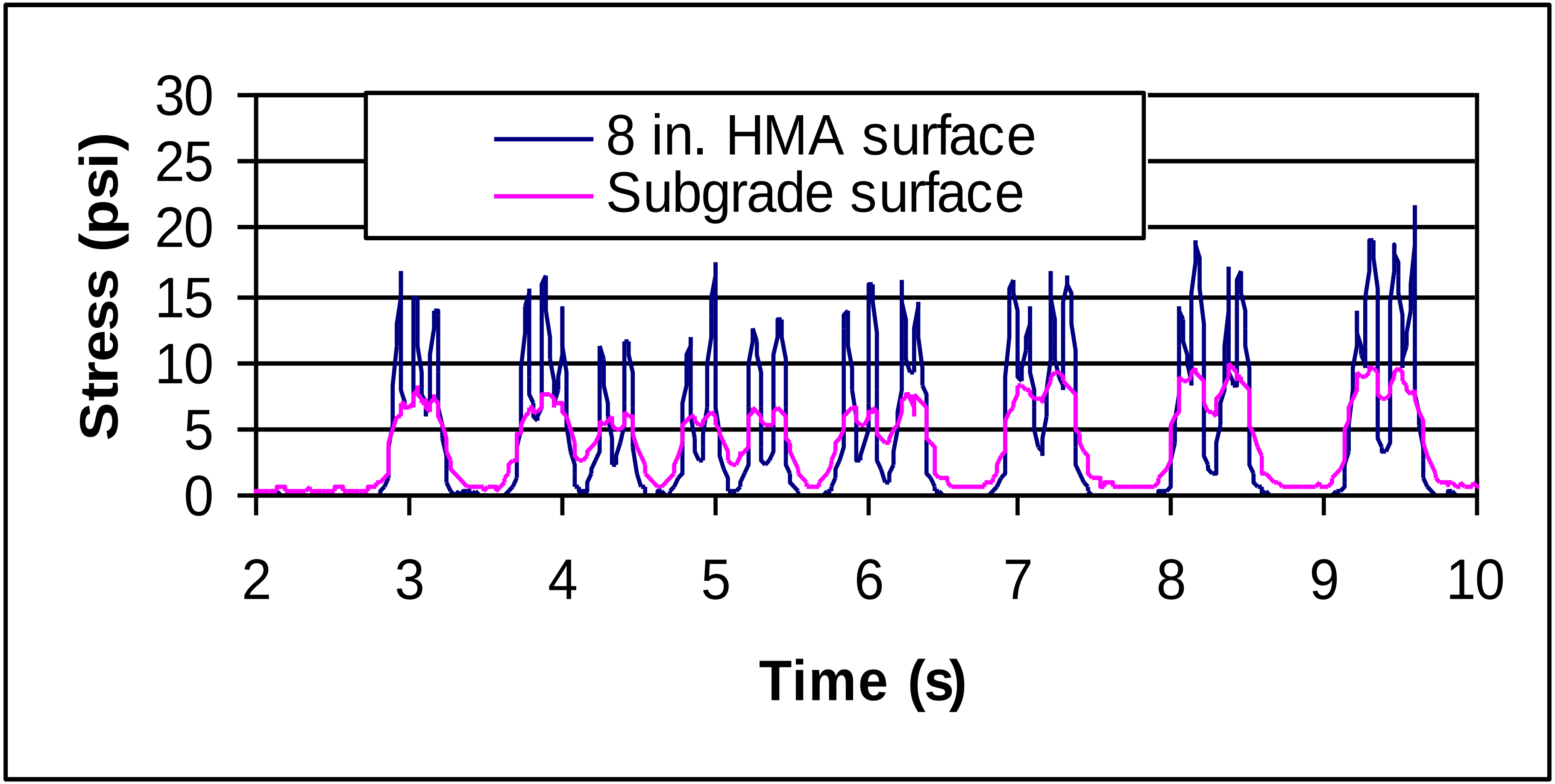
13 - 17 psi

2 - 4 psi

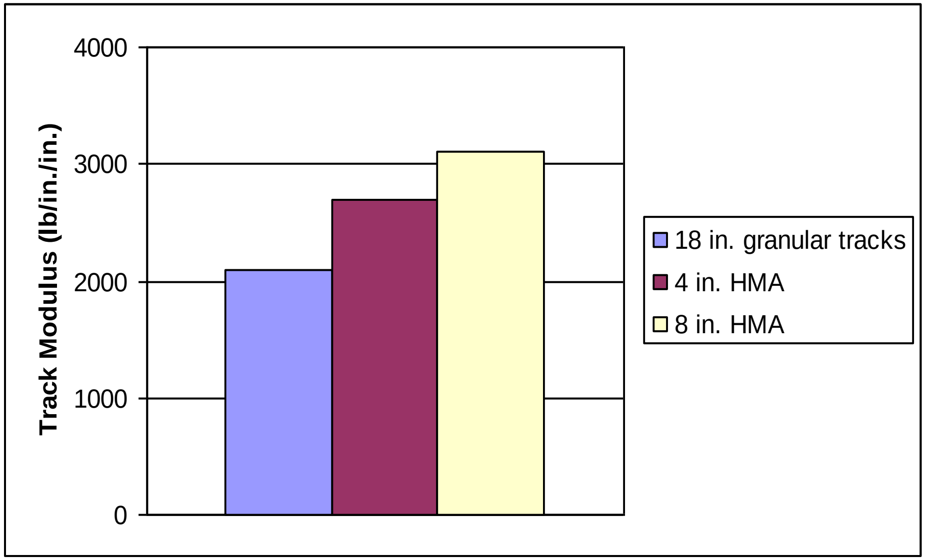
6 psi

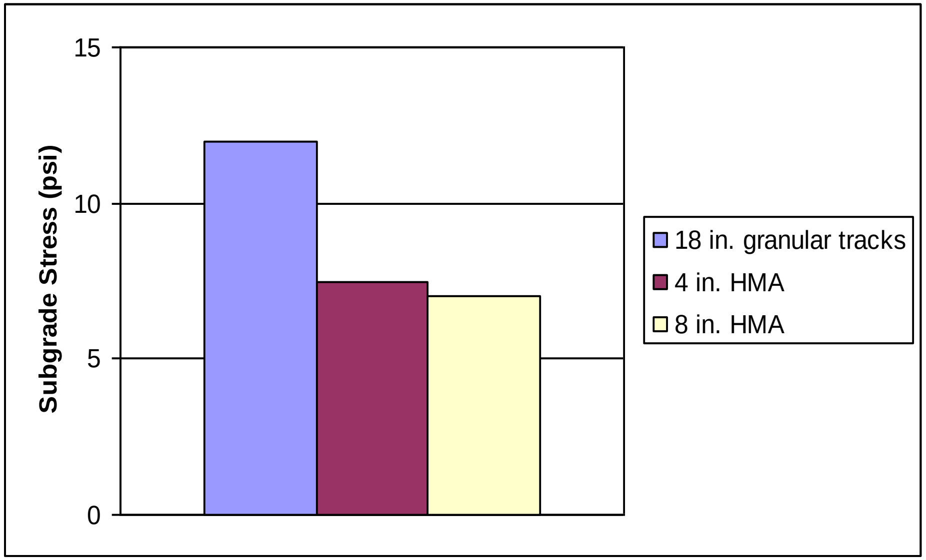
100 - 200+ psi

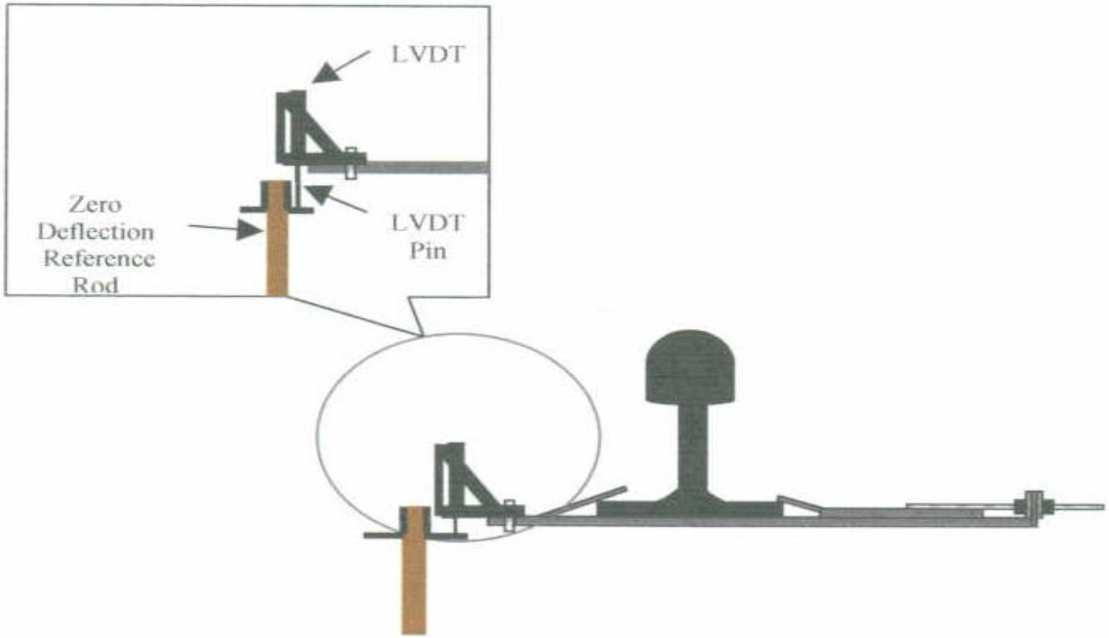
Reduction of Dynamic Stresses



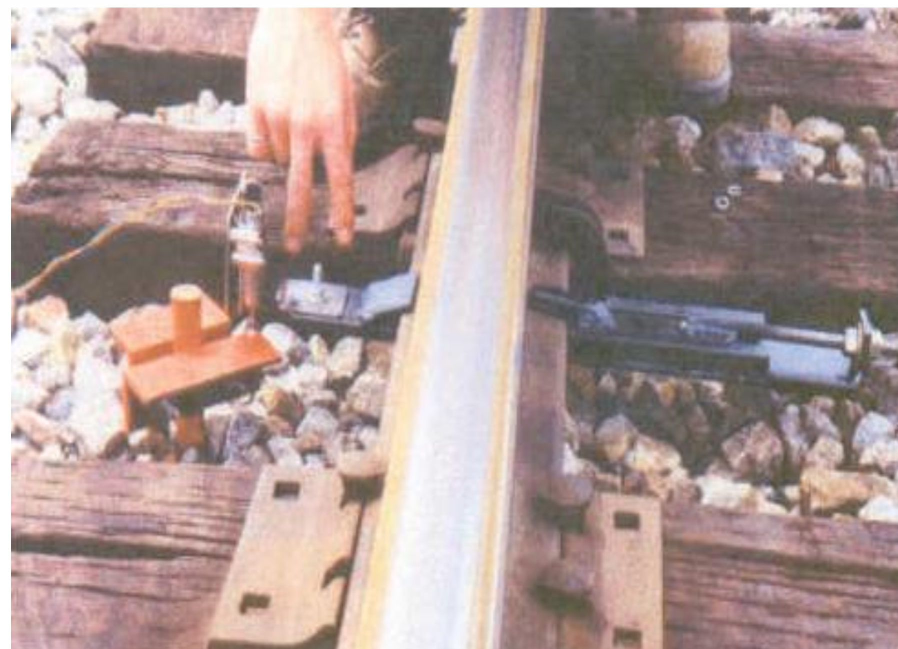
Test Results in Track Modulus and Subgrade Stress



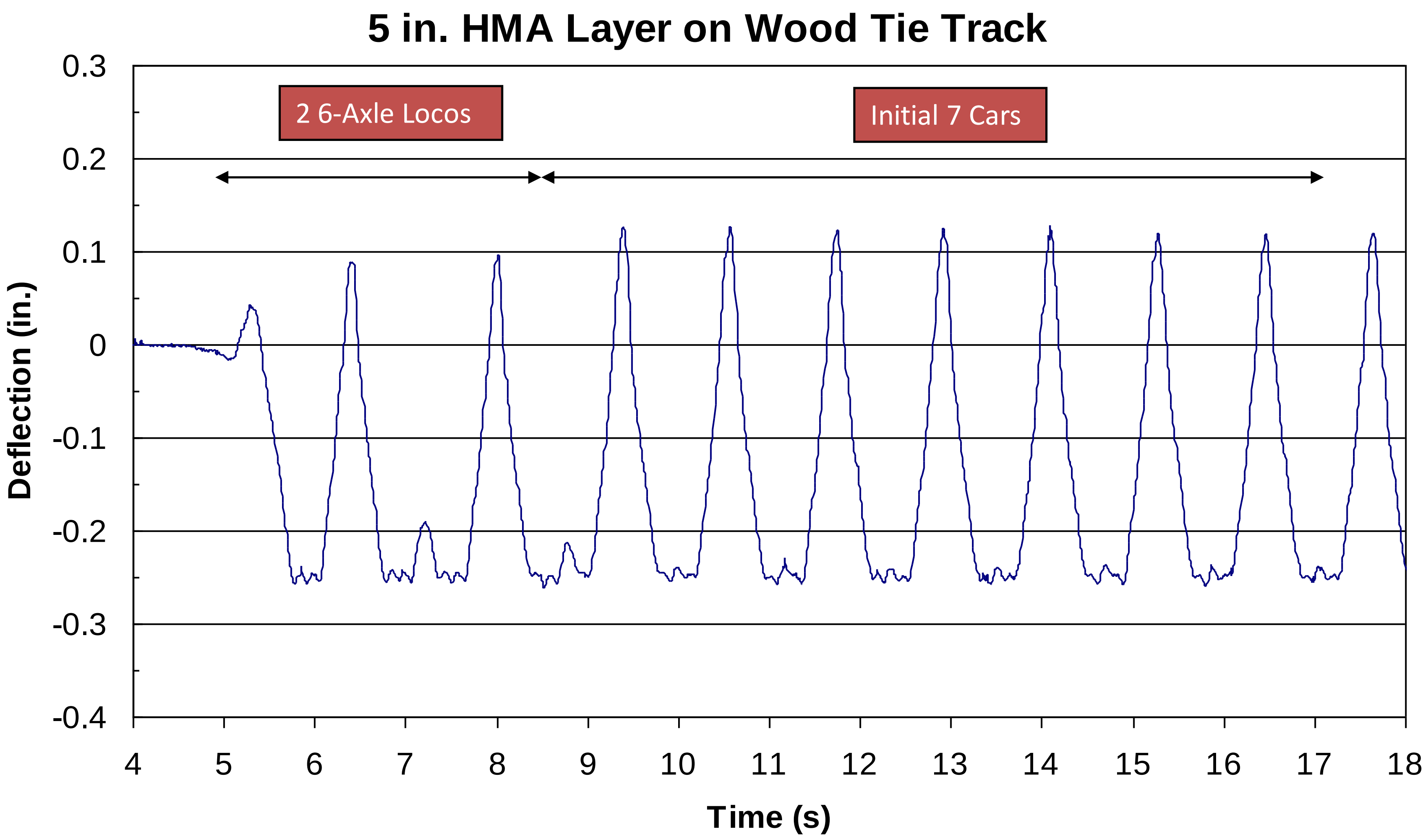



LVDT
Zero Deflection Reference Rod
LVDT Pin

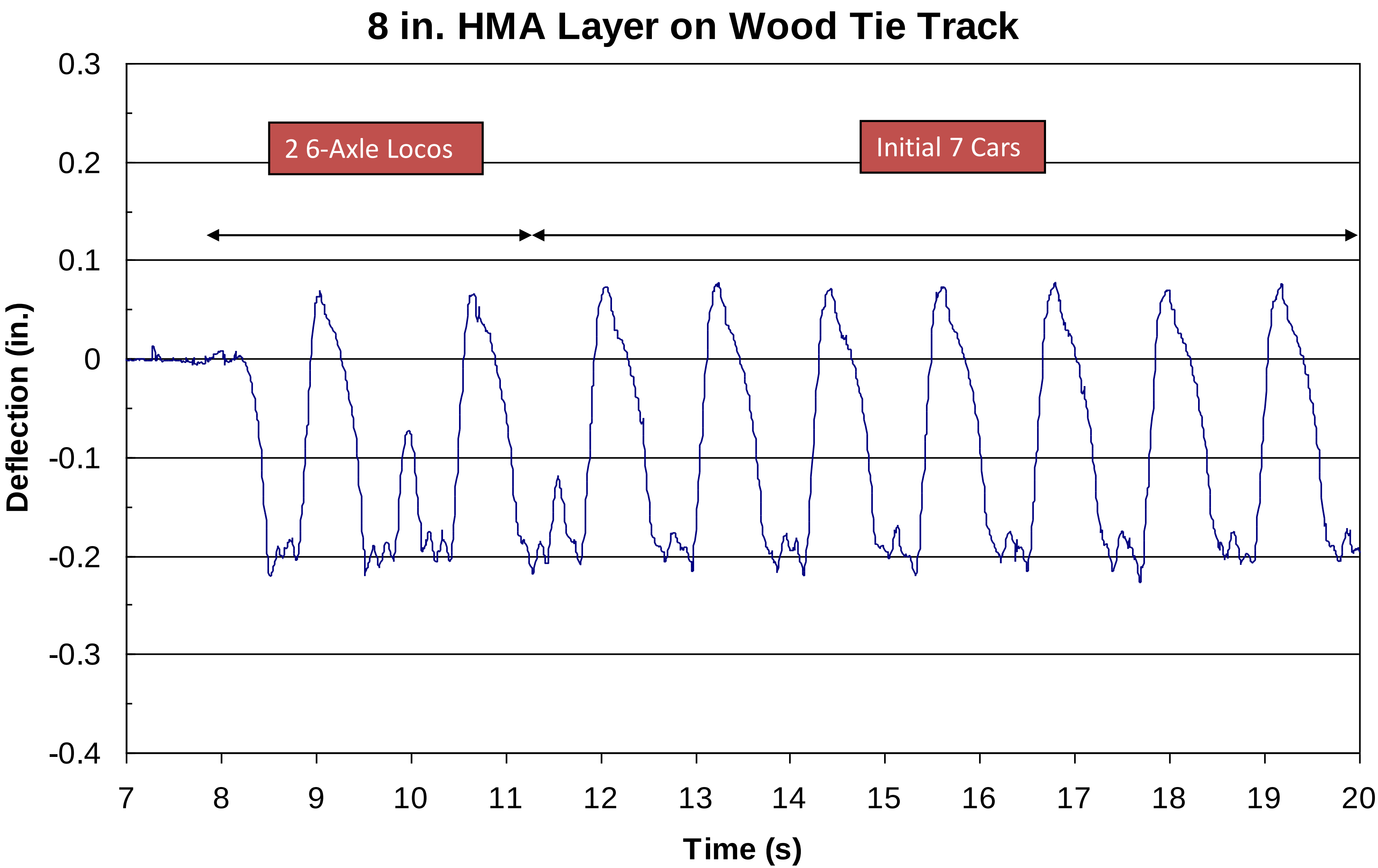

LVDT



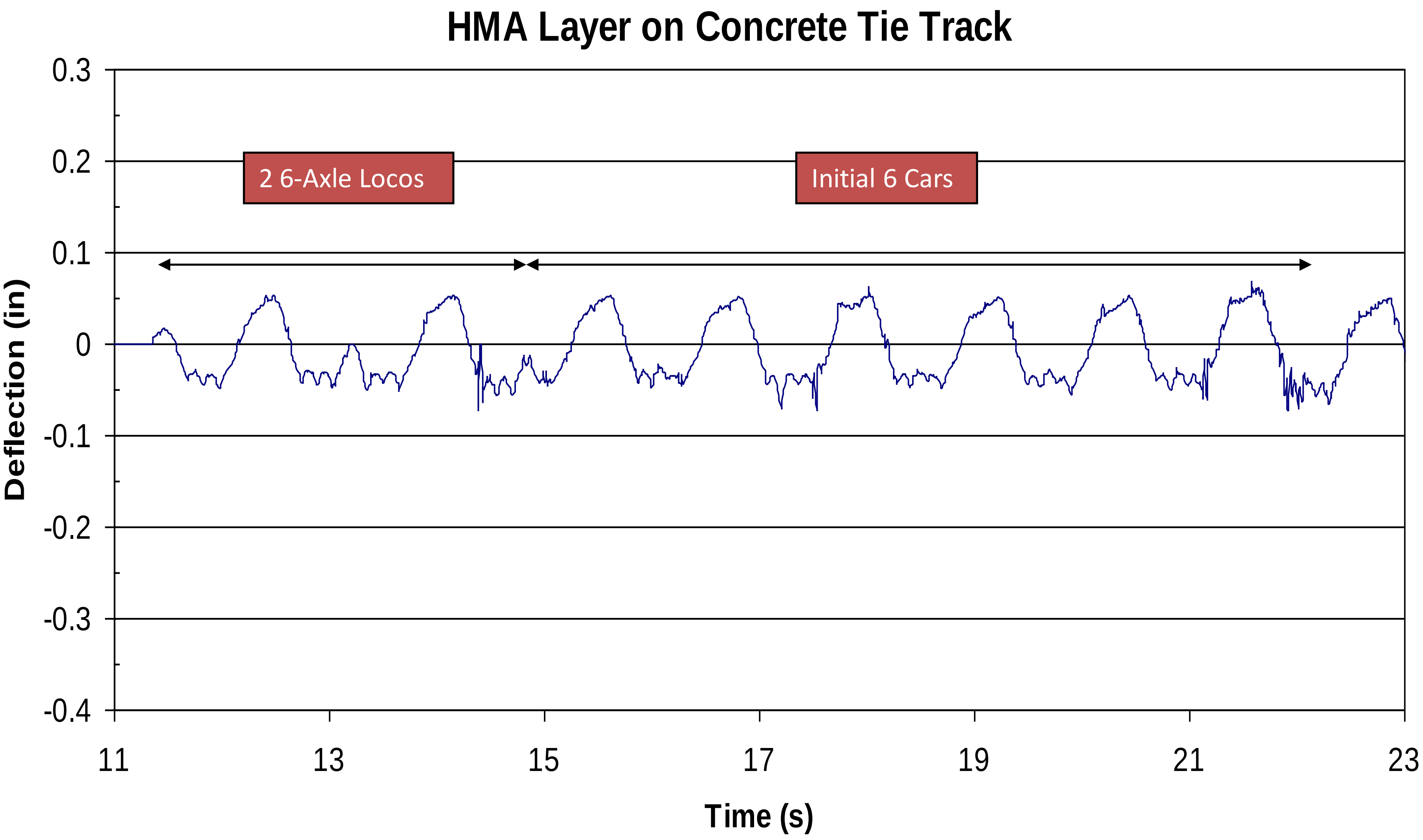
Loaded Coal Train at Conway



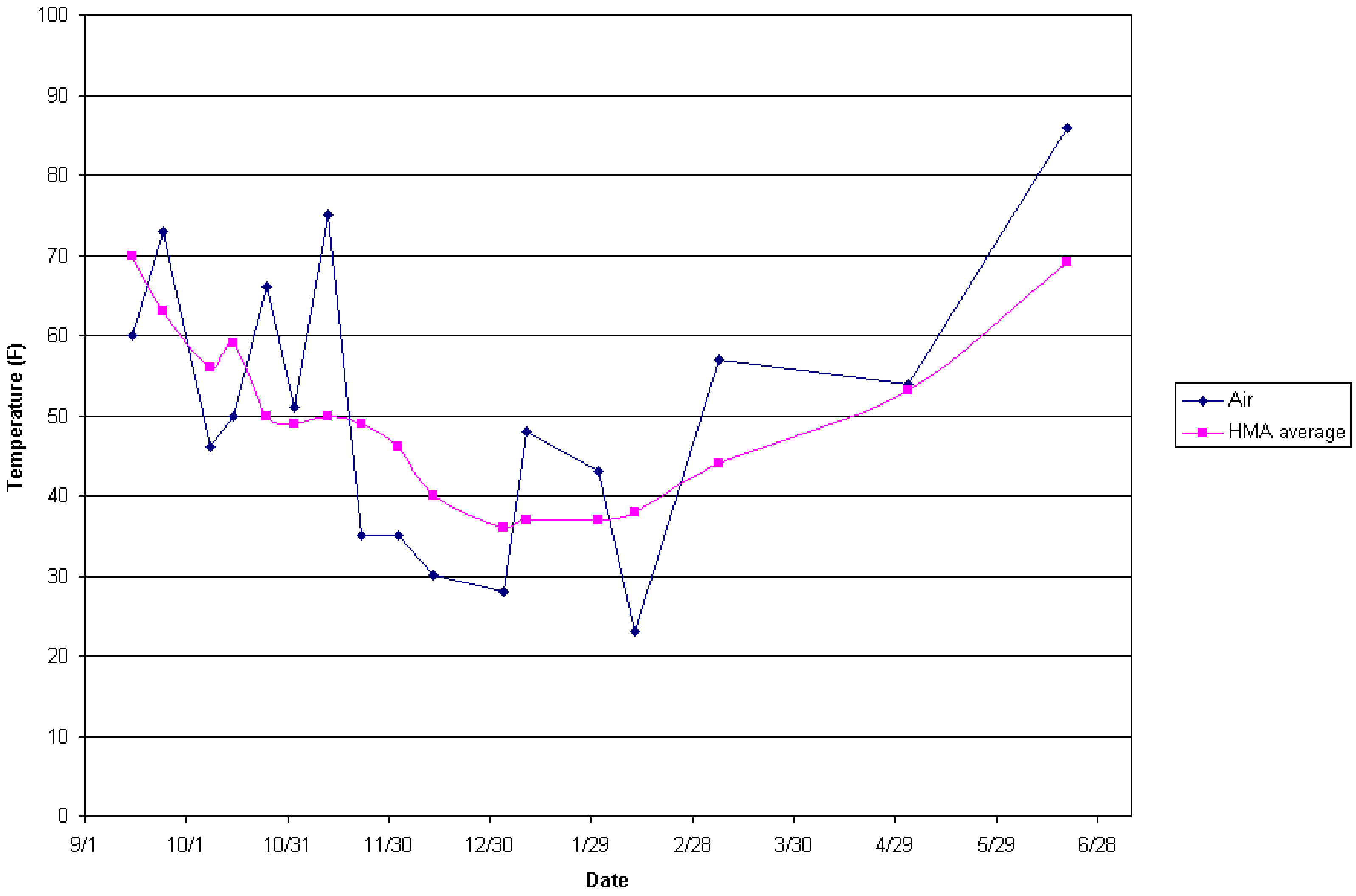
Loaded Coal Train at Conway



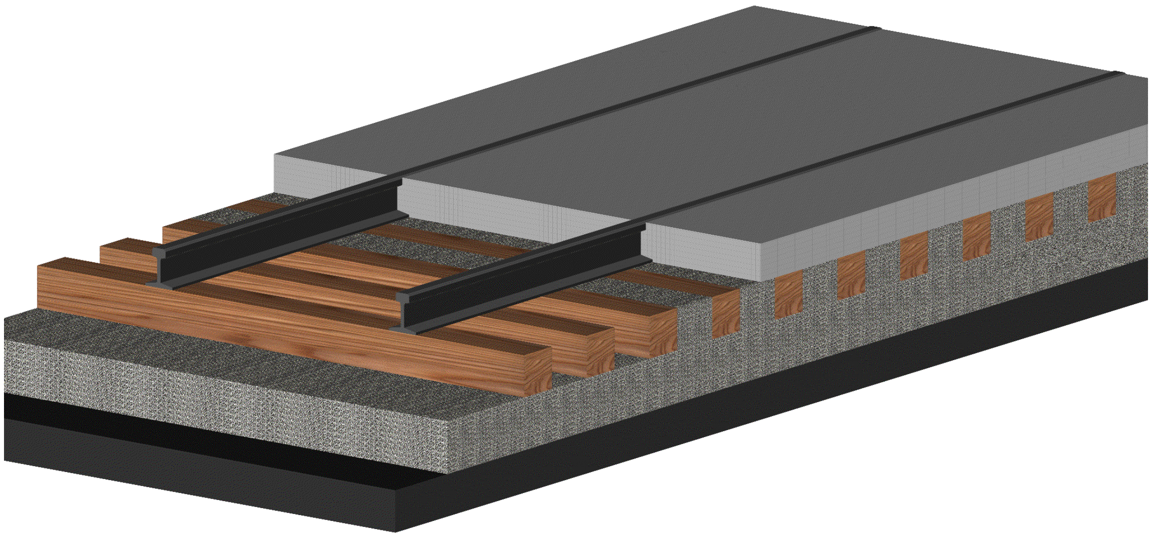
Loaded Coal Train at Brush Creek

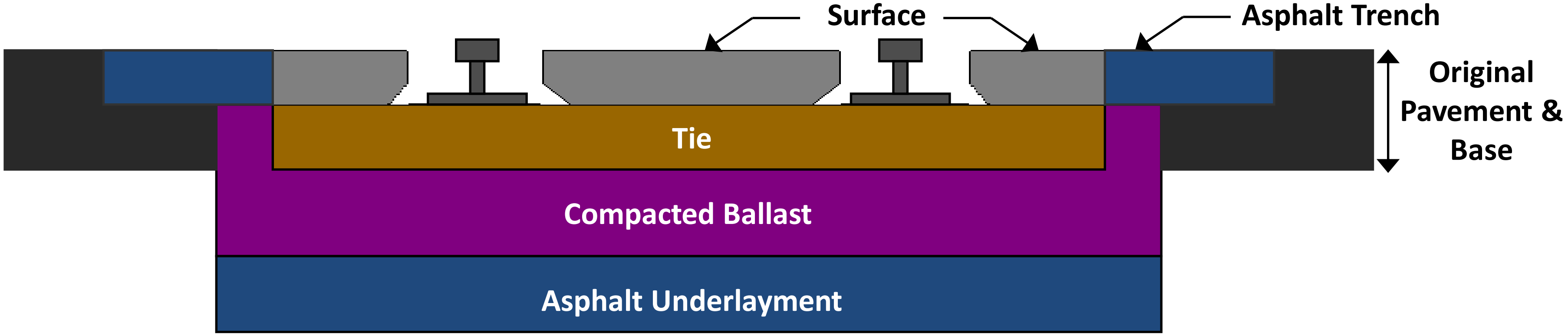


HMA Temperature vs. Air Temperature



Typical Cross-section



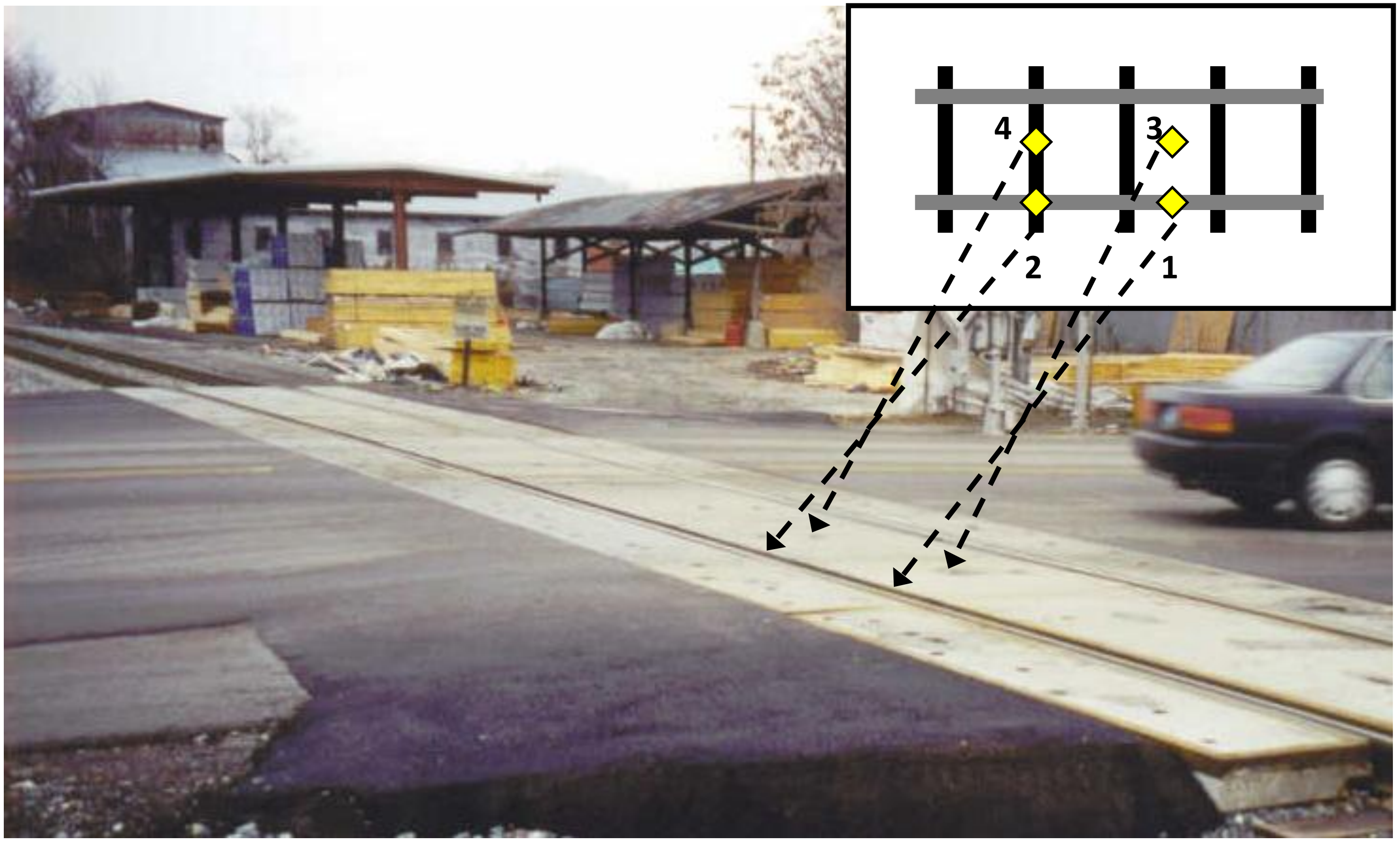


Pressure Cell

- Geokon Model 3500-2
- 9 in. Diameter
- Strain Gage
- Snap-Master
- Thermistor

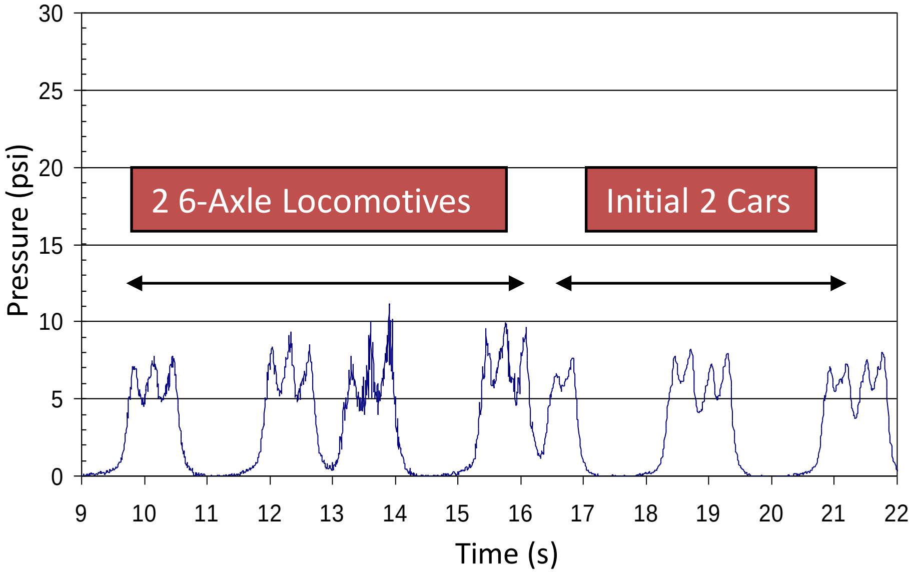
Cell Placement on Asphalt

Cell Location at Richmond

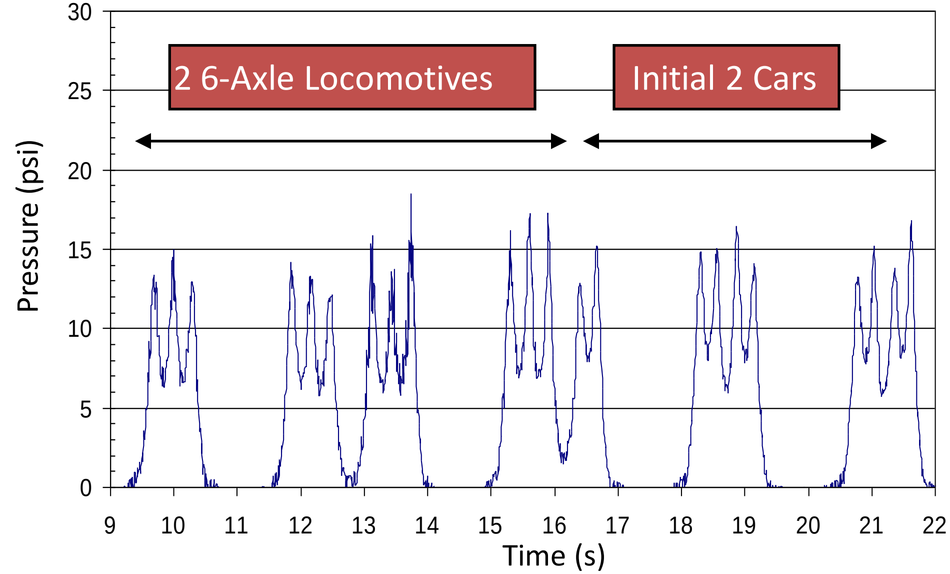


Loaded Coal Train at Richmond

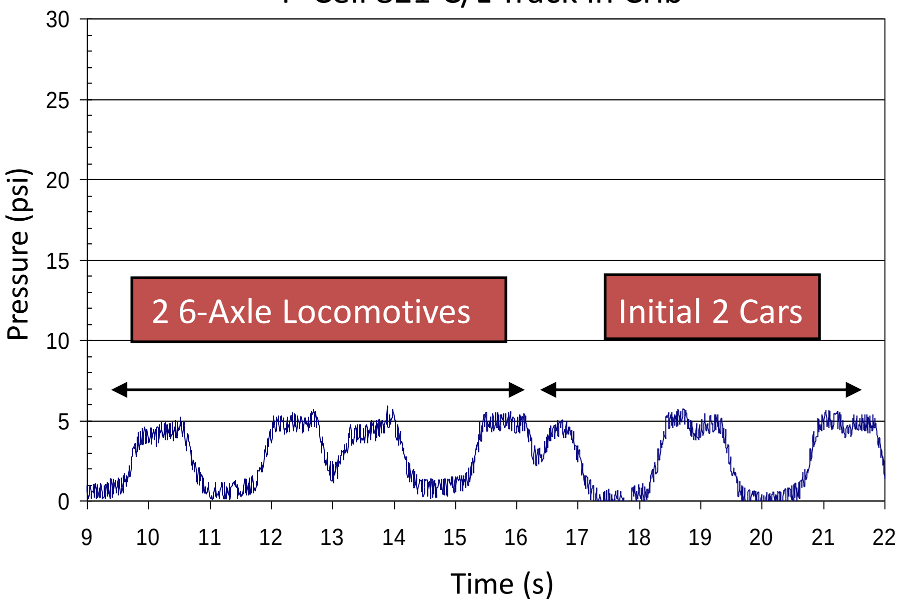
P-Cell 819 Beneath Rail in Crib



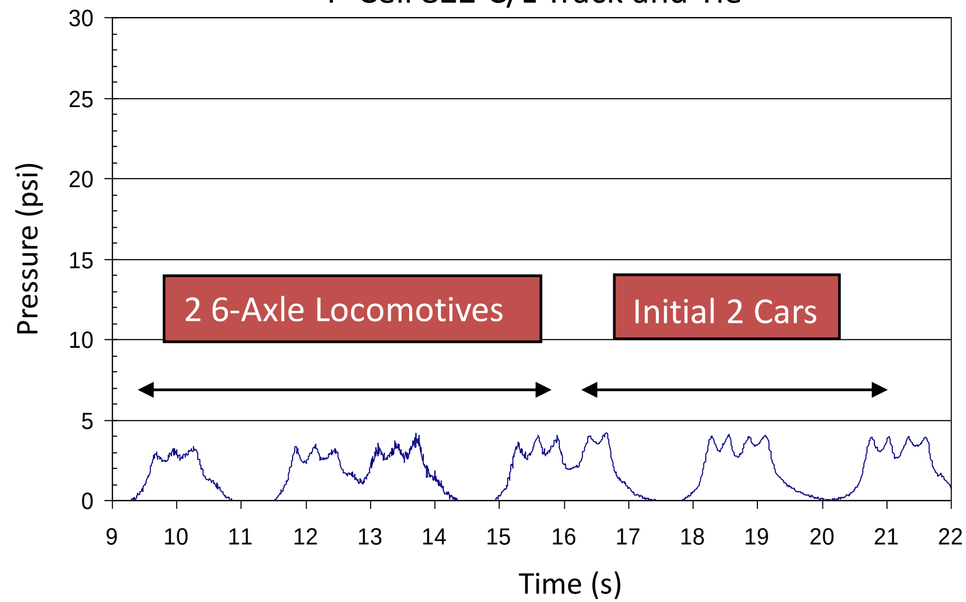
P-Cell 820 Beneath Rail and Tie



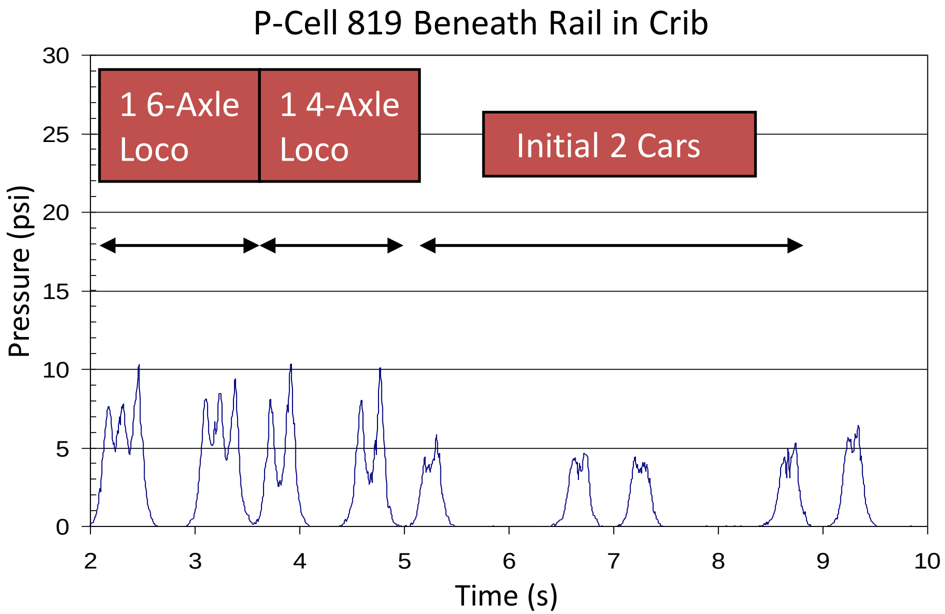
P-Cell 821 C/L Track in Crib

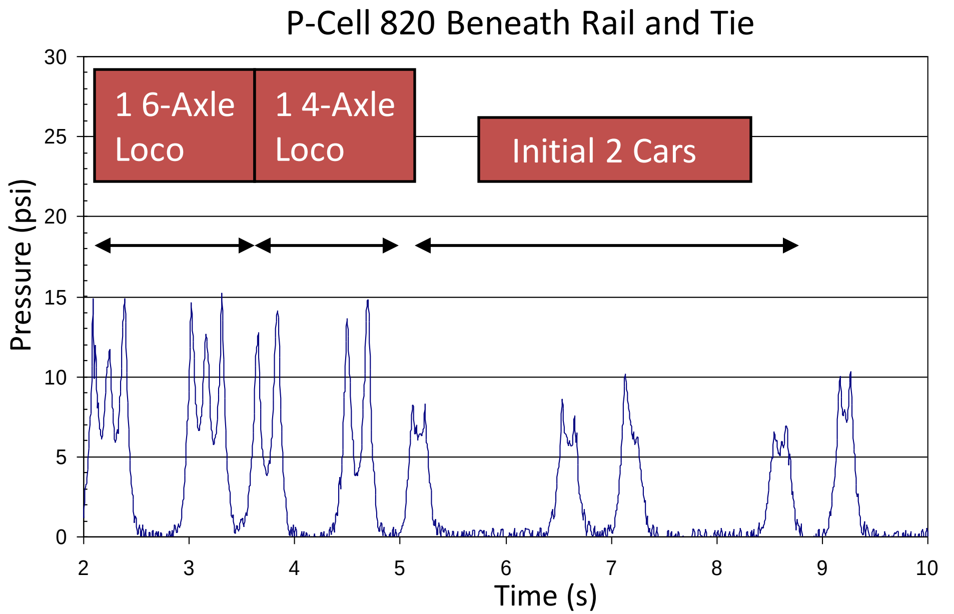


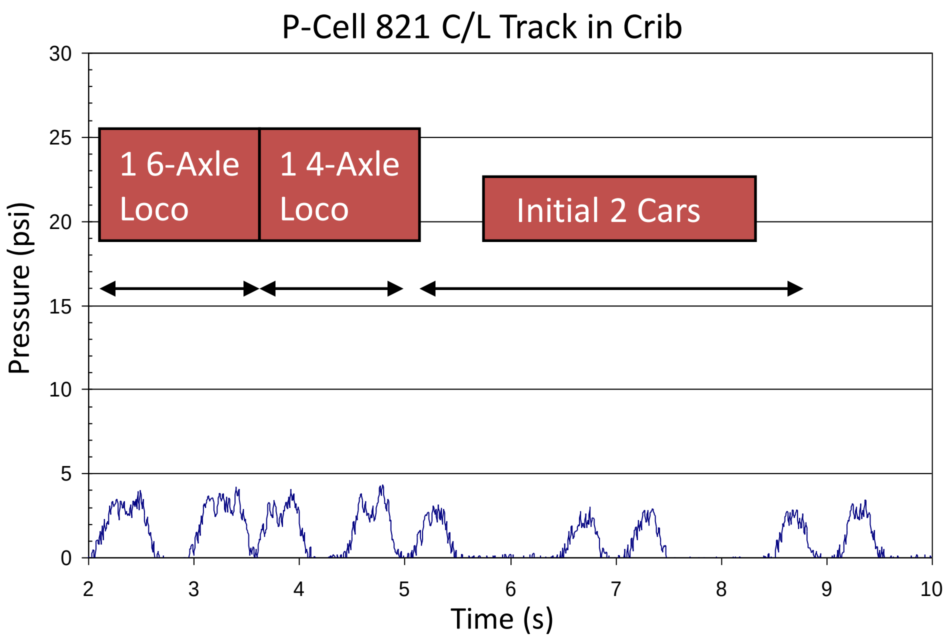
P-Cell 822 C/L Track and Tie

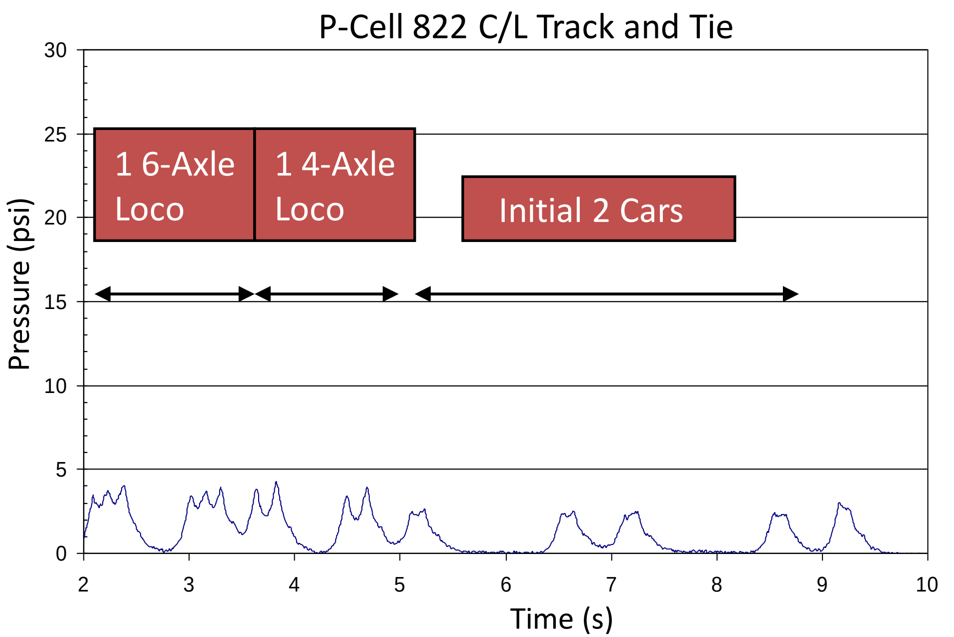


Loaded Auto Train at Richmond

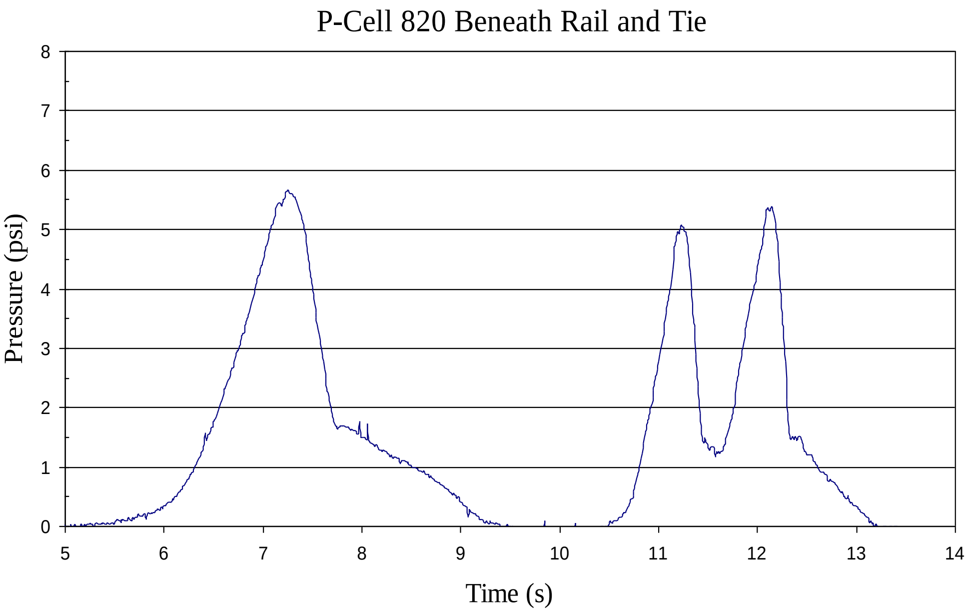




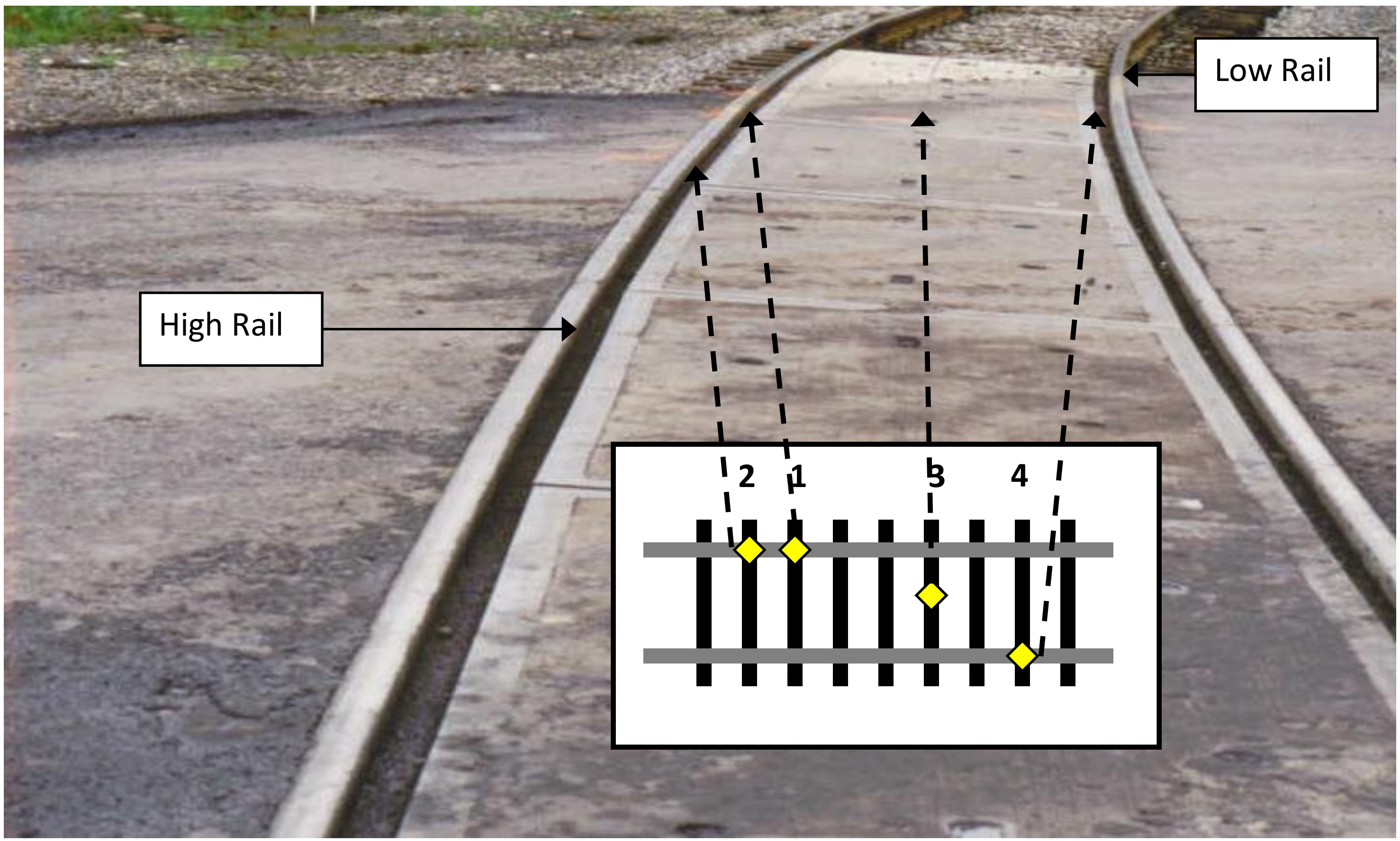




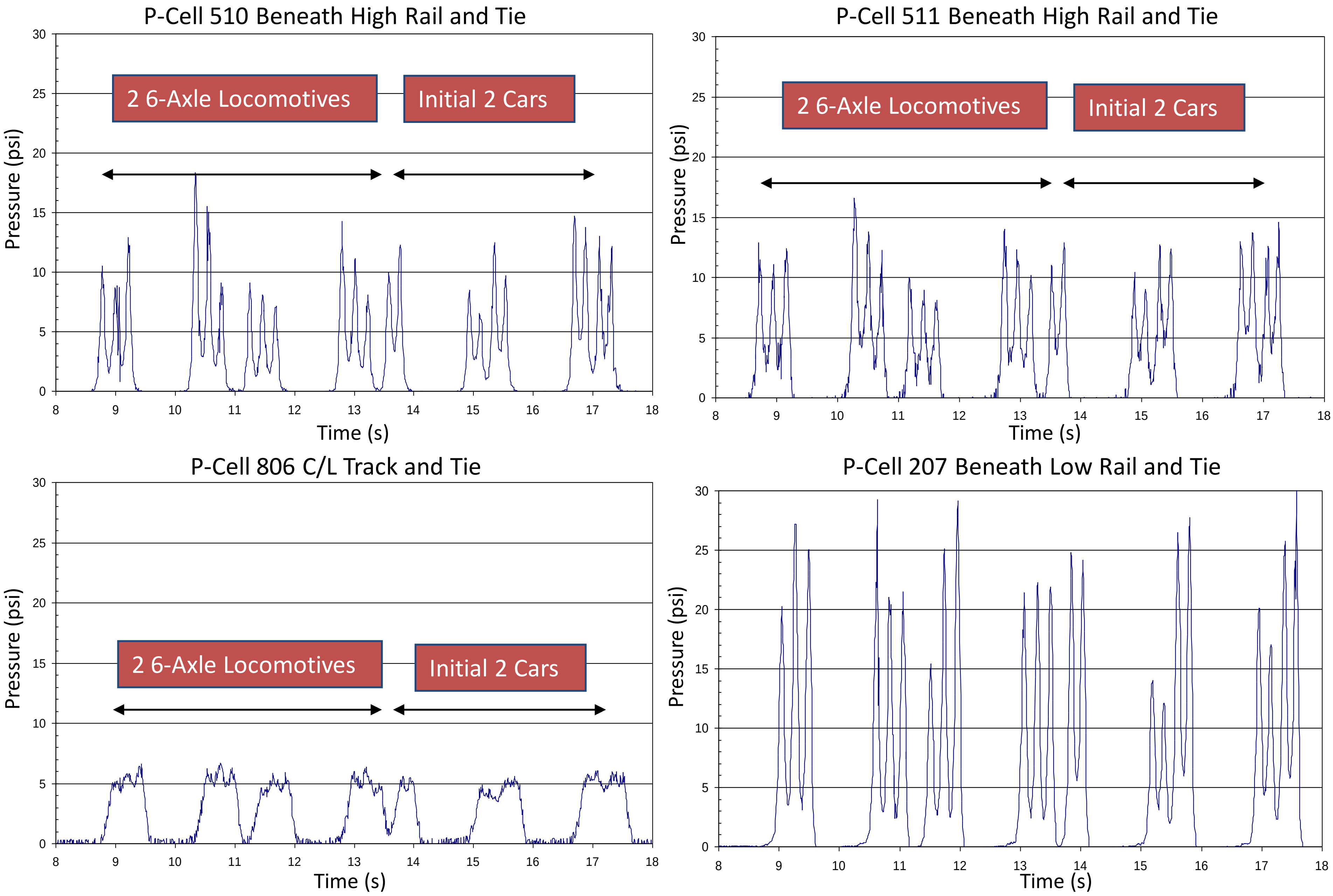
Loaded Concrete Truck at Richmond



Cell Location at Lackey

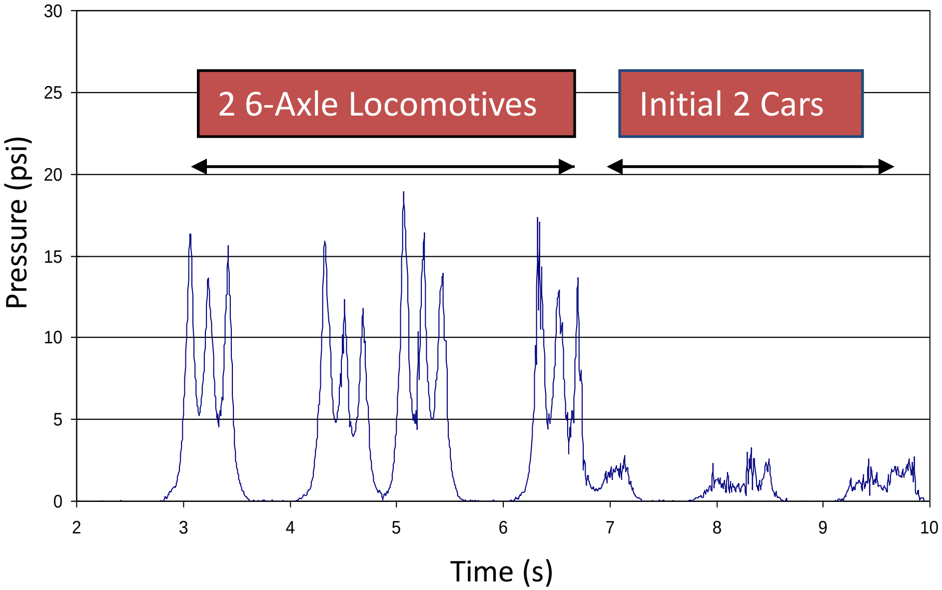


Loaded Coal Train at Lackey

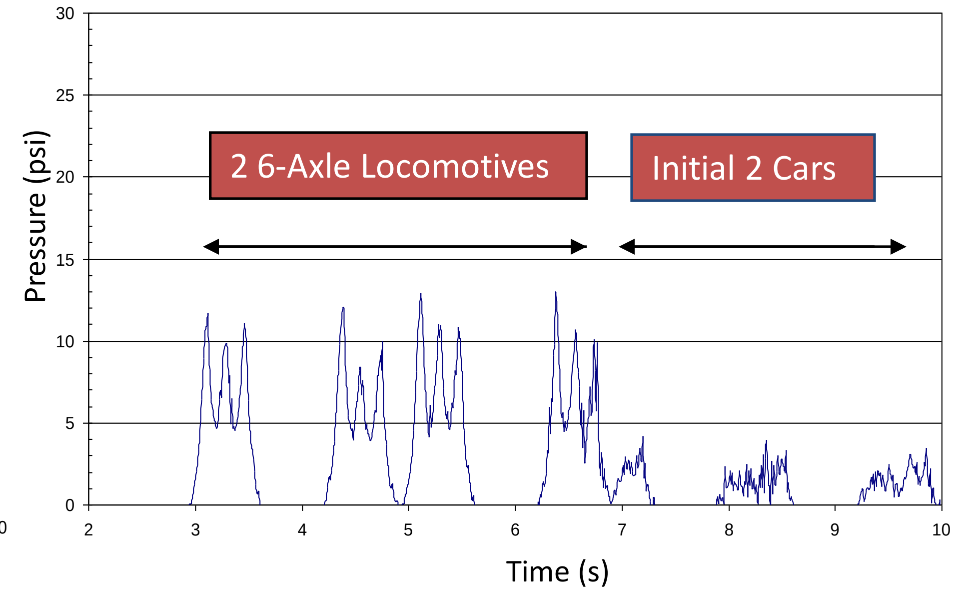


Empty Coal Train at Lackey

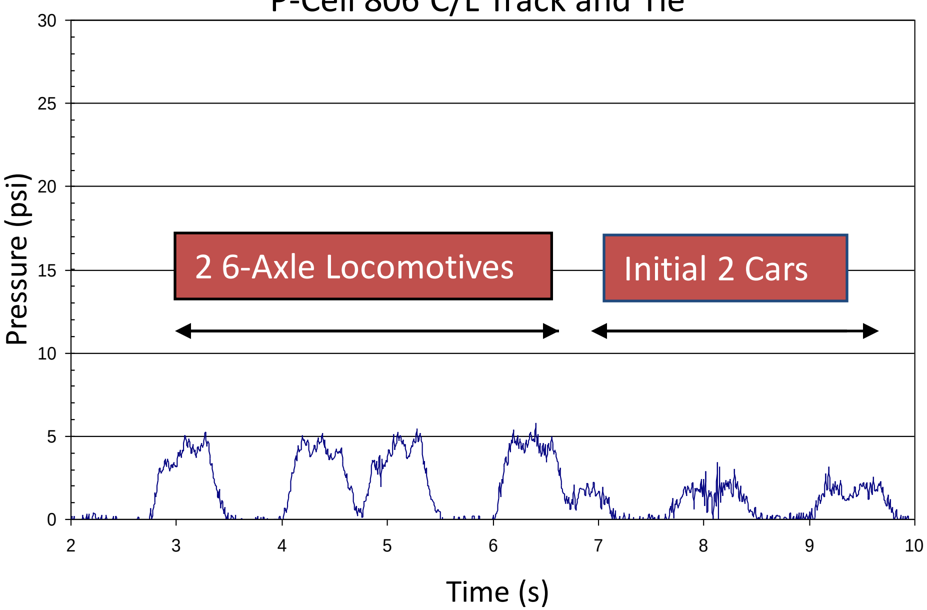
P-Cell 510 Beneath High Rail and Tie



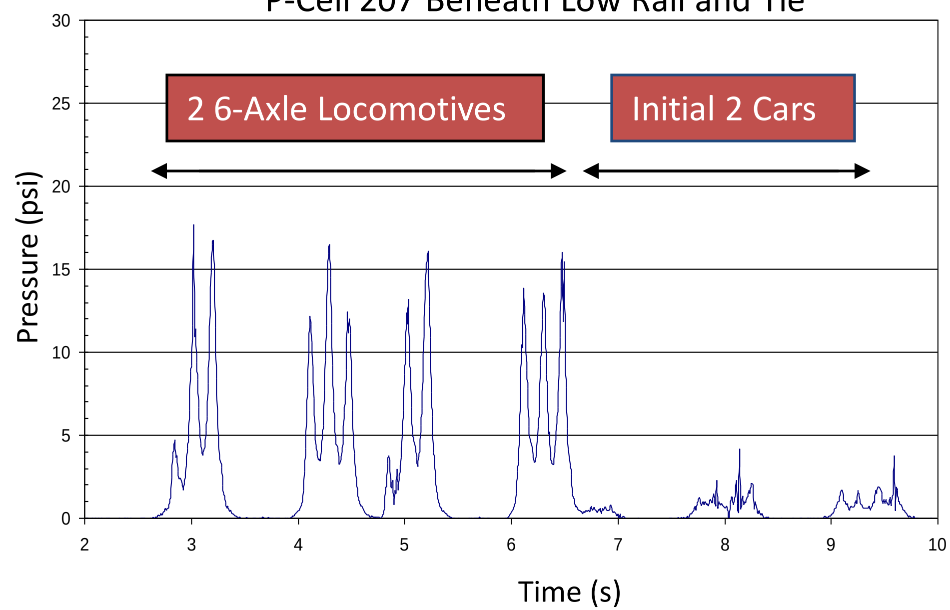
P-Cell 511 Beneath High Rail and Tie



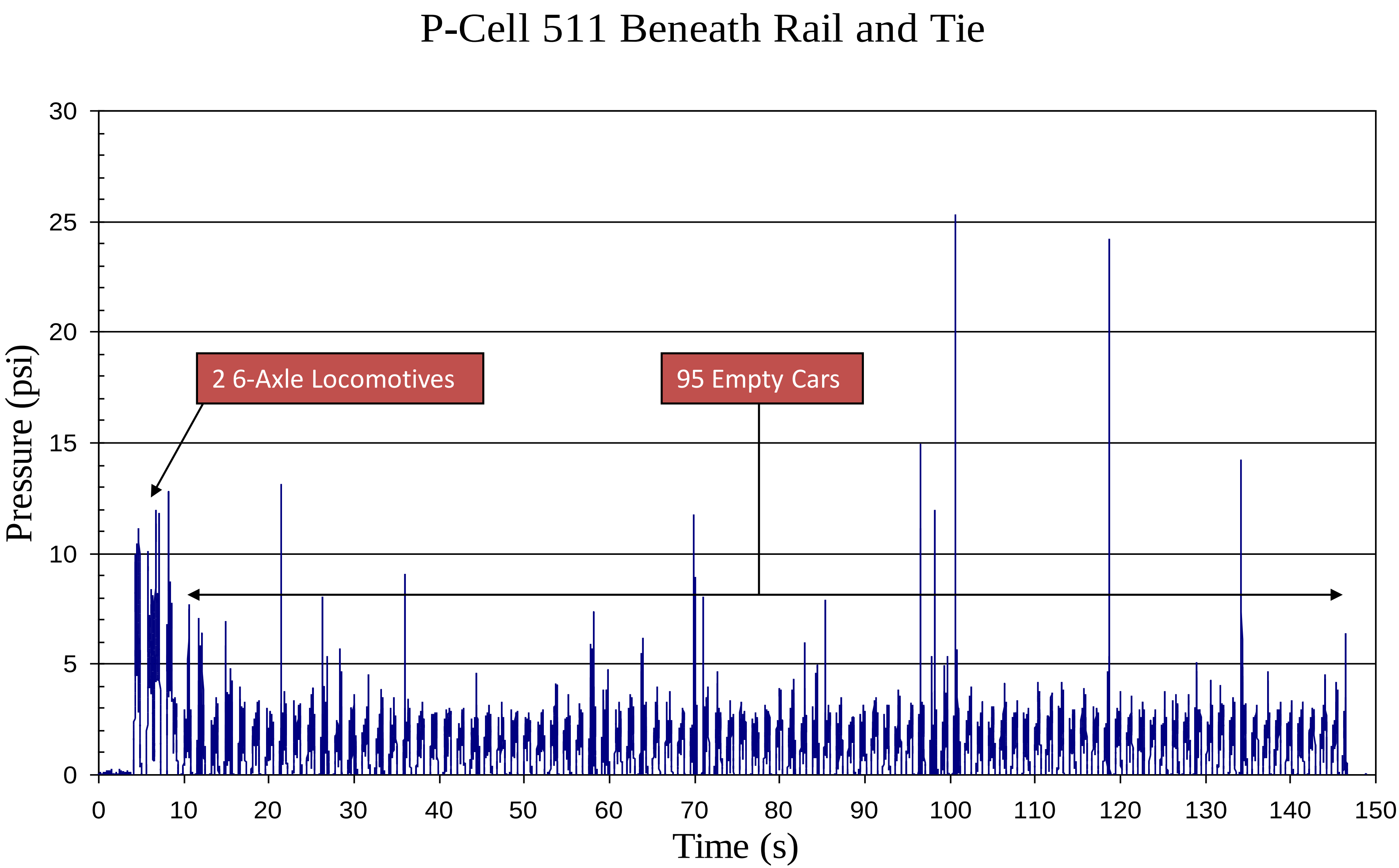
P-Cell 806 C/L Track and Tie



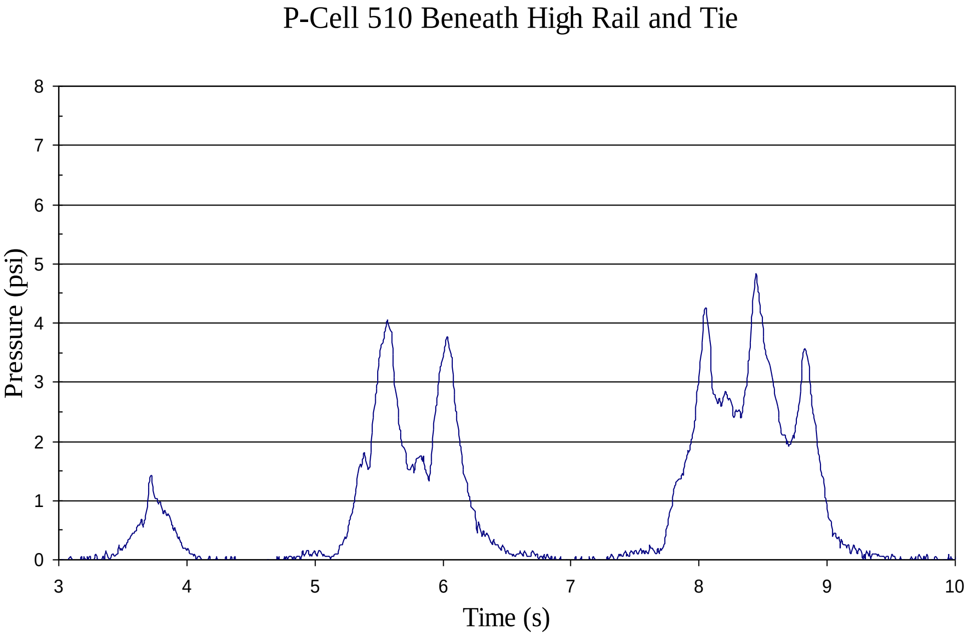
P-Cell 207 Beneath Low Rail and Tie



Flat Wheel on an Empty Coal Train at Lackey



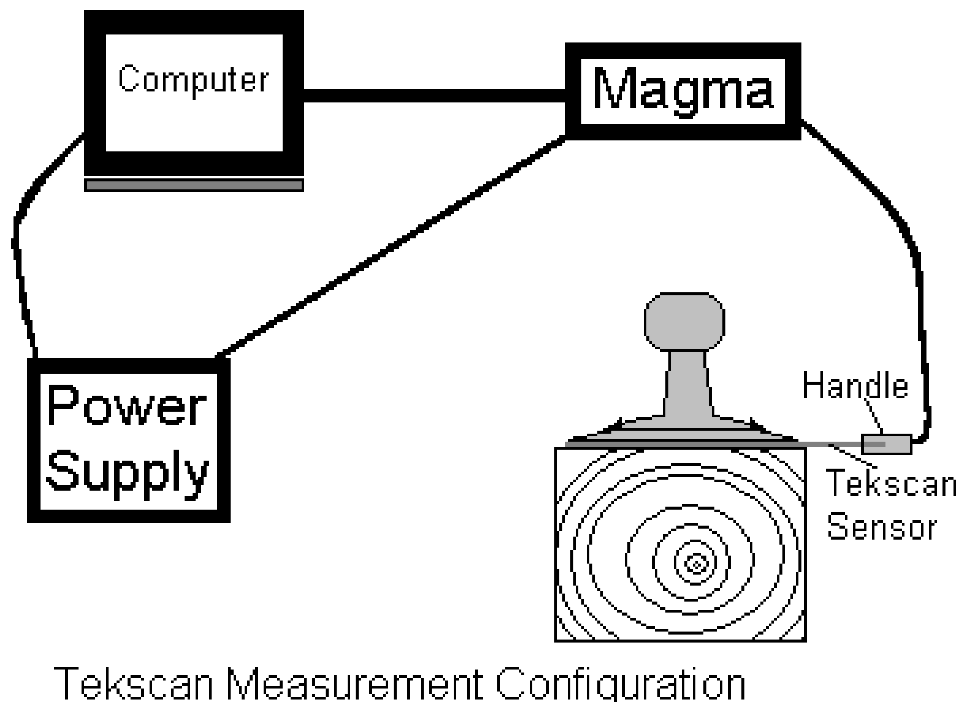
Loaded Coal Truck at Lackey



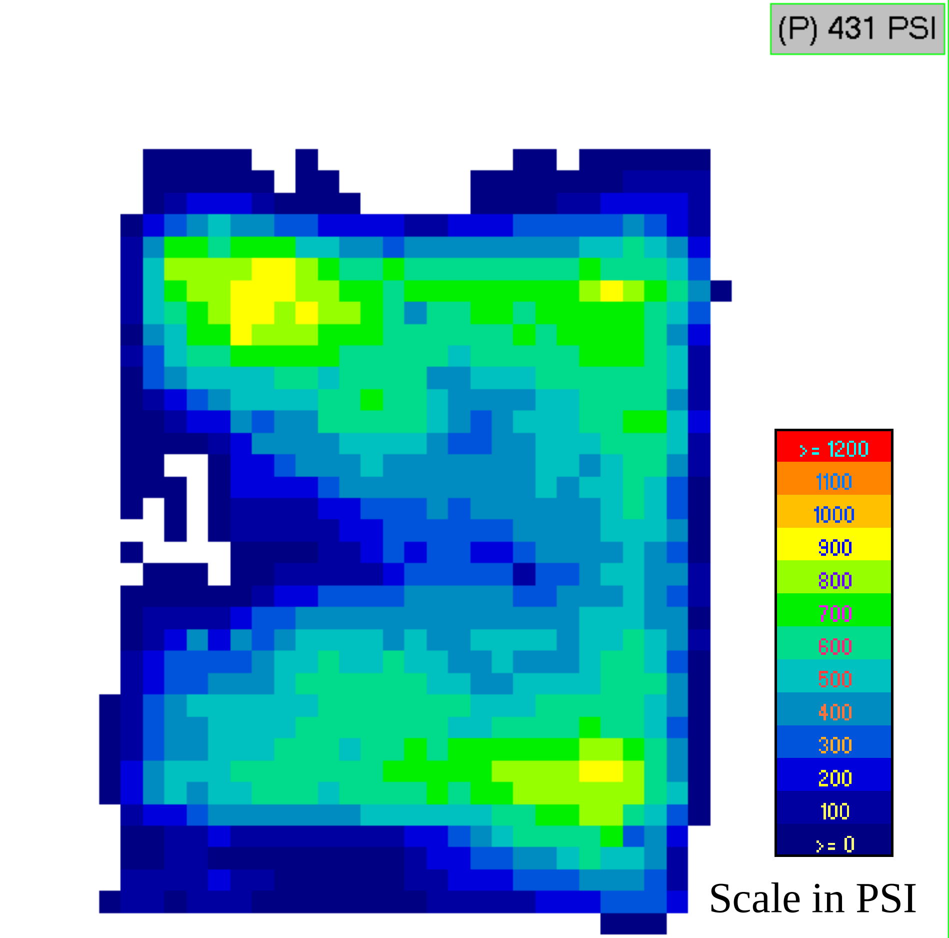
View of Tekscan Sensors

- Matrix-based array of force sensitive cells
- Silver conductive electrodes
- Pressure sensitive ink – Conductivity varies
- Crossing of ink – strain gauge

Tekscan Measurement Configuration

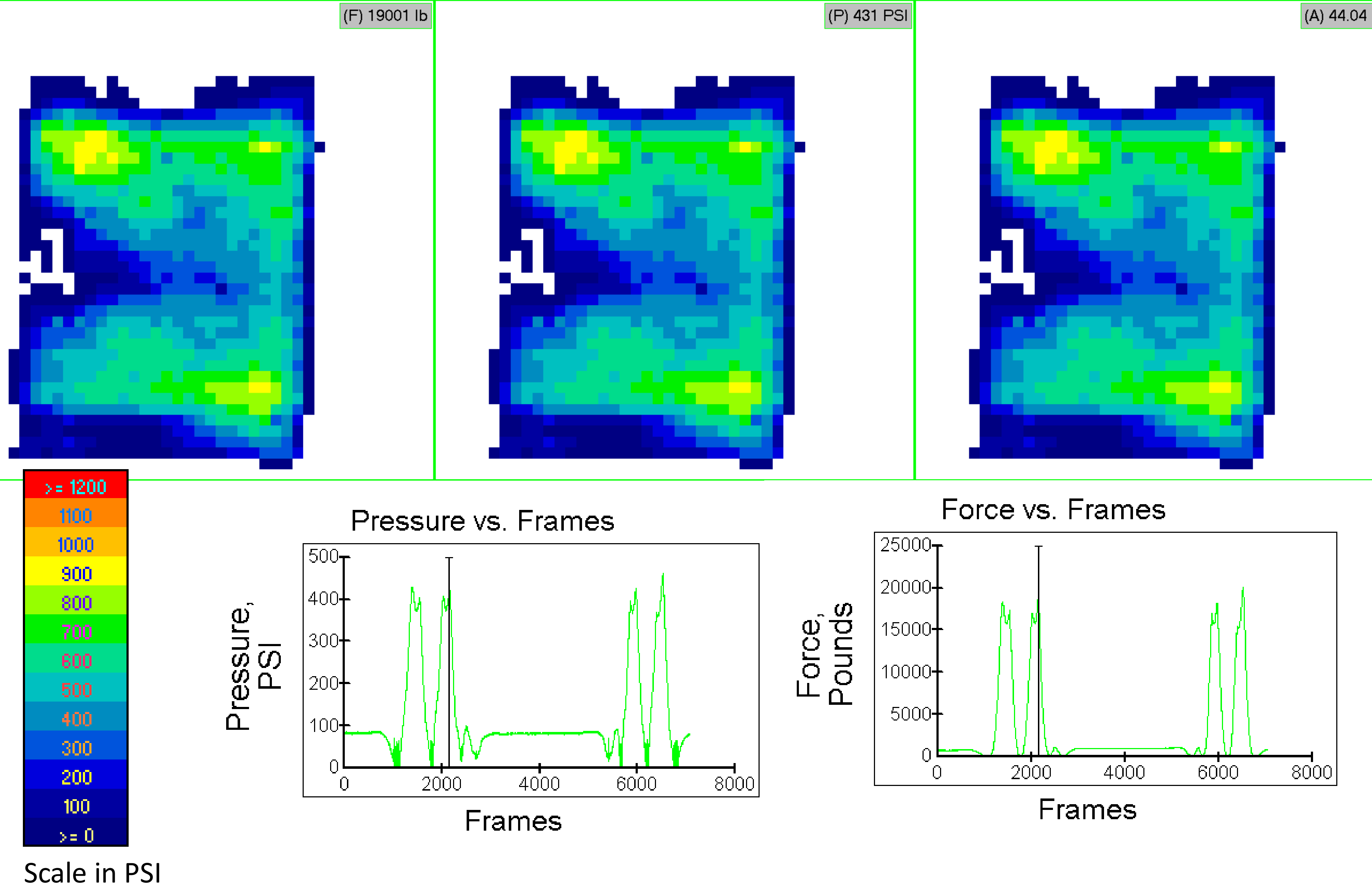


In Track Placement During First Test

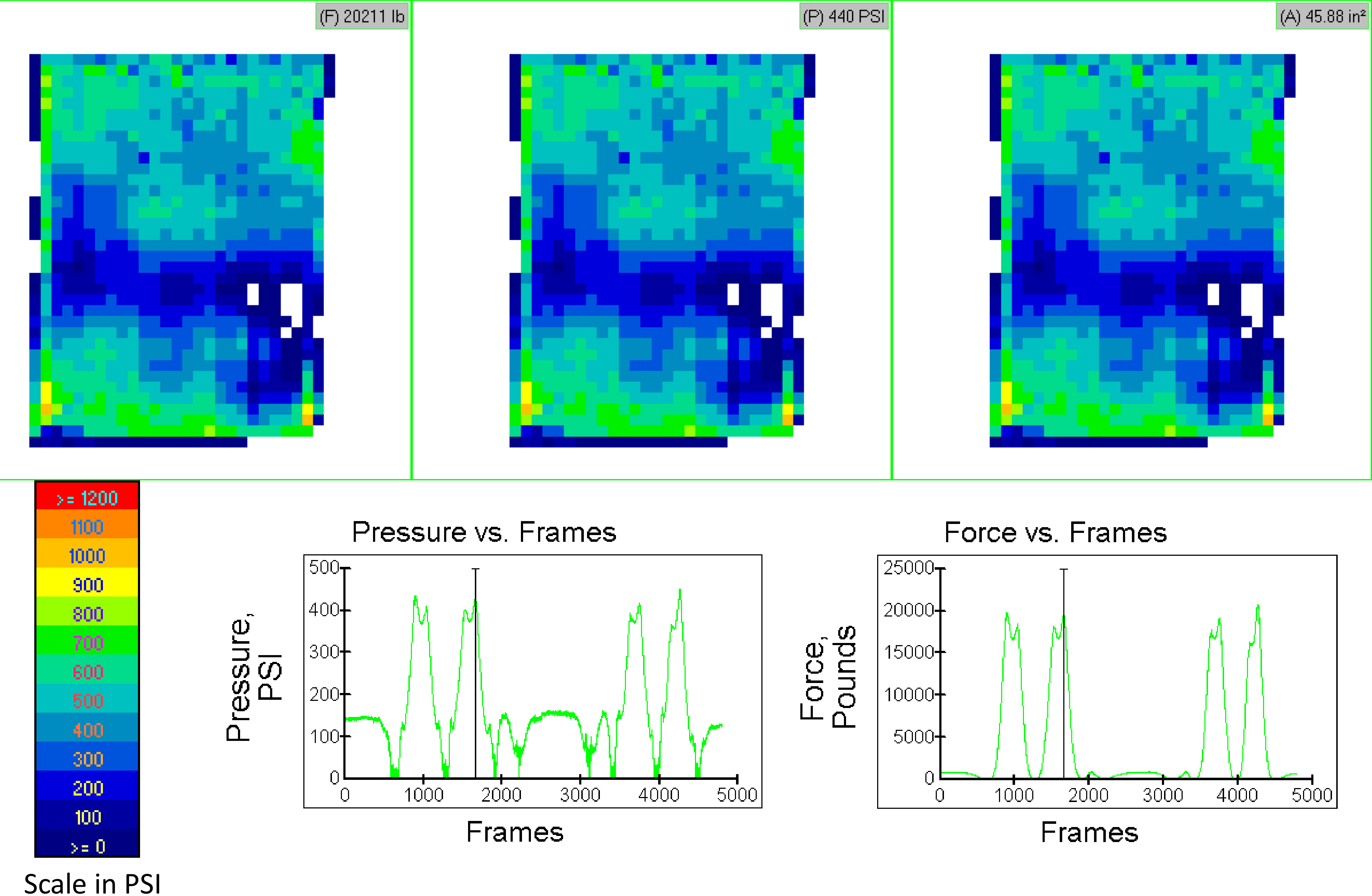


Scale in PSI

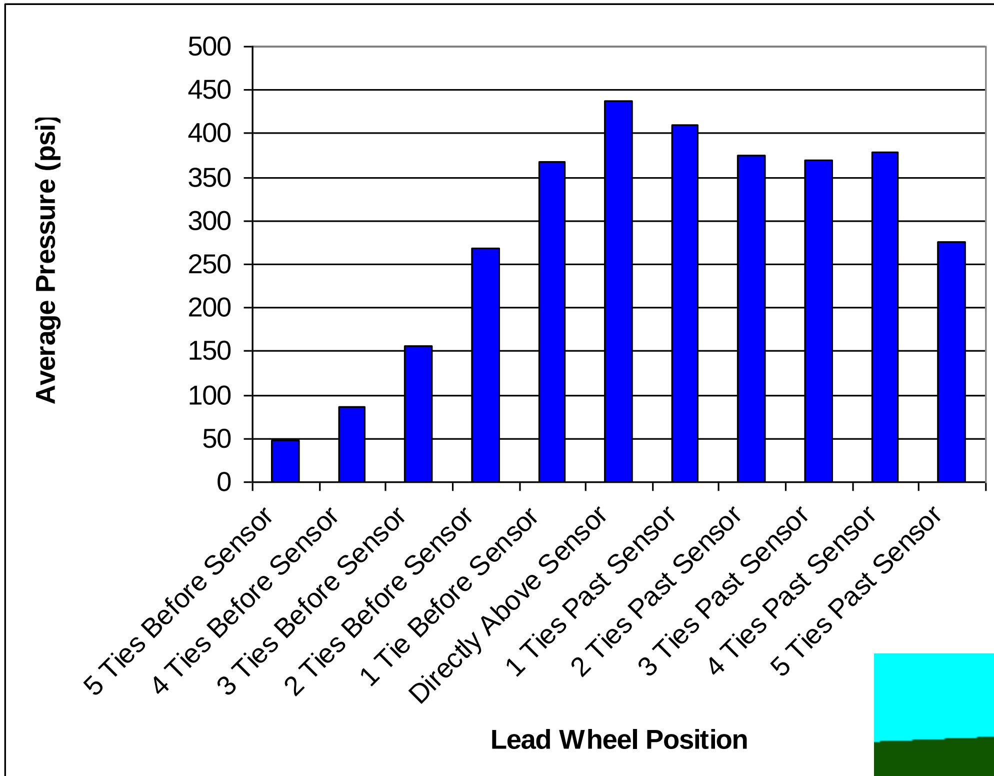
Typical Pressure Distribution Plot from Tekscan System



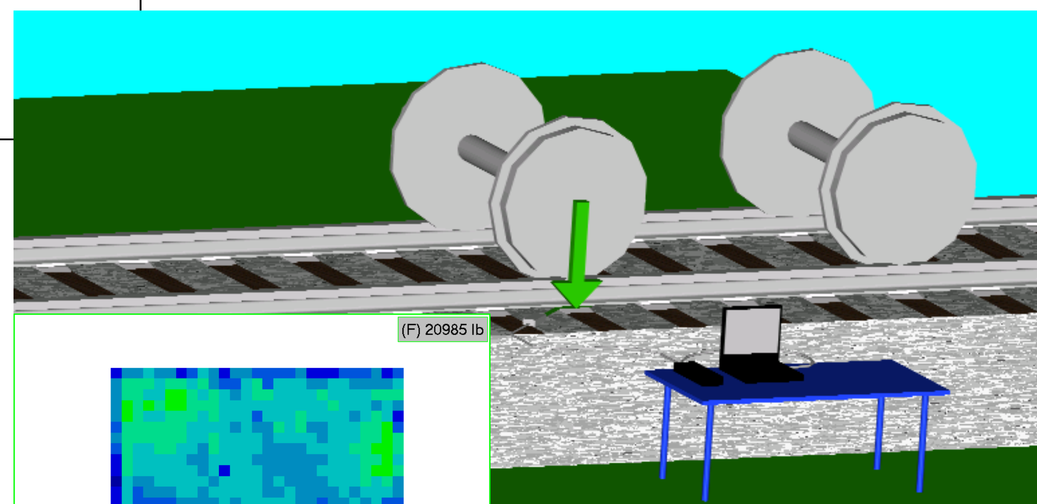
This represents a typical pressure distribution between a machined steel tie plate and the rail with an included rubber bladder.

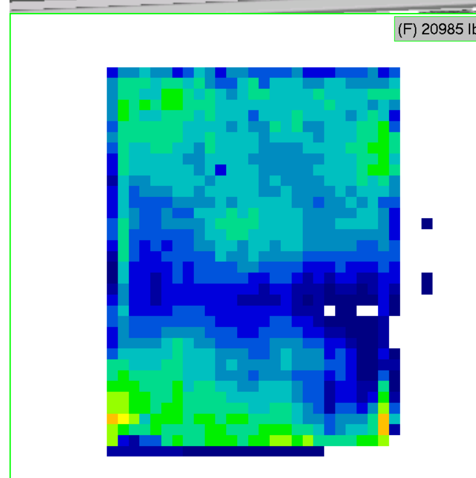


This represents a typical pressure distribution between a polyurethane plastic tie plate and the rail.



Positioning of Lead Wheel with Respect to Sensor

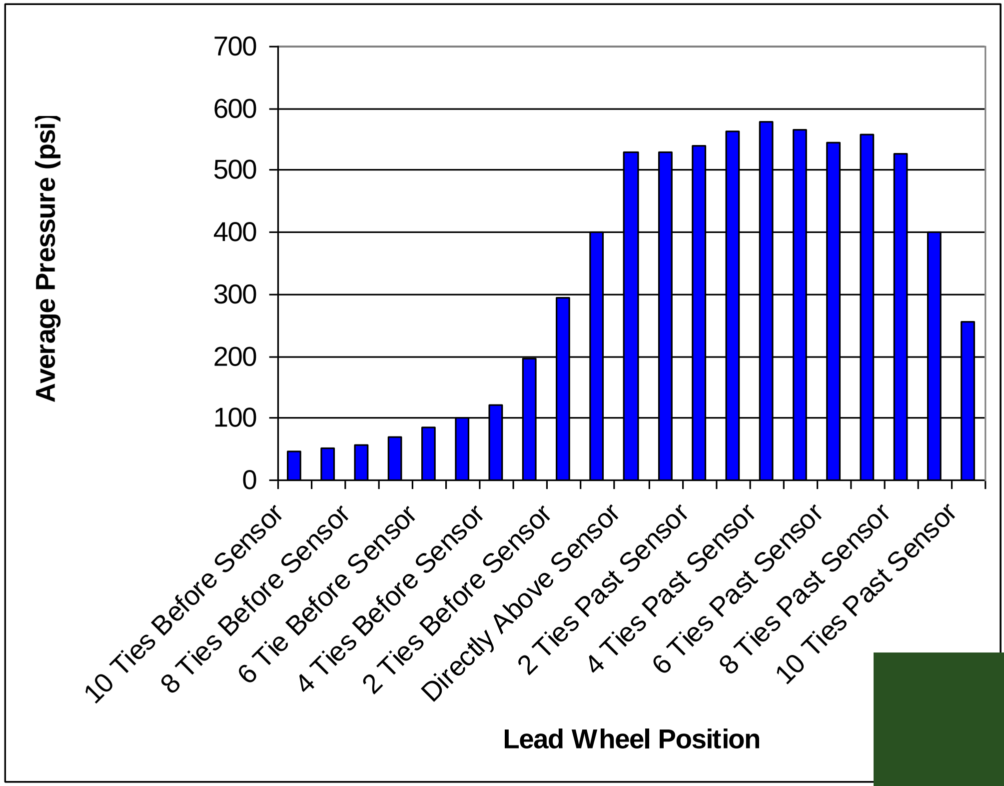




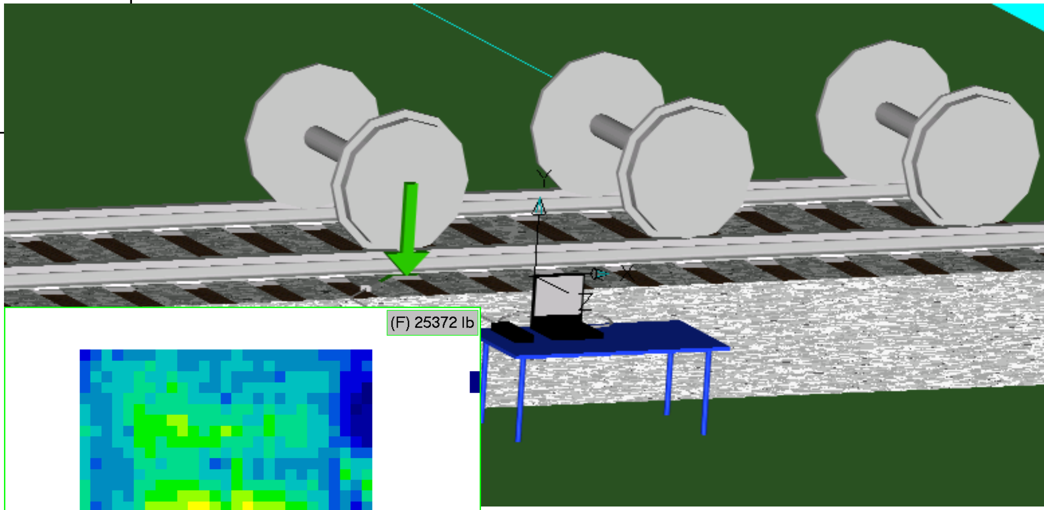
Snapshot of the Lead Wheel Directly above the Sensor

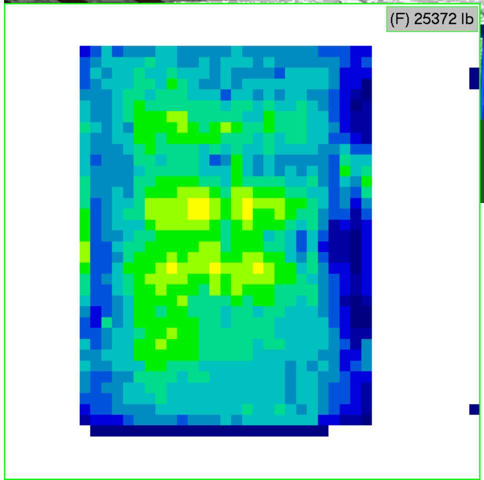
Lead Wheel Over Sensor

F = 20985 lbf, P = 437 psi



Positioning of Lead Wheel with Respect to Sensor



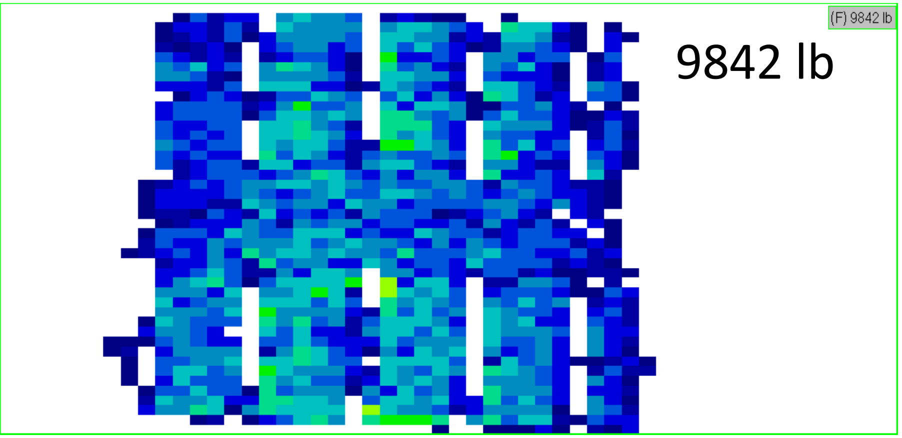


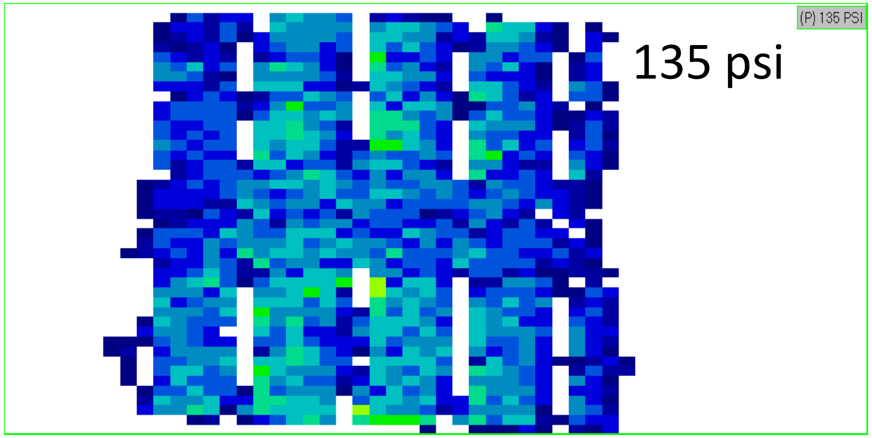
Snapshot of the Lead Wheel Directly above the Sensor

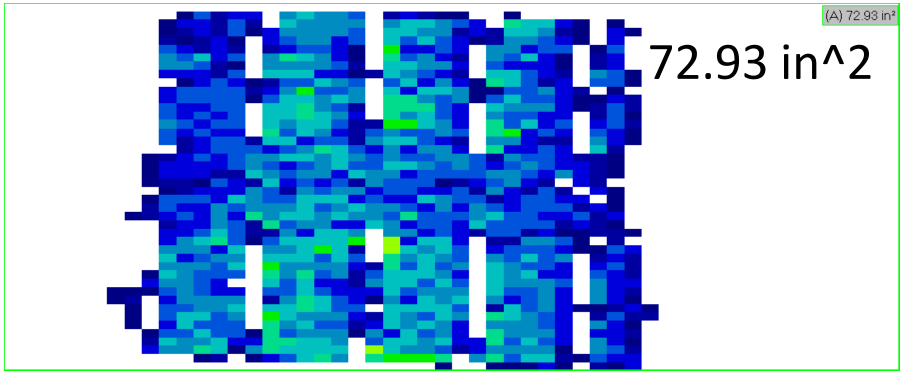
Lead Wheel Over Sensor

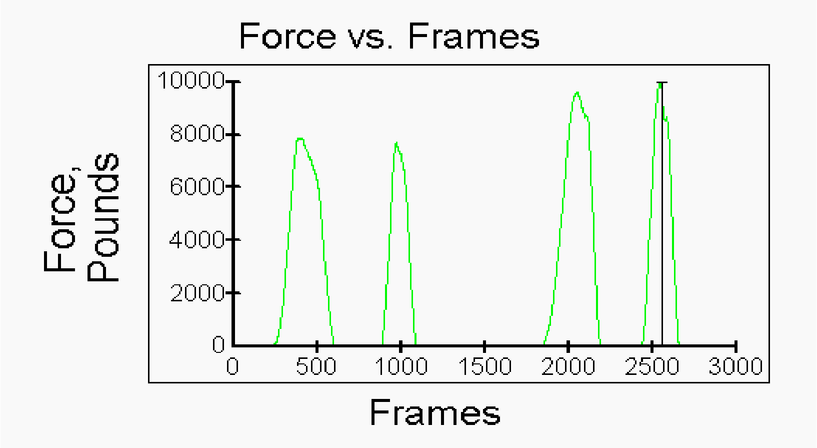
F = 25372 lbf, P = 529 psi

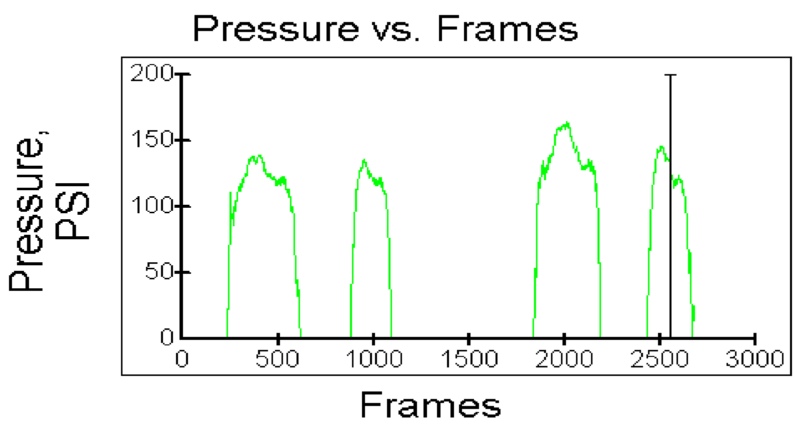

Rear Tires of Tractor of a 151,000 lb Loaded Coal Truck on Concrete Crossing of Kentucky Coal Terminal, Mile Post 6.6. May 25, 2004





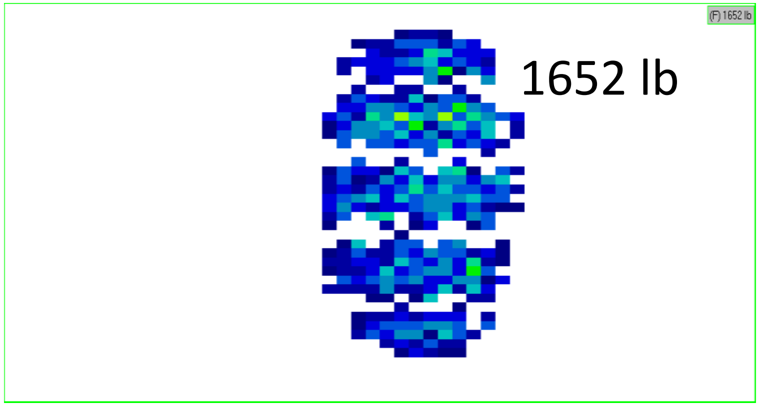


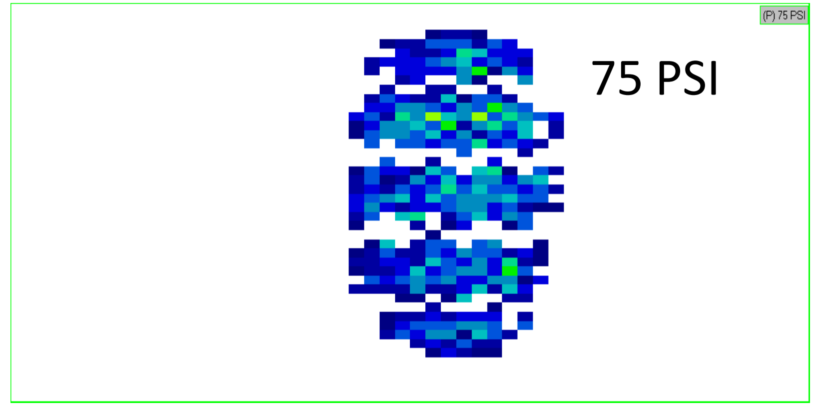


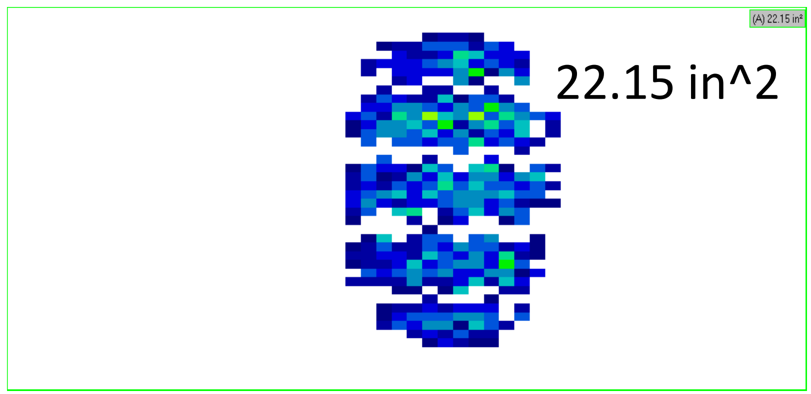


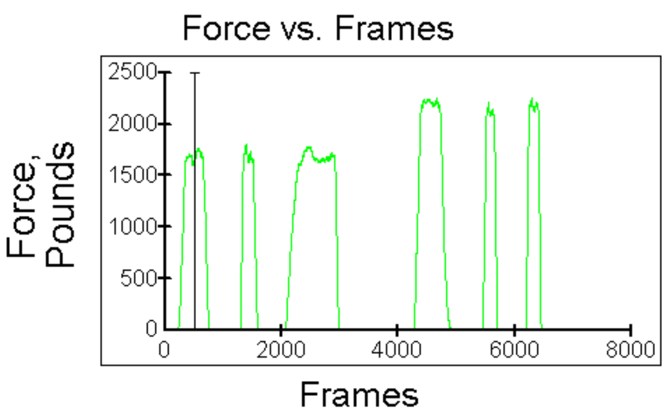

GMC

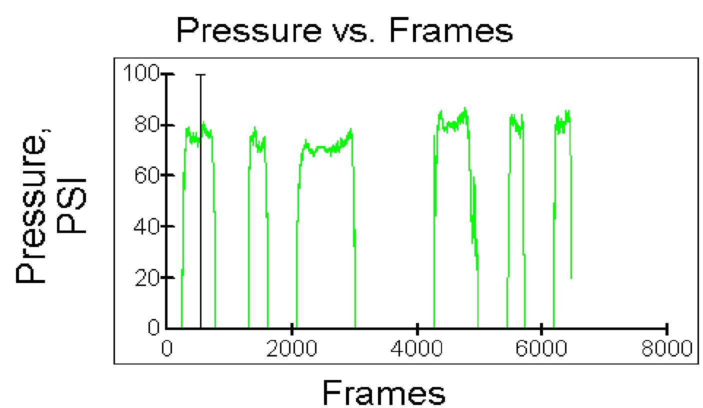
Front Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company. May 2 2004



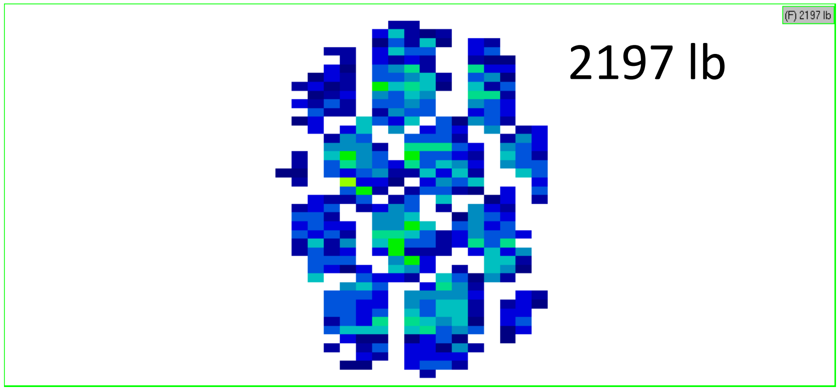


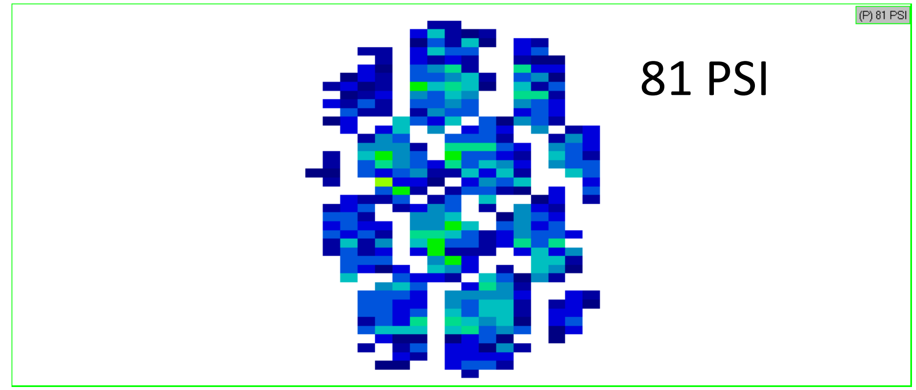


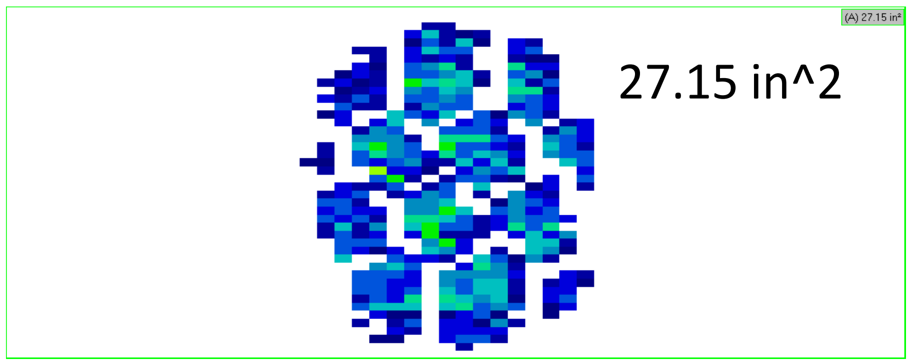


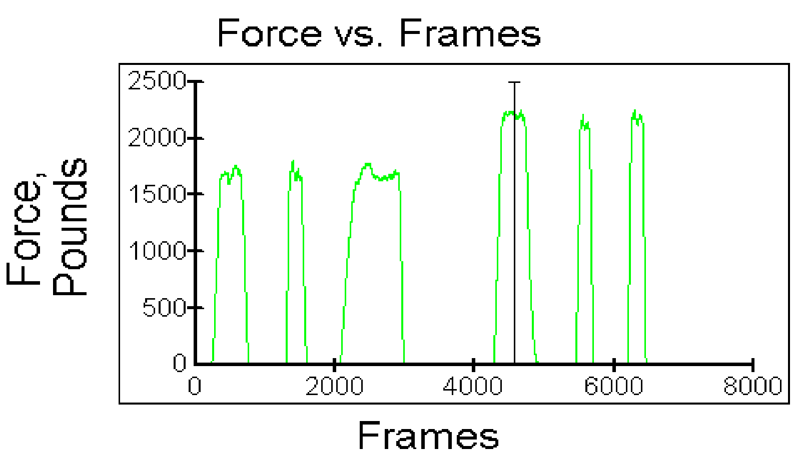


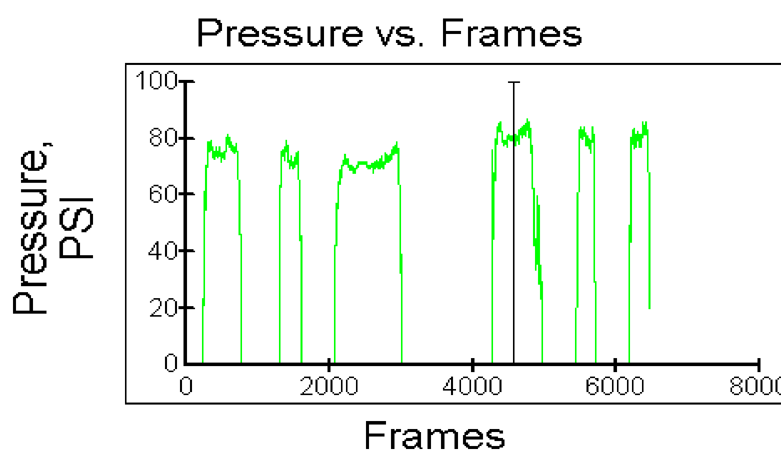
Rear Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company. May 25, 2004











Summary

Asphalt Trackbeds – 286,000 lb (130 metric ton) Loading

Dynamic Pressure @ Rail Base/ Tie Plate
400 – 600 psi (2800 – 4200 kPa)

Dynamic Pressure @ Top of Asphalt Mat
13- 17 psi (90 – 120 kPa)

Dynamic Pressure @ Asphalt/ Subgrade Interface
7 – 8 psi (50 – 55 kPa)

Dynamic Track Deflection
0.25 in. (6.4 mm) – Wood, 0.05 in. (1.3 mm) - Concrete

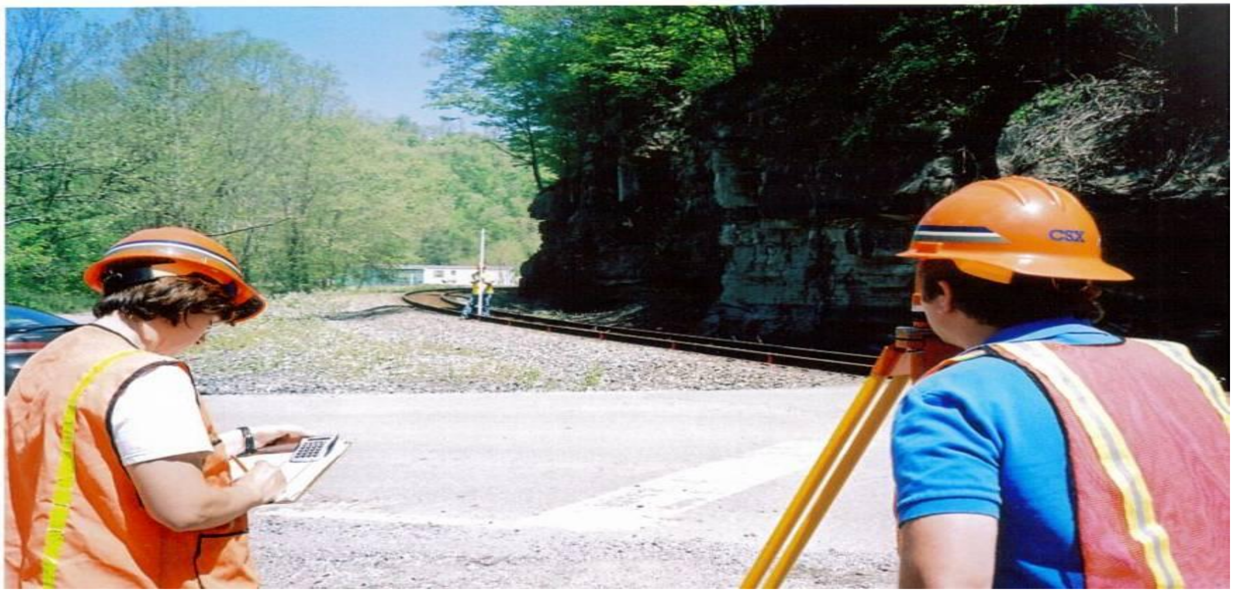
Dynamic Track Modulus
2900 lb/in/in (20 MPa) – Wood, 7200 lb/in/in (50 MPa) - Concrete

Tire- Pavement Contact Pressure

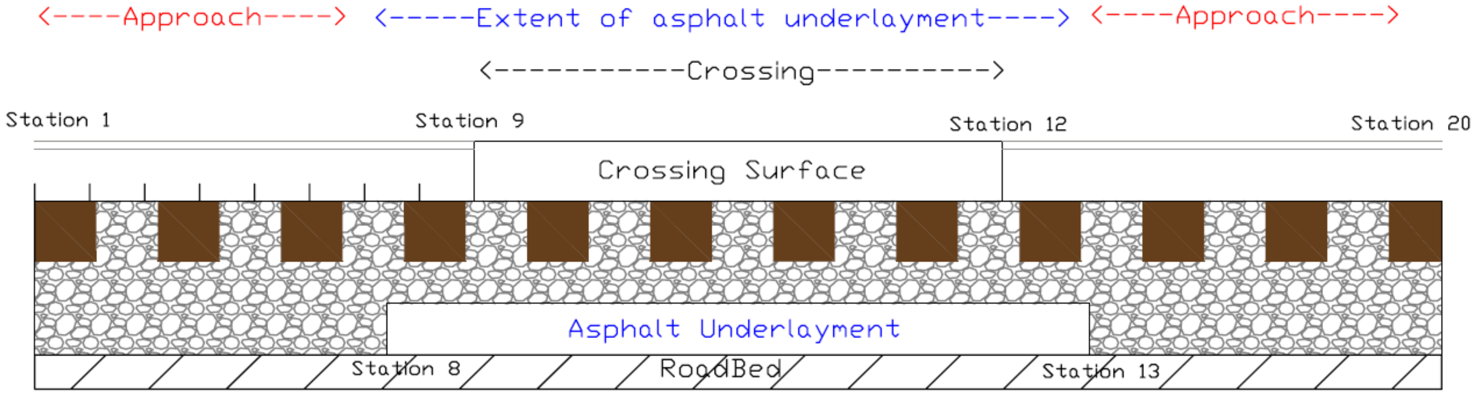
- **Similar to Tire Inflation Pressure**

Long-Term Track Settlements

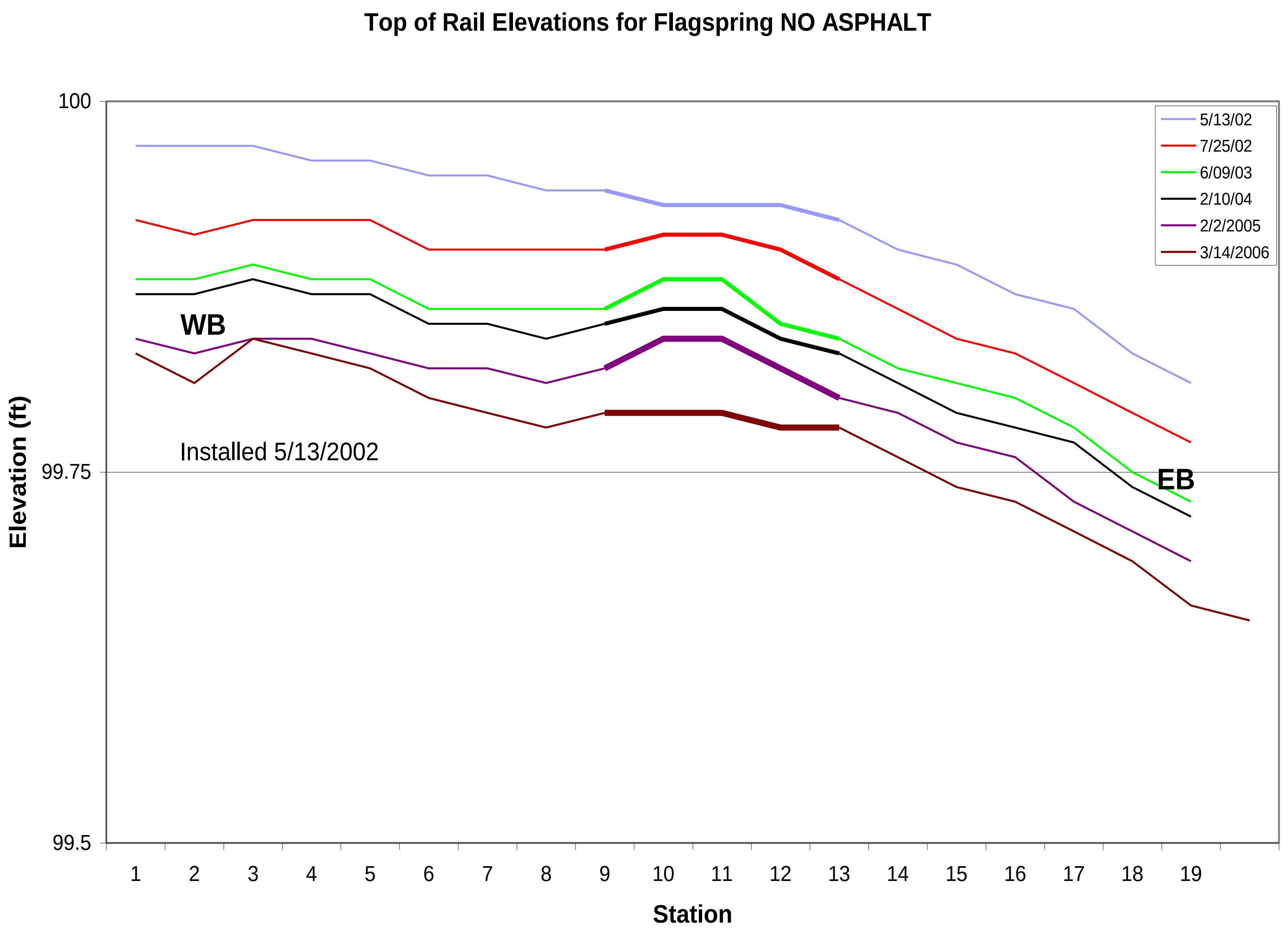
(Top-of-Rail Elevations)



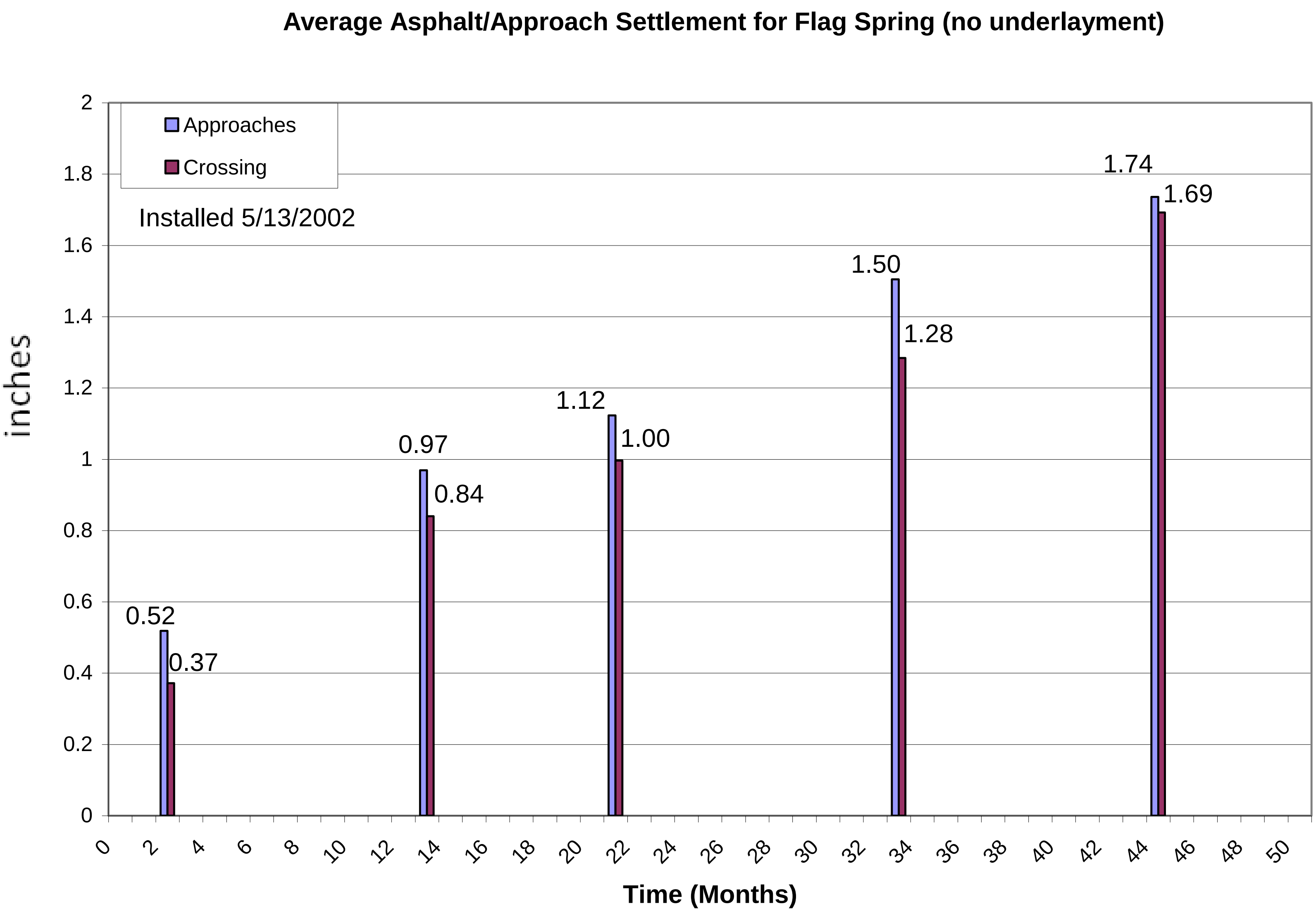
Longitudianl view of highway/rail crossing containing asphalt underlayment



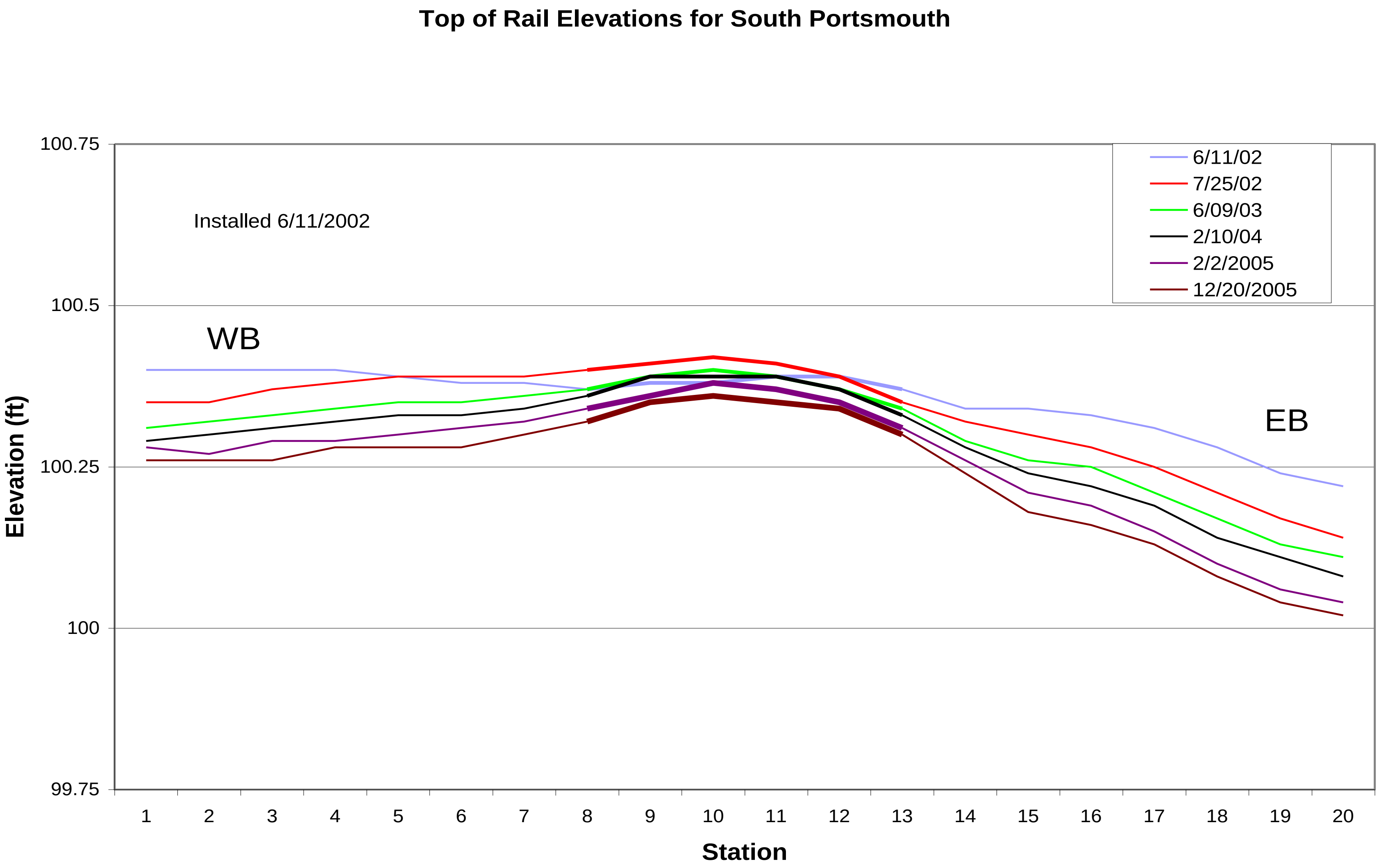


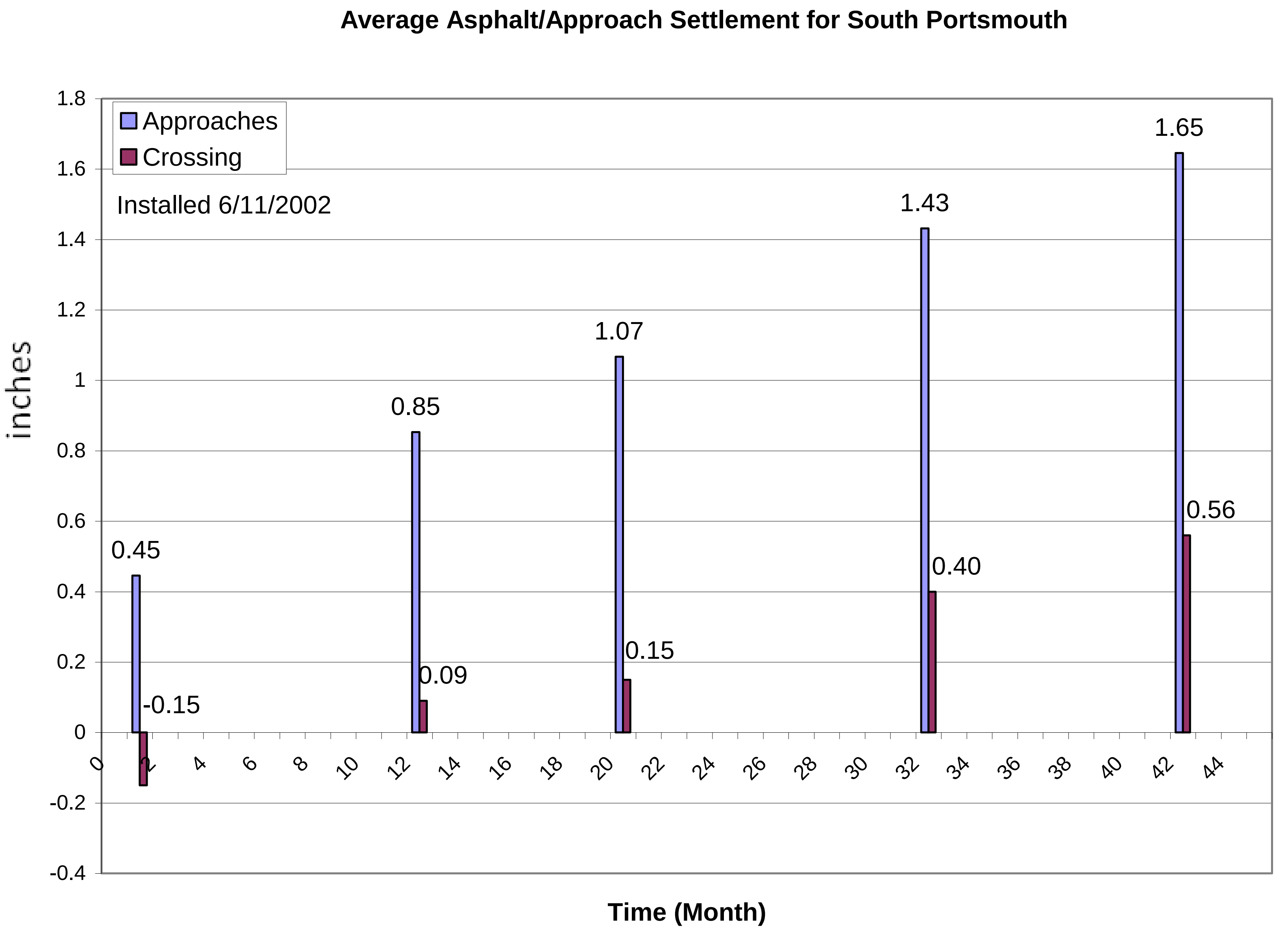



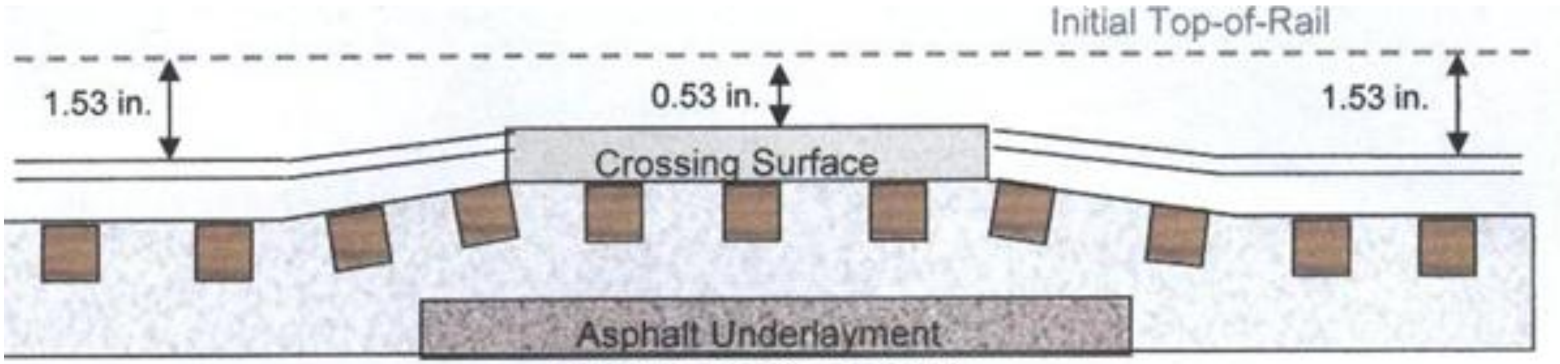
Top of Rail Elevations for Flagspring NO ASPHALT
100
99.75
99.5
Elevation (ft)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Station
5/13/02
7/25/02
6/09/03
2/10/04
2/2/2005
3/14/2006
WB
EB
Installed 5/13/2002



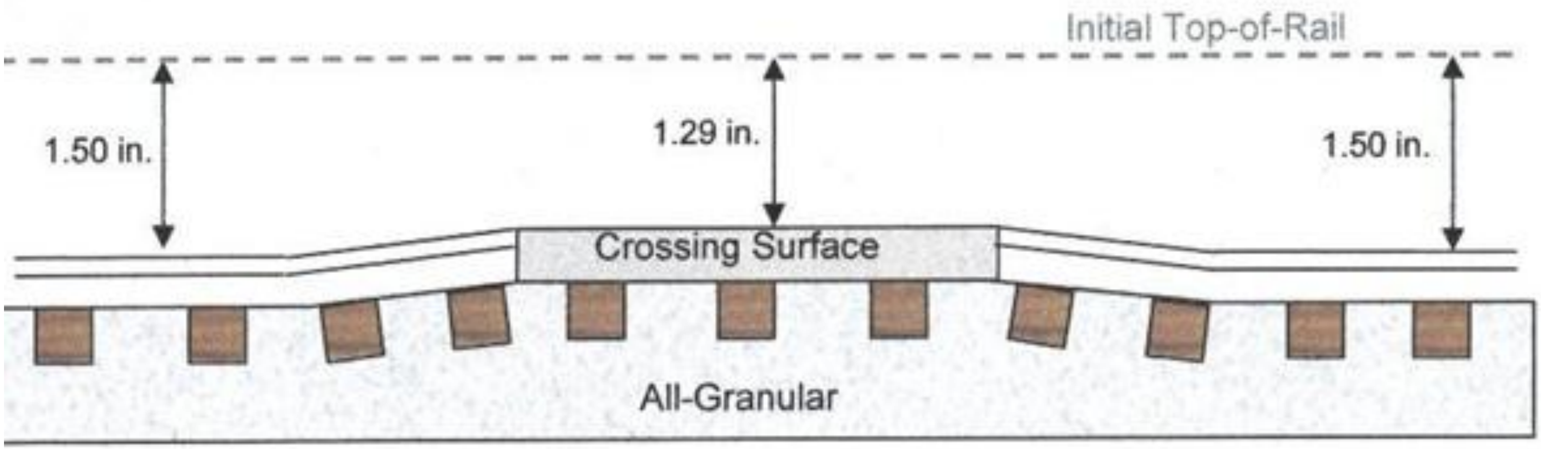
Average Asphalt/Approach Settlement for Flag Spring (no underlayment)
Approaches
Crossing
Installed 5/13/2002
inches
Time (Months)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
0.52
0.37
0.97
0.84
1.12
1.00
1.50
1.28
1.74
1.69


Top of Rail Elevations for South Portsmouth
Installed 6/11/2002
WB
EB
6/11/02
7/25/02
6/09/03
2/10/04
2/2/2005
12/20/2005
Elevation (ft)
100.75
100.5
100.25
100
99.75
Station
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20


Average Asphalt/Approach Settlement for South Portsmouth
Approaches
Crossing
Installed 6/11/2002
inches
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0.45
-0.15
0.85
0.09
1.07
0.15
1.43
0.40
1.65
0.56
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
Time (Month)



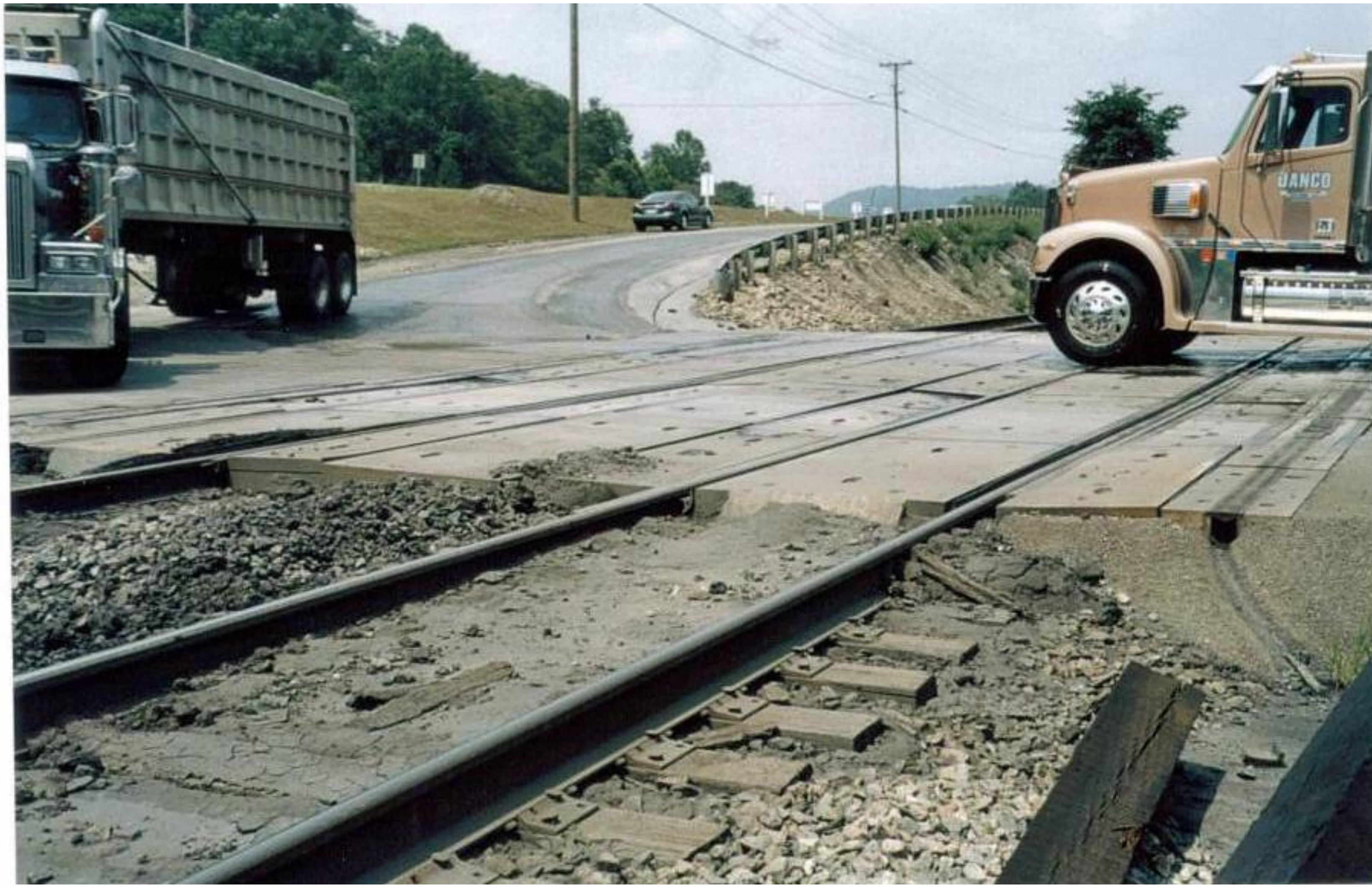
(42 Months in service)

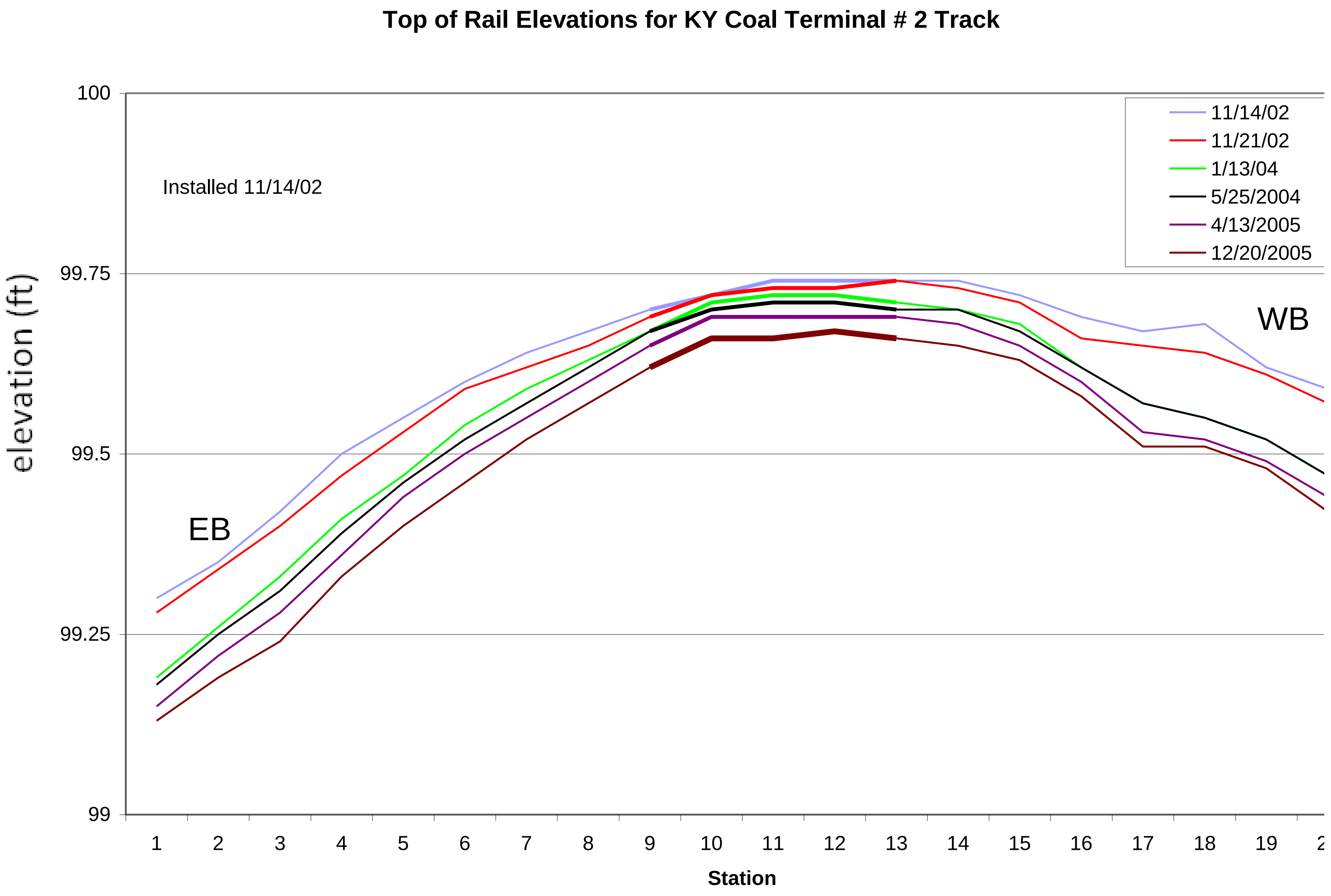


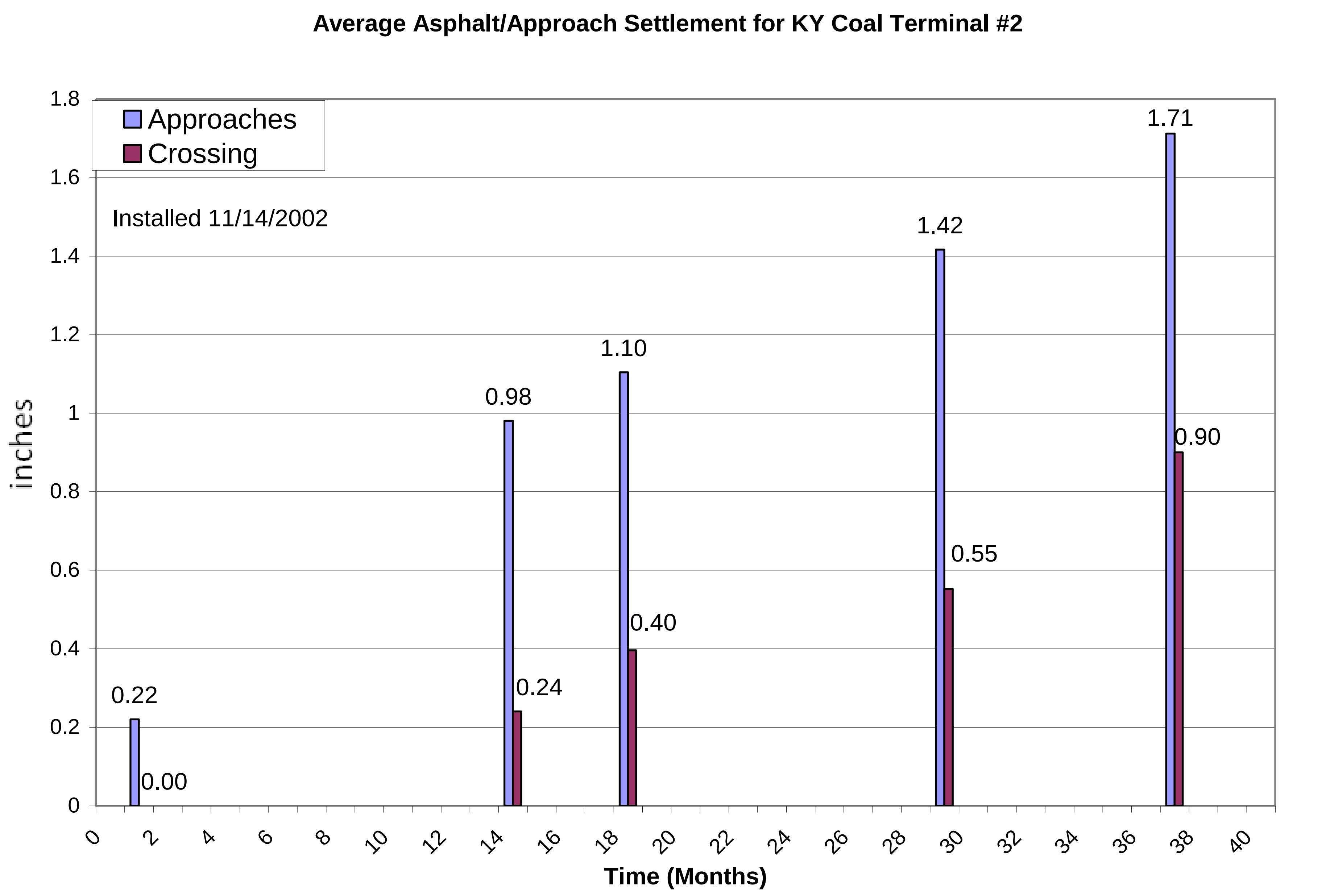
(33 Months in service)

1.0 in. = 25.4 mm

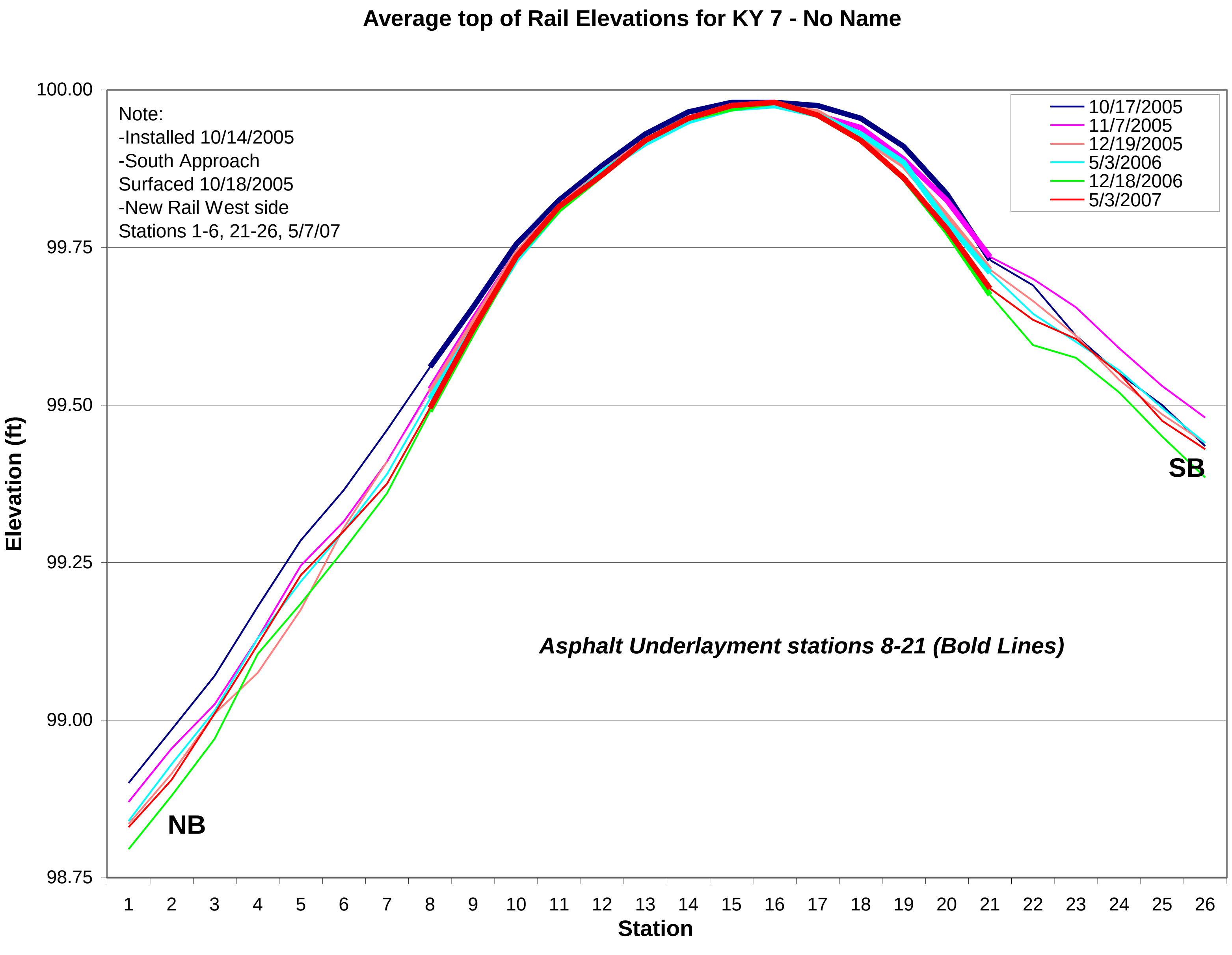
KY Coal Term

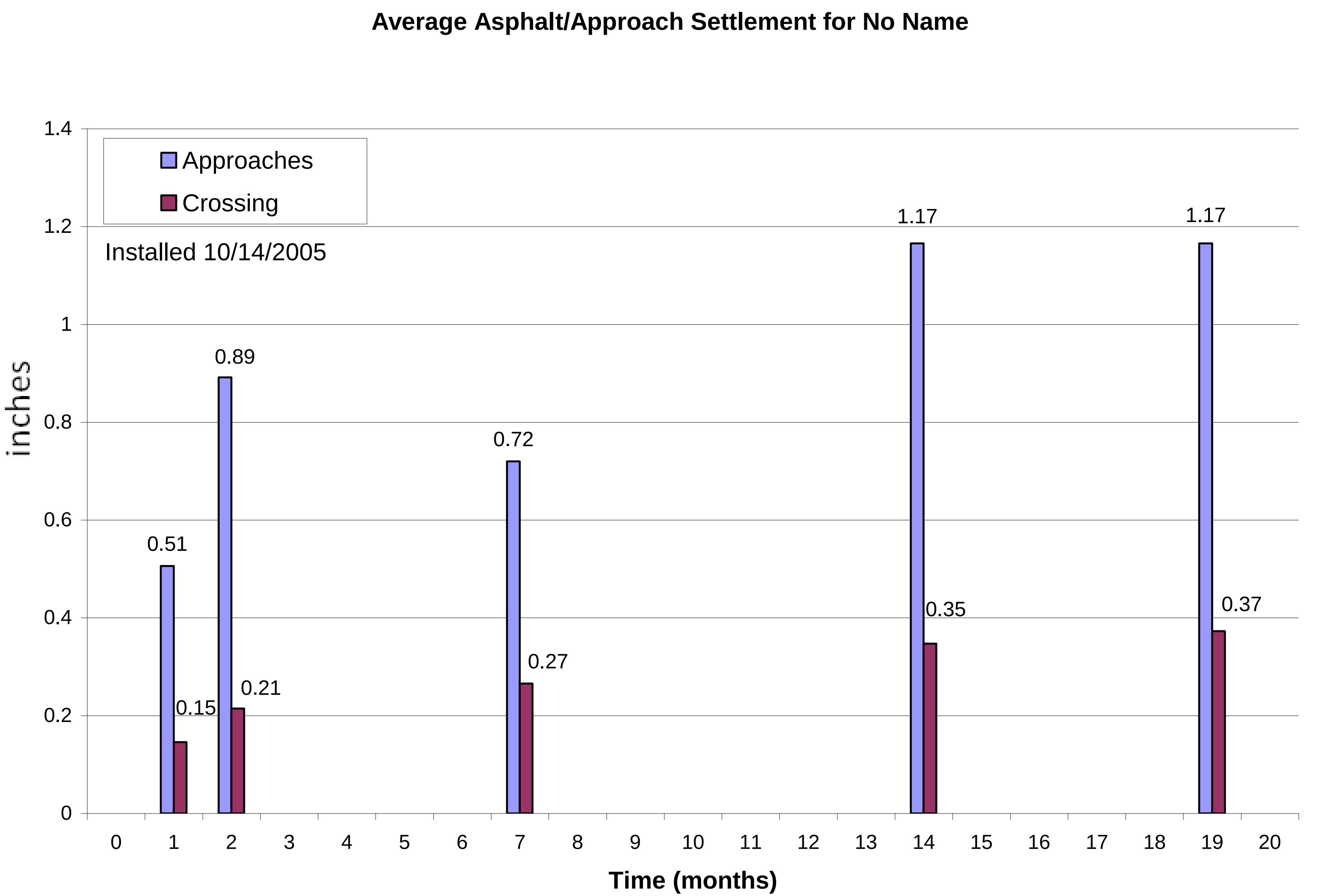



Top of Rail Elevations for KY Coal Terminal # 2 Track
100
99.75
99.5
99.25
99
elevation (ft)
Installed 11/14/02
EB
WB
11/14/02
11/21/02
1/13/04
5/25/2004
4/13/2005
12/20/2005
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Station



Average Asphalt/Approach Settlement for KY Coal Terminal #2
Approaches
Crossing
Installed 11/14/2002
inches
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.22
0.00
0.98
0.24
1.10
0.40
1.42
0.55
1.71
0.90
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time (Months)

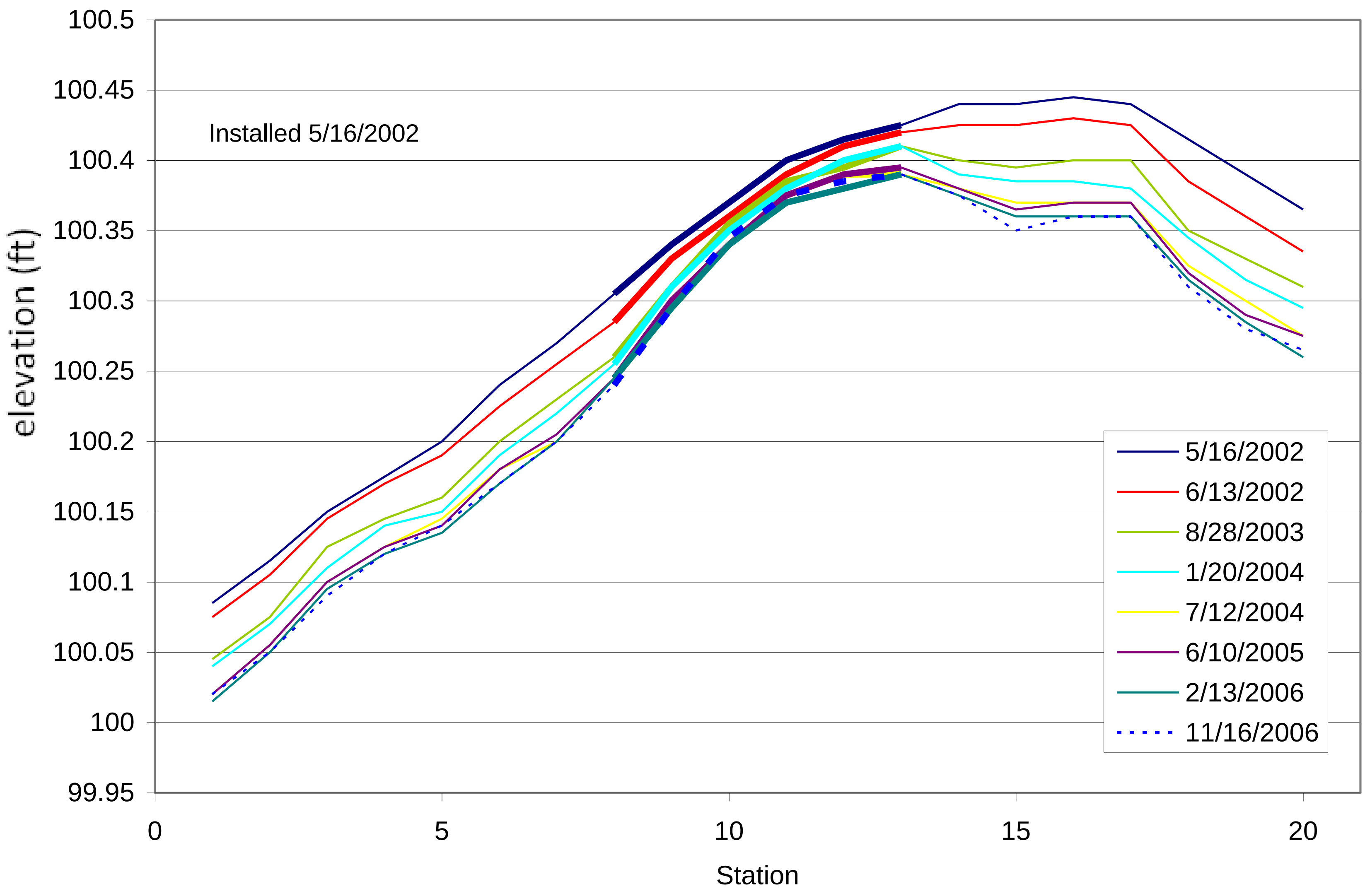

Average top of Rail Elevations for KY 7 - No Name
Note:
-Installed 10/14/2005
-South Approach
Surfaced 10/18/2005
-New Rail West side
Stations 1-6, 21-26, 5/7/07
10/17/2005
11/7/2005
12/19/2005
5/3/2006
12/18/2006
5/3/2007
Asphalt Underlayment stations 8-21 (Bold Lines)
NB
SB
Elevation (ft)
Station
100.00
99.75
99.50
99.25
99.00
98.75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

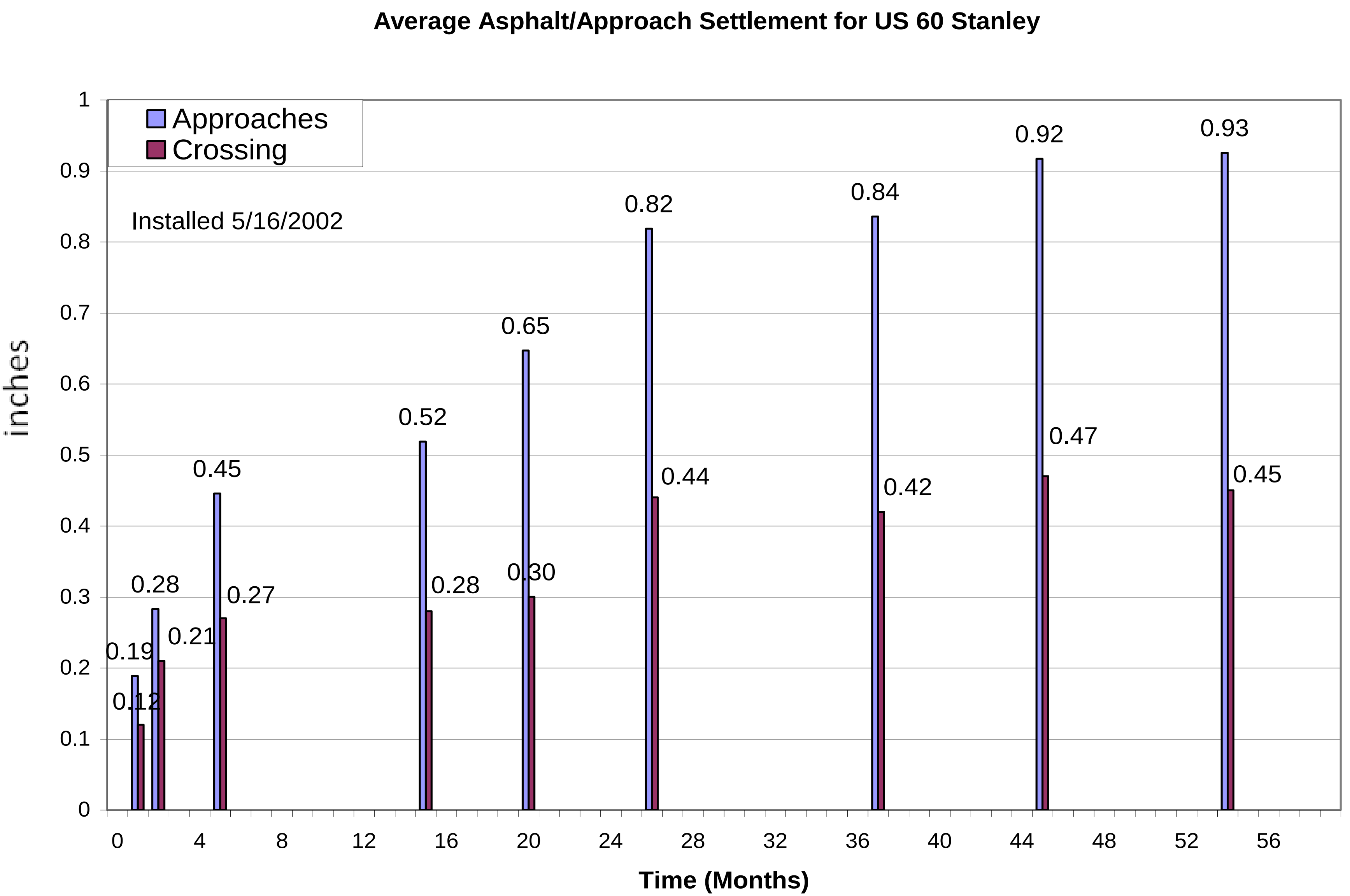


Average Asphalt/Approach Settlement for No Name
Approaches
Crossing
Installed 10/14/2005
inches
Time (months)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0.51
0.15
0.89
0.21
0.72
0.27
1.17
0.35
1.17
0.37

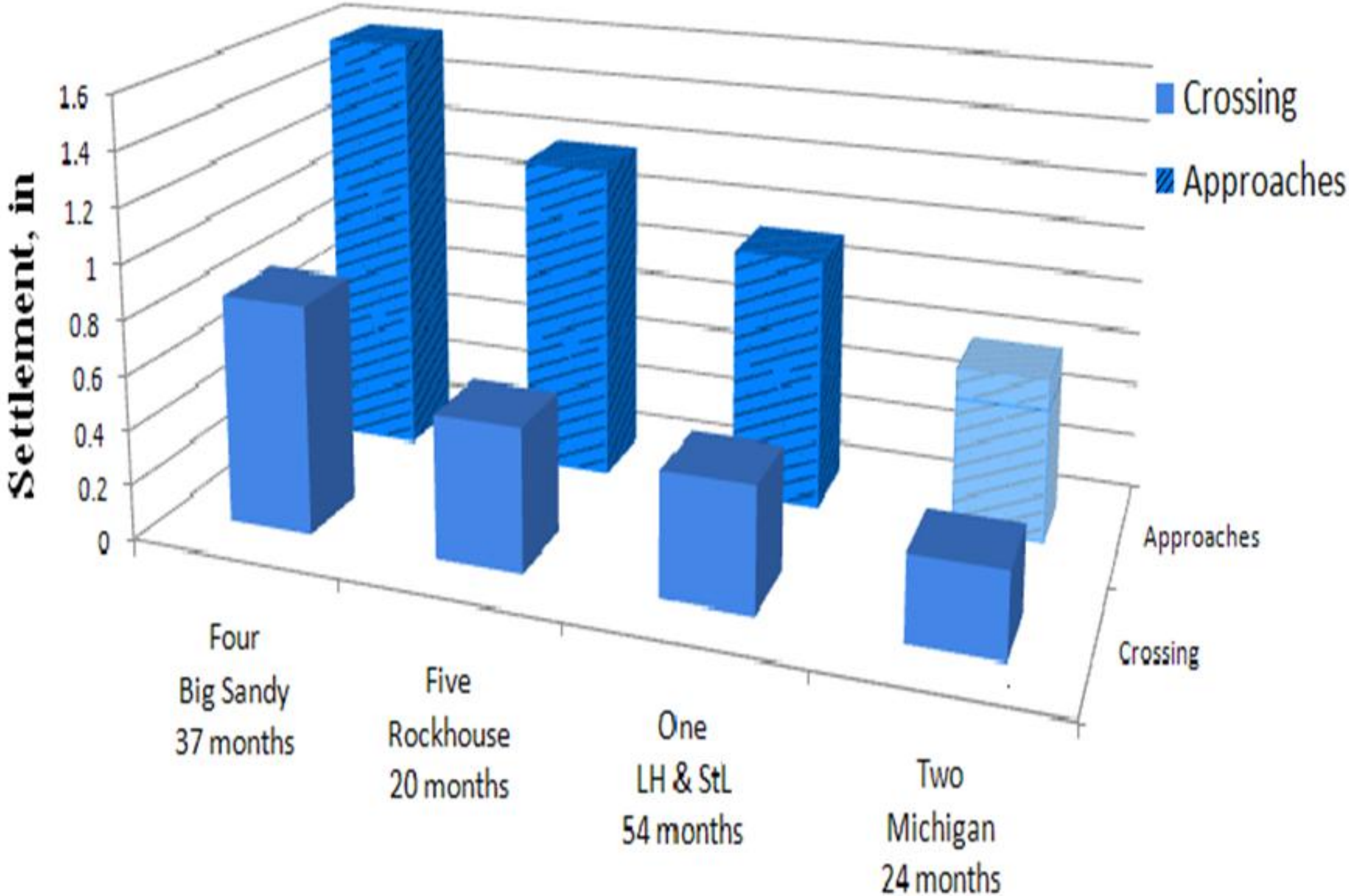
Stanley

Average Top of Rail Elevations for US 60 Stanley





Average Asphalt/Approach Settlement for US 60 Stanley
Approaches
Crossing
Installed 5/16/2002
inches
Time (Months)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
0.19
0.12
0.28
0.21
0.45
0.27
0.52
0.28
0.65
0.30
0.82
0.44
0.84
0.42
0.92
0.47
0.93
0.45


Settlement, in
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Crossing
Approaches
Approaches
Crossing
Four
Big Sandy
37 months
Five
Rockhouse
20 months
One
LH & StL
54 months
Two
Michigan
24 months

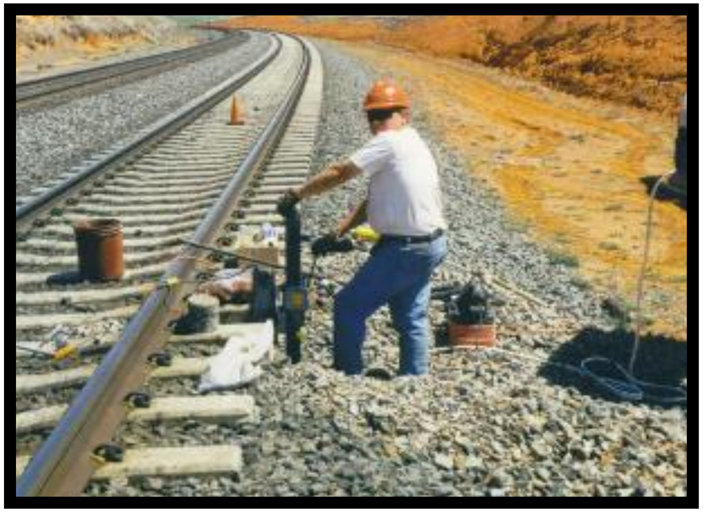
Advantages of Enhanced Support

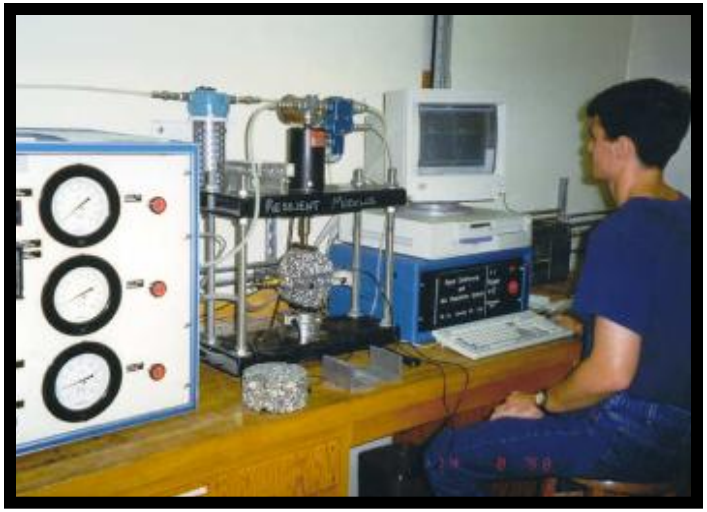
- Clearly Demonstrated
- Minimize Long-Term Settlement

- Settlement Asphalt Crossings was 41% of non-Asphalt Crossings
- Settlement Asphalt Crossings was 44% of Abutting Approaches
- Settlement of Non-Asphalt Crossings & Approaches – Similar

- Fast- Track is Feasible
- Cooperative Approach is Desirable

Trackbed Materials Classifications





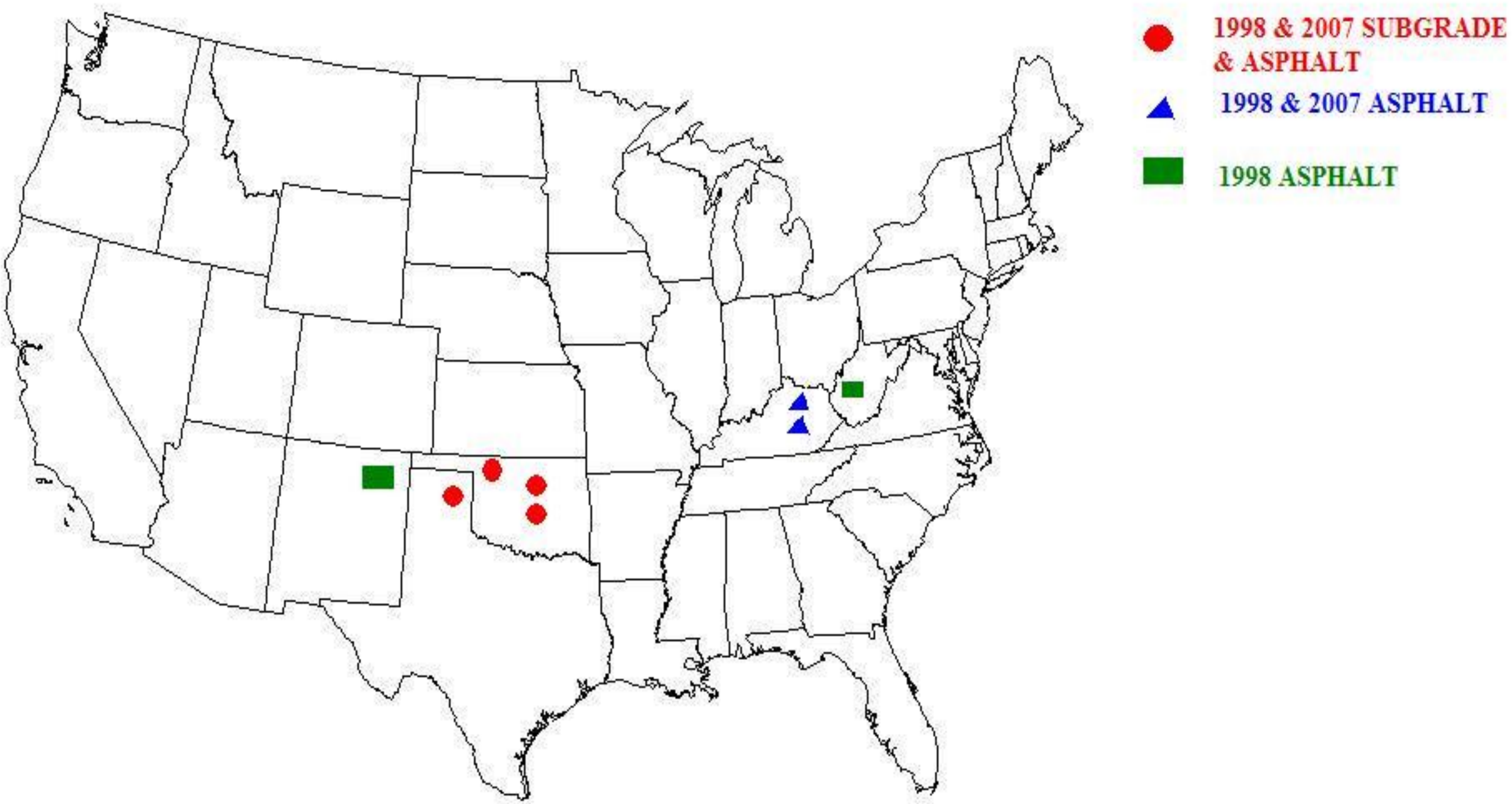
Tests and Evaluations

Trackbed Materials

- **Ballast**
- **Subgrade** Moisture Content
  Proctor Moisture-Density
  Classification
  CBR
- **Asphalt** Core Tests
  Recovered Binder Tests

1998 - 2007

Trackbed Test Sites



Core Drilling

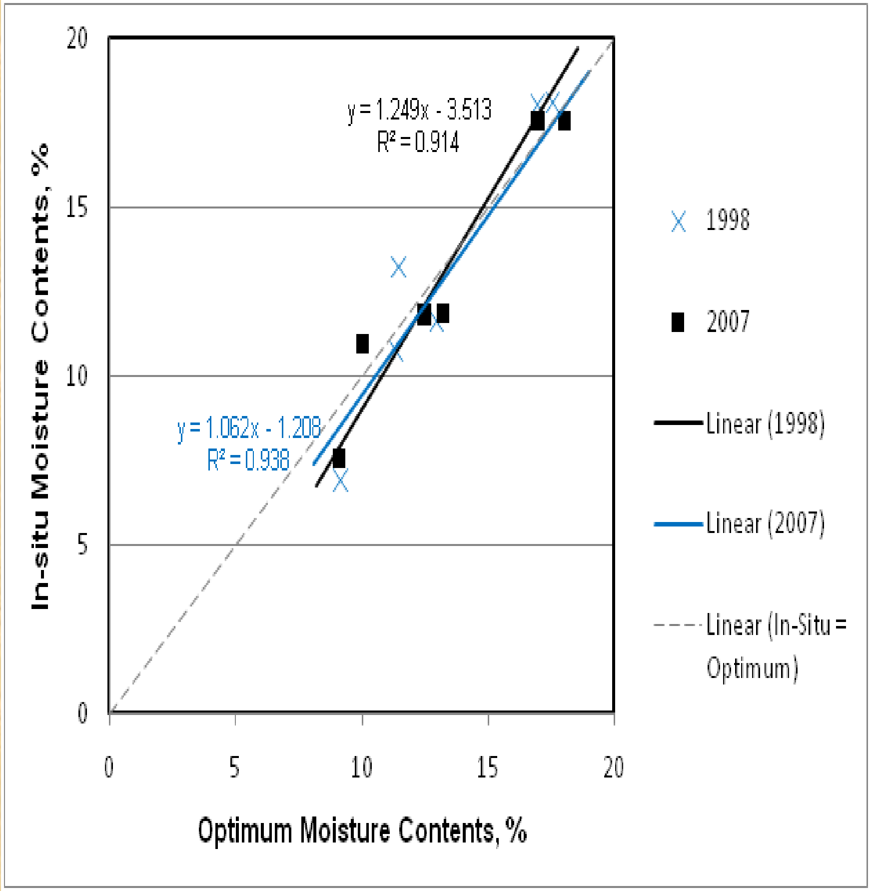
Core Drilling

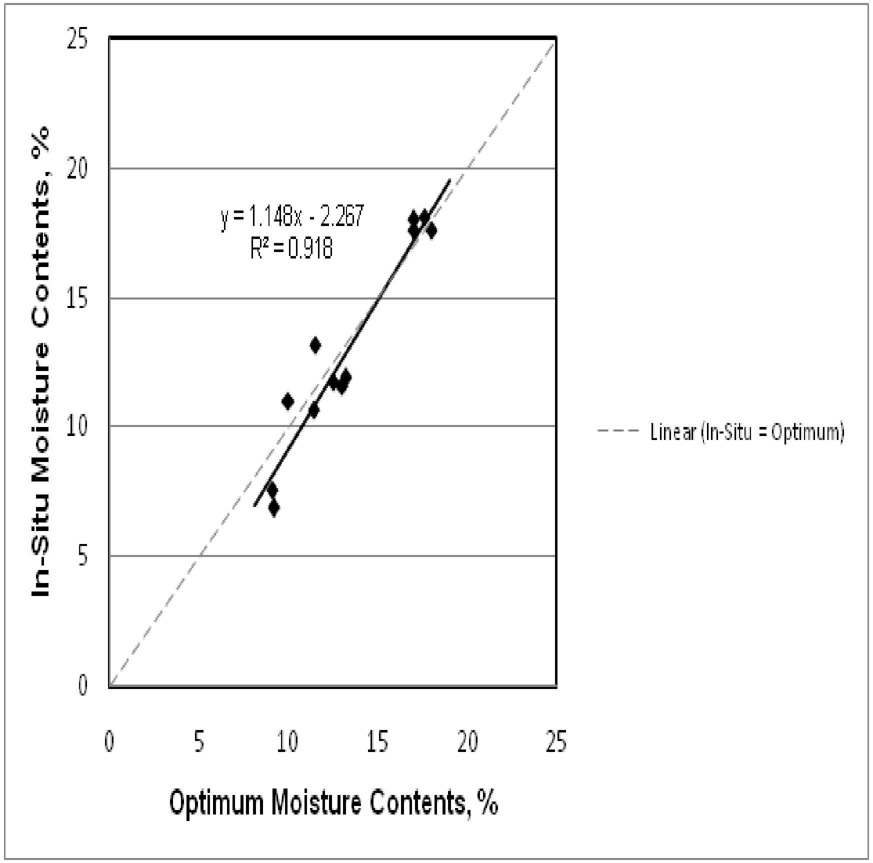
Core Drilling

Soil Tests


U.S.A. STANDARD TESTING SIEVE
NO.10
FISHER SCIENTIFIC COMPANY
FISHER SCIENTIFIC COMPANY
NO.100
FISHER SCIENTIFIC COMPANY
NO.200
FISHER SCIENTIFIC COMPANY
Durant

Relationships for Roadbed/Subgrade In-Situ and Optimum Moisture Contents





Unified Soil Classification

Project	Date	Unified		OMC	CBR
Guthrie	1989	Silty sand	SM	12%	14/5
OK City	1992	Lean clay	CL	18%	8/3
Quinlan	1995	Lean clay	CL	17%	9/4
Quinlan	1995	Sandy silt	ML	13%	3 3/26
Hoover	1994	Subballast	GP-GM	9%	56/46
Hoover	1994	Clayey sand	GC-GM	11%	7/4

Subgrade Findings/Discussions

- In-situ Moisture Contents
  - Remain Consistent Over Time
  - Compare Favorably With Optimum
- Assume Unsoaked, Optimum Condition
- Bearing Capacity Remains At or Near Optimum
- Wide Range of Subgrades Evaluated
- Minimum Loading Induced Stress on Subgrade

ASPHALT TESTS

Resilient Modulus
25ºC (77ºF)
1Hz

Dynamic Shear Rheometer
25ºC (77ºF)

Asphalt Findings/Discussions

- Resilient Modulus Values are Intermediate in Magnitude – Typical of Unweathered Asphalt Mixes
- Asphalt Binders do not Exhibit Excessive Hardening (brittleness), Weathering, Deterioration or Cracking
- Asphalt is Insulated from Environmental Extremes
- Asphalt Experiences Minimal Loading Induced Stress
- Conditions Influencing Typical Failure Modes Experienced by Asphalt Highway Pavements don't Exist in Asphalt Railroad Trackbeds ???

UTILIZATION APPLICATIONS FOR ASPHALT TRACKBEDS

Domestic and International

Typically as an Underlayment Layer Topped with Ballast Layer
but can have
Ties or Slab Positioned Directly on Asphalt without Ballast Layer

NEW TRACKBEDS – PAVER LAID WITH HIGHWAY PAVING EQUIPMENT

Long Distances – New Alignments and Double-Tracking

Re-Alignments of Existing Tracks – Approaches to New Bridges, etc.

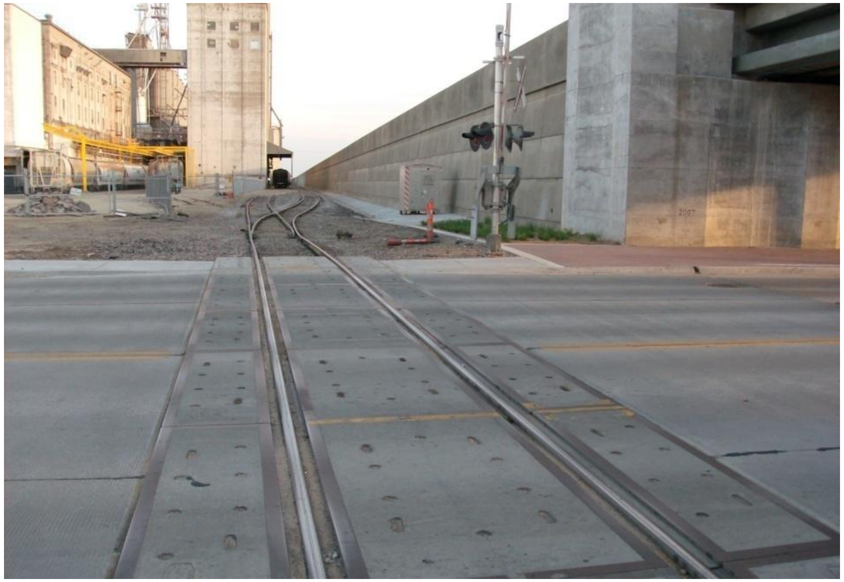
REHABILITATION (RENEWAL) OF EXISTING TRACKBEDS – BACK DUMPED

- Short Distances – Quick Fixes under Traffic
- Typically Special Trackworks
  - Turnouts, Crossovers, Railroad Crossing Diamonds
  - Highway At-Grade Crossings
  - Bridge Approaches
  - Tunnel Floors and Approaches
  - Various Types of Detectors
- Short Sections of Unstable Trackbeds


Ingersoll Rand


CHINA SHIPPING

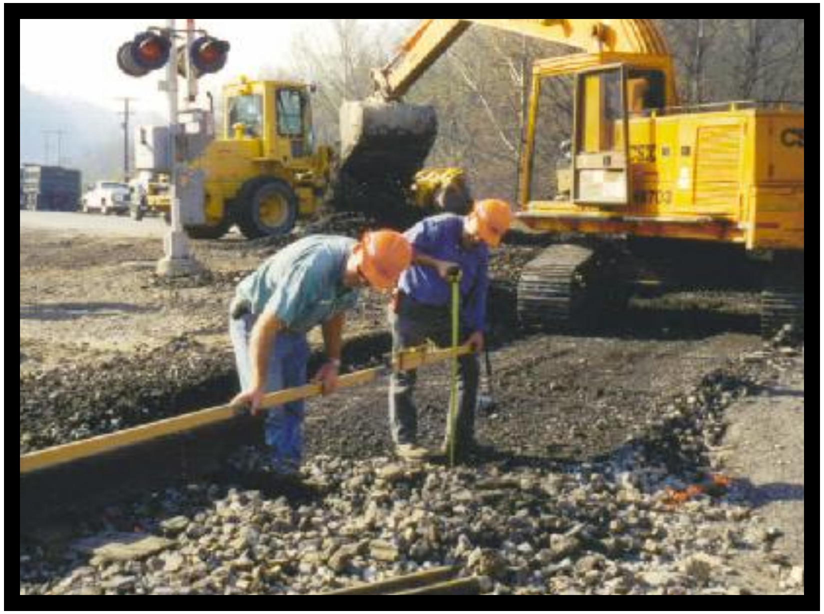

641
641



KY 3 Condition prior to rebuild

Removing old crossing 08:30

Began excavating



Excavating trackbed and checking grade

Dumping asphalt 10:15

Spreading asphalt

Compacting asphalt and dumping ballast

Dumping and spreading ballast

Compacting ballast 11:20

Positioning new panel

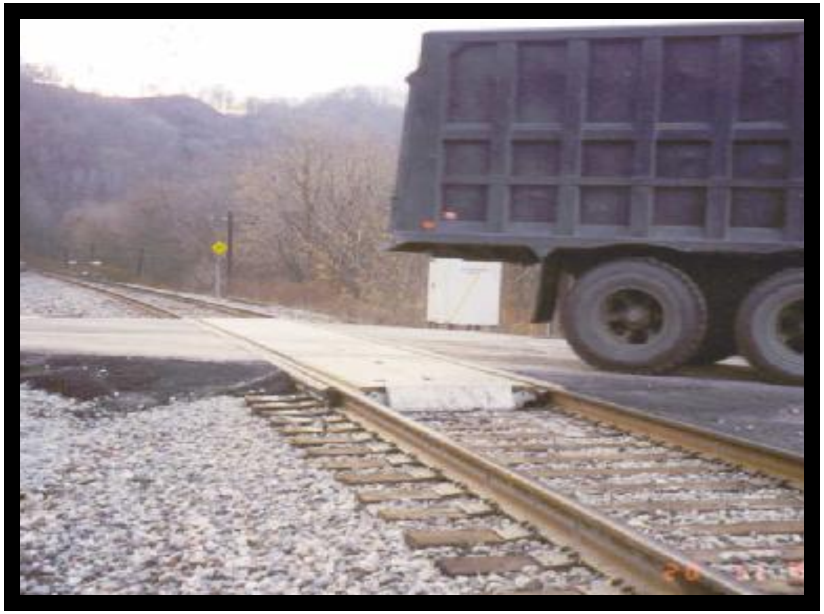
Spreading cribbing rock 11:30

Tamping ballast

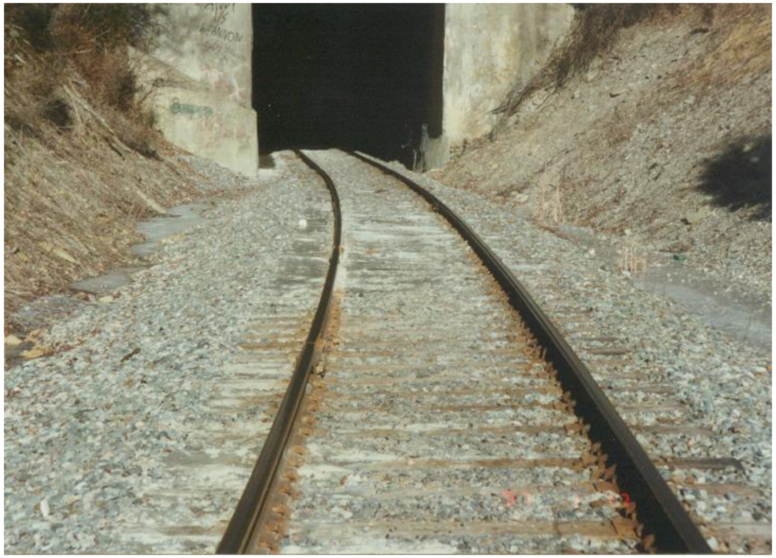
Regulating ballast 12:40

Compacting hand-spread approaches

Finished compacting asphalt approaches 16:50



3 weeks later



Removing track and location 2 (1/30/97)

Hauling fouled ballast from tunnel

Loading steel ties and roadbed at north end

Excavating trackbed material

Unloading hot mix asphalt for transloading to hi-rail dump

Unloading hot mix asphalt at north end to be distributed by loader

Unloading hot mix asphalt inside tunnel

Spreading cold mix on floor

Wood panel on asphalt layer prior to adding ballast

Looking north at south portal to tunnel #3 at PN 2.5. Pumping station at left. All 4 tunnels have sump pump systems. All 4 have asphalt

South portal to tunnel #1 from 22nd Street station, PN 1.9. Asphalt placed in tunnels and approaches during 1999. No surfacing required. Wood ties used in tunnels.



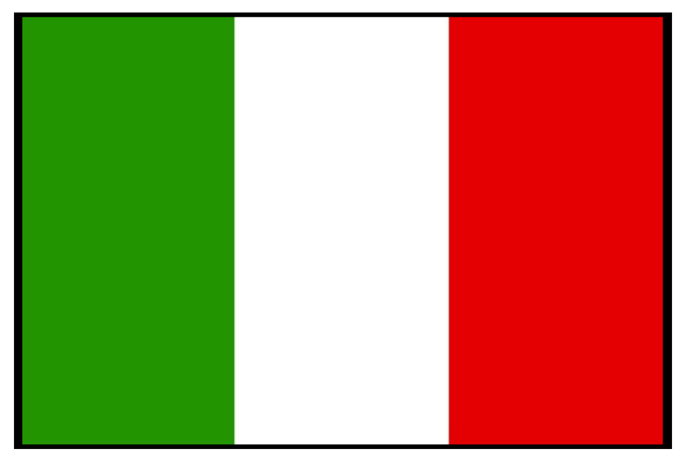


HULCHER



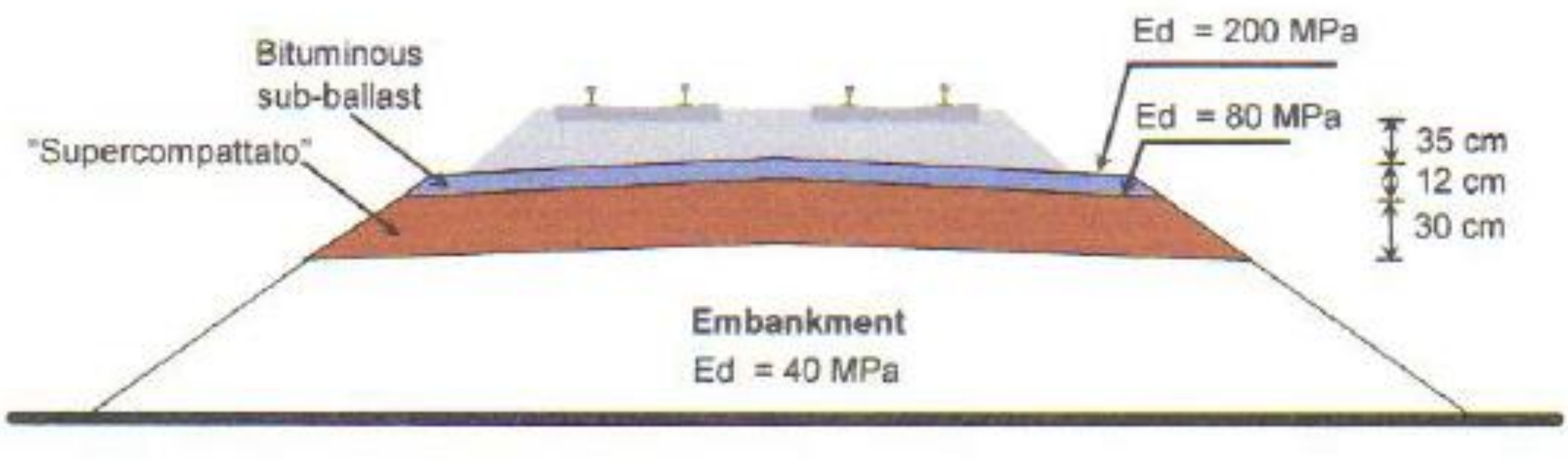

Italian High-Speed Passenger Lines

- Rome-Florence: First High Speed Line – 252 km – 1977-1986
- Debated between cement and asphalt
- Asphalt performed better – opted for use on all high-speed passenger lines



Typical Cross Section

- 12 cm of asphalt with 200 MPa modulus
- 30 cm of super compacted subgrade with 80 MPa modulus
- 35 cm of ballast on top



High Speed Rail Construction

Asphalt Over Super Compacted Layer

Spreading Ballast

Compacting Ballast

Finished Product

Turin To Salerno - 2009

- Turin-Milan
- Milan-Bologna
- Bologna-Florence
- Florence-Rome
- Rome-Naples
- Naples-Salerno

Germany

- German Getrac ballastless track
- Track Panels are directly supported by asphalt
- Two Types: Getrac A1 and Getrac A3

Dimensions

- Getrac A1:
- 300 cm of asphalt
- 600 cm of subgrade
- Concrete Ties
- Used for open track

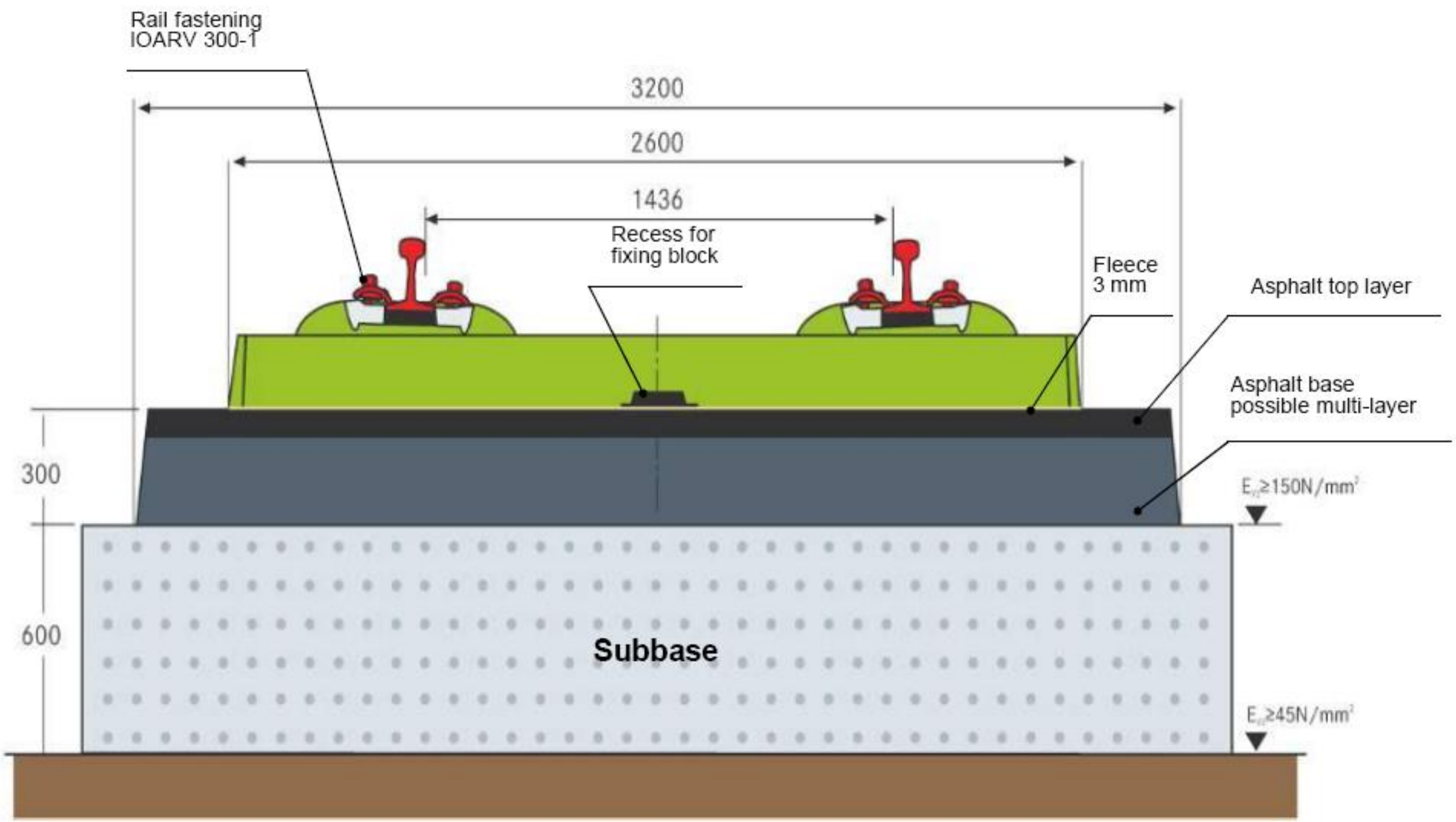
- Getrac A3:
- 260 cm of asphalt
- 600 cm of subgrade
- Concrete Ties
- Used for restricted spaces: tunnels

Asphalt Layer

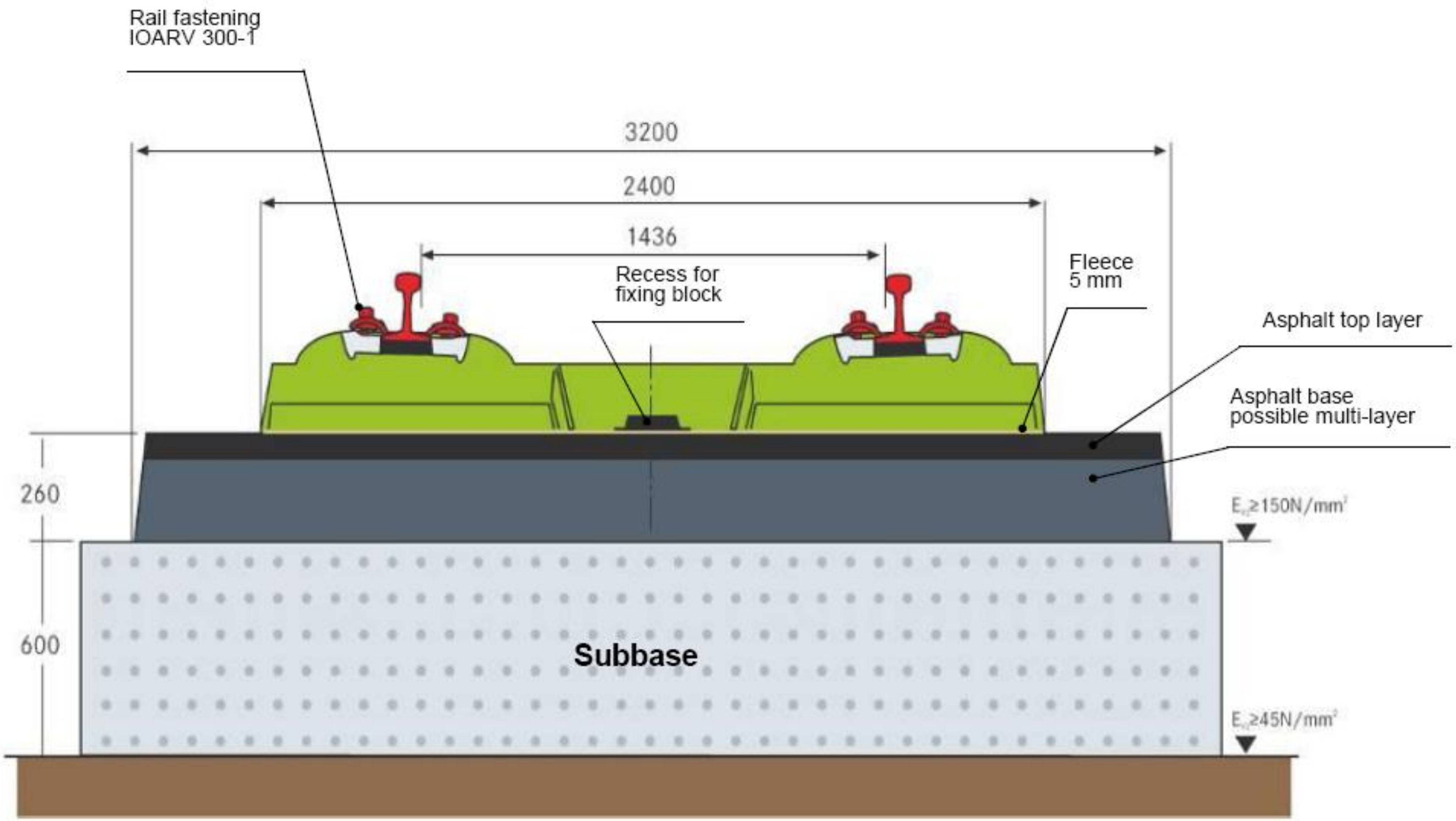
- Paved in 3 different layers:

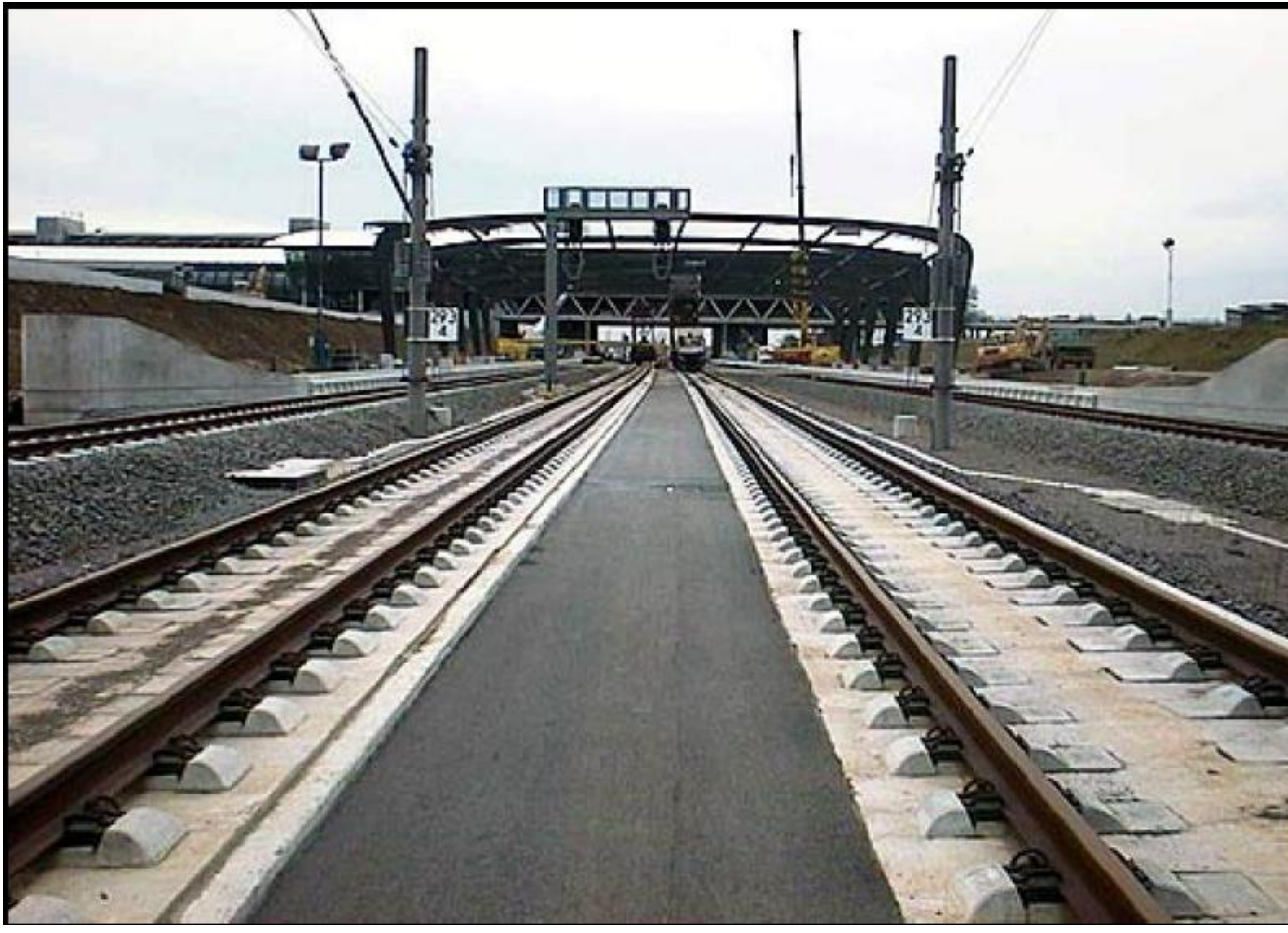
1. 0/22 mm aggregate – initial base layer
2. 0/16 mm aggregate – medium layer
3. 0/8 mm aggregate – covering layer

Getrac A1 Cross-Section

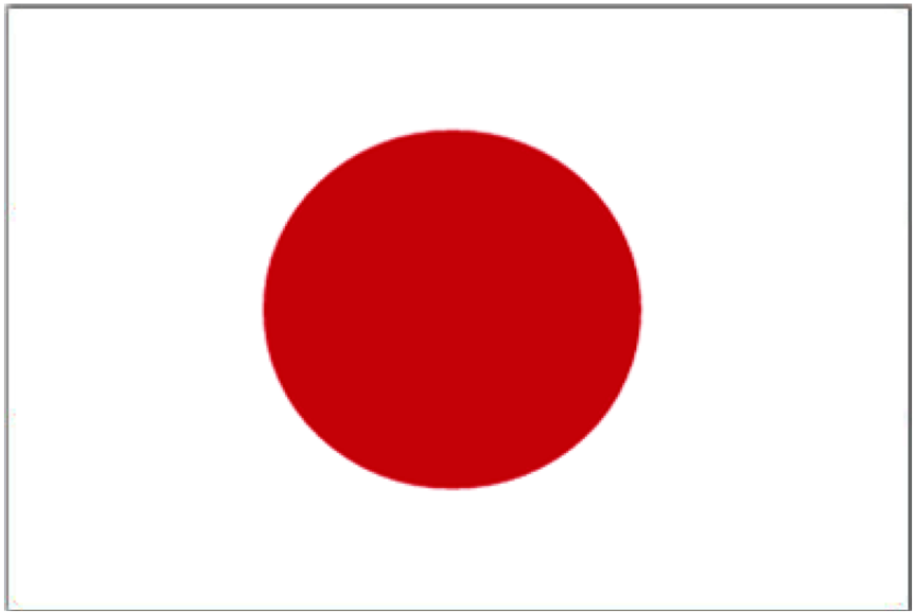


Getrac A3 Cross Section





Japan



- Shinkansen Lines "Bullet Train"
- 1964 – Tokyo to Osaka
- Other lines branched off
- Estimated 396 billion people*km using trains

Ballasted Cross Section

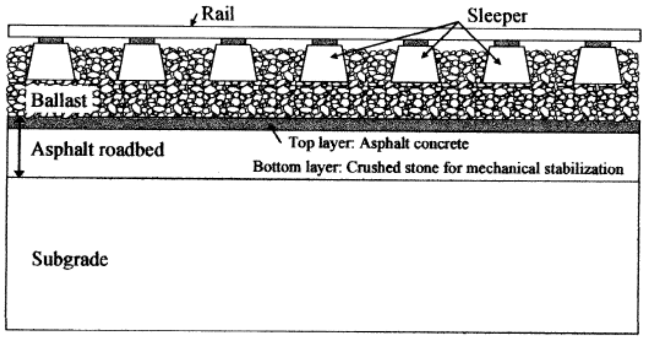


Figure1: Typical cross-section of railway asphalt roadbed.

Asphalt Thickness – 5cm

Well-Graded Crushed Stone Thickness – 15-60 cm

Ballastless Cross Section

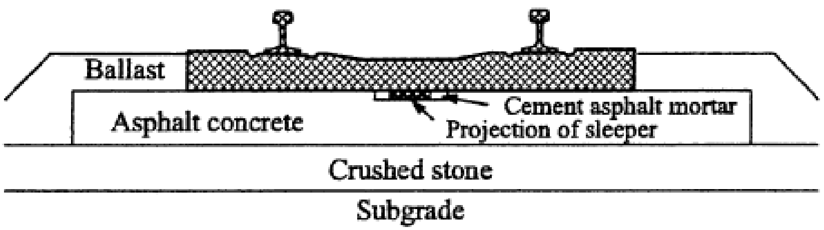


Fig. 1 The first test track of solid bed track on asphalt pavement

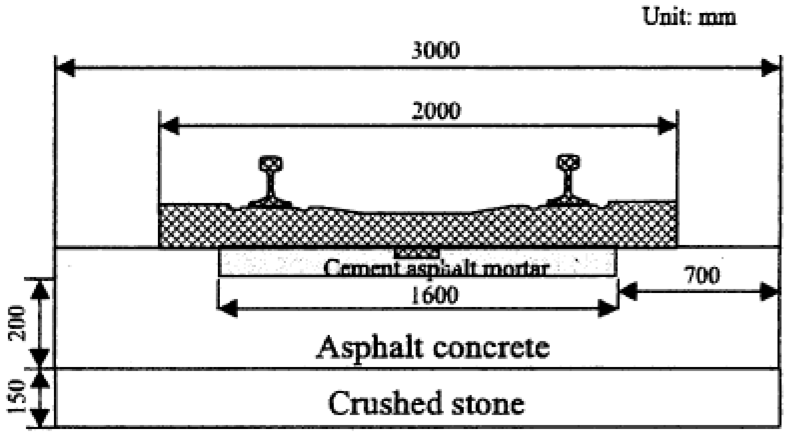


Fig. 7 Cross section of the improved solid bed track on asphalt pavement

- Mainly used for viaducts and tunnels
- Proposed a low noise solid bed track on asphalt pavement