

Lessons from Recent Laboratory and Field Instrumentation Projects



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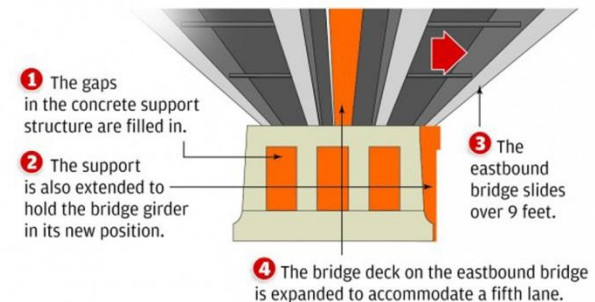
Indian Institute of Science (IISc), Bengaluru

Organization

- Introduction
- Bridge Instrumentation
 - ❖ Steel Orthotropic Deck
 - ❖ Temp-Varying Fatigue Tests
 - ❖ HPC Prestressed Girders
- Pavement Project
 - ❖ Precast Pre-/Post-Tensioned
- Dam Instrumentation
 - ❖ Tainter Gate Instrumentation
- Lessons Learnt

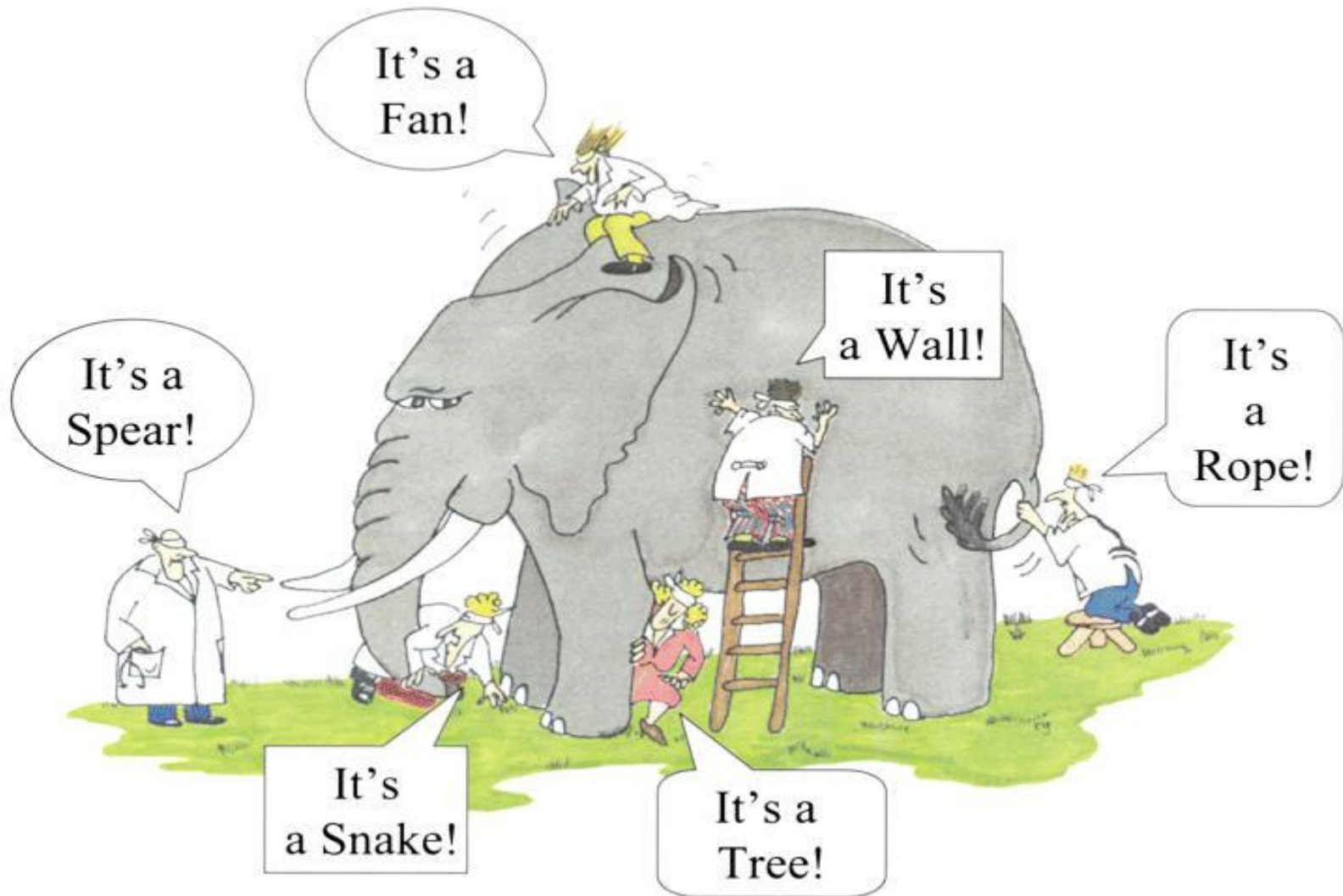


View toward Illinois from Missouri



SOURCE: HDR Engineering Inc. | Post-Dispatch

Experimental measurements...

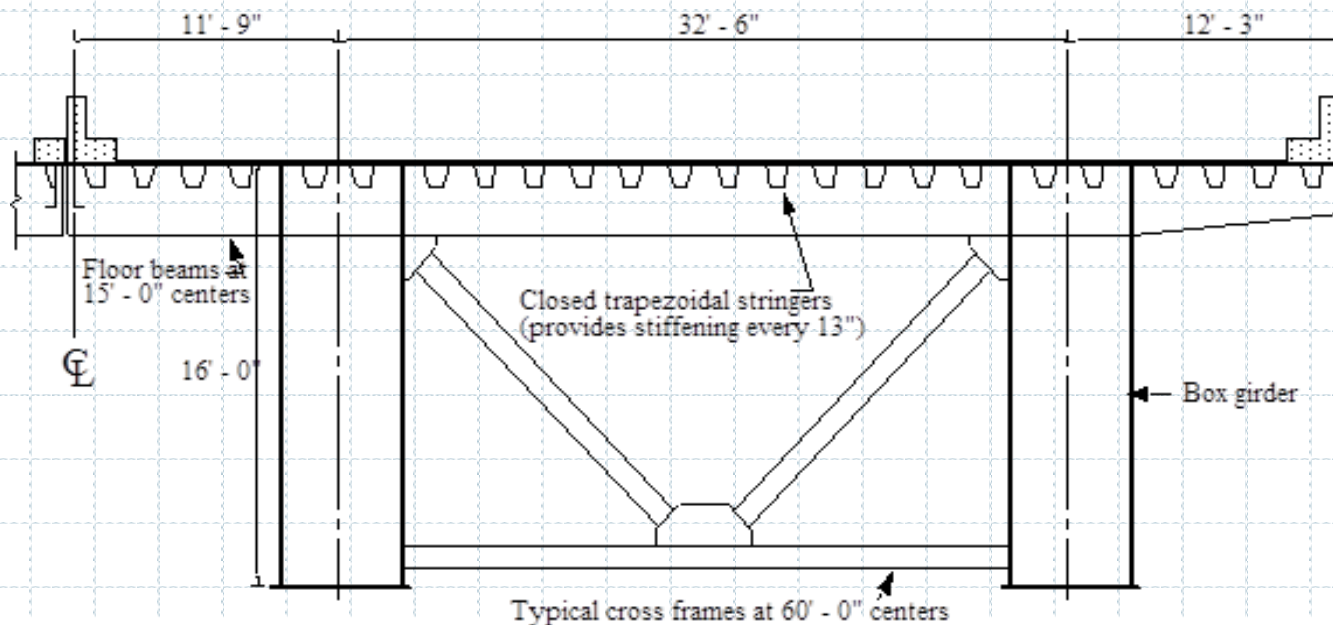


Strain Measurements on Steel Deck

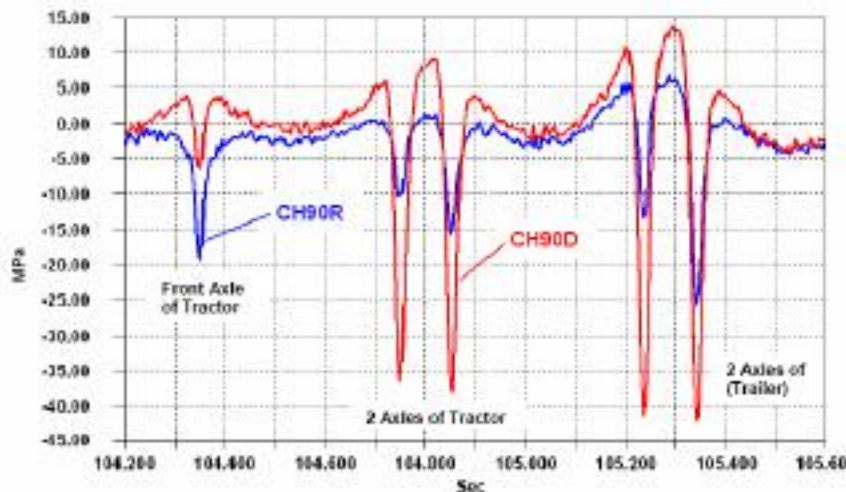
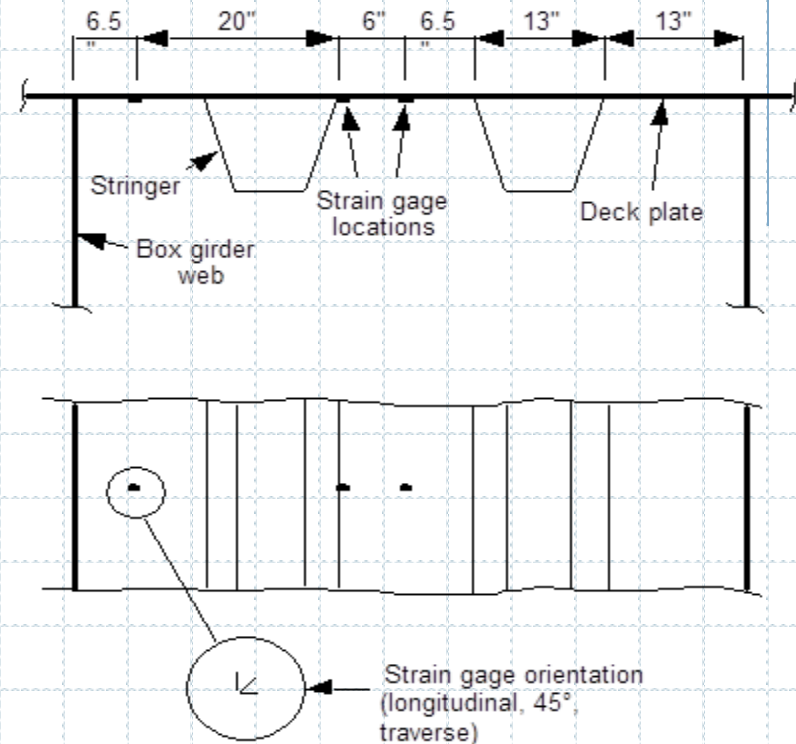
Develop strain time-histories and histograms for laboratory fatigue simulations of steel-wearing surface composite specimens:



Poplar Street Bridge, St. Louis (MO)

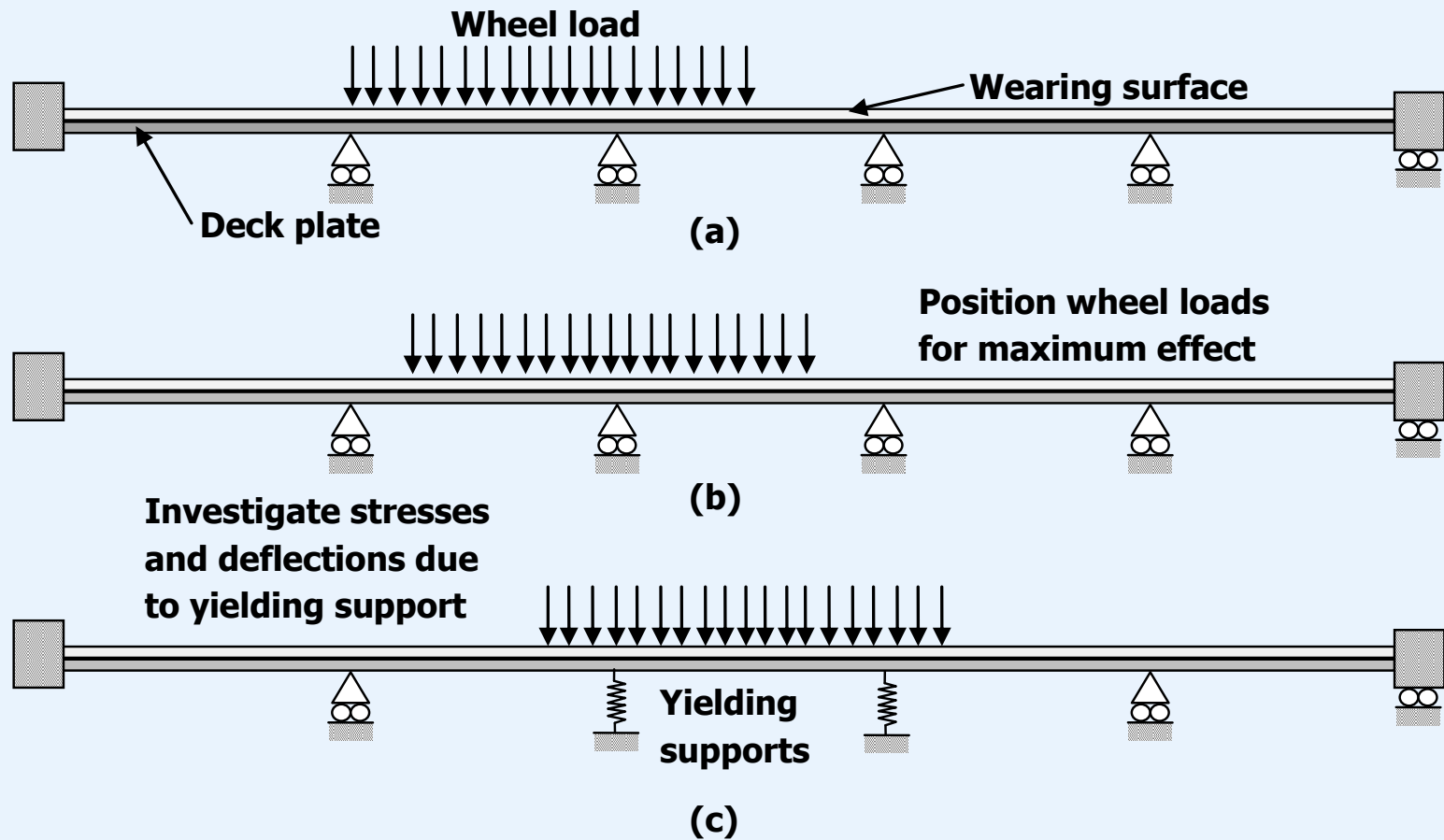


Wearing Surfaces: Service Strains

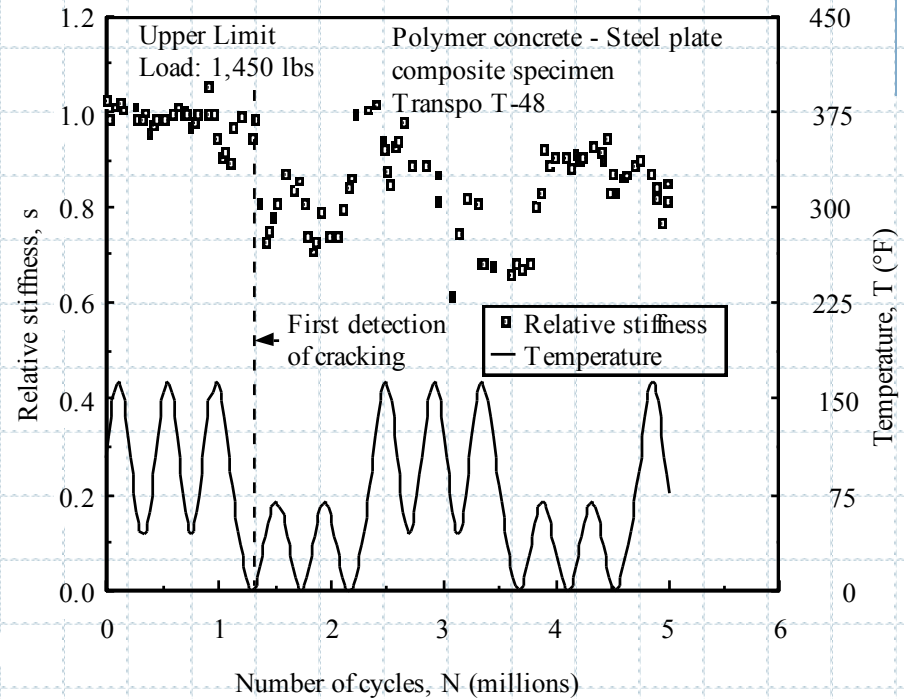
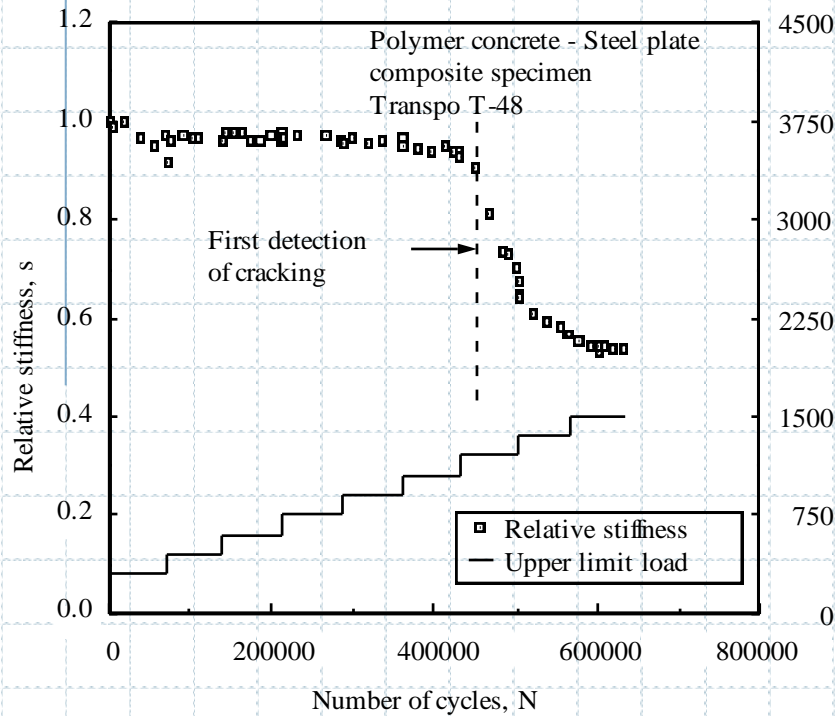


- ❖ Nicolet digital storage oscilloscope with strain gage amplifier/conditioners
- ❖ PC-based data acquisition system with safe sequential powering up

Idealized Analyses of Transverse Bending



Combined Fatigue/Thermal Loading



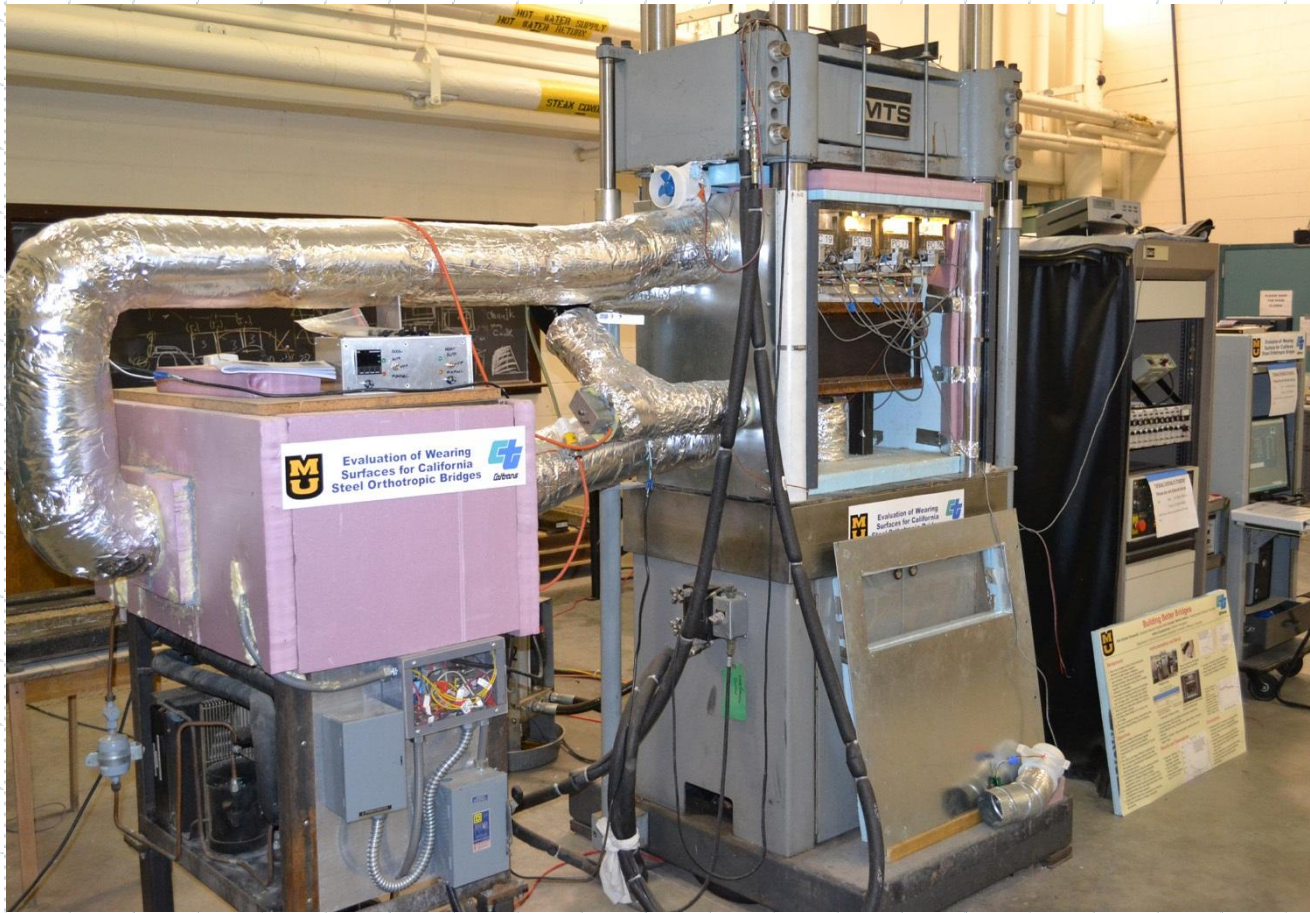
Temperature Varying Laboratory Fatigue Tests on Bridge Composites

Investigate static and flexural fatigue performance of composite specimens simultaneously subjected to thermal loading

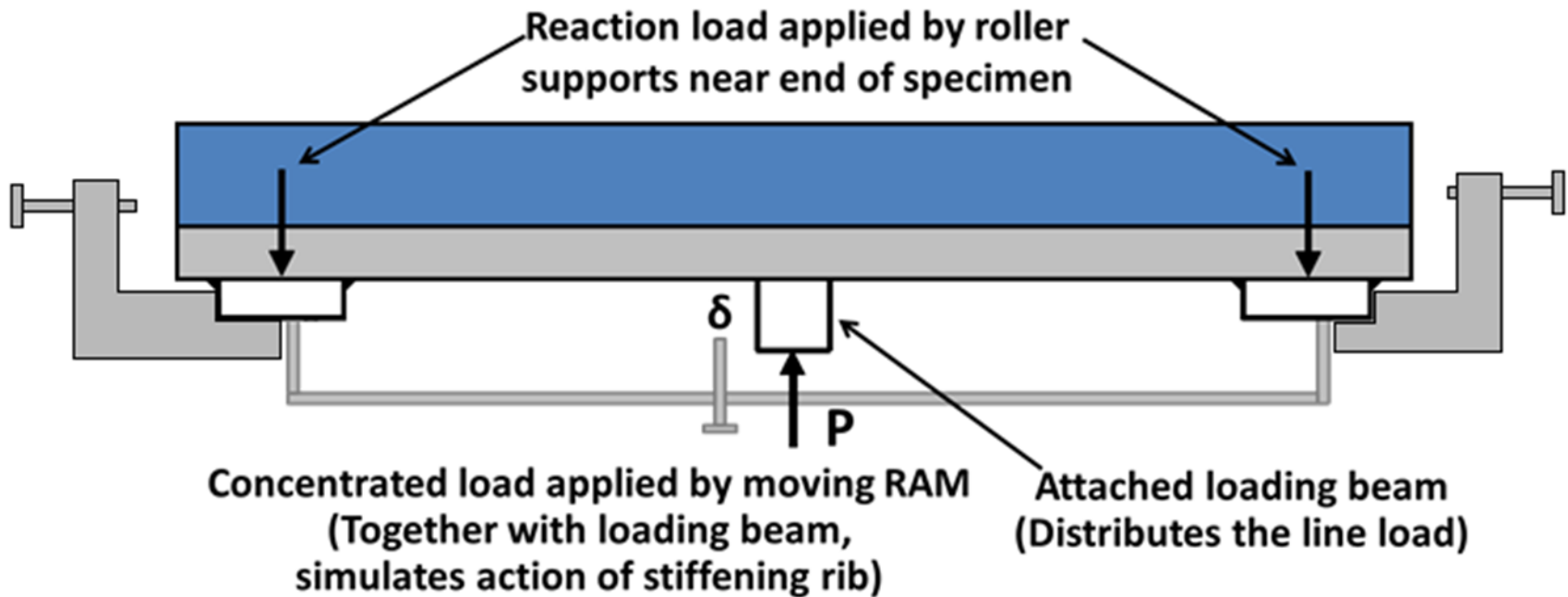
- ❖ Poplar St. Bridge, St. Louis
- ❖ Bronx-Whitestone Bridge, NY
- ❖ San-Mateo Hayward Bridge, San Francisco



Flexural Test Set-Up



Flexural Set-Up Schematic



Flexural Test Set-Up



Automated Digital Imaging System Regular Observation of Cracks





Evaluation of the Fatigue Performance of Wearing Surface Systems for San-Mateo Hayward Bridge Deck

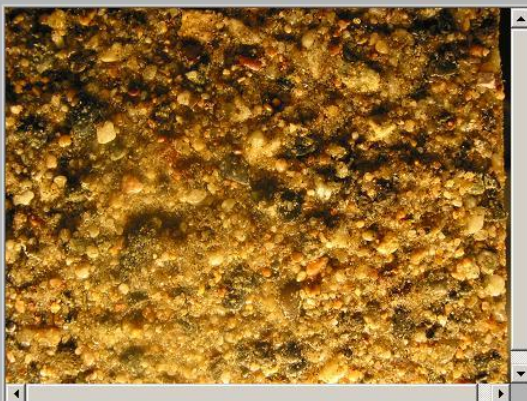
Automated digital imaging system



E:\CaltransPics\Cam1_07-29-2011_10-15-24_0001.jpg



E:\CaltransPics\Cam2_07-29-2011_10-17-39_0001.jpg



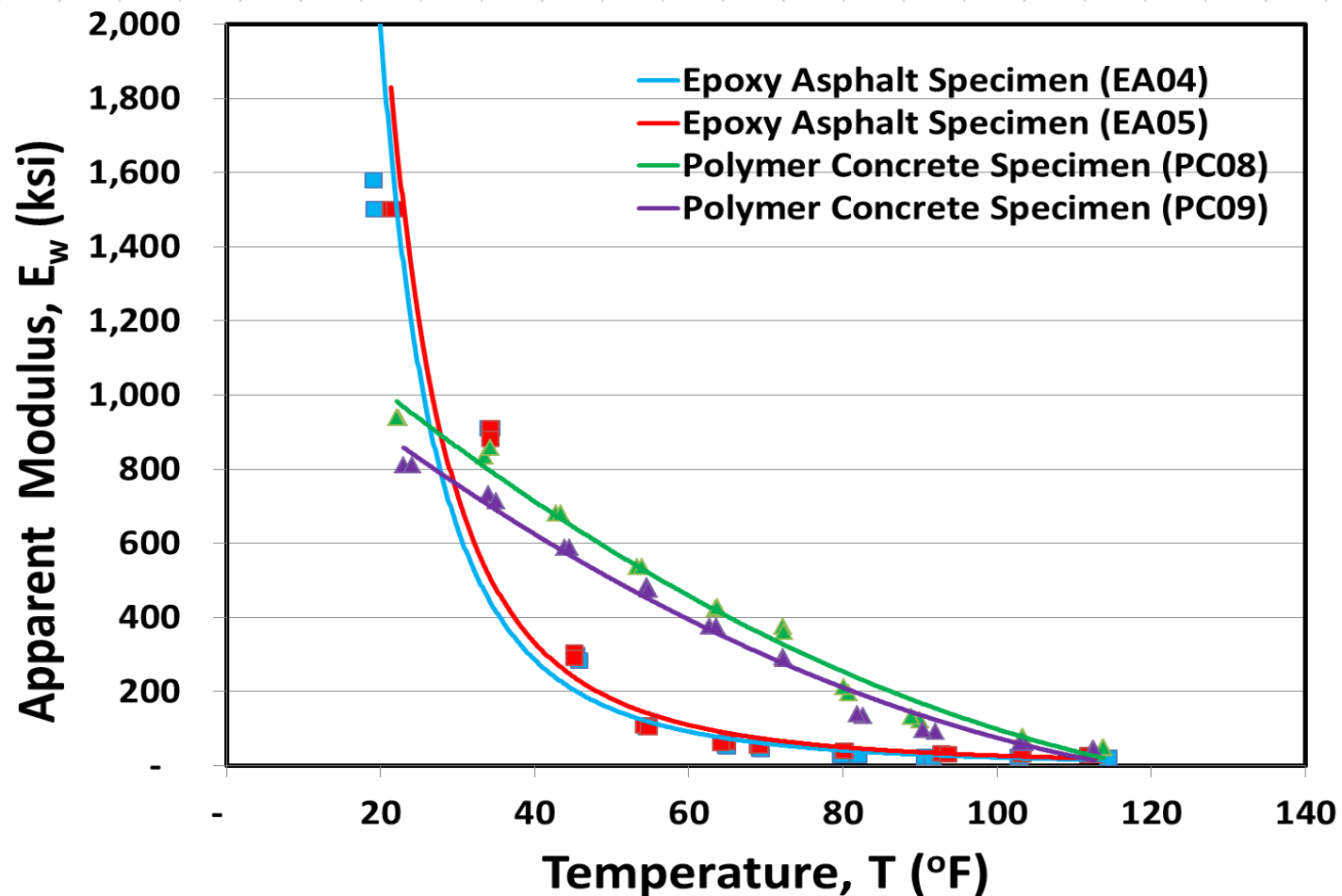
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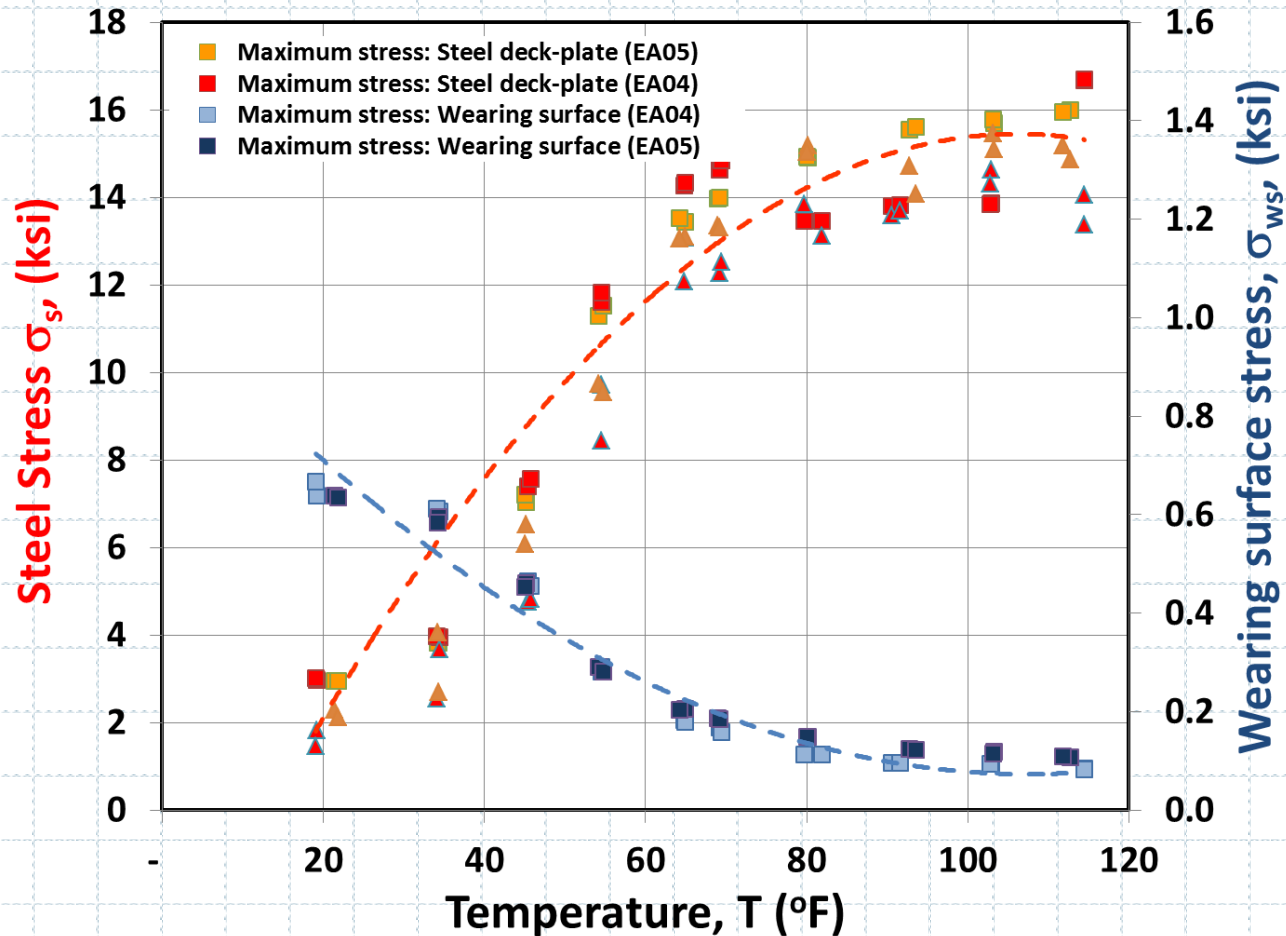
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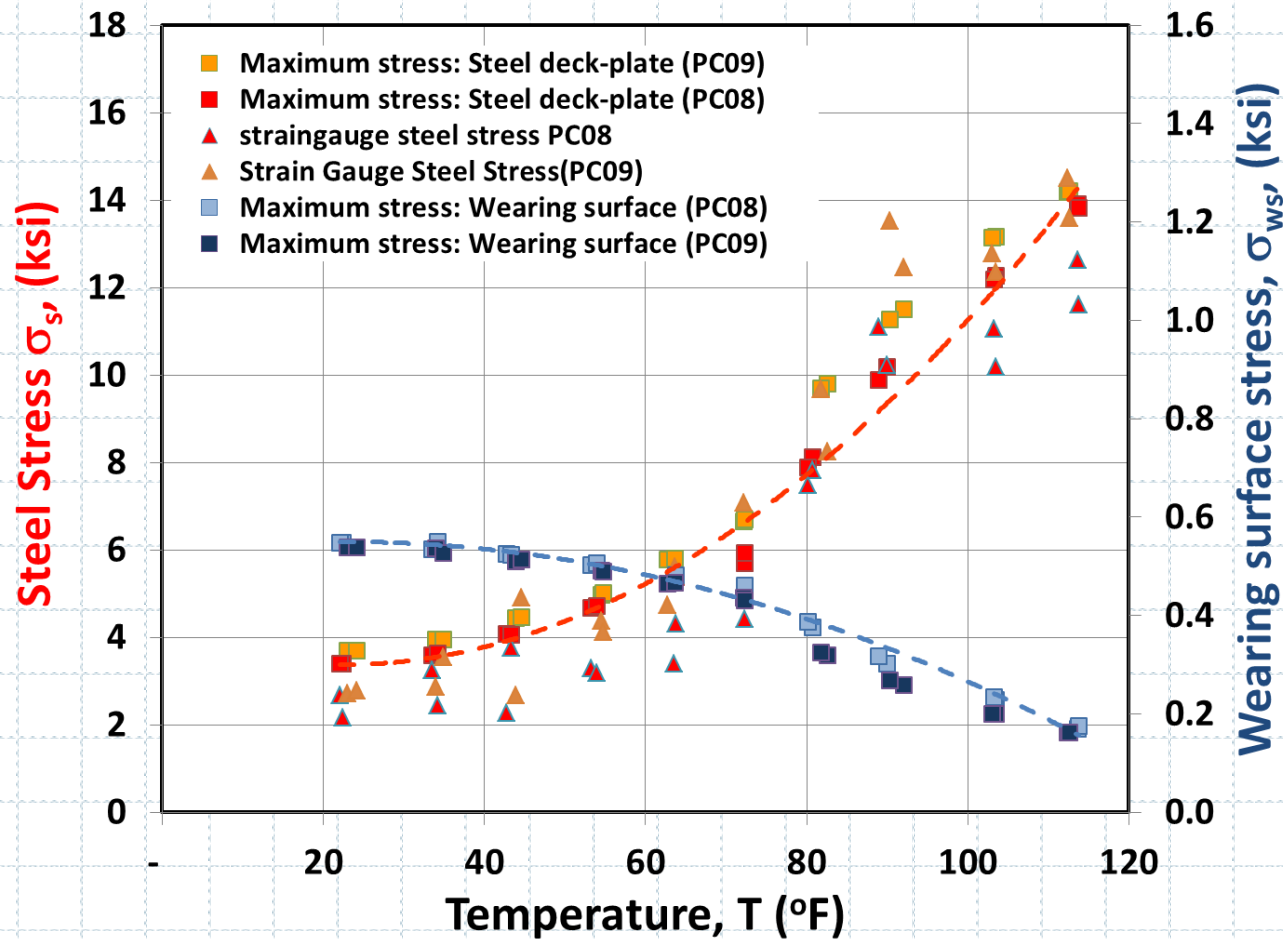
Apparent Flexural Modulus Static Tests



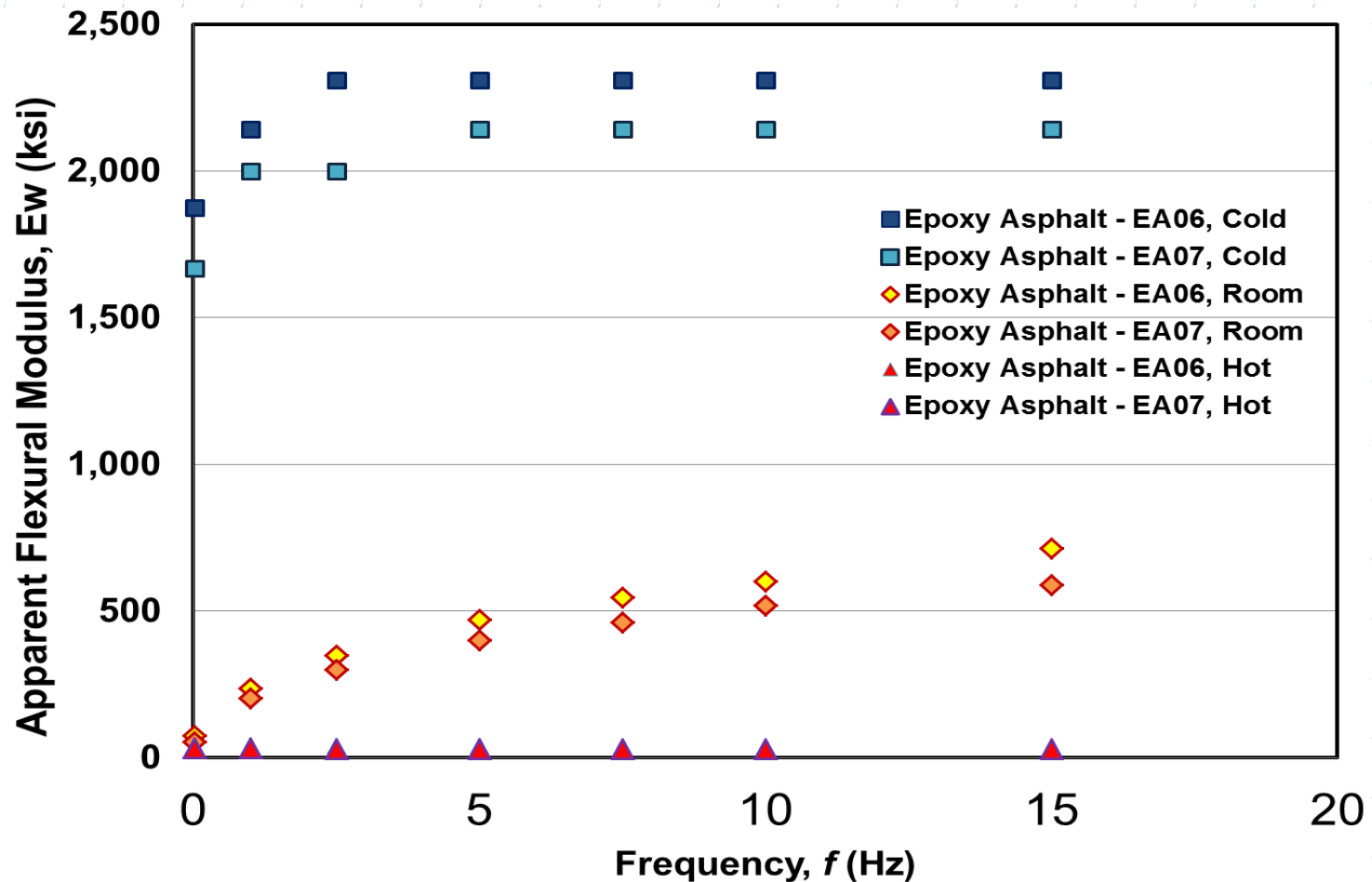
Wearing Surface and Steel Stresses Influence of Temperature (EA)



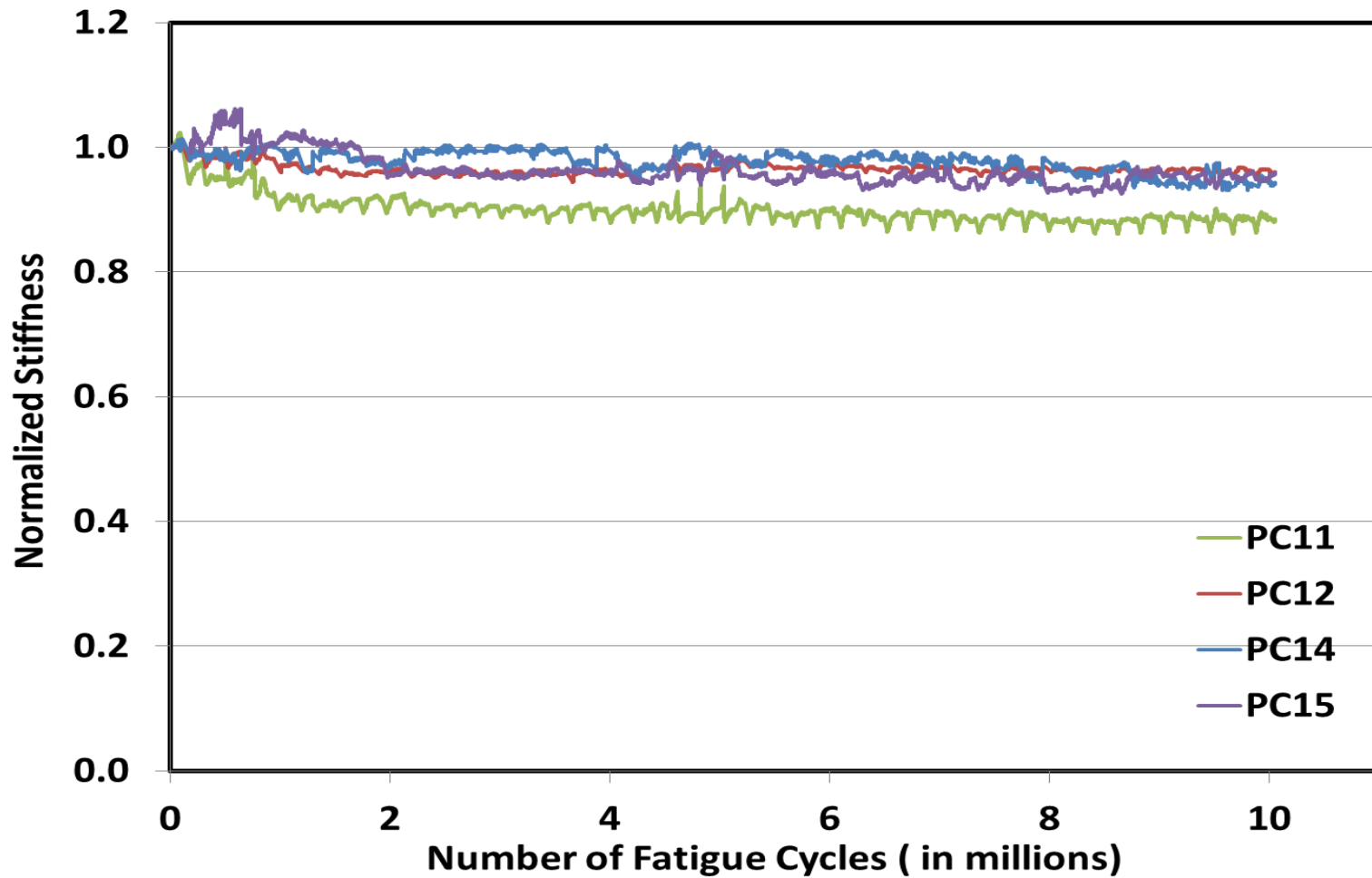
Wearing Surface and Steel Stresses Influence of Temperature (PC)



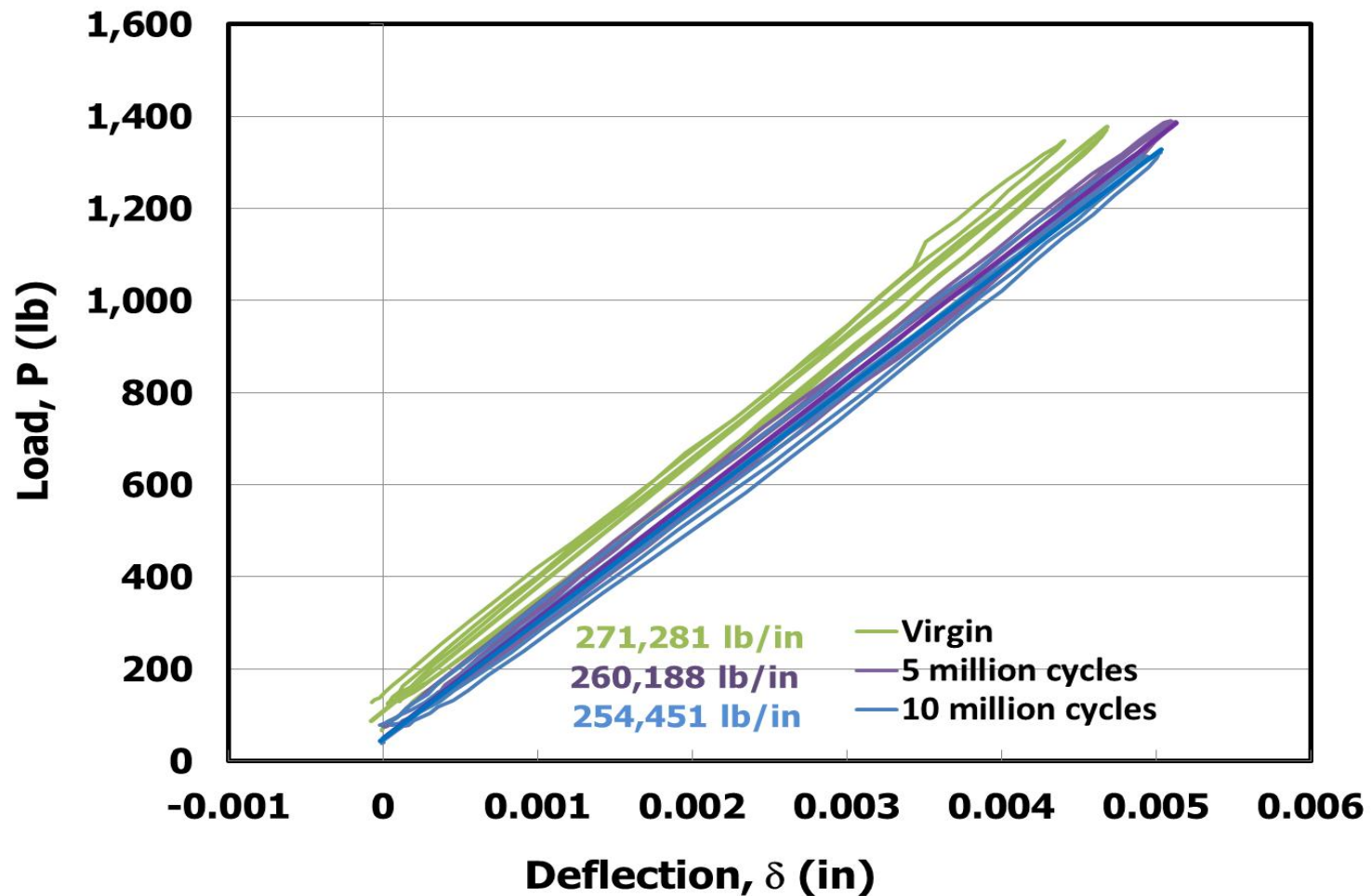
Rate of Loading Effect (EA)



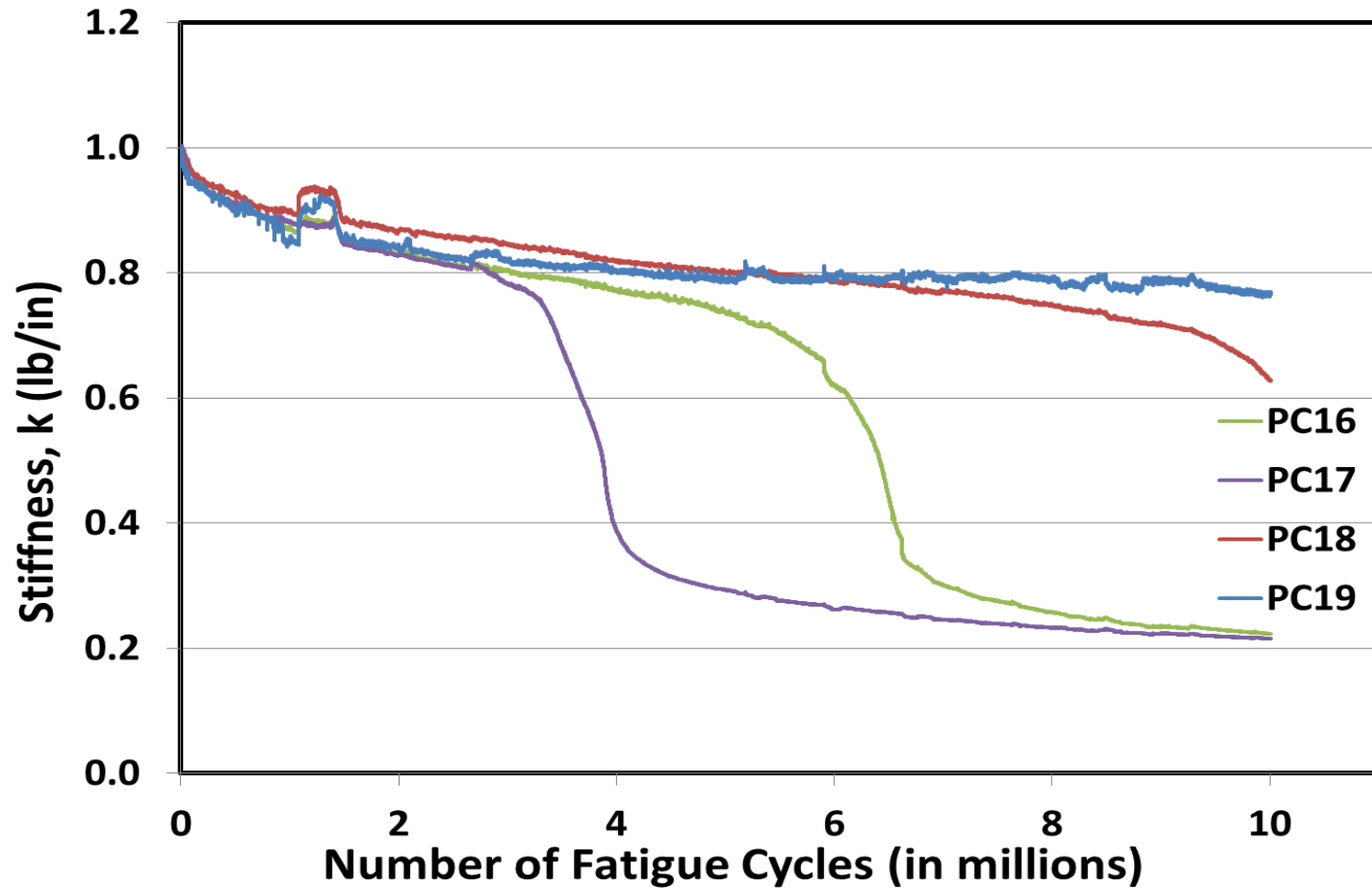
Cold Temp Fatigue Results (PC)



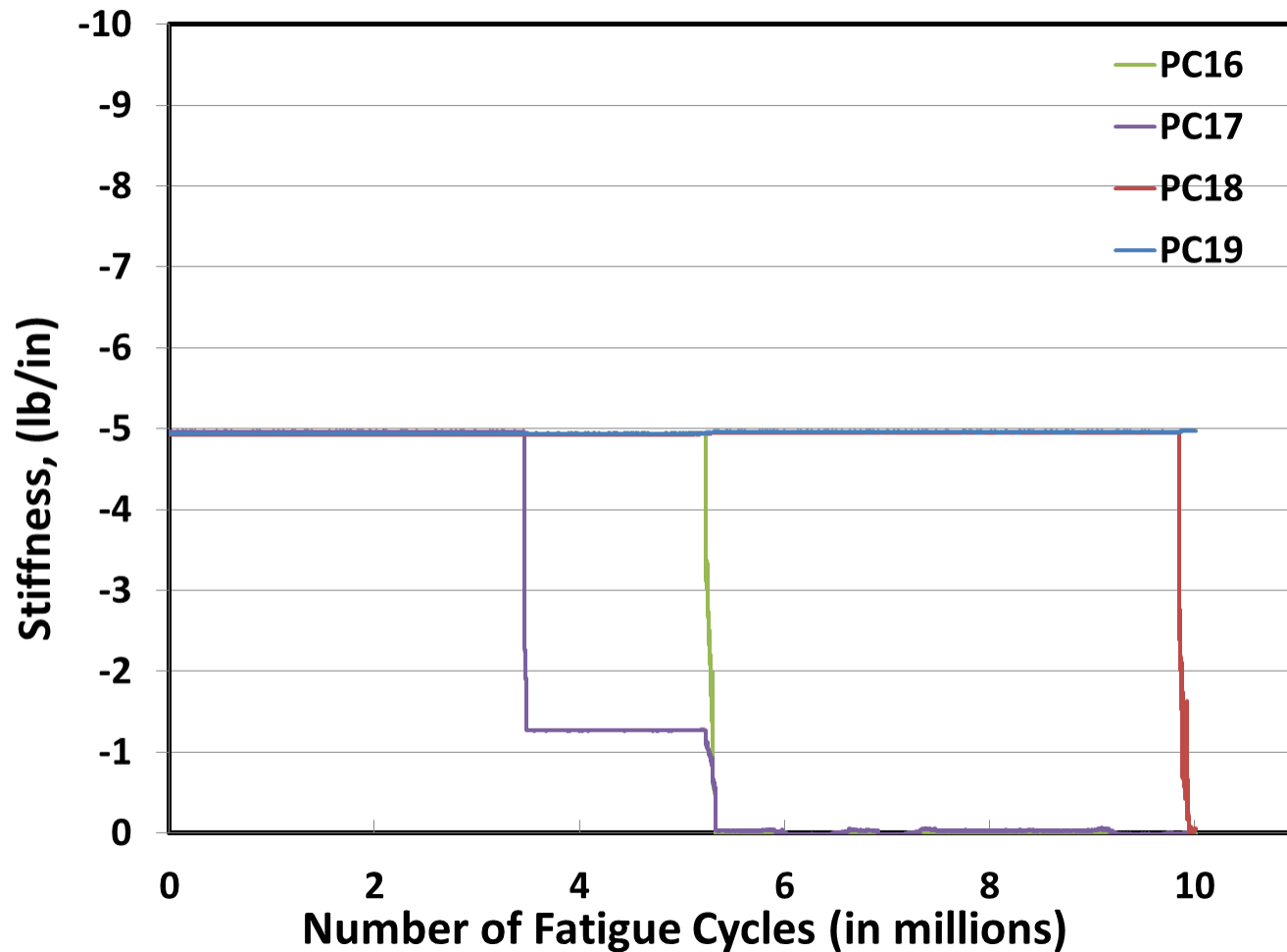
Cold Temp Fatigue Results (PC)



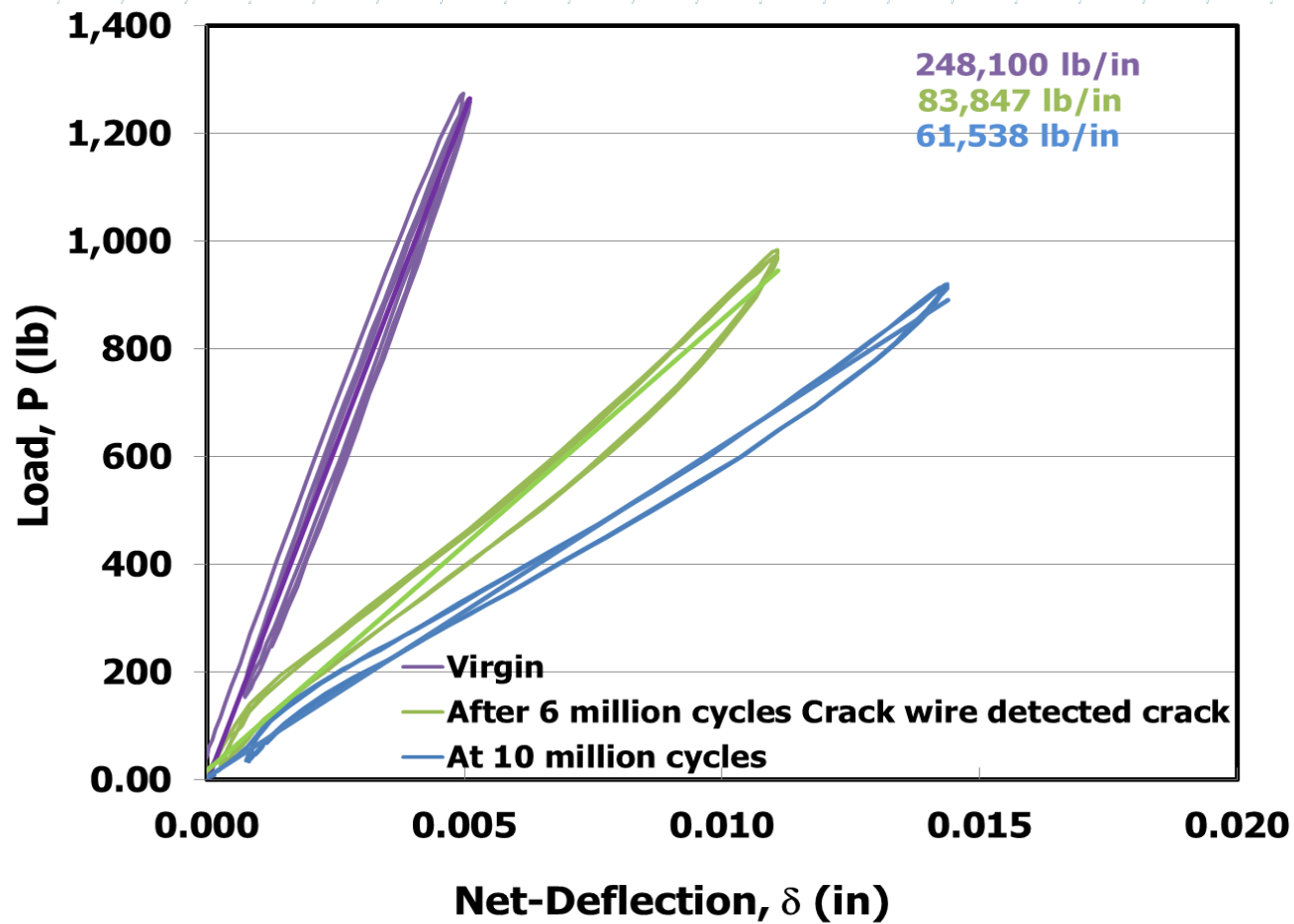
Room Temp Fatigue Results (PC)



Room Temp Fatigue Results (PC)



Room Temp Fatigue Results (PC)



Wearing Surfaces: Pull-Out Test

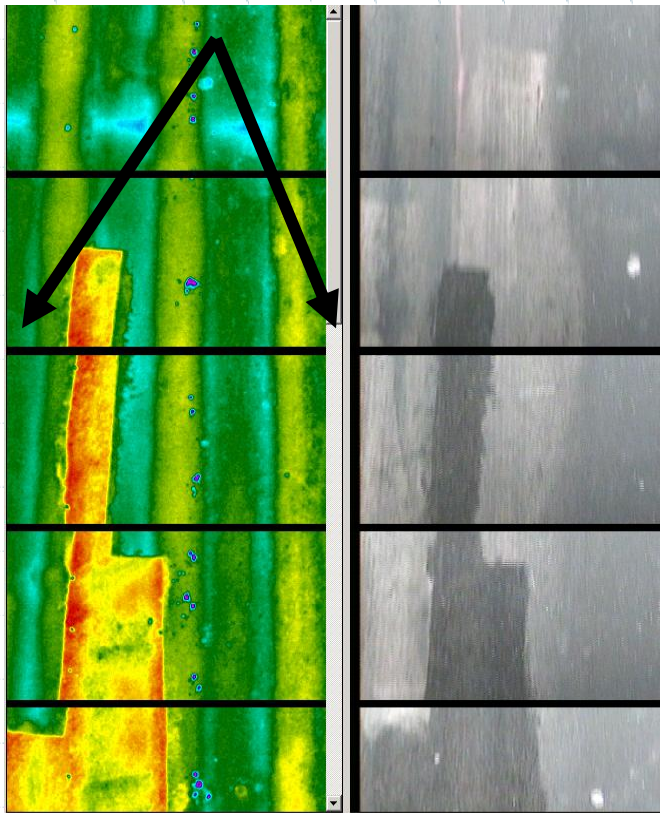


Wearing Surfaces: Resistivity Test

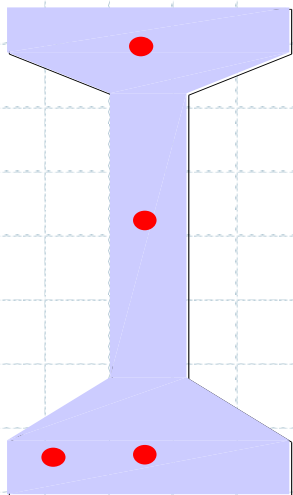
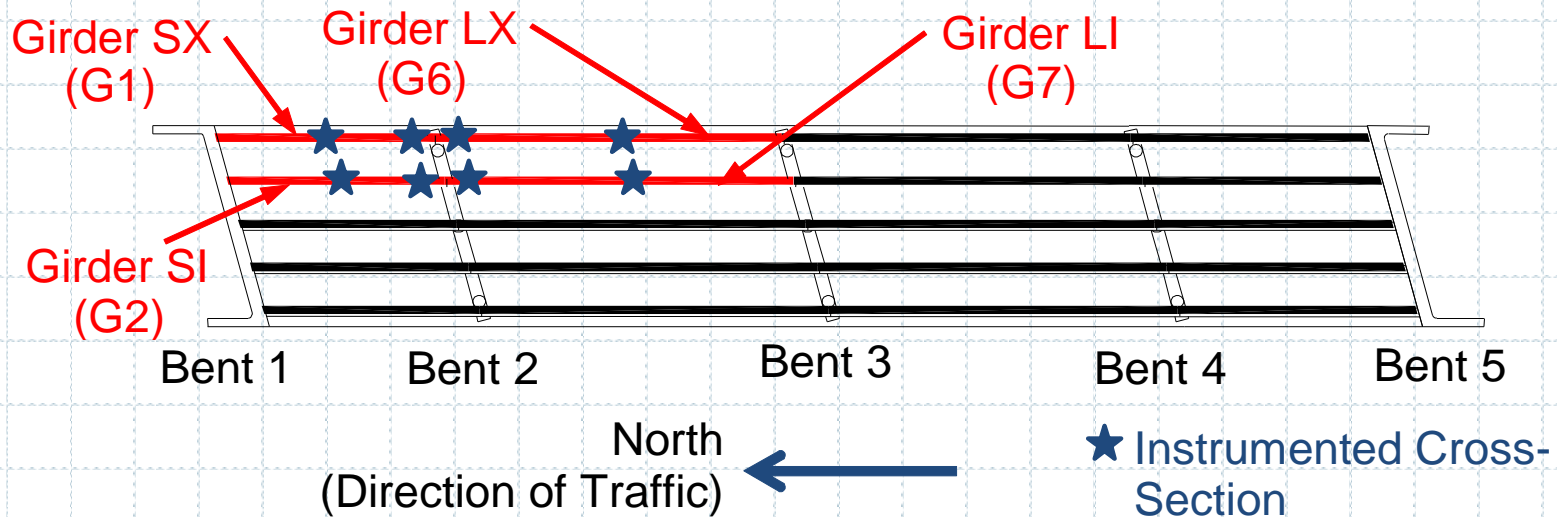


Infrared and Video Images

Poplar St. Bridge, St. Louis, MO

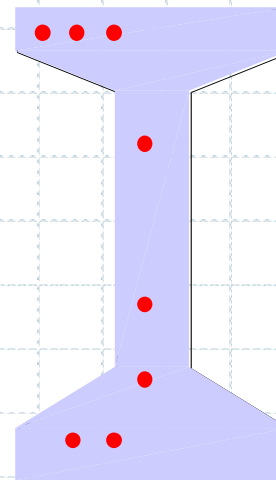


Prestressed HPC Bridge Girders



Typical Location of:

- Strain-Gaged Bars
- Vibrating Wire Gages
- Thermistors



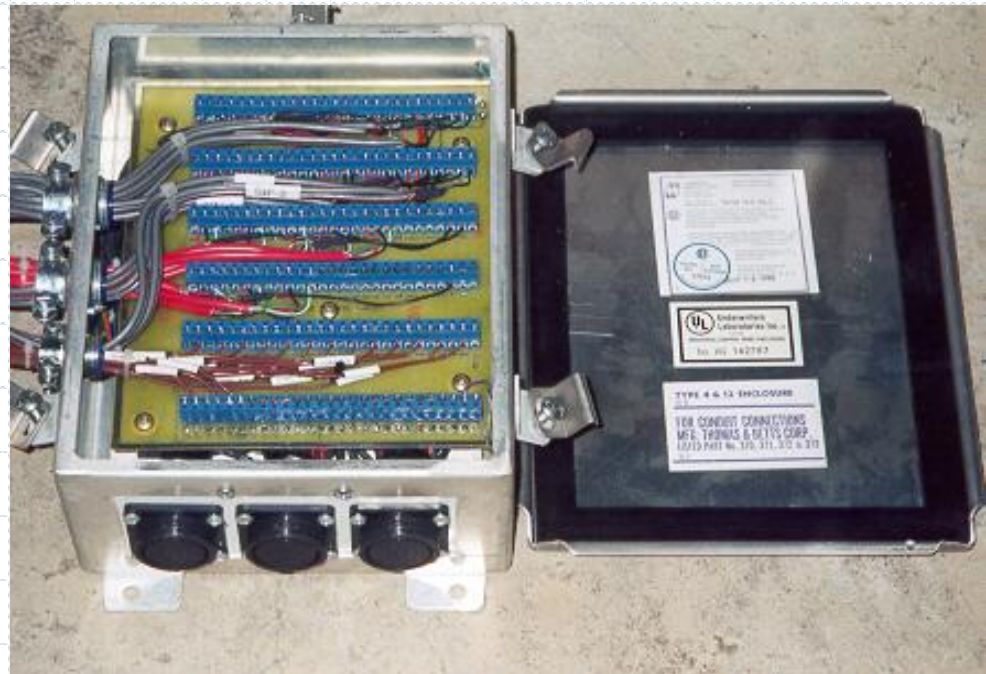
Typical

Location of:

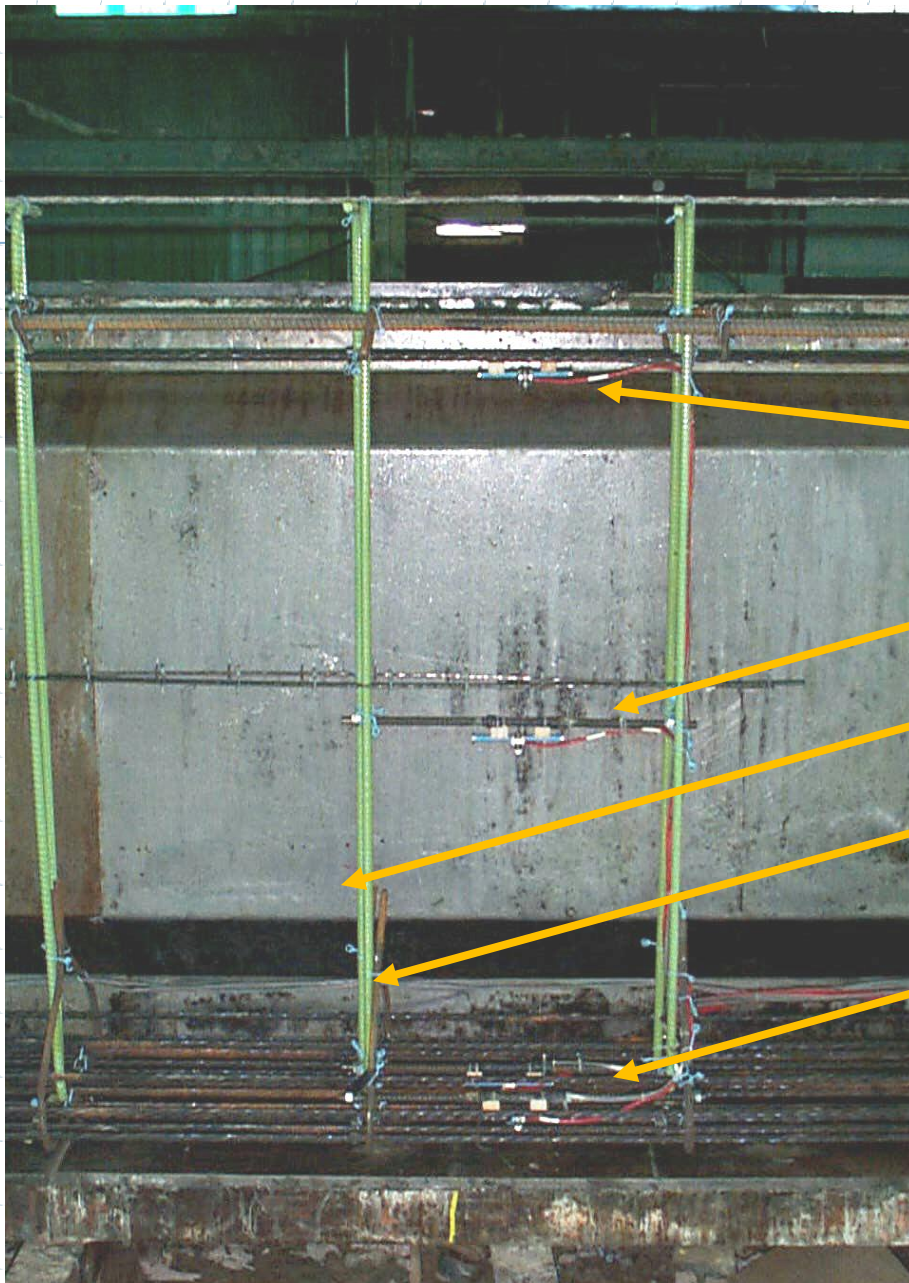
- Thermocouples



- **Vibrating Wire Gage**
- Rugged, long-term stability, insensitive to noise, simultaneous temperature measurement, ideal for long-term strain measurements
- **Instrumented Rebar**
- Electrical resistance strain gages, full-bridge circuit, temperature compensated, prone to drift, sensitive to noise, suitable only for short-term strain measurements



Typical instrumentation at one girder cross-section



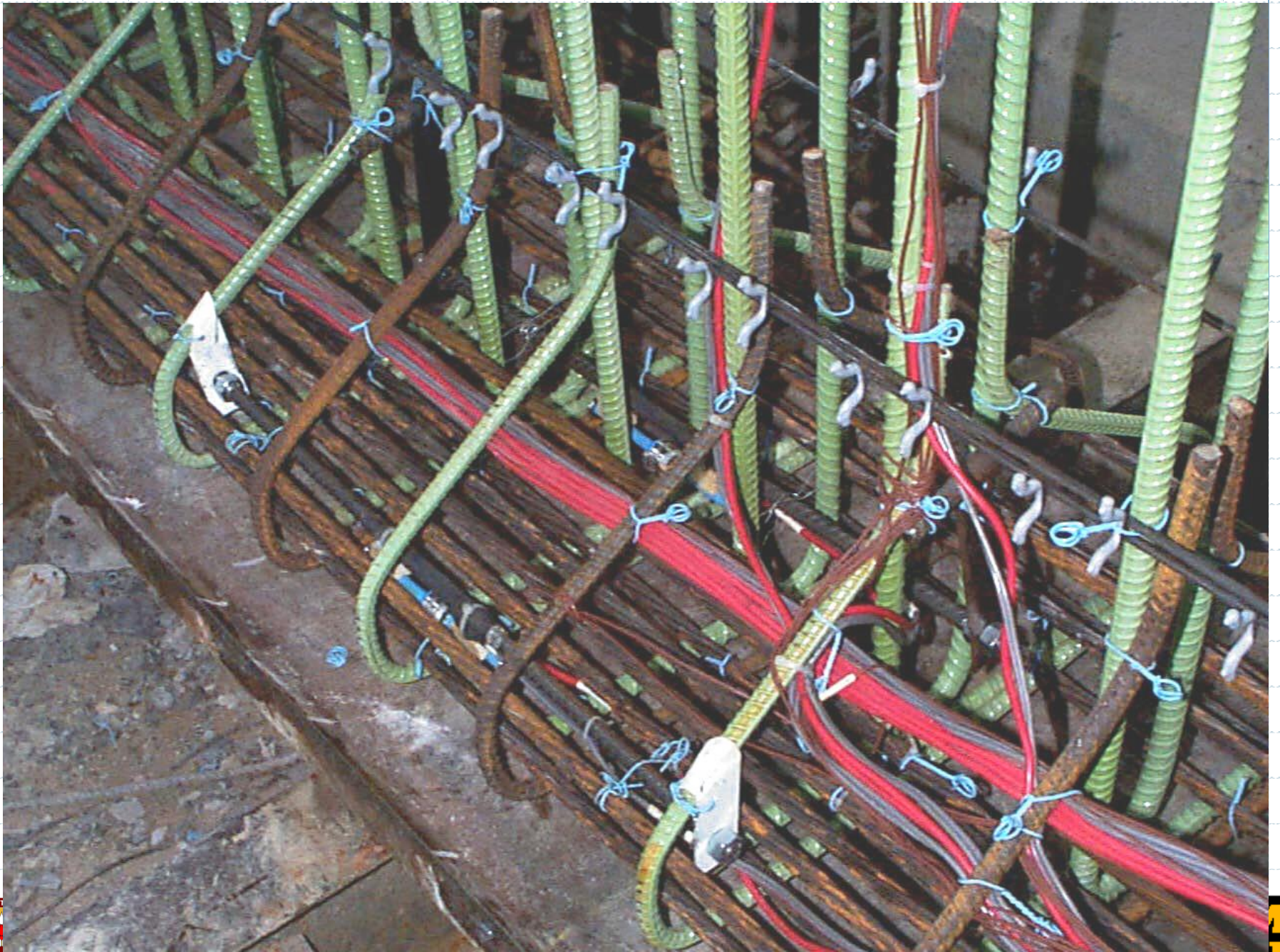
SG1, VW1
T1, T2, T3

SG2, VW2

T4

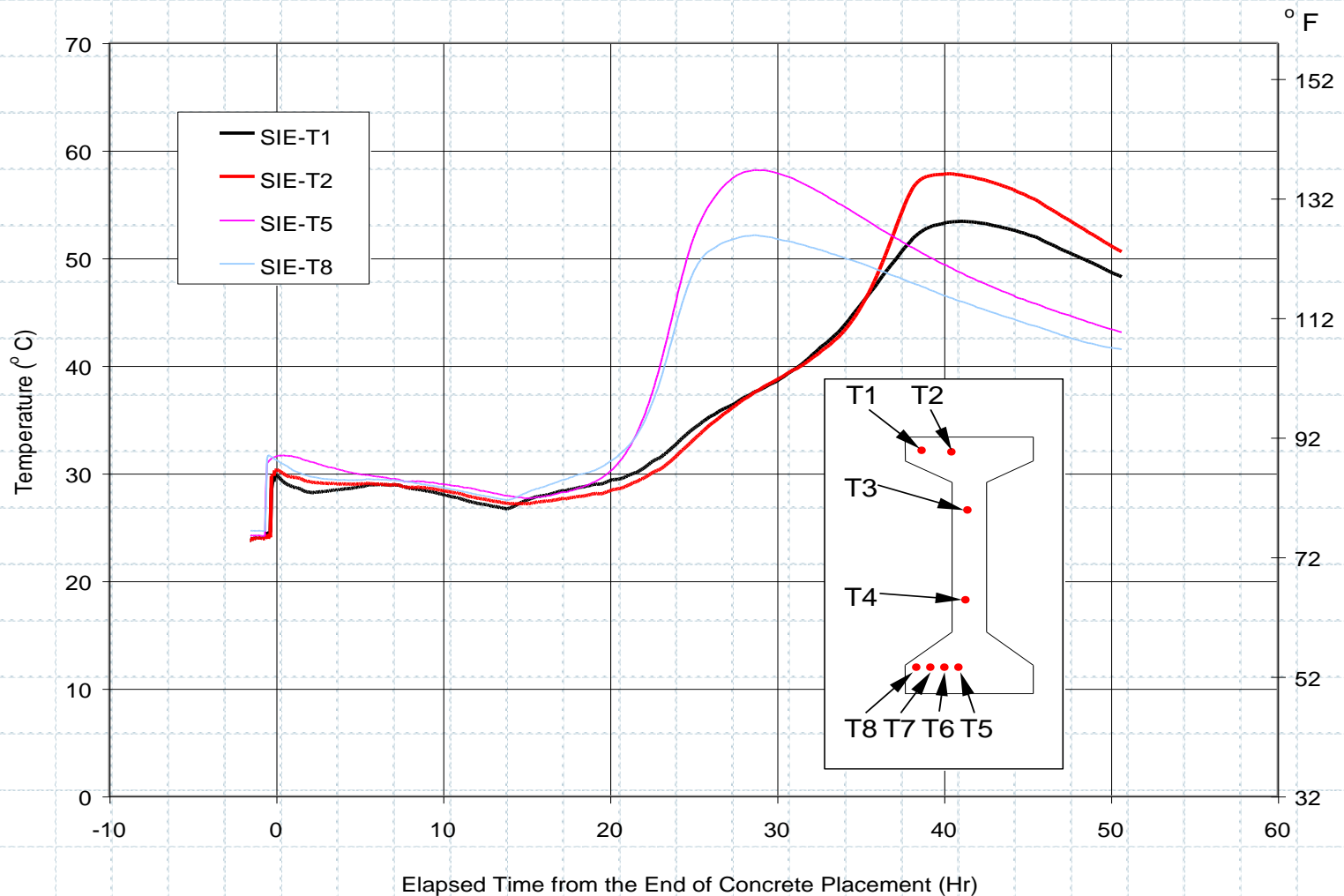
T5

SG3, SG4
VW3, VW4
T6, T7, T8

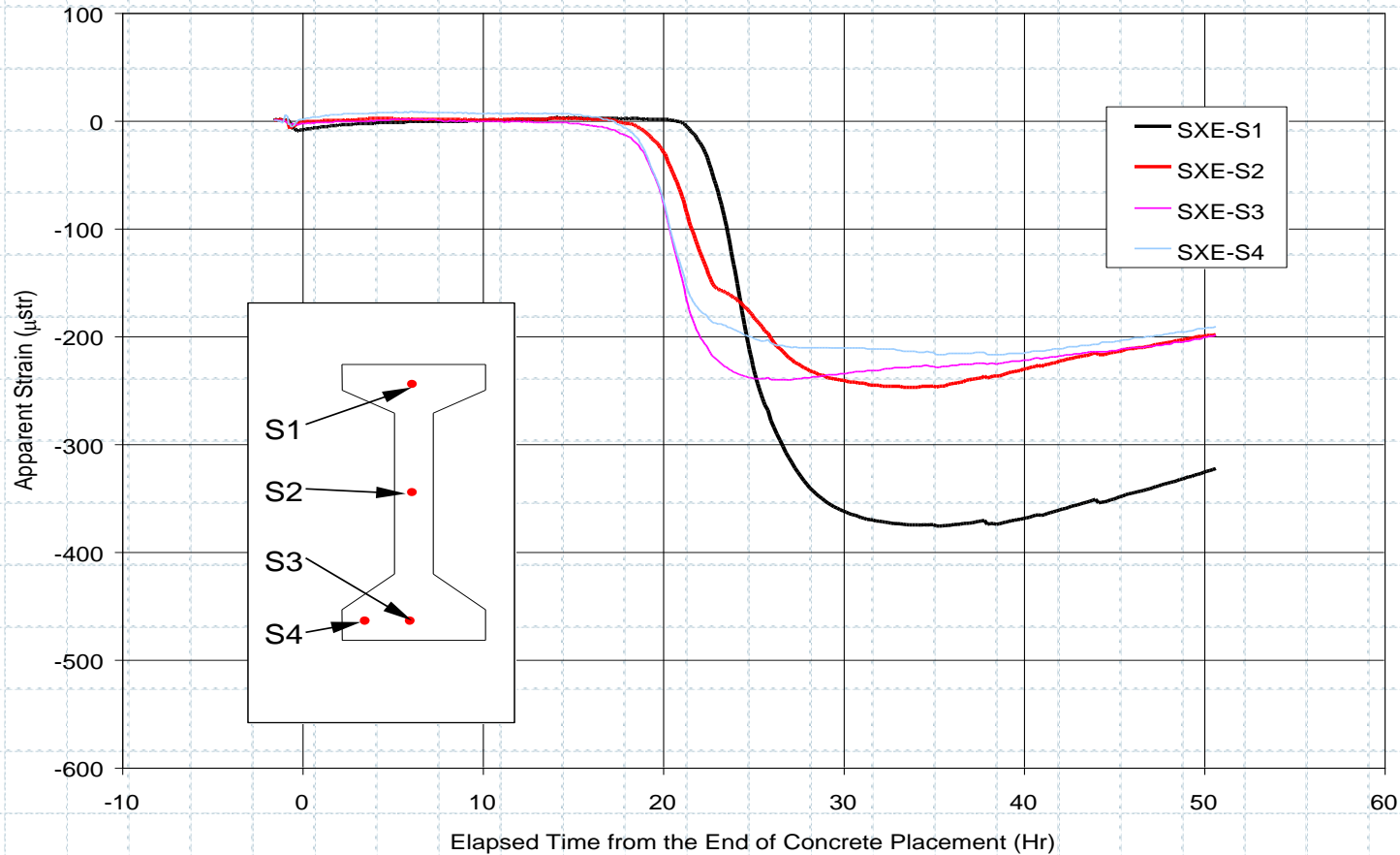




Curing Temperatures



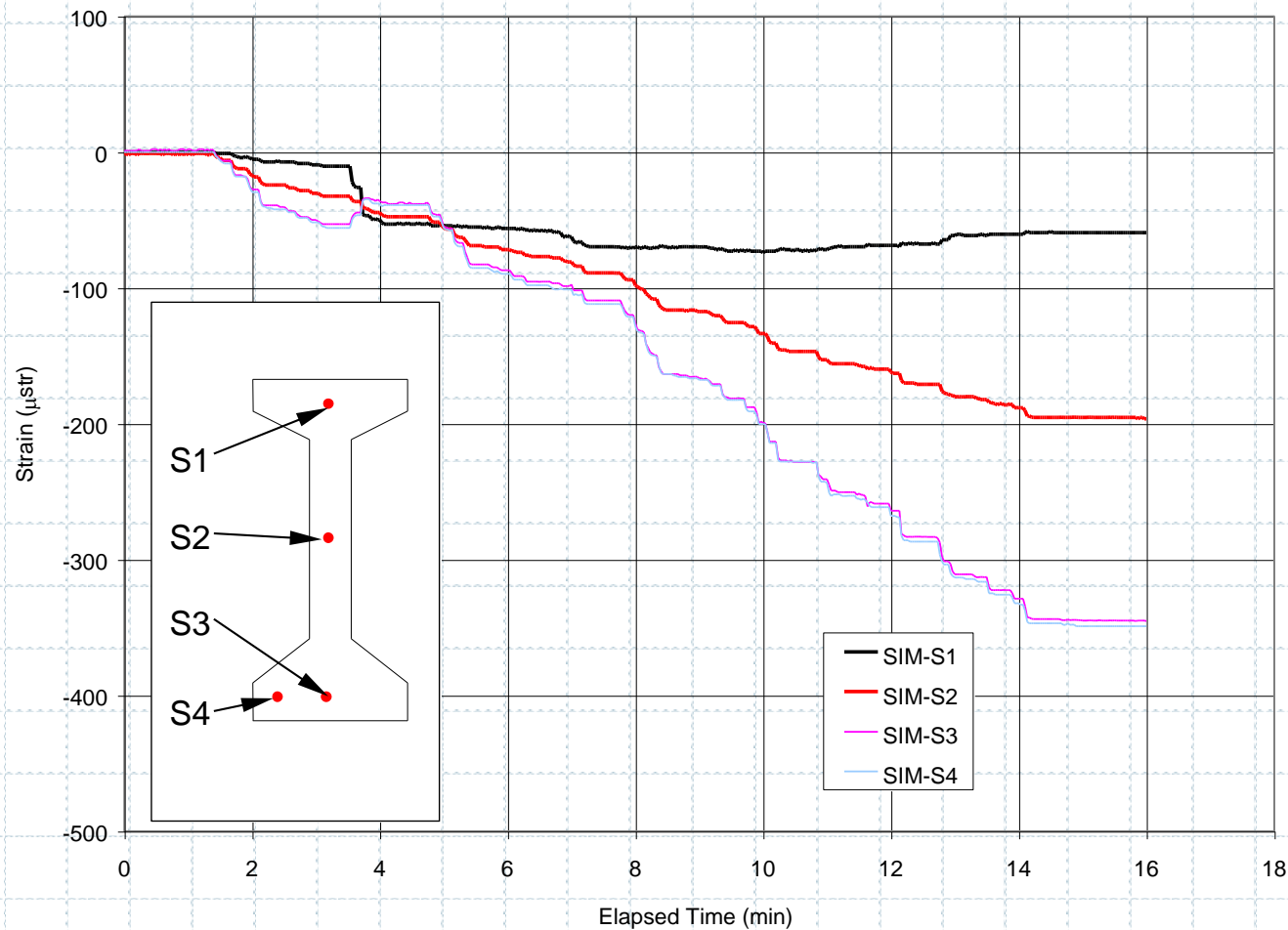
Strains During Curing





PRESTRESS TRANSFER

Straight Strands

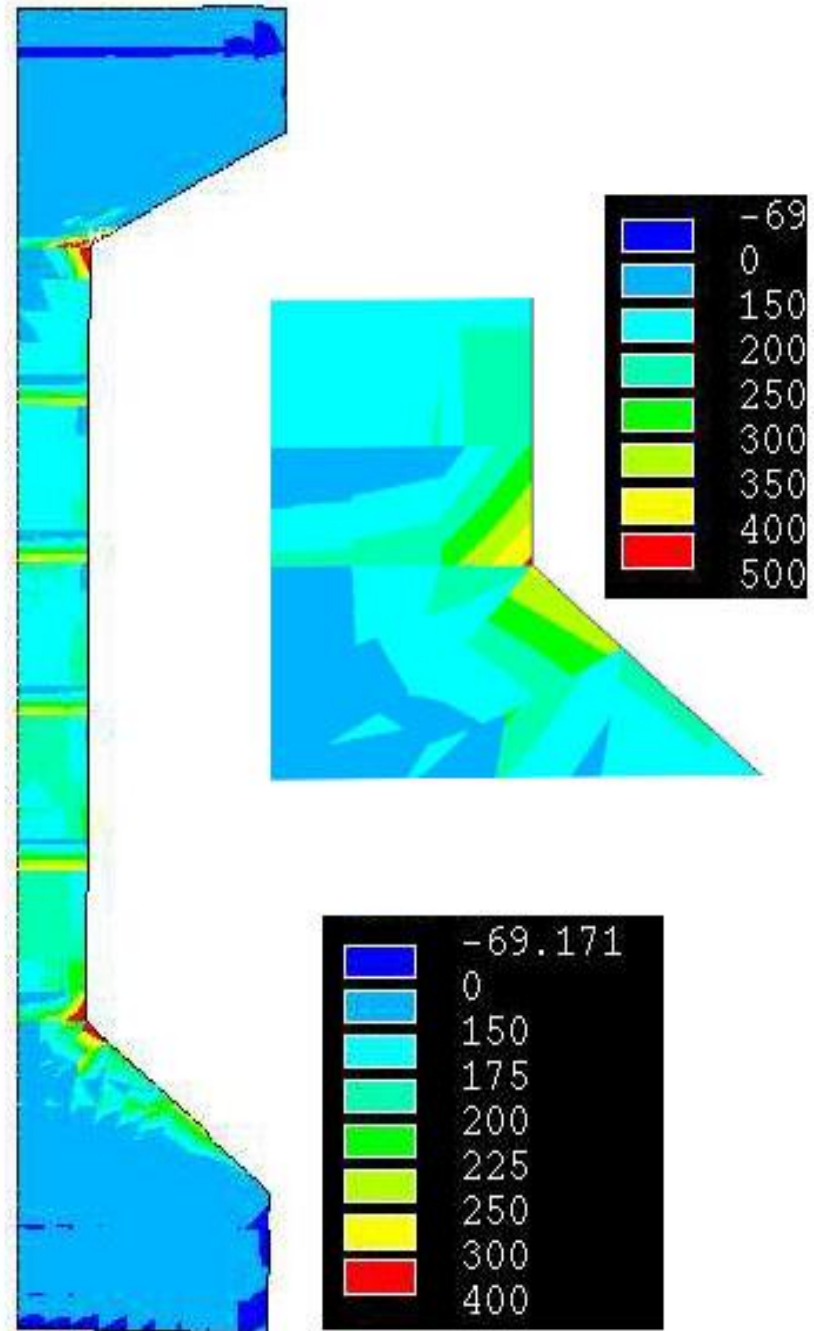


Residual Stress Profile

Type VI HPC Girder Residual Stress Profile

Max. stress of 440 psi

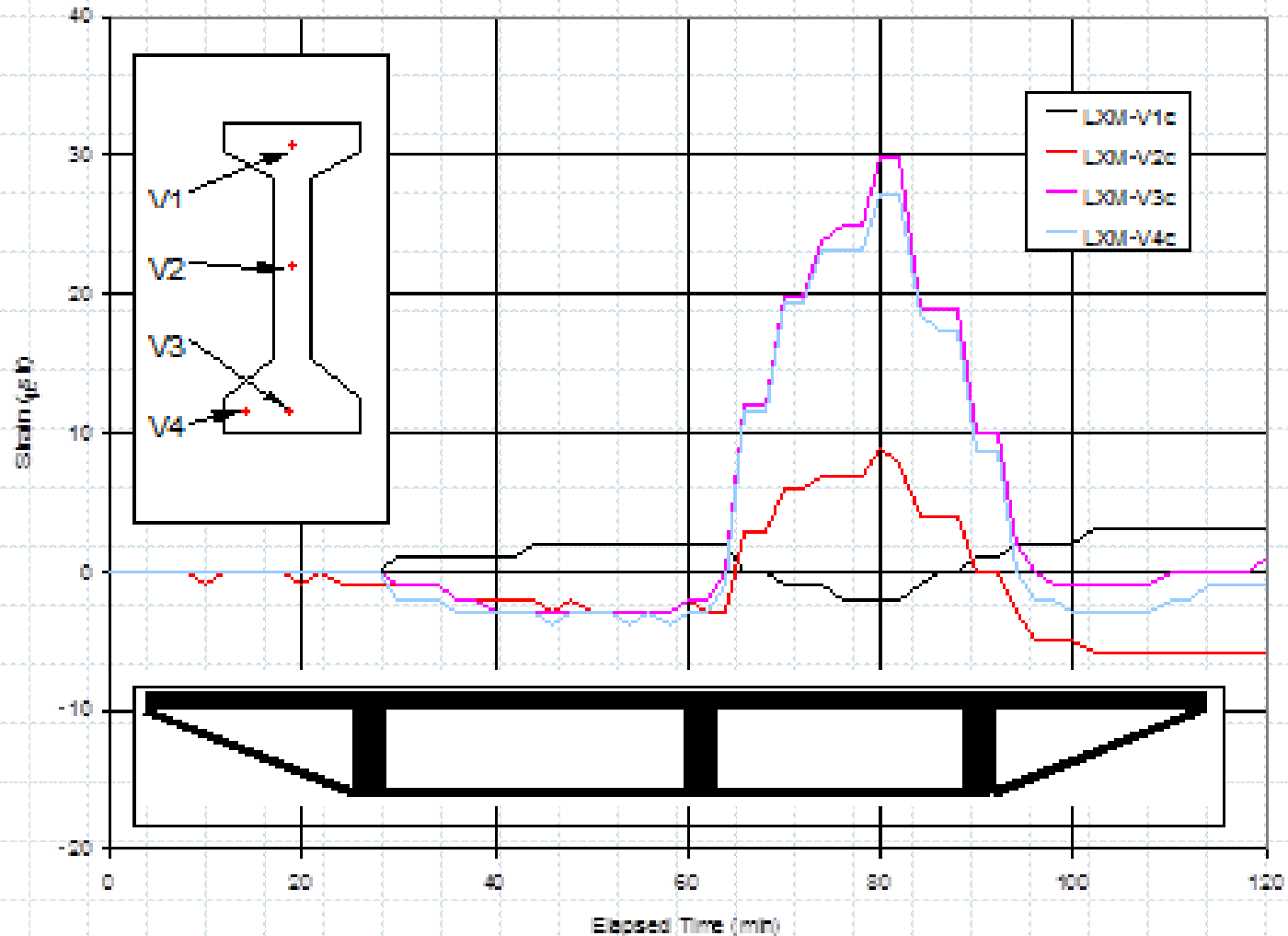
Avg. tensile stress in
the web of 190 psi



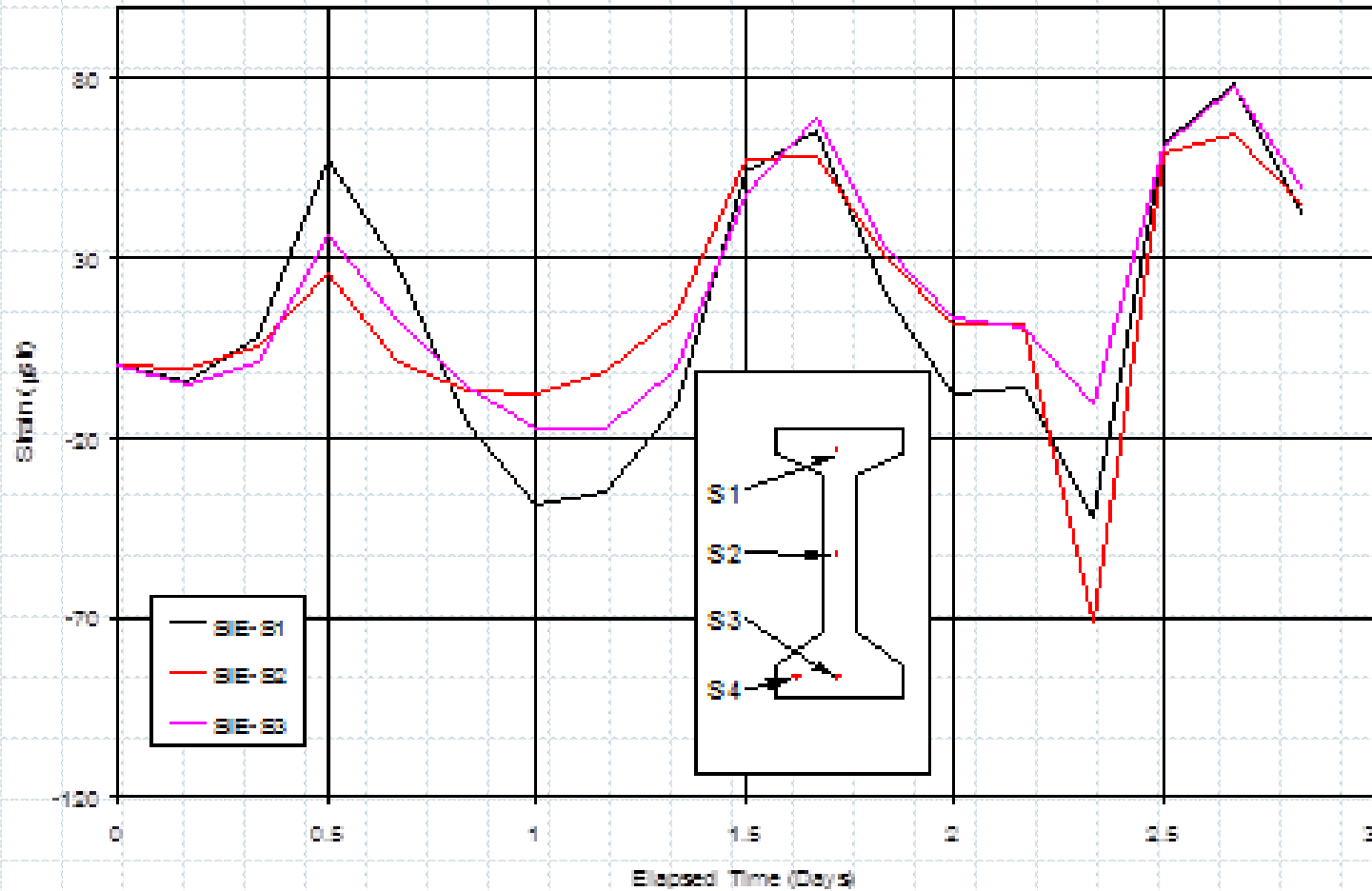


LOAD TEST

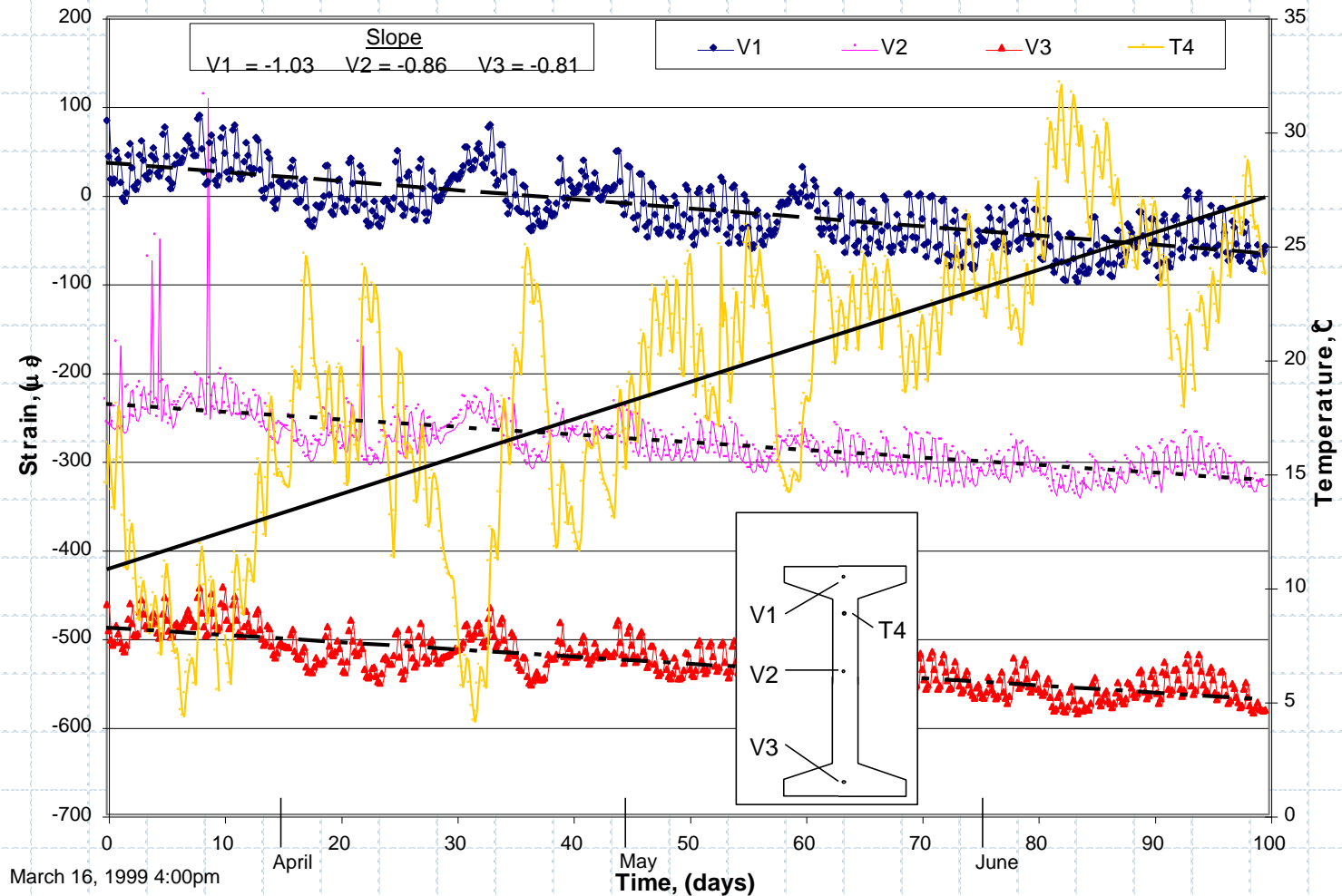
Quasi-Static Load Test



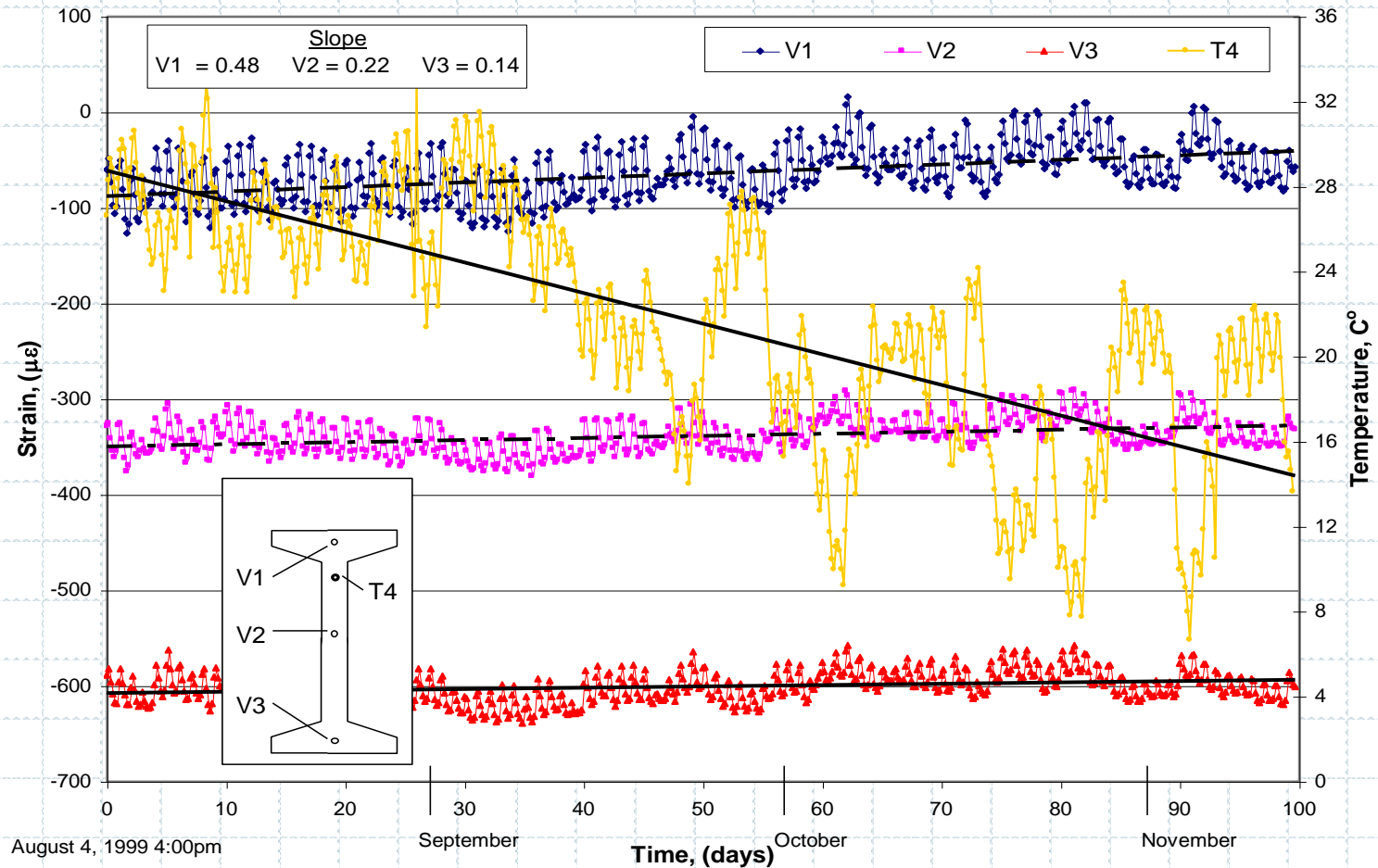
Daily Strain Variations



Service Strains - Increasing Temperature



Service Strains - Decreasing Temperature

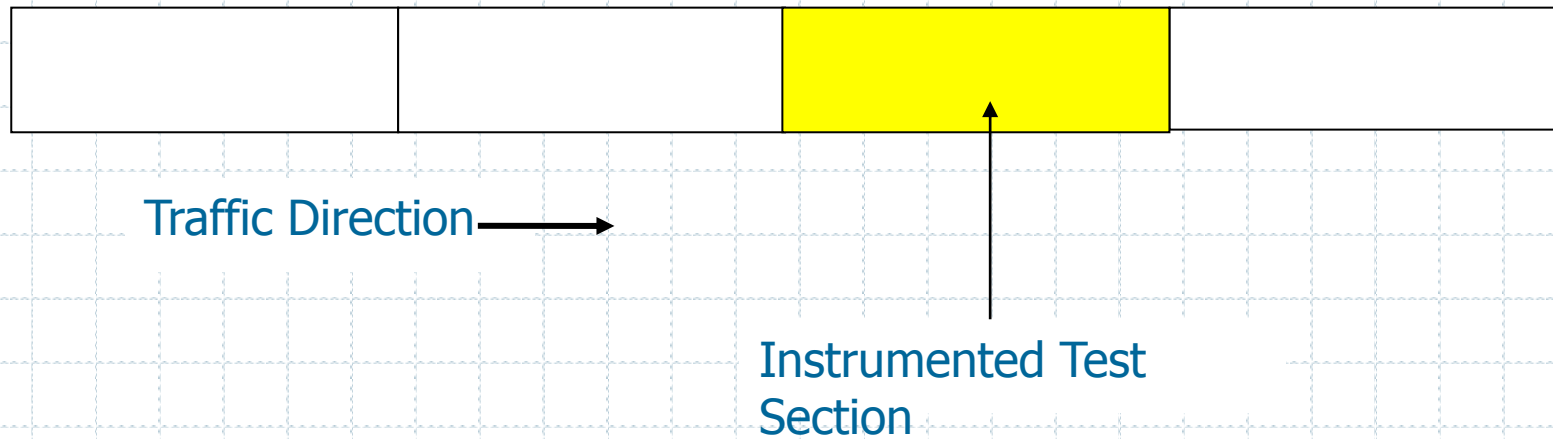


Precast Prestressed Pavement

- Evaluate the performance of precast prestressed panels during fabrication, construction and service:
 - ❖ Joint FHWA / MODoT Project
 - ❖ Site – Northbound I-57, existing pavement has been in poor shape for nearly a decade.
 - ❖ 1,000' of precast pavement
 - ❖ Heavy truck traffic
 - ❖ Severe environmental conditions (temperature, deicing, precipitation)



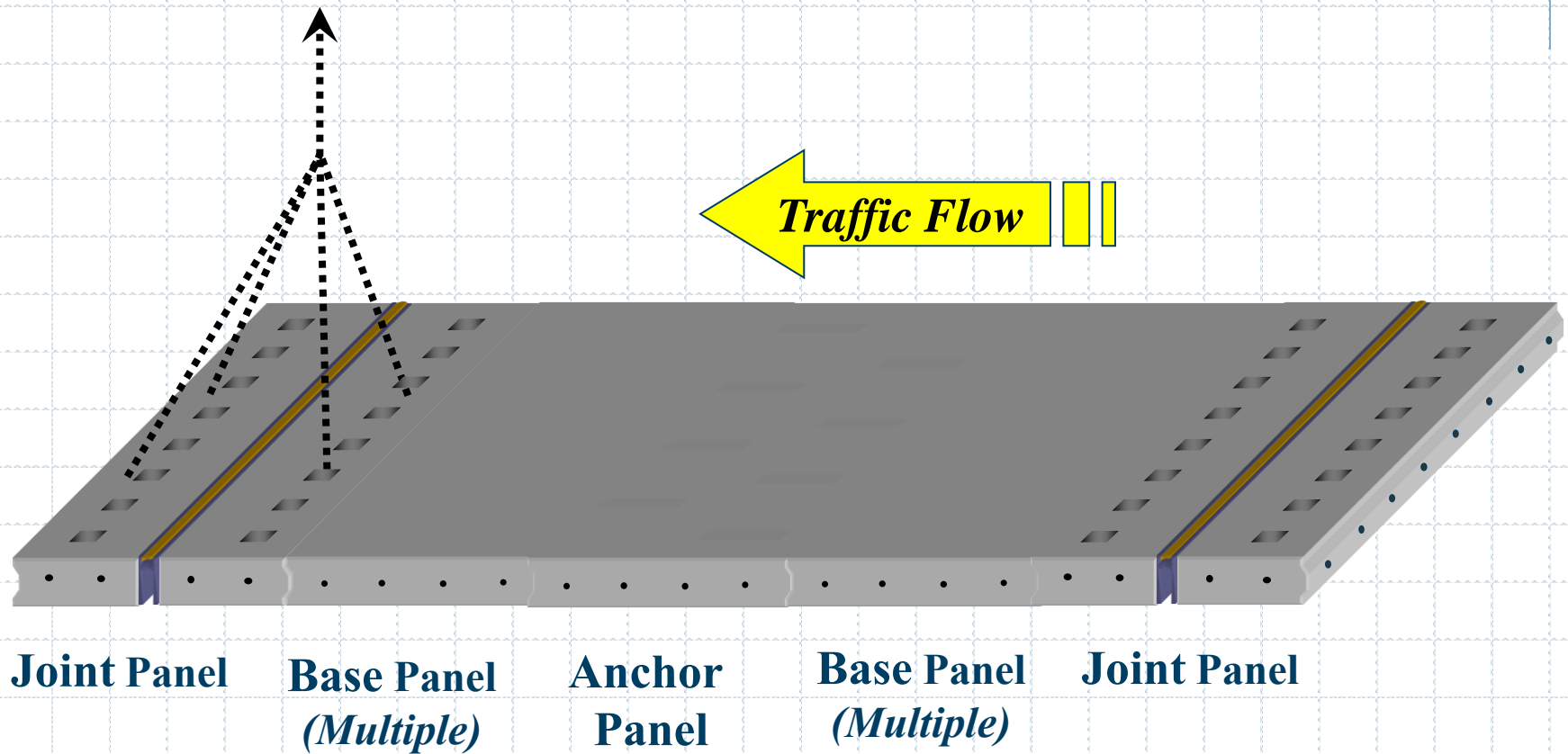
Instrumented Precast Sections



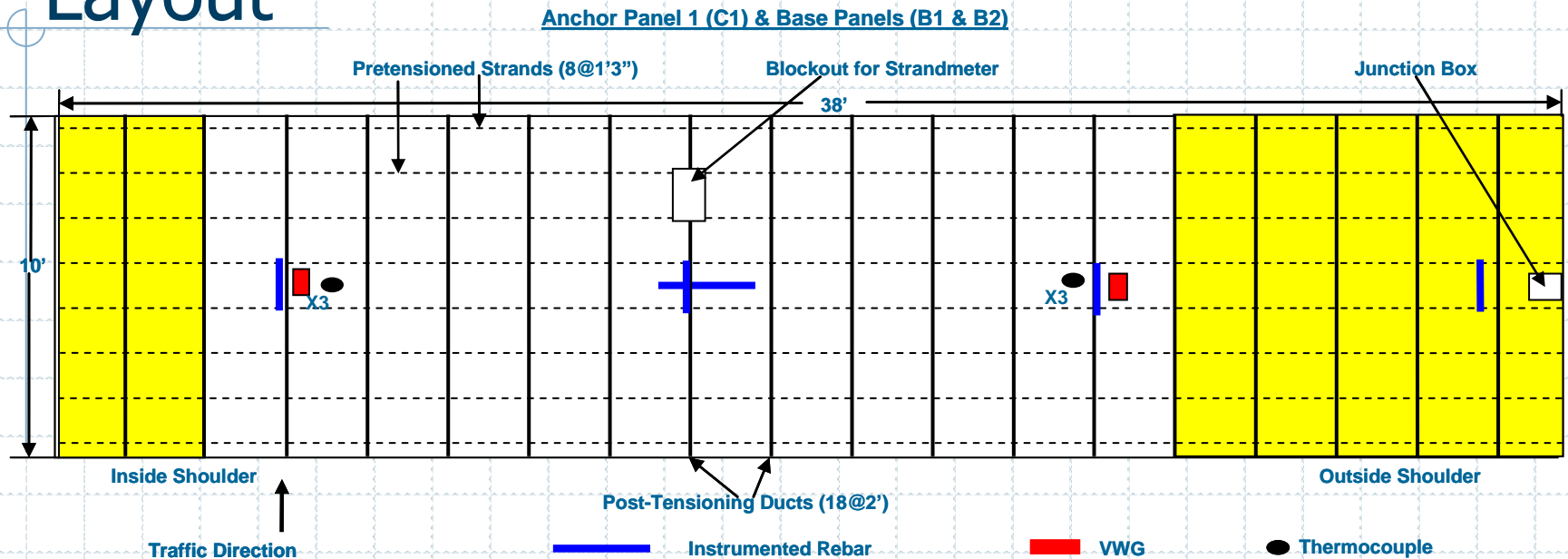
- Divided into four – 250' sections of 25 slabs each
- All slabs pre-tensioned transversely at the yard
- Each 250' section was post-tensioned at the site

Pavement Design

- Comprises three panel types: joint, base, and anchor panels



Typical Panel Design & Instrumentation Layout



- Panels are 10' by 38'
- Prestressed in the transverse direction and post-tensioned longitudinally
- Stabilized base with polyethylene sheeting for friction reduction

Casting



Casting of Joint Panel

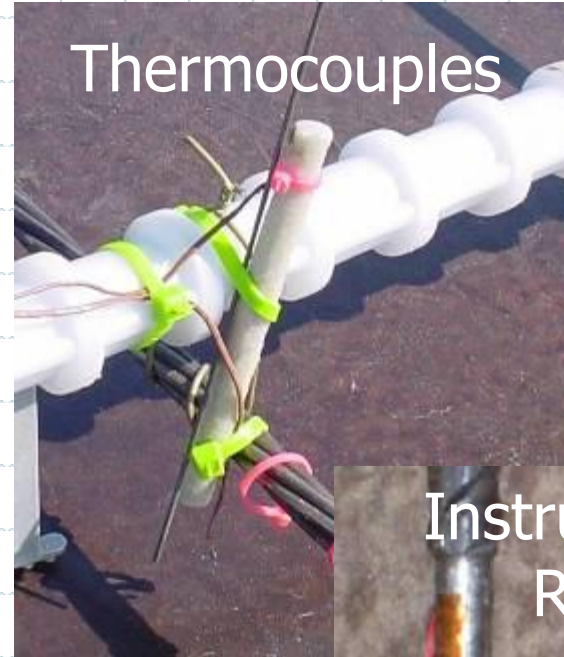


Instrumentation

Strandmeter



Thermocouples



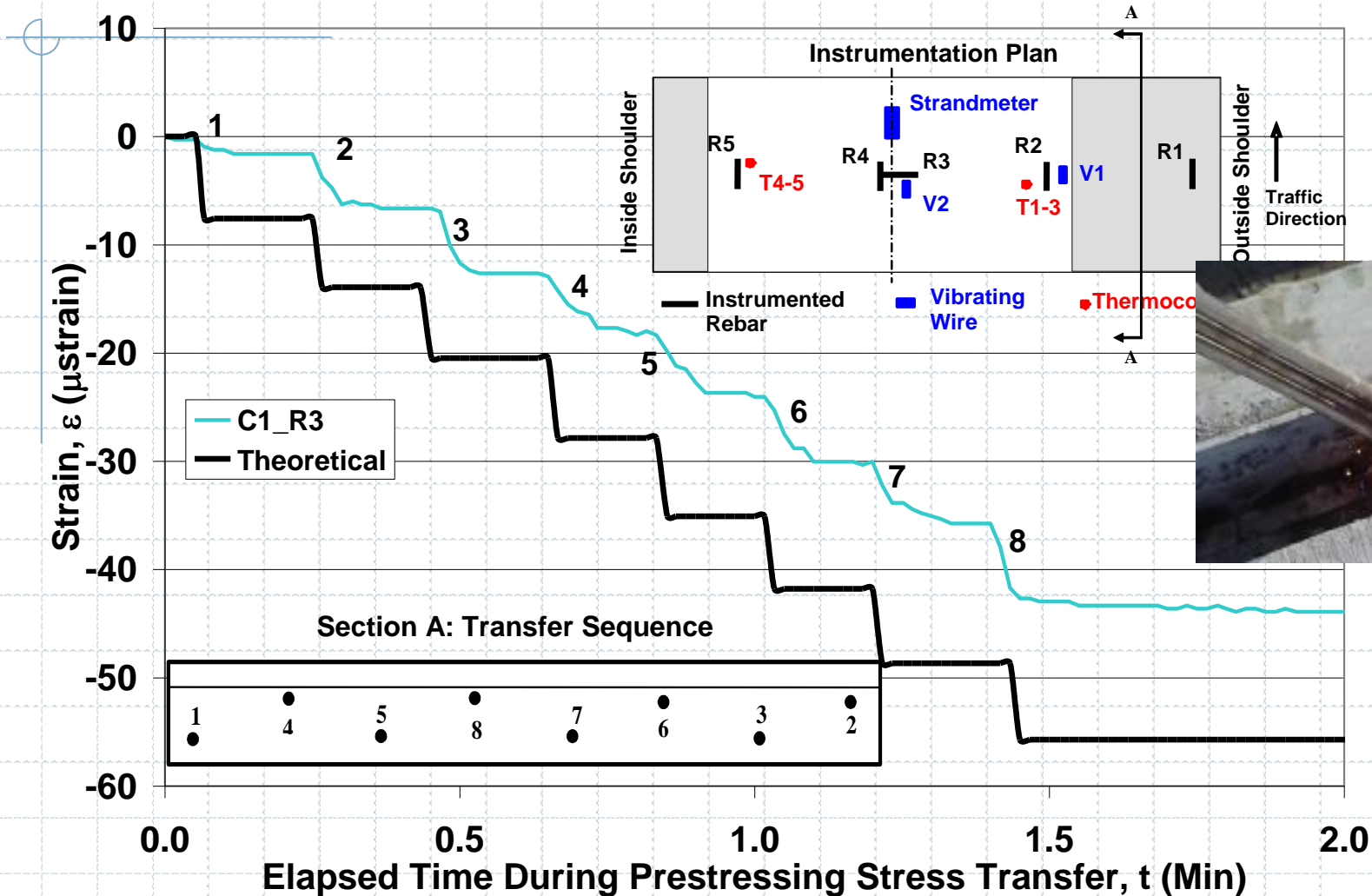
Instrumented Rebar



Vibrating Wire Gage



Pretension Stress Transfer

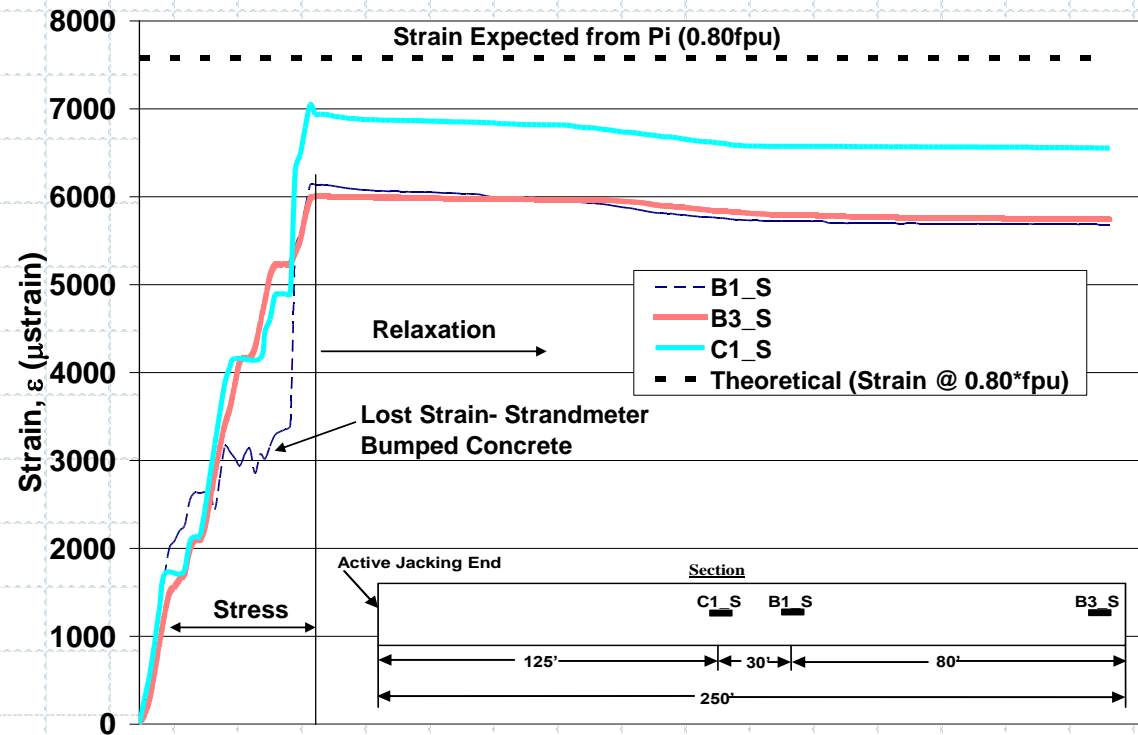


Construction

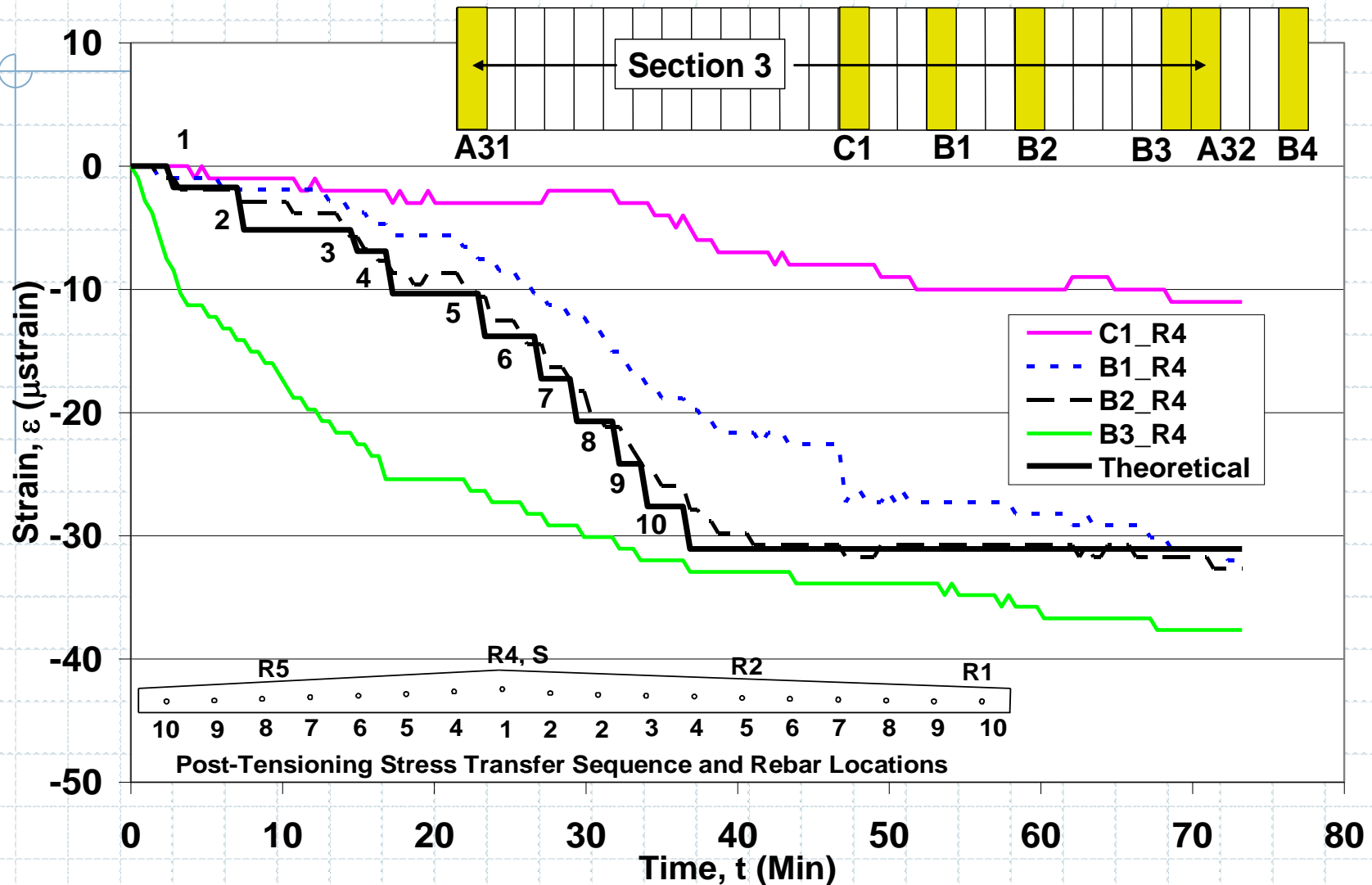


Strandmeter During Post-tensioning

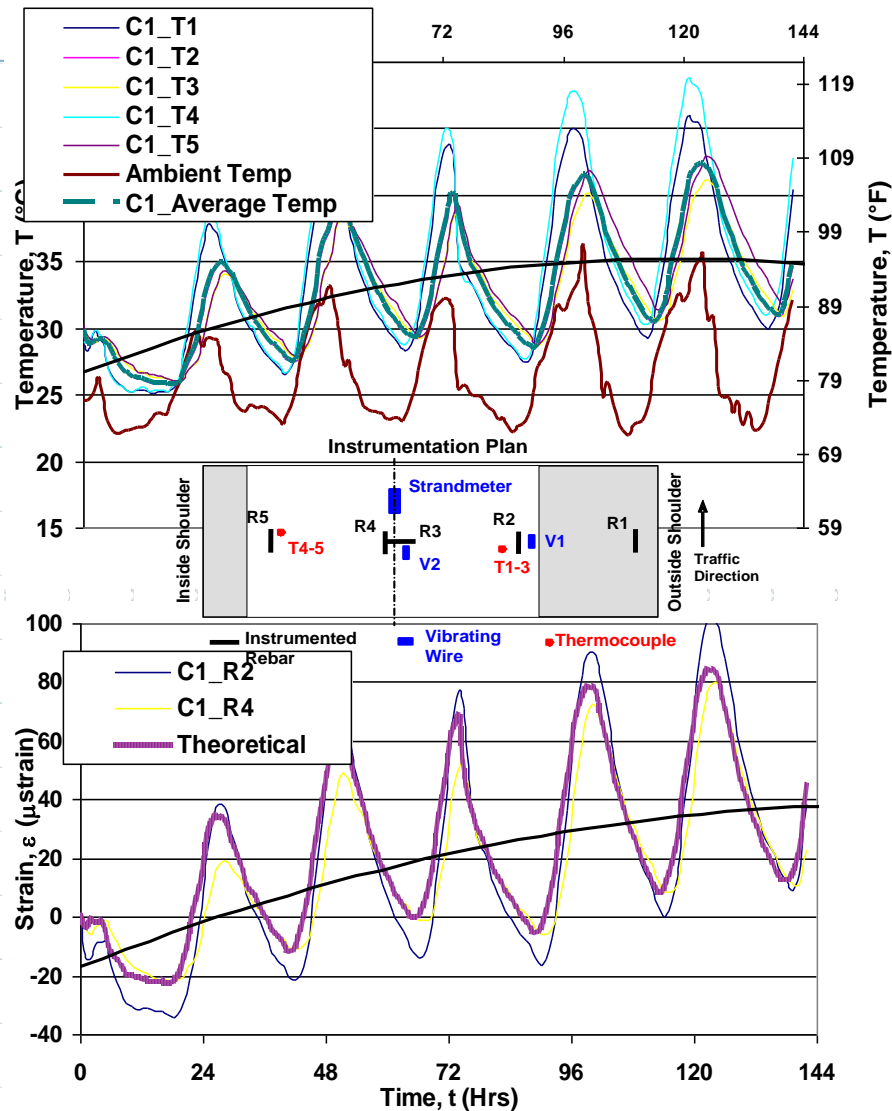
- Prestressing force lost in PT ducts = 61.8 lb/ft/duct



Post tensioning concrete strain at center of crown (R4)



Service Performance Medium Window



Trends

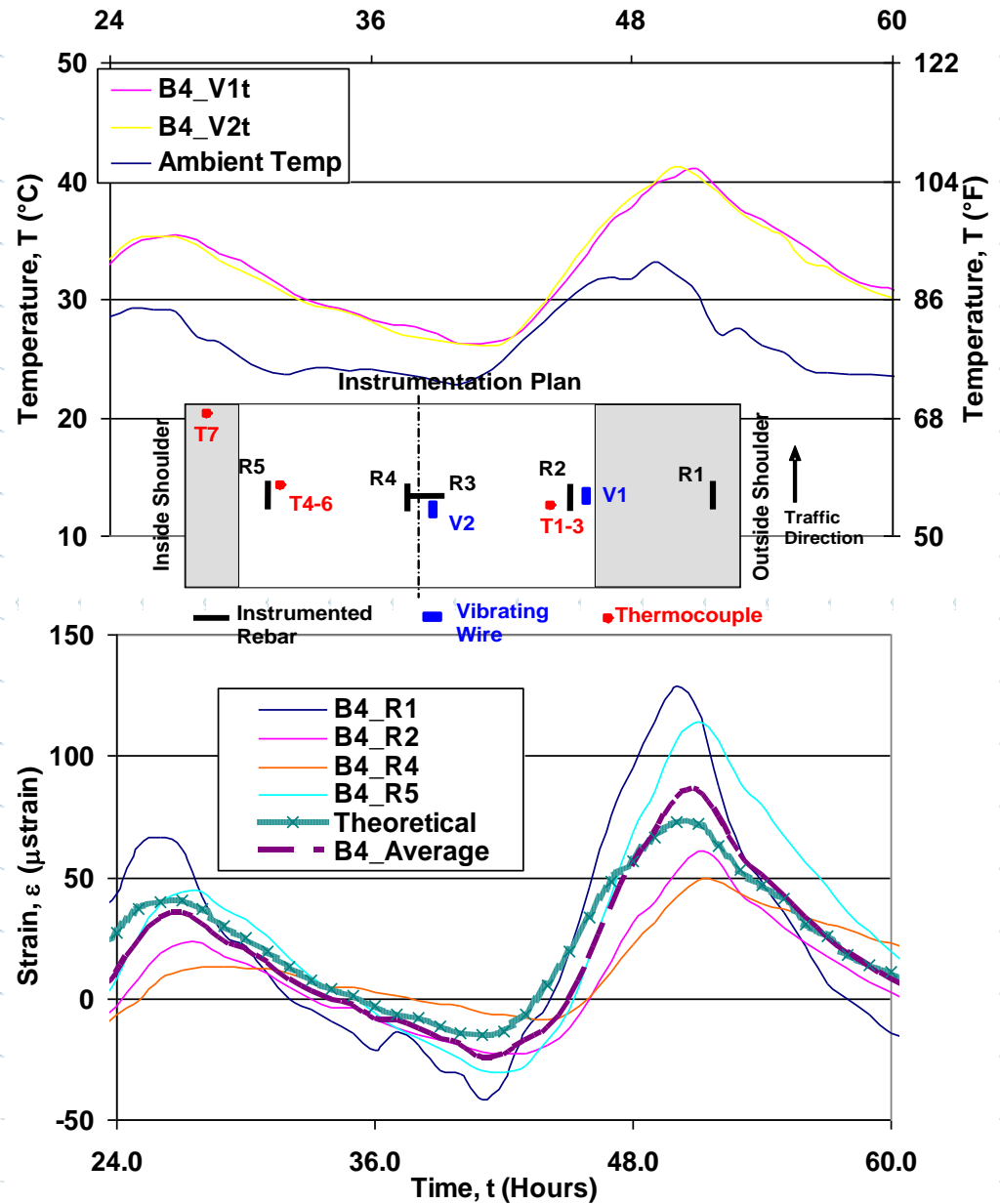
Increase in temperature = 8 C

Increase in relative strain
= 52 μ strain

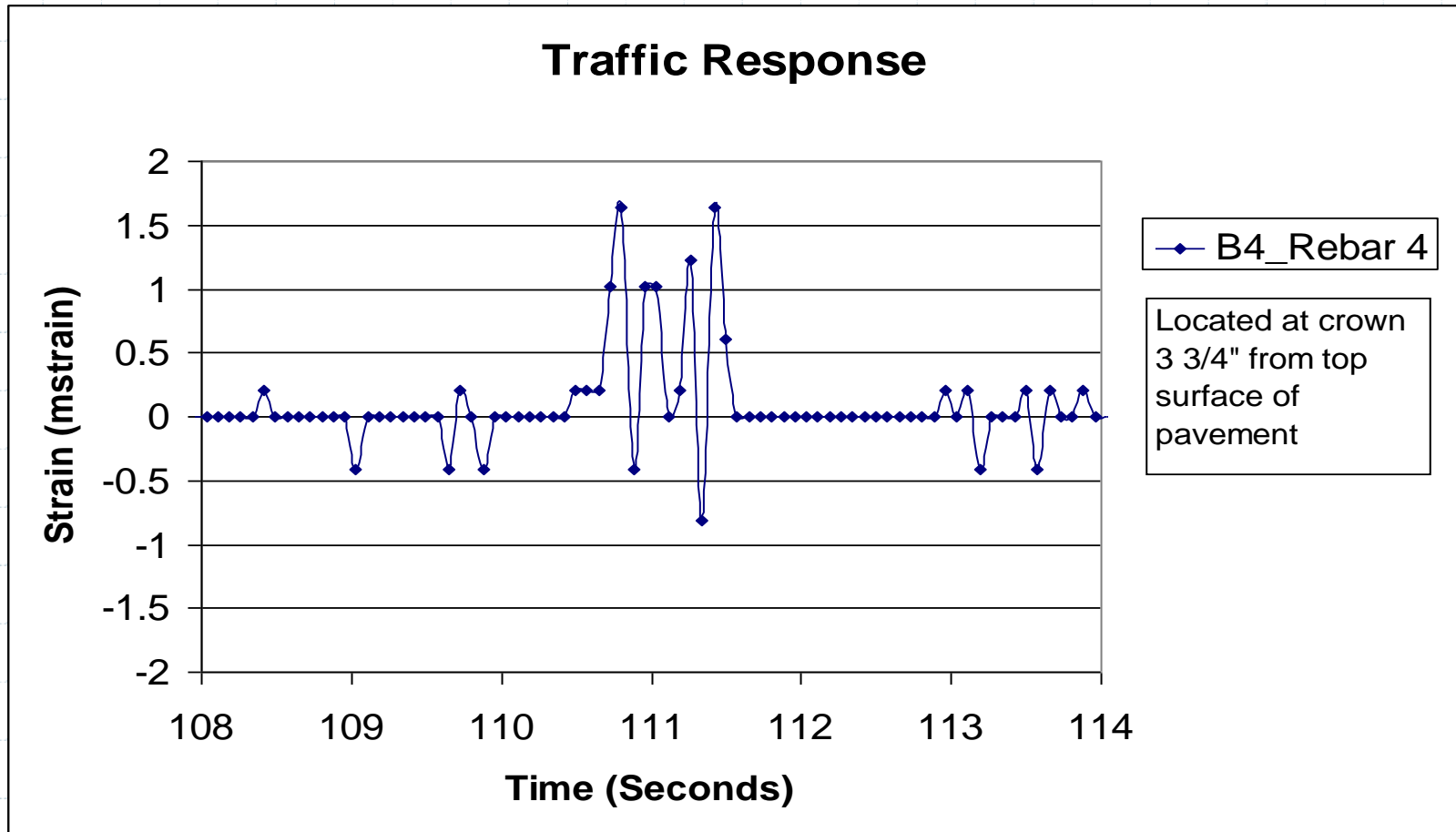
$$52 / 8 = 6.5$$

(Close to CTEconcrete as assumed of 6.0)

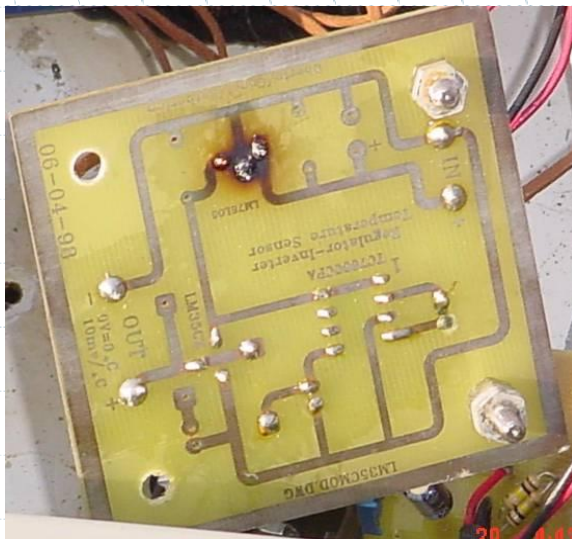
Service Performance Short Term Window



Vehicle Response

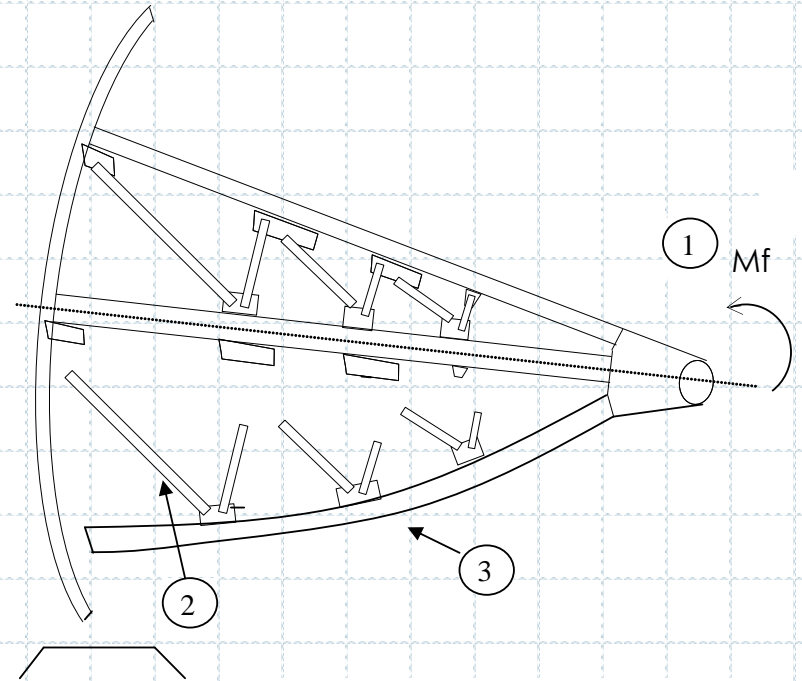


Environmental Issues



- Heat
- Moisture
- Lightning

Folsom Dam Failure

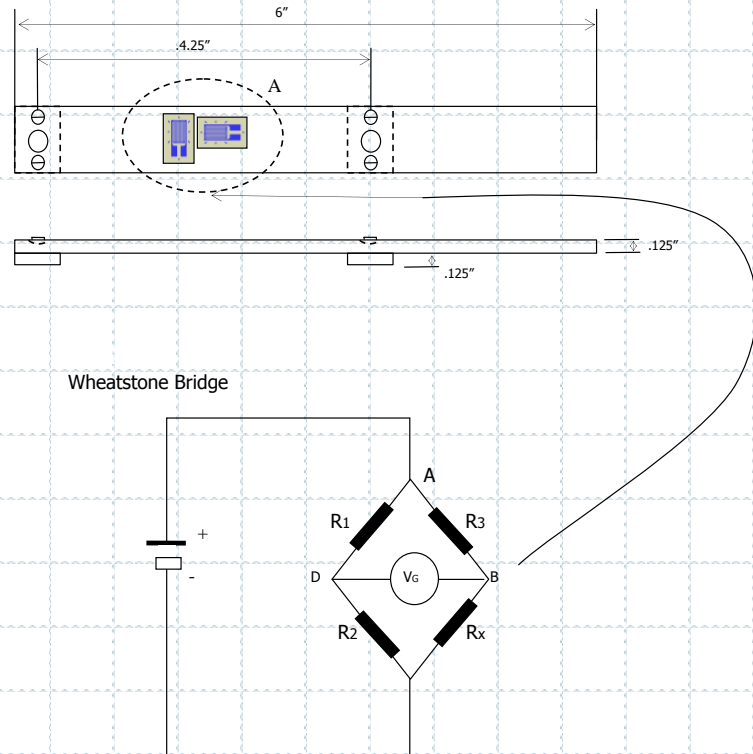


1. Moment developed from trunnion friction.
2. Bracing fails because of stress overload
3. Strut Buckles

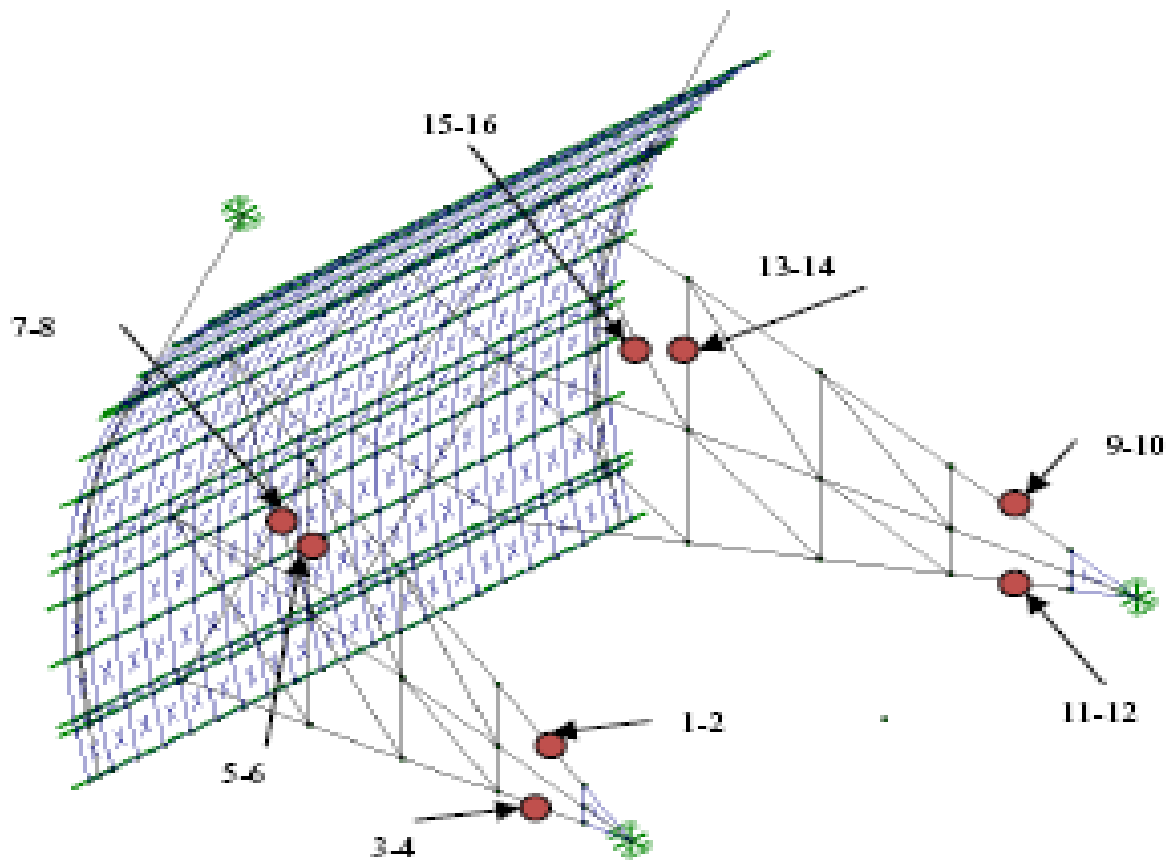
Carlyle Lake Dam



Reusable Strain Transducer



Gage Locations



Gage Locations



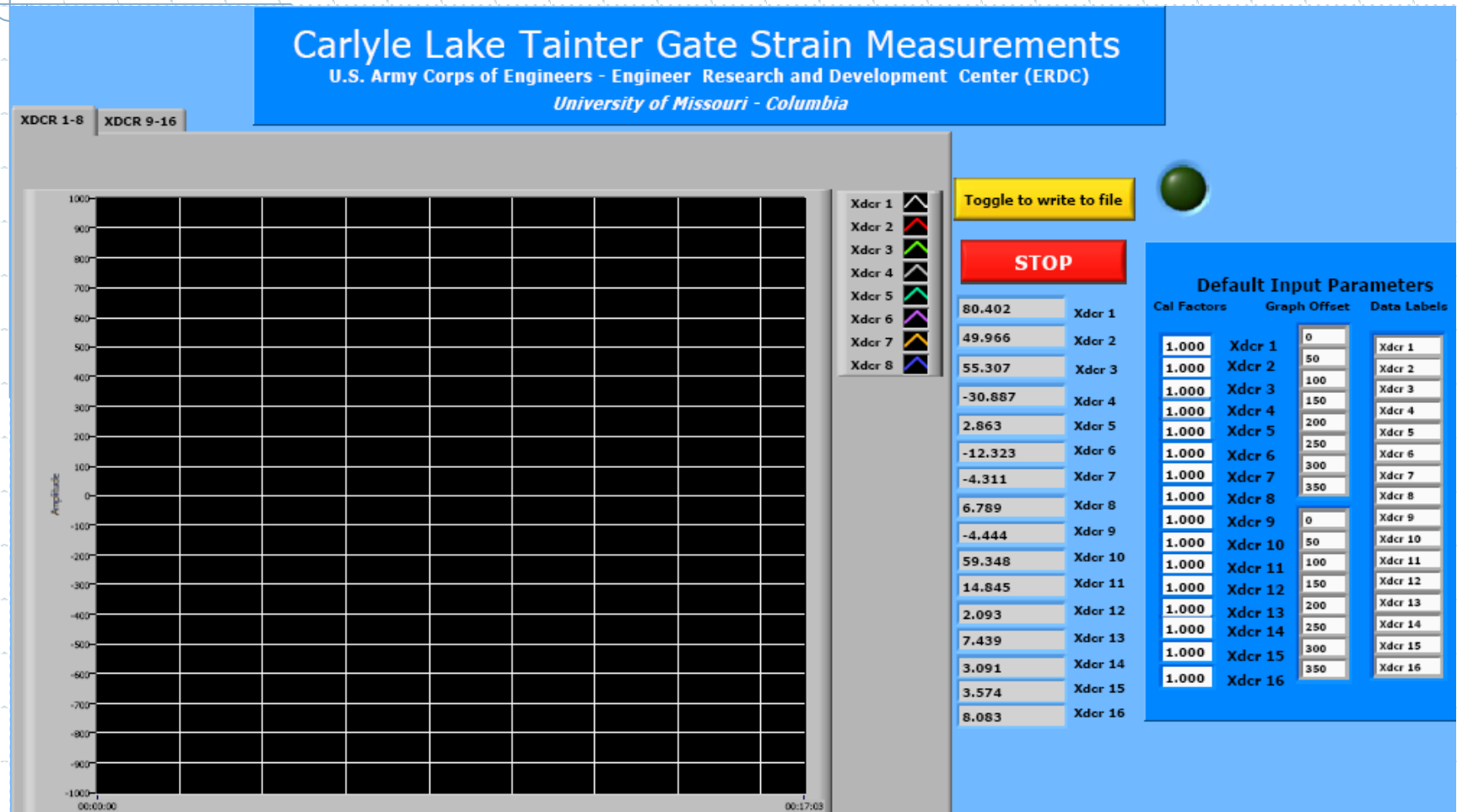
Installing Strain Gages



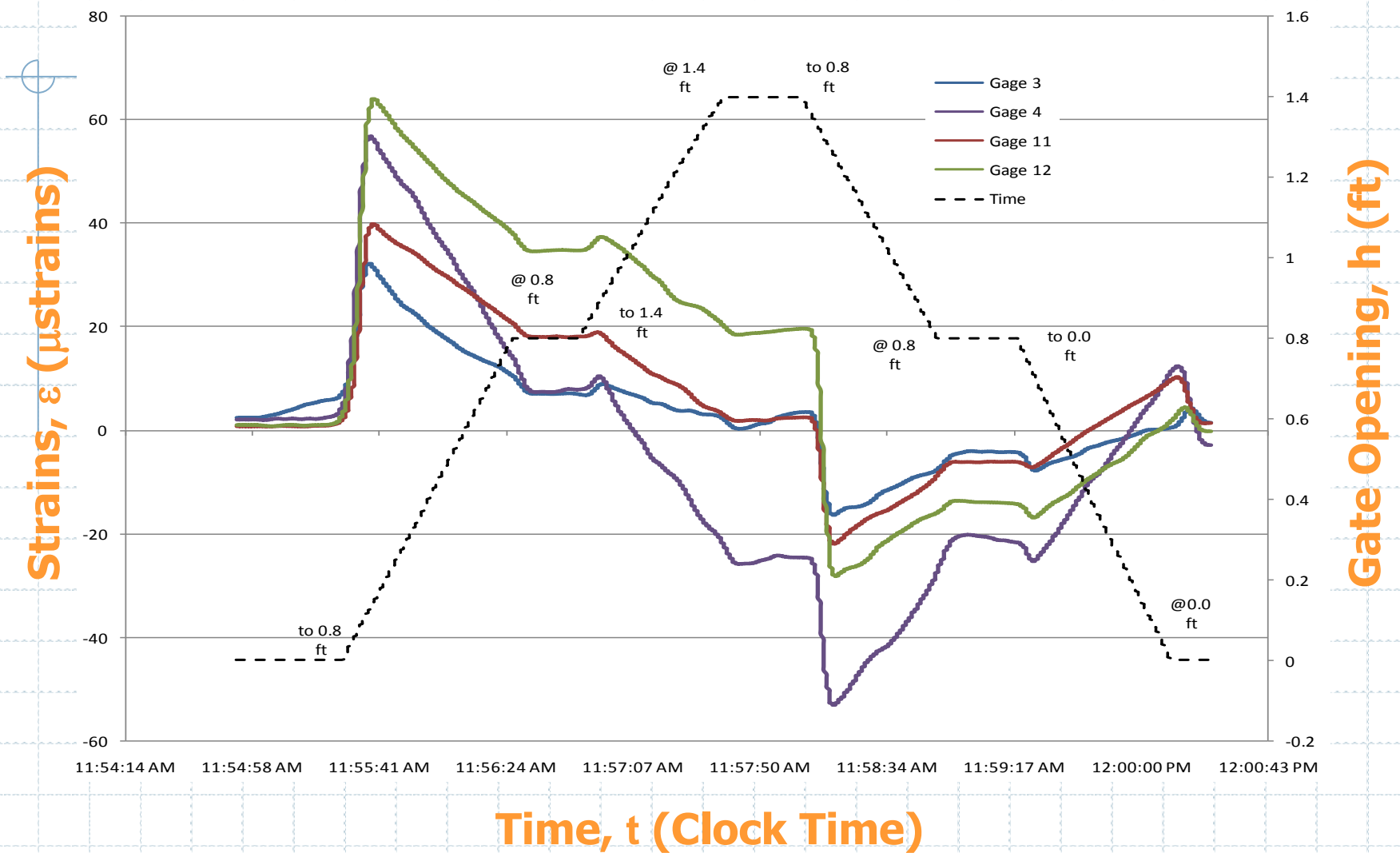
Instrumentation



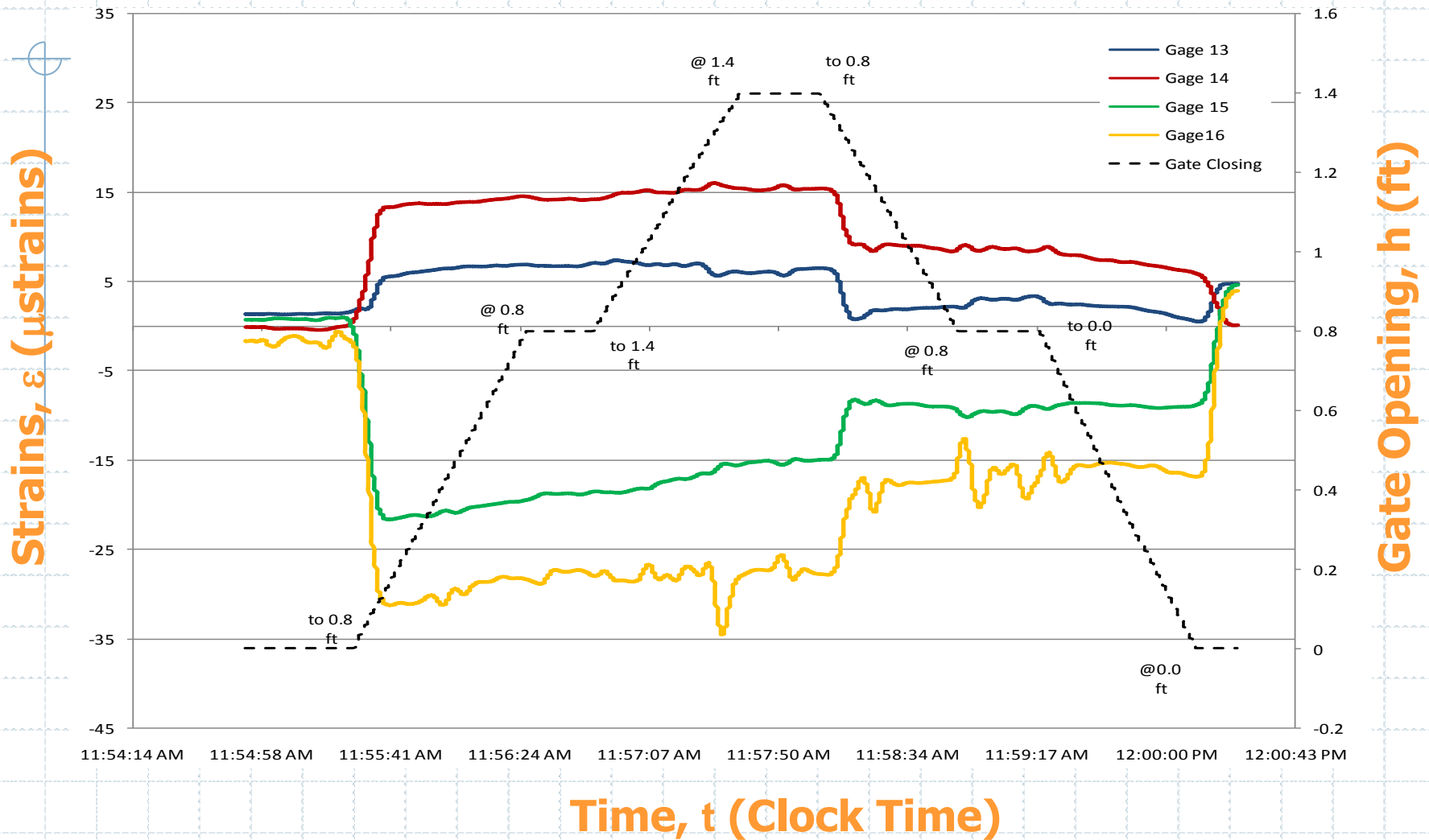
LabView Program



Typical Results (smoothed)



Typical Results (smoothed)



Lessons Learnt

Summary Observations (1/2)

- Know signal content – amplitudes, profile histories, and frequency content
- Identify differential and RSE signals
- Adequate planning, documentation, calibration and labeling of channels
- Pictures and video with audio commentary
- Redundant instrumentation
- Power supply and back-up/start-up logistics
- Understand ground signals to avoid spurious loops
- Shielding to mitigate electromagnetic noise
- Temperature compensation?



Lessons Learnt

Summary Observations (2/2)

- Dust protection to secure electronics
- Moisture protection – condensate, drains and desiccants
- Fusing to avoid voltage spikes
- Grounding for lightning protection
- Cooling of electronic circuitry for optimum performance
- Robust graphical visualization software to allow better data screening and manipulation

Ignorance IS Bliss!?

