Long-Term Monitoring and Instrumentation for Steel and Concrete Bridges

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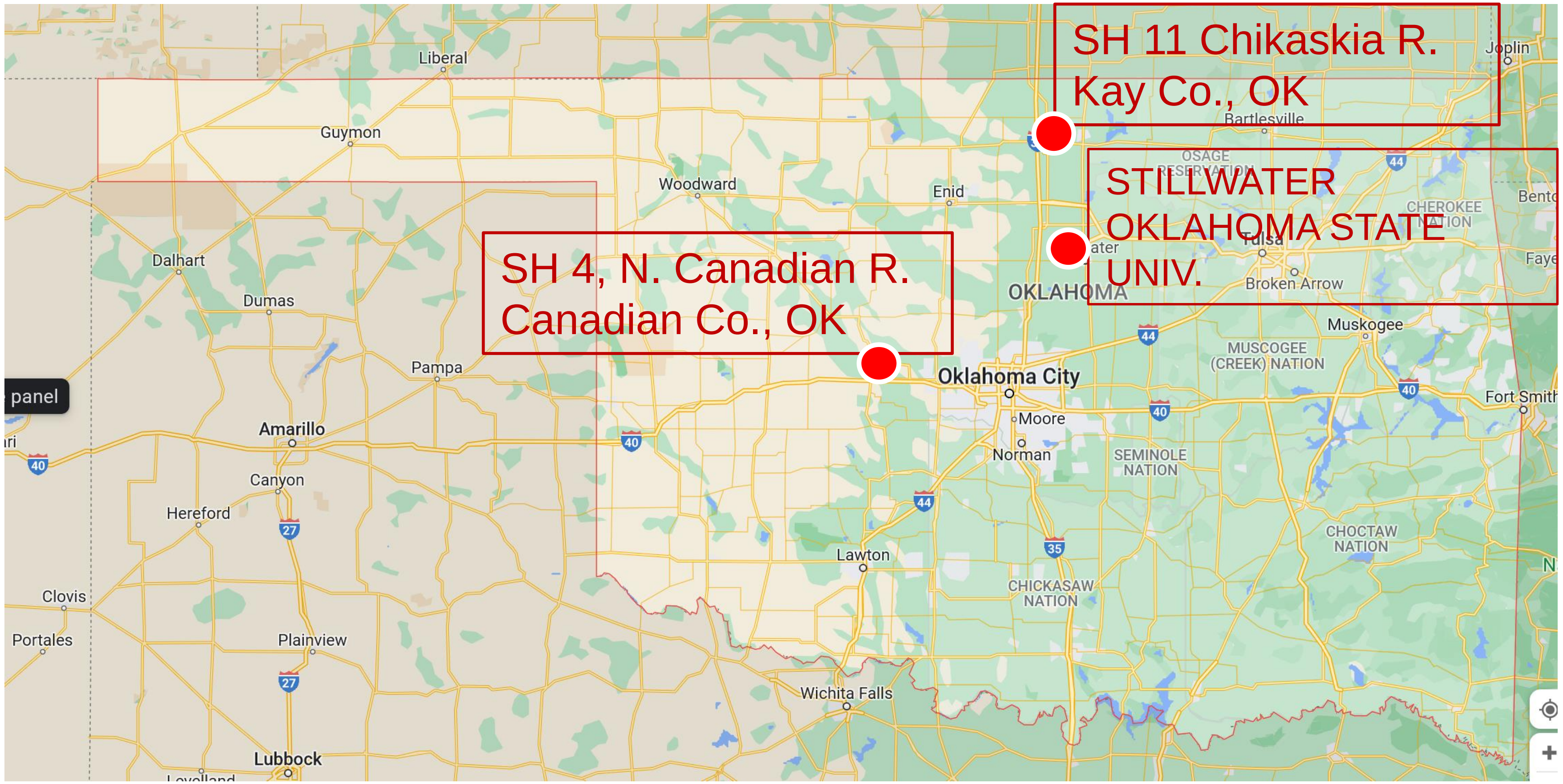
Inspiring Greatness

Structural Monitoring Projects in Oklahoma



Monitoring Methods for Full-Sized Protype Bridge

- Practical means of monitoring bridge performance through instrumentation and structural monitoring of full-size prototype bridge and field bridge
- Selection of instruments and sensors
- Types of sensors employed in bridge instrumentation
- Installation procedures and type of data collected for analysis
- Real time data acquisition and analysis from a large variety of sensors
- Design and planning stages for long-term monitoring of field bridges

Monitoring Methods for Full-Sized Protype Bridge

- Full size bridge built at the bert Cooper Engineering Laboratory (BCEL)
- Replica of Eagle Chief Creek Bridge “A” on SH14 in Woods Co., Oklahoma.

Monitoring Methods for Full-Sized Protype Bridge

LVDTs

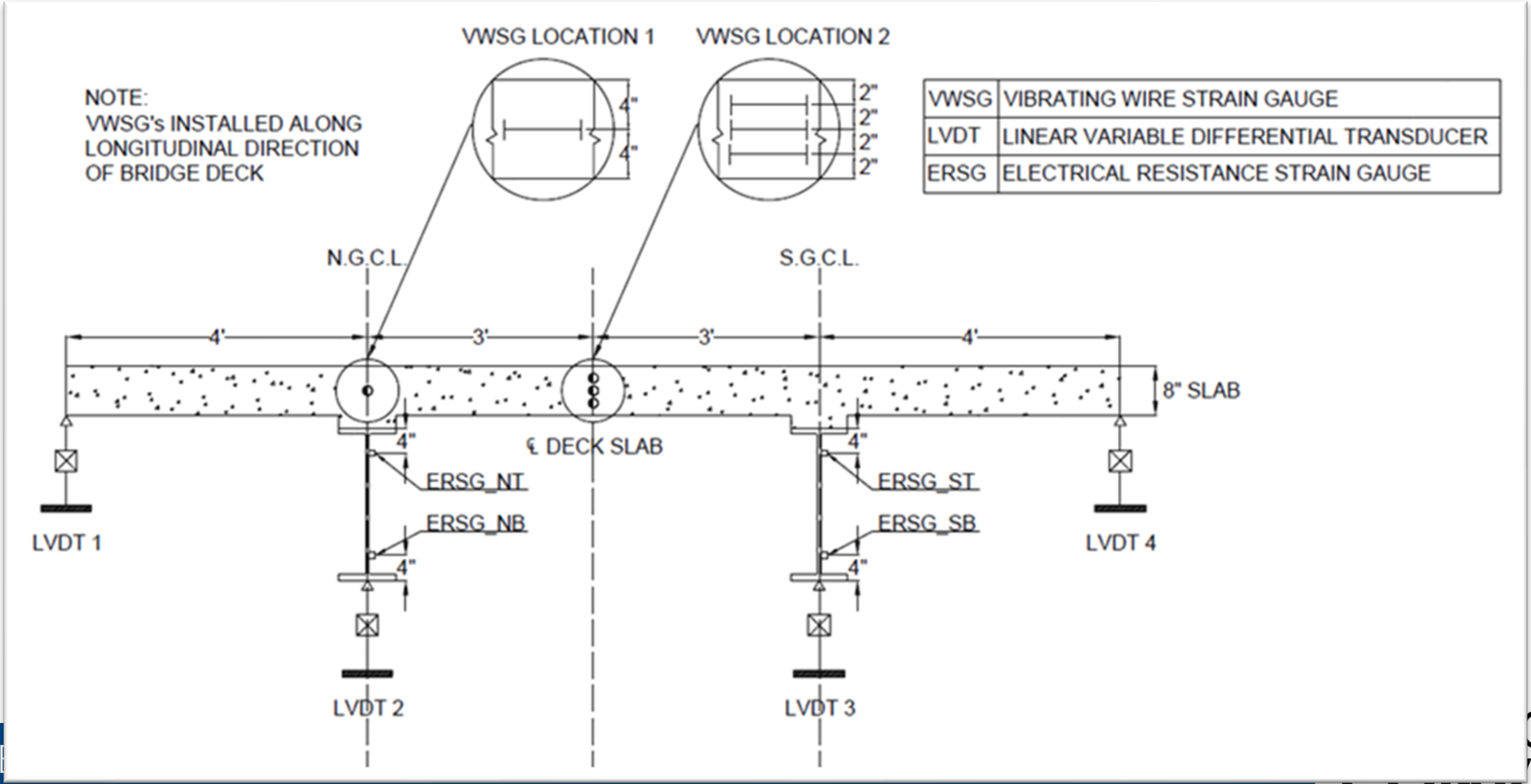
Thermocouples

ERSGs

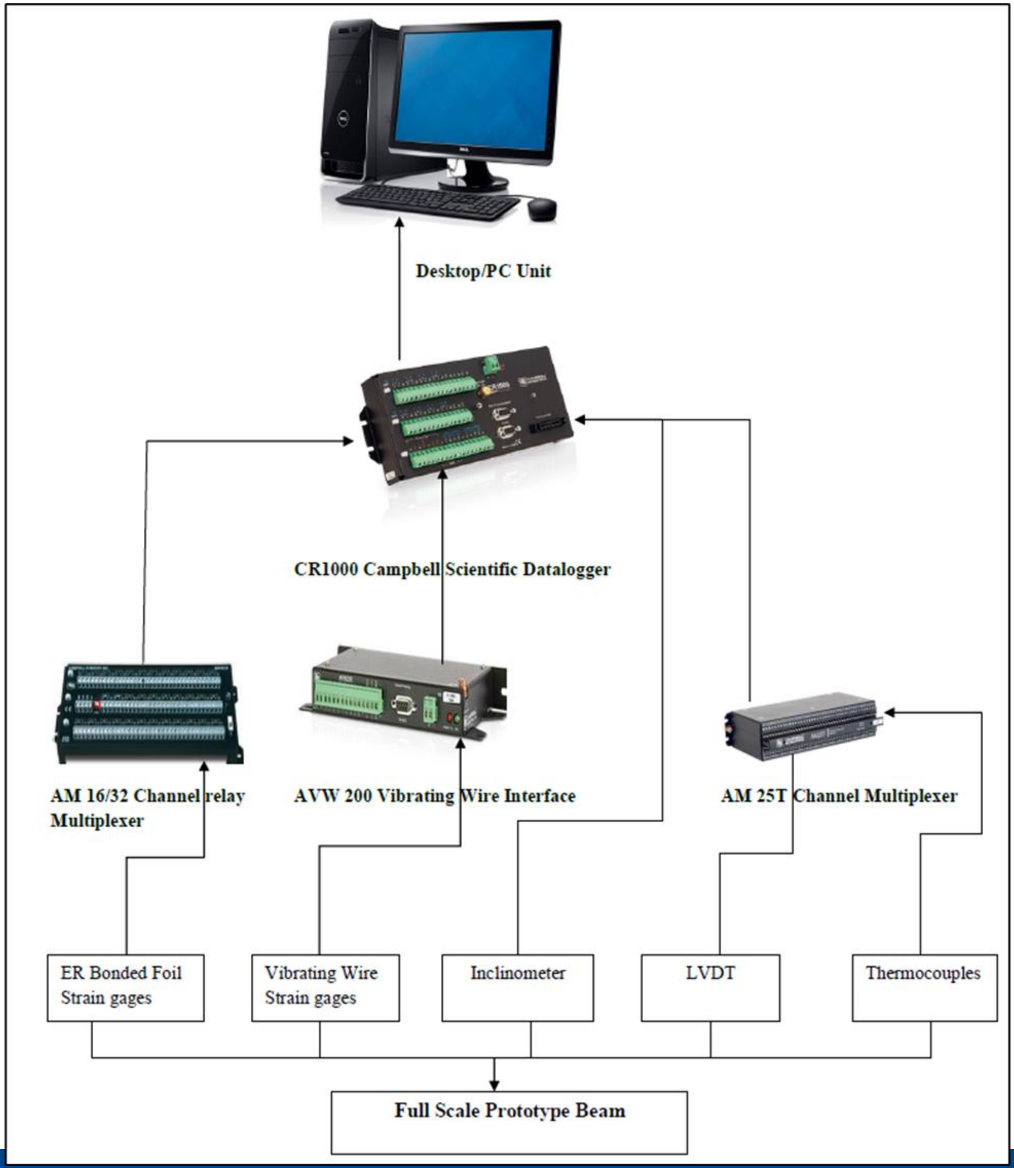
VWSGs

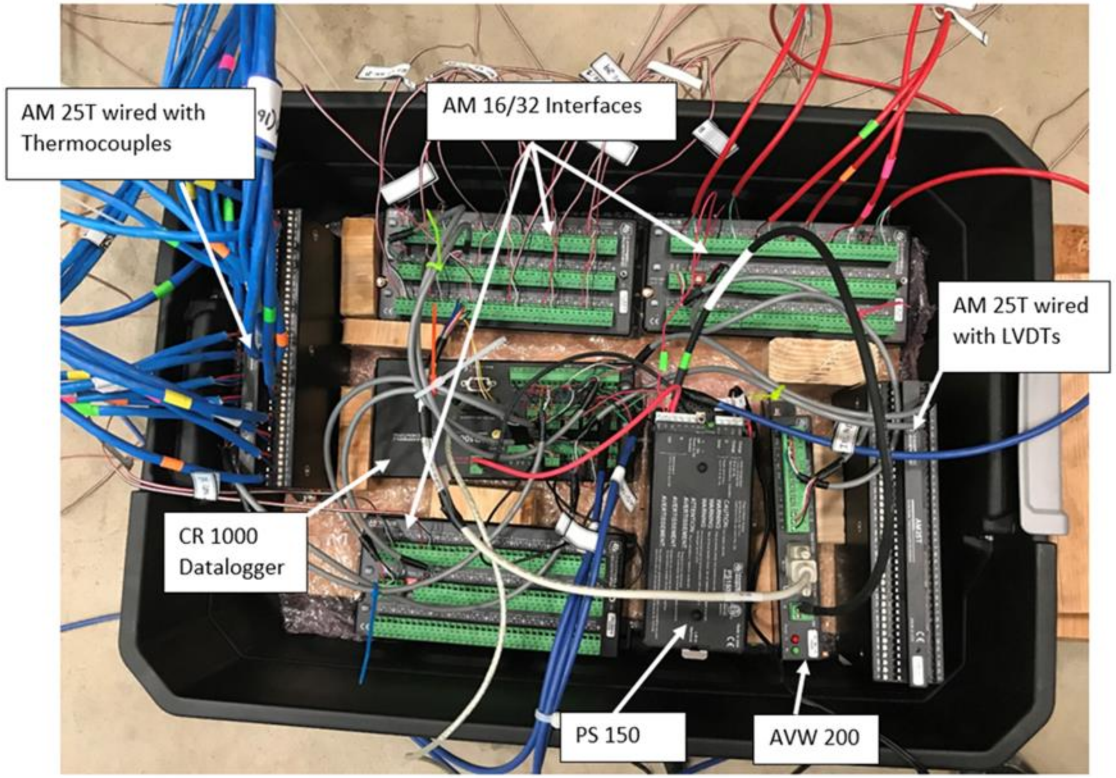
Inclinometers

Monitoring Methods for Full-Sized Protype Bridge



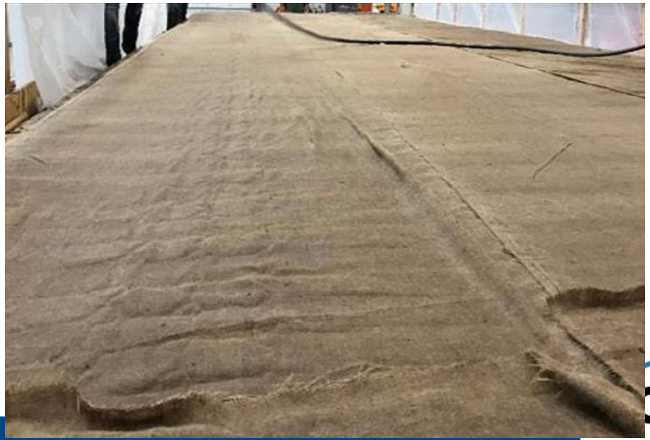
Monitoring Methods for Full-Sized Protype Bridge



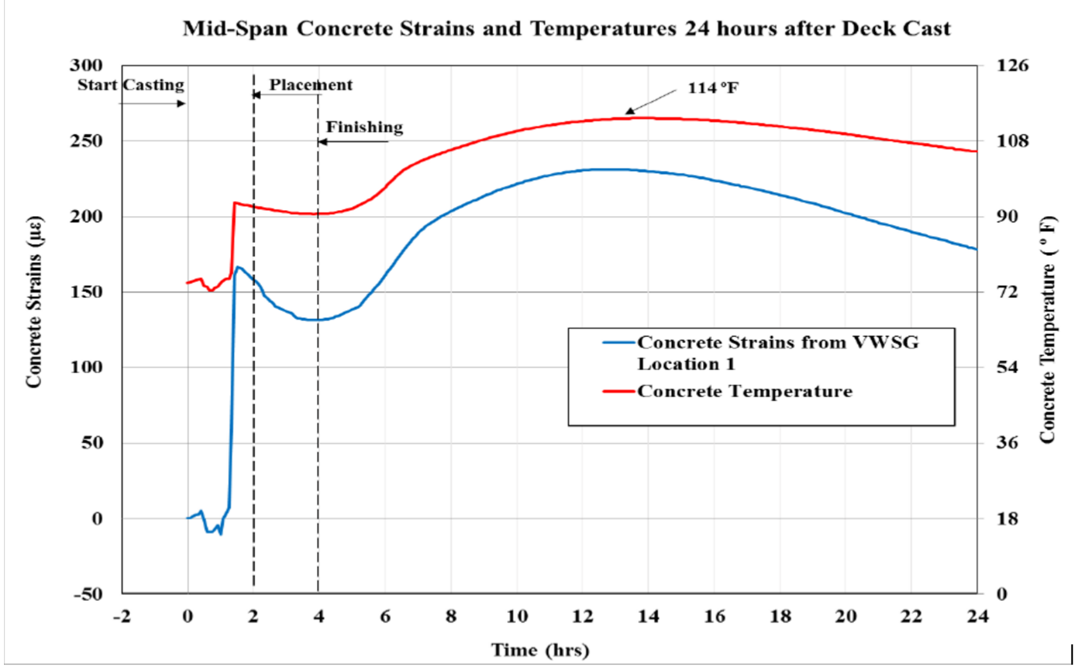


Casting 8 in. (203 mm) deck slab

- Casting
- Covering with Wet Burlap (at about 10 hours)
- Covering with plastic sheeting for 14 days



Full-Sized Prototype Bridge: Early Age Temperatures and Concrete Strains

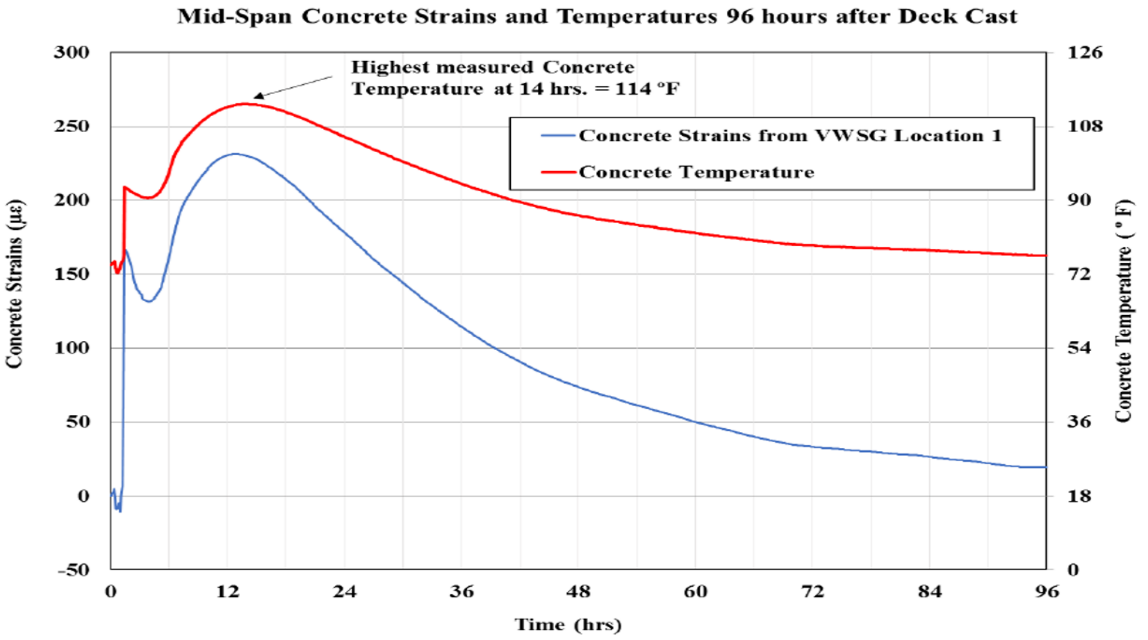


First 24 hours

- High Temperature ≈ 114˚F (46˚C)
- At 12 to 13 hrs. after casting
- Measured strains are driven by temperatures

24 to 96 hours

- Temps. approach ambient (73˚F or 23˚C)
- Concrete Strains from 12 to 96 hours are tensile strains ≈ 200 με

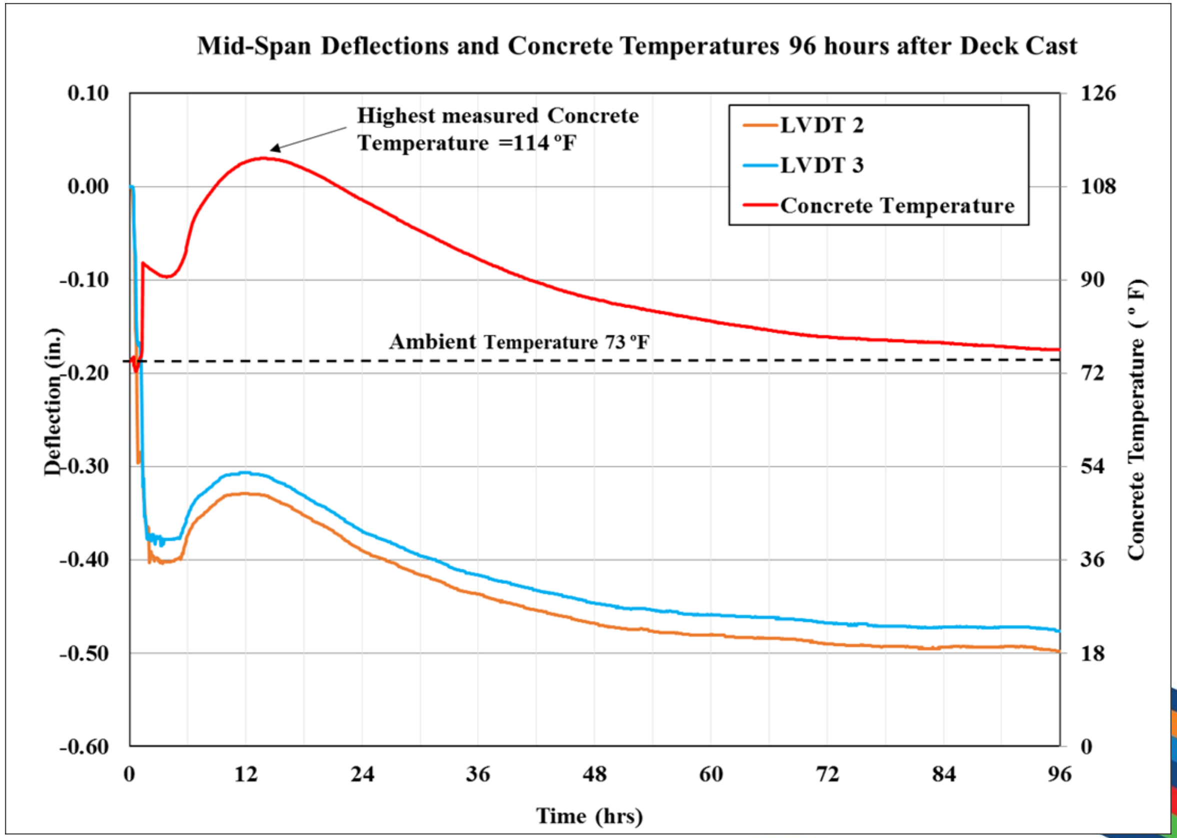


Full-Sized Protype Bridge : Early Age Concrete Temperature and Deflections

First 96 hours:

Bridge Deflections mirror the Temperature Variations in the Concrete Deck Slab

- **Self-weight of fresh concrete caused downward deflection of 0.40 in.**
- **Heating of the slab during curing caused upward deflection of 0.10 in.**
- **Cooling and shrinkage of the slab causes additional downward deflections**



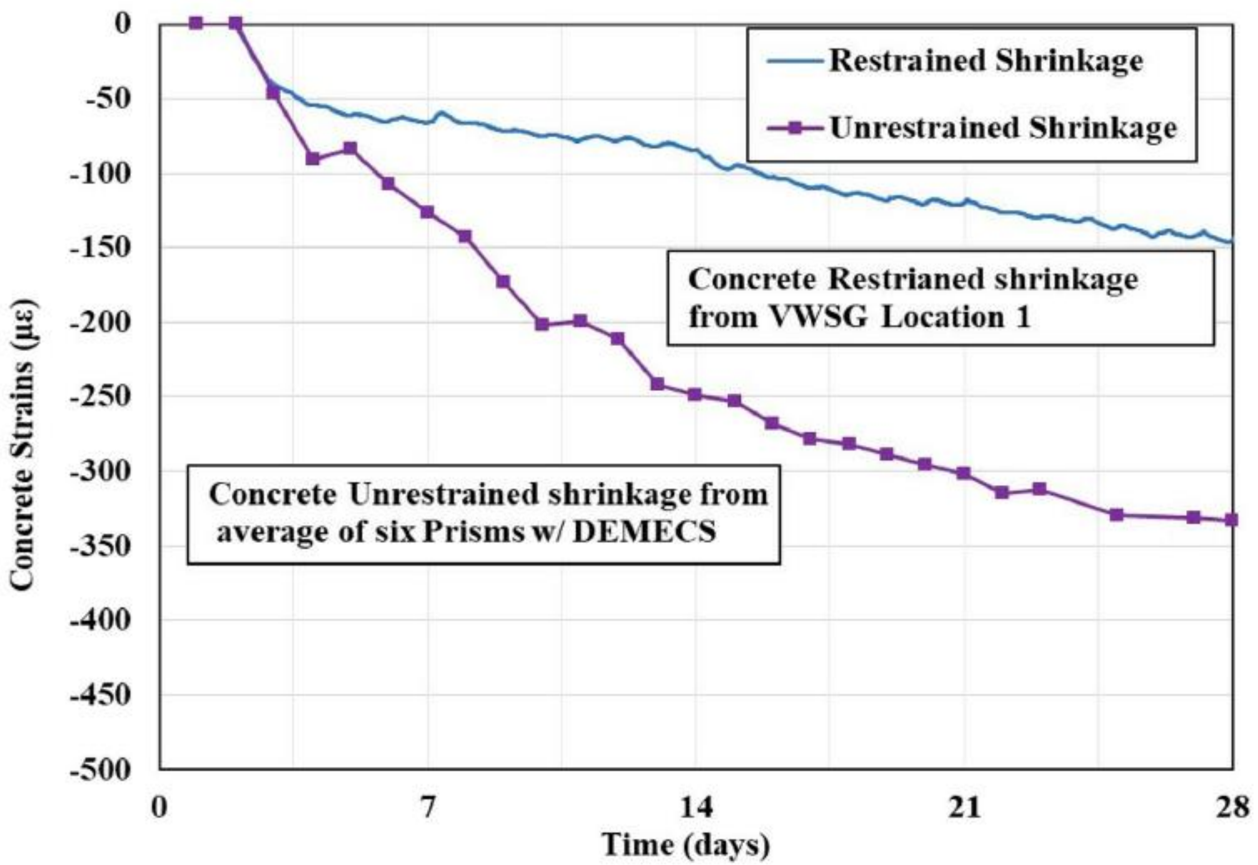
Restrained Shrinkage of Deck Slab

Unrestrained Shrinkage Prisms

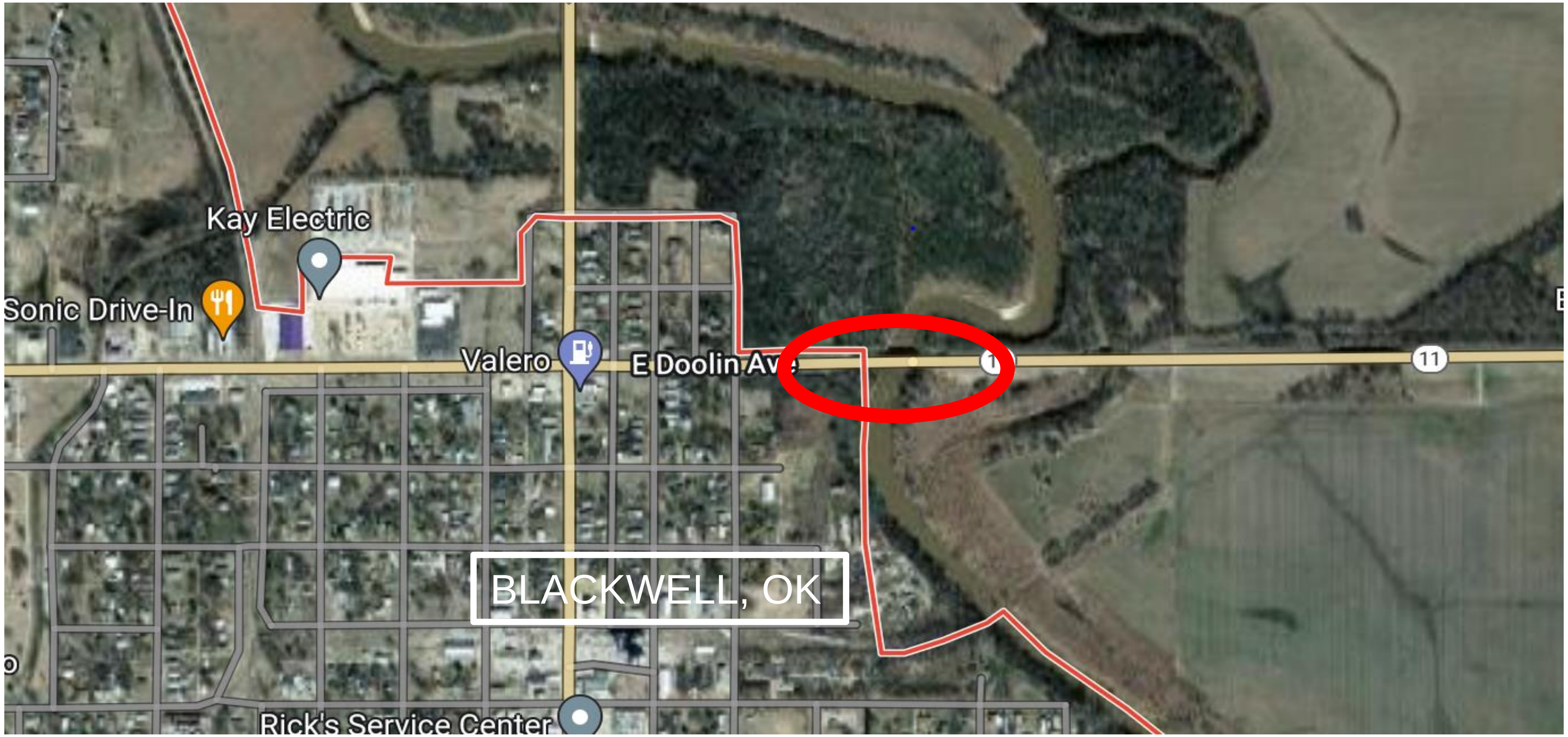
- ASTM C157
- ≈ 330 με after 28 days
- Shrinkage Specimens are not subjected to elevated curing temperatures

"Restrained" shrinkage of Slab

- Strains measured by embedded wire gages
- ≈ 150 με after 28 days
- Difference of 180 με equivalent ≈ 800 psi (5.5 MPa)
- But No Cracking in the Slab



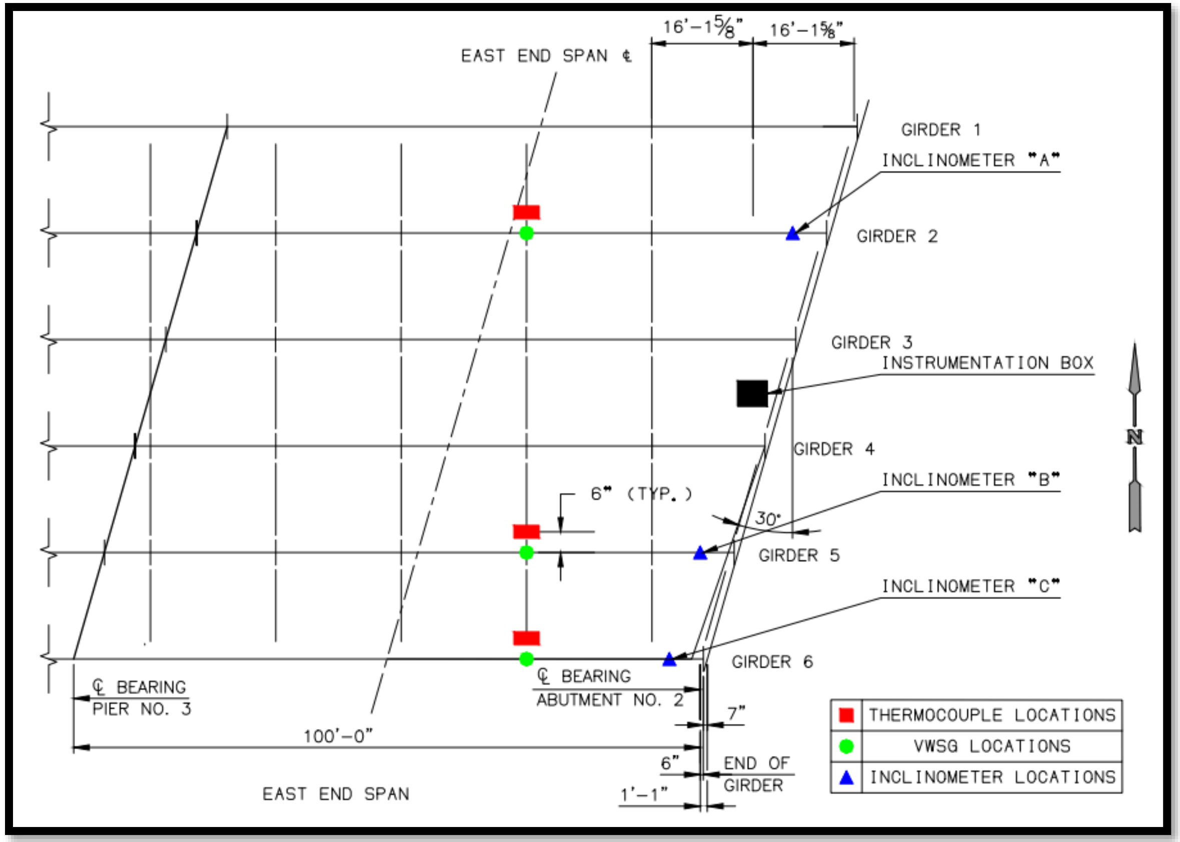
SH 11 over the Chikaskia River Kay Co., Oklahoma, USA



SH 11 over the Chikaskia River

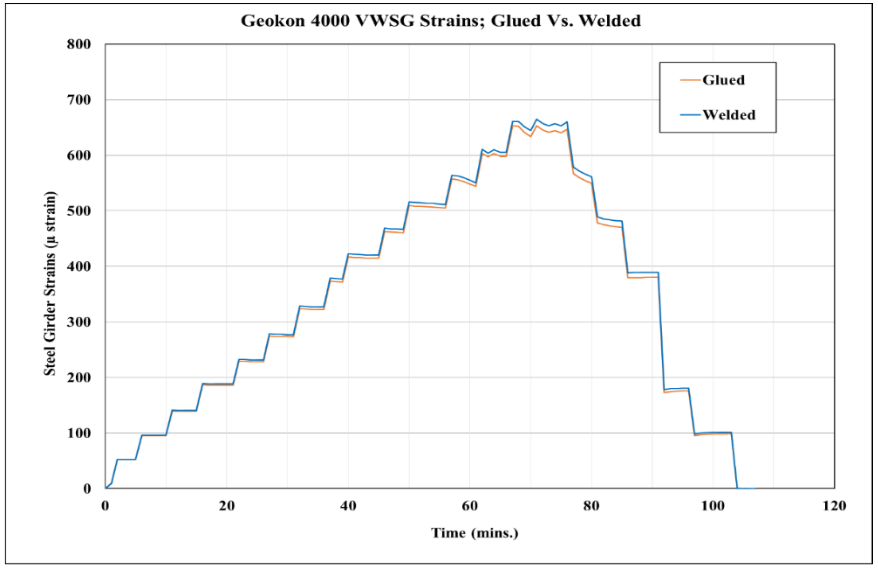
SH 11 Rehabilitation = New Deck Slabs
Use Existing Steel Girders, 100 ft (30 m) spans

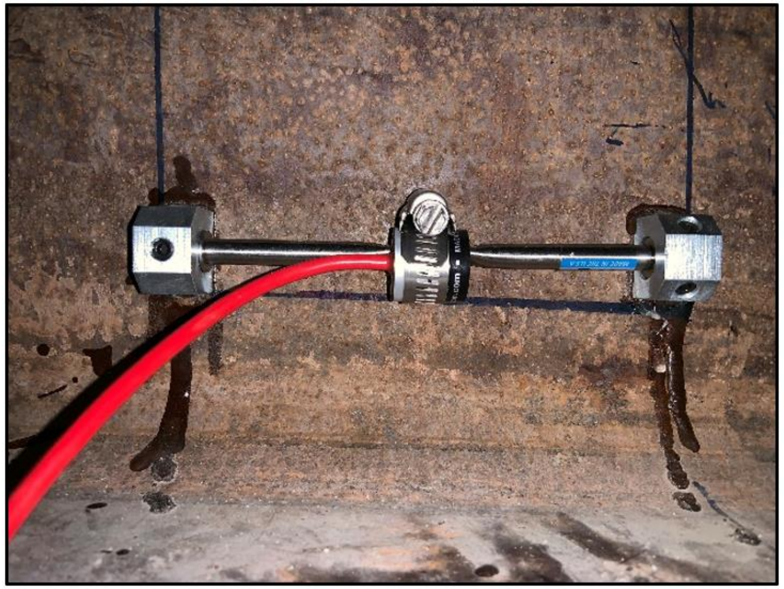
Total Span 120 m - Four 100 ft (30 m) spans – 6 girder lines w/ 30˚ Skew and Cross Bracing



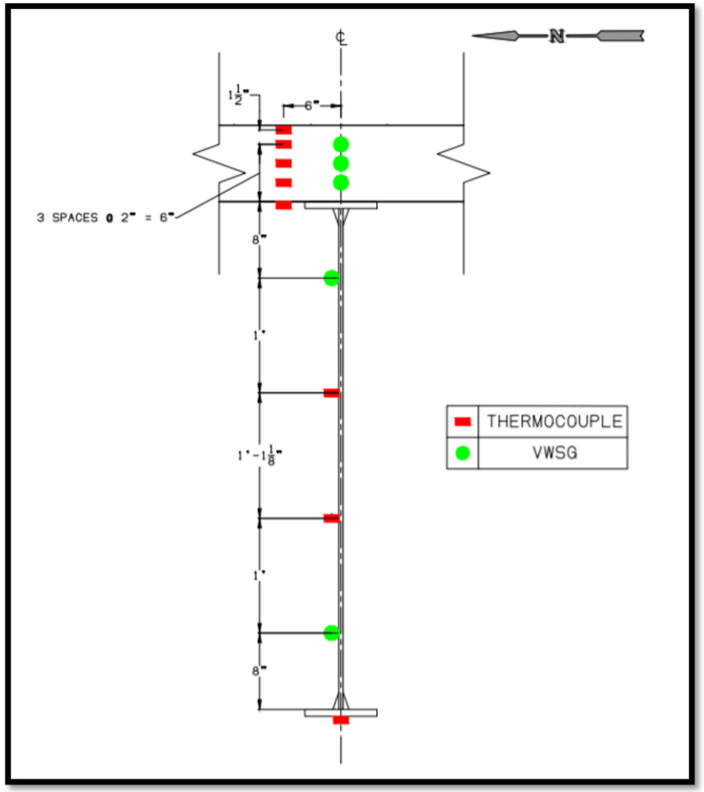
- Instrumented East-most Span (Accessibility Reasons)
- Three of the Six Girders
- Thermocouples
- Vibrating Wire Gages
- Concrete Deck Slab
- Steel Girders (glued gages)
- LVDT's (Because we can for load testing only)

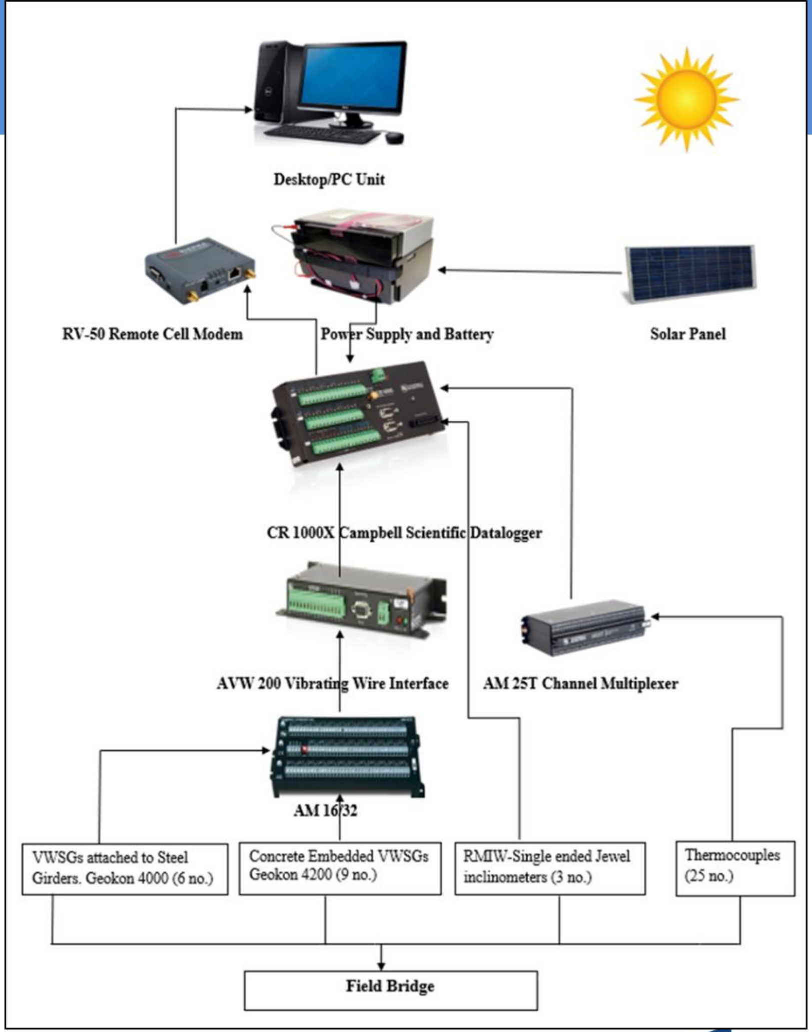
Vibrating Wire Gages – Glued vs. Welded



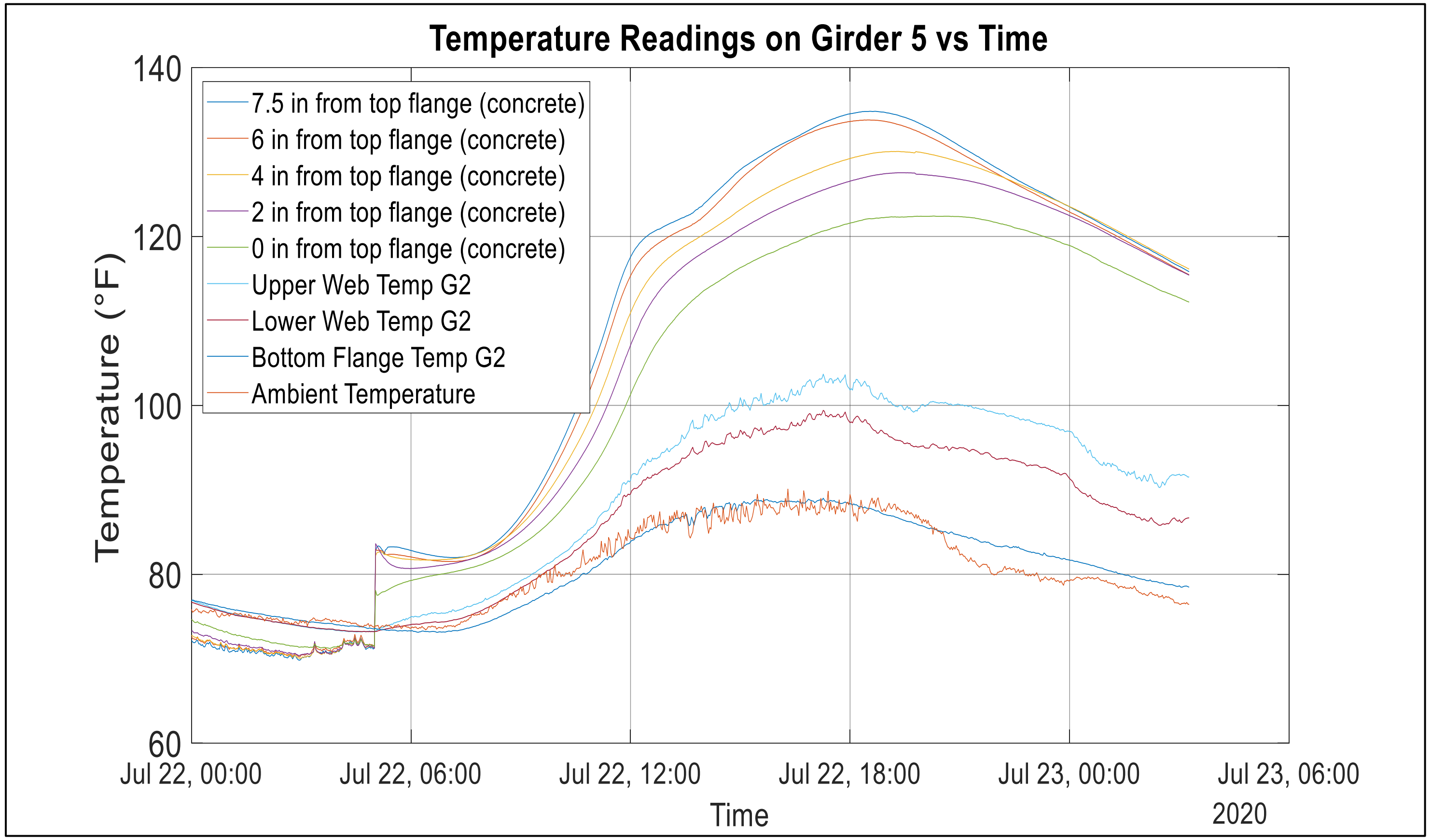


SH 11 – Instrumentation and Data Acquisition Scheme





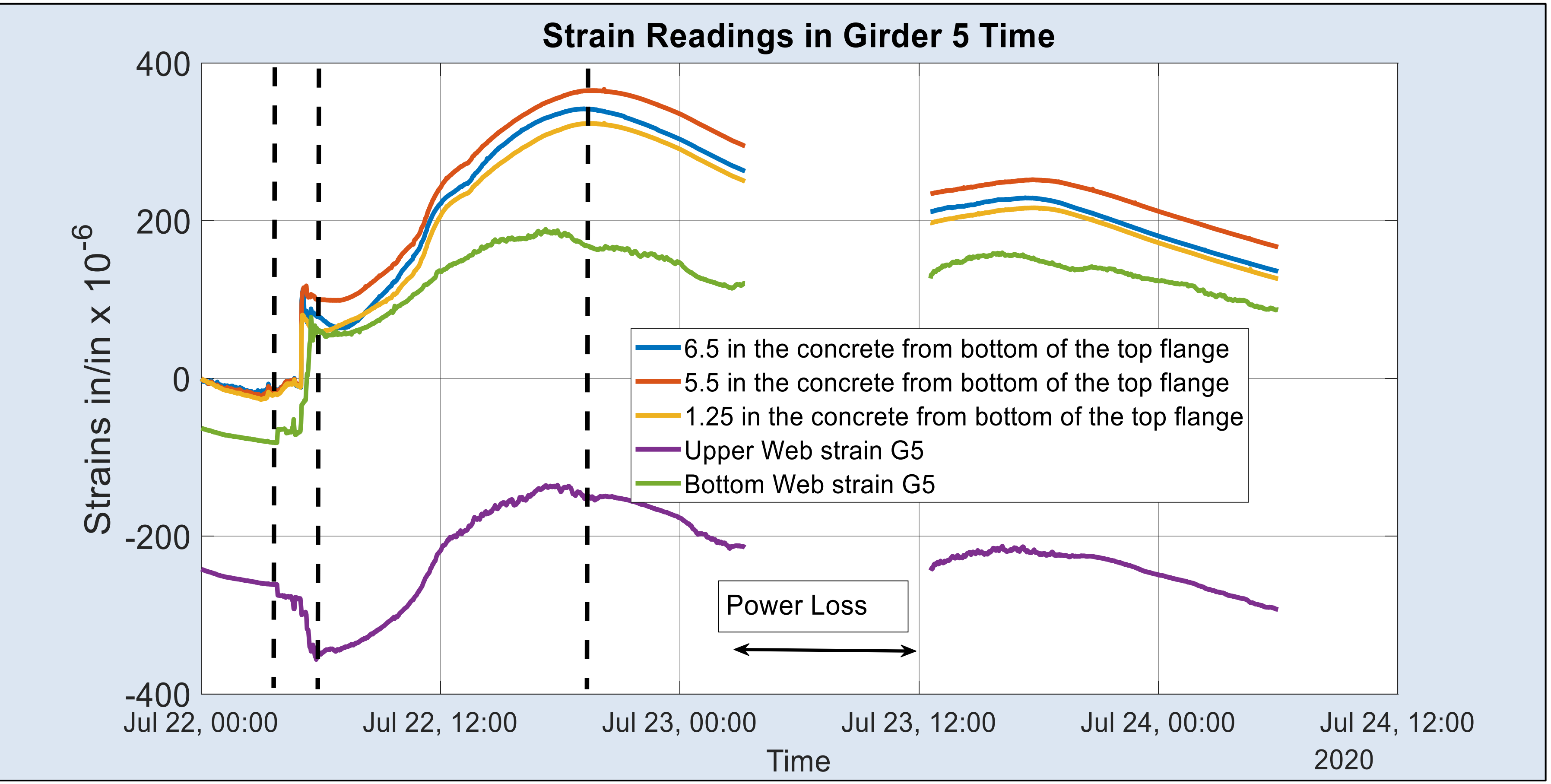
SH 11 Chikaskia River Bridge Monitoring Temperatures during Deck Slab Casting



Deck Slab Cast on July 22, 2020

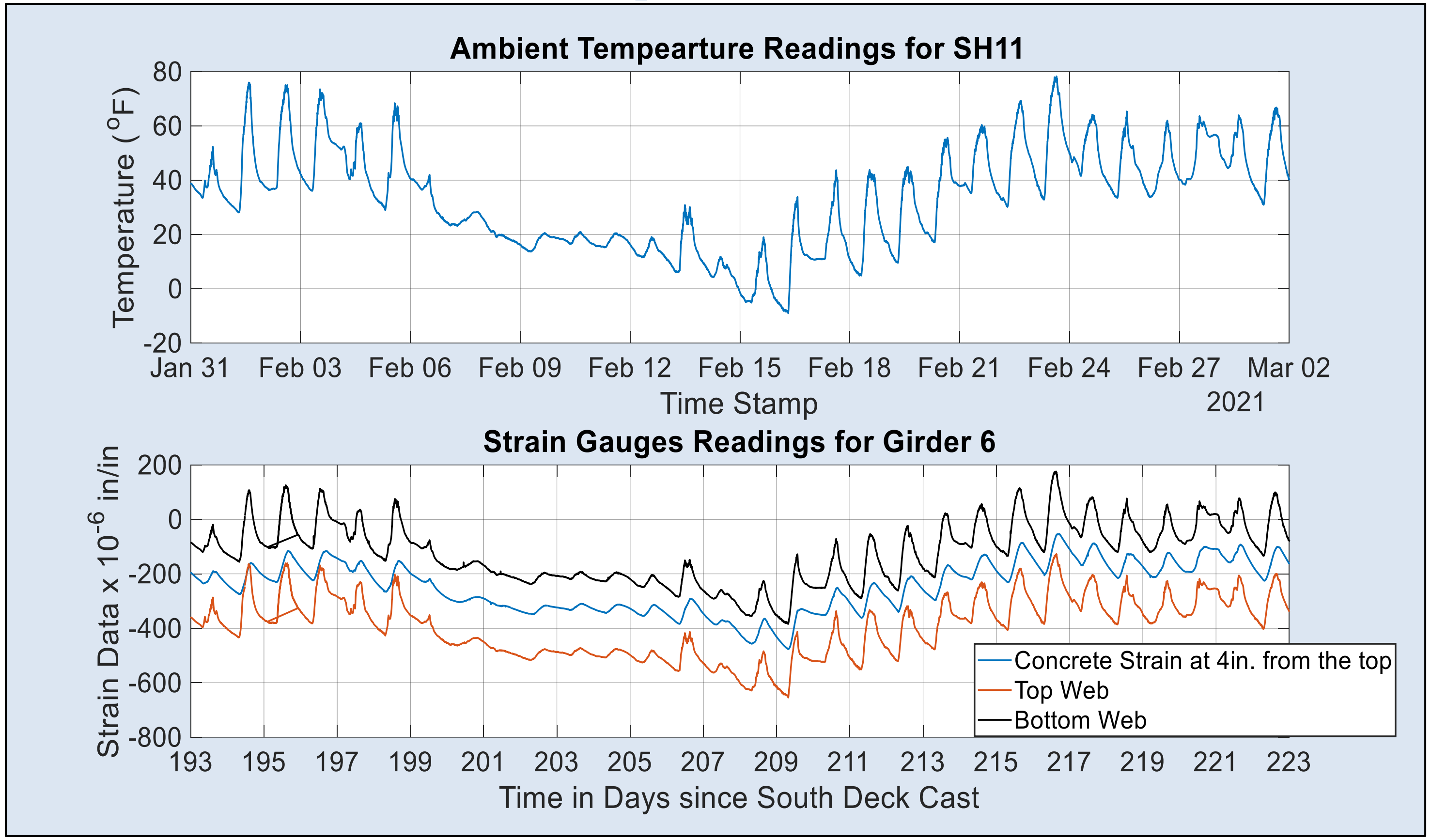
- 5:00 AM (early morning)
- Ambient T ≈ 73 F (23 C)
- Max Slab Temperature≈ 130 F (54C) at 18:00.
- Top Flange of the Steel Girder Max T = 100 F (39 C)
- Bottom Flange of Steel Girder matches ambient Temps

SH 11 – Concrete and Steel Strains during Casting

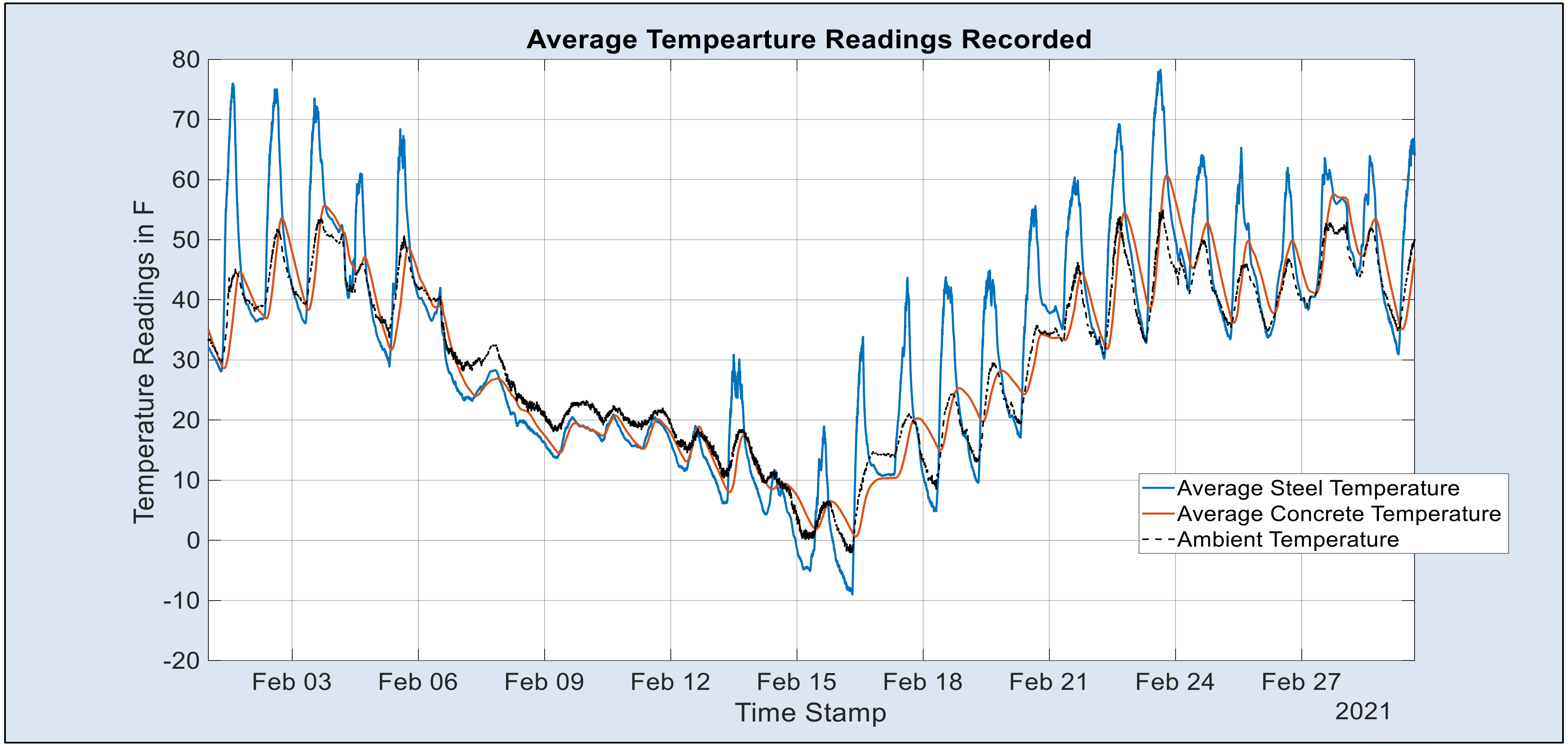


- Concrete Strain Readings reflect Temperature changes
- Steel Strains – Compression at the top, tensile at the bottom
- Steel strains are influenced by temperatures as well

SH 11 – Long-term Monitoring – 1st Quarter of 2021 – Temperatures and Strains



Structural Monitoring – Temperatures in February 2021 – Record Cold – and Extreme Variation



Measurement of Camber and Prestress Losses

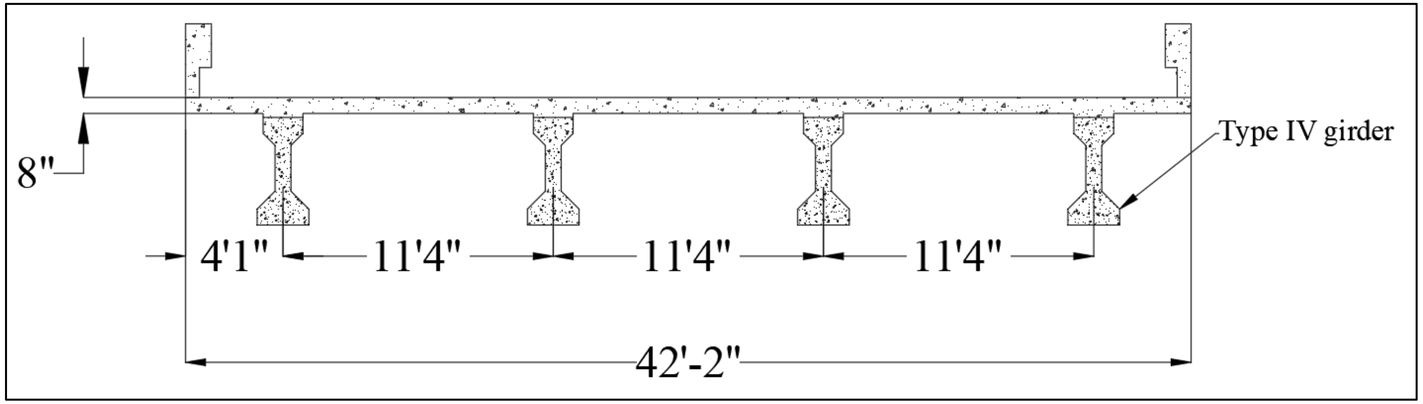
SH 4 over the North Canadian River, Canadian Co., OK

Bridge Details:

- Fifteen 100 ft. spans
- Clear Roadway Width = 40’-0
- Each Span supported by four AASHTO Type IV PC Girders
- Girders are simply supported on neoprene bearing pads with “poor-boy continuous” deck slabs over the joints.

Bridge Properties

- This work is based on a research project of the SH 4 bridge over the North Canadian River in Yukon, OK
- The bridge consists of 15 spans, each 99.67 ft. long.
- All spans were constructed using four Type IV prestressed girders.
  - Specified concrete strength of 7 ksi and 10 ksi at transfer and 28-days, respectively.



Aerial View of SH 4 Bridge Location

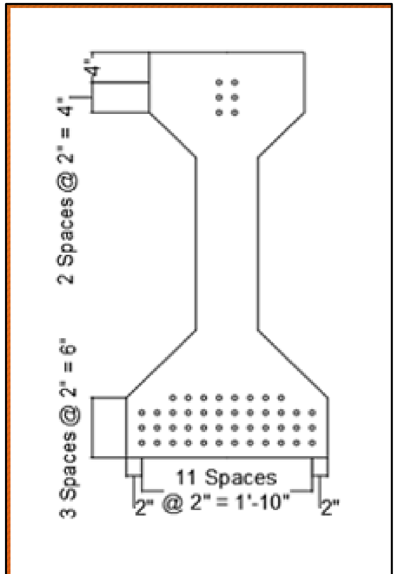
SH 4 Bridge Location over the N. Canadian R., Canadian Co., OK.

	No. Strands	Distributed (Y or N)	No. of Debonded Strands	Bundled Verticals (Y or N)	L-Bar	Mild Steel Bottom Flange
Span 1	50	1	2	1	0	0
Span 2	50	1	2	1	1	0
Span 3	50	0	12	1	0	0
Span 4	50	0	12	0	0	0
Span 5	50	1	2	0	0	0
Span 6-1	50	1	2	0	0	(4) #7's
Span 6-2	50	1	2	1	0	(4) #7's
Span 7-1	50	1	2	0	0	(4) #7's
Span 7-2	50	1	2	1	0	(4) #7's
Span 8-1	48	0	8	0	0	(4) #7's
Span 8-2	48	0	8	0	0	(4) #7's
Span 9-1	48	0	8	0	0	(4) #7's
Span 9-2	48	0	8	1	0	(4) #7's
Span 10-1	48	0	8	0	0	0
Span 10-2	48	0	8	0	0	0
Span 11	50	1	2	0	0	0
Span 12	50	0	12	0	0	0
Span 13	50	0	12	1	0	0
Span 14	50	1	2	1	1	0
Span 15	50	1	2	1	0	0

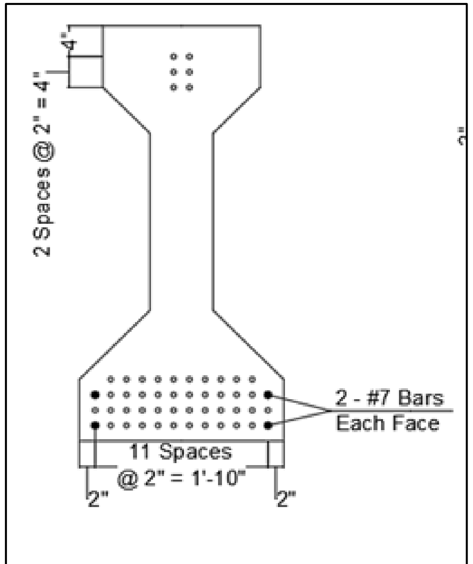
Girder Reinforcement

- Girder reinforcement varies between each of the 15 spans.
  - Variations in reinforcement include:
    - Strand pattern
    - Number of strands
    - Inclusion of mild steel reinforcement in the bottom flange, (4) #7 bars
    - Debonded strands and length of debonding
    - Bundled shear reinforcement in end regions
    - L- bars in end regions
- 4 standard longitudinal reinforcement layouts exist between all spans.

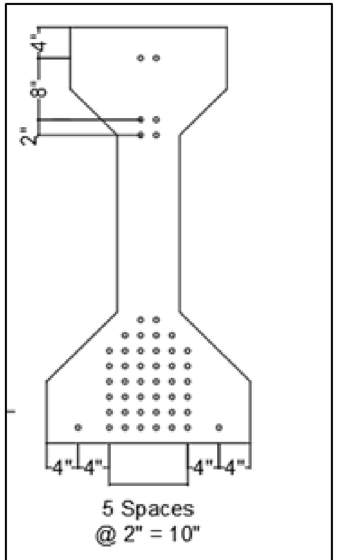
Reinforcement Layouts



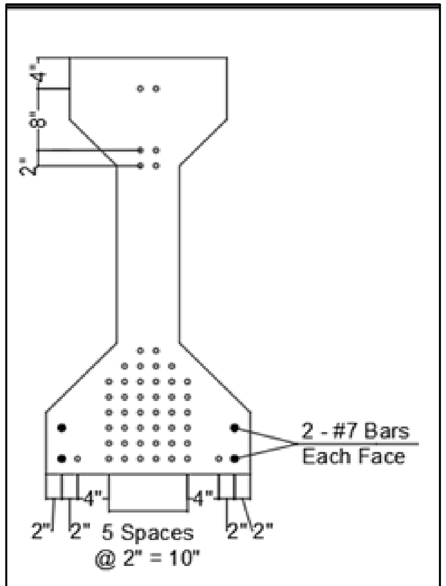
Case A



Case B



Case C



Case D

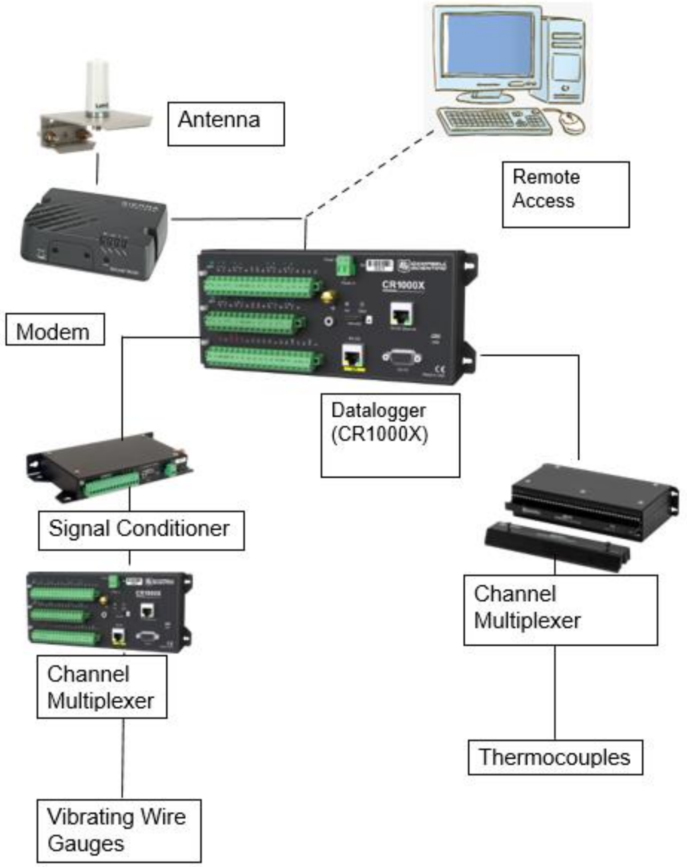
- “Traditional”
- No mild steel

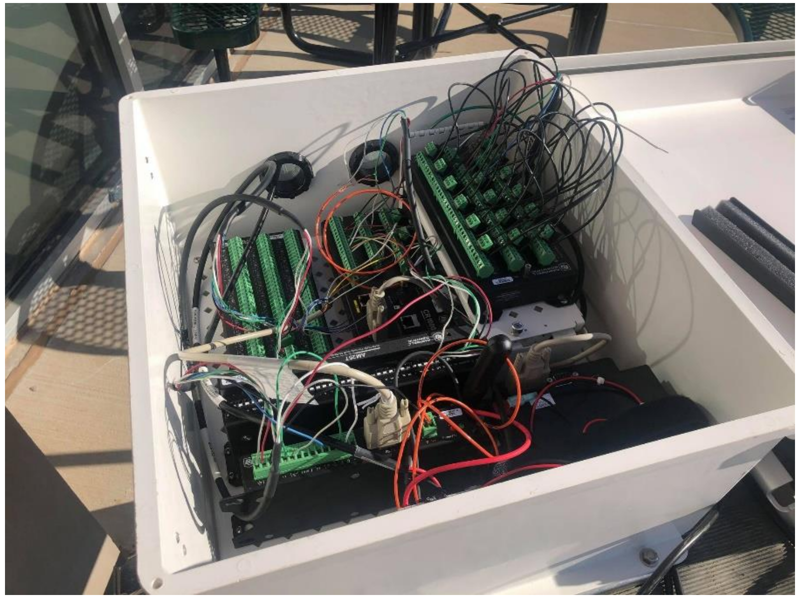
- “Traditional”
- (4) #7 bars

- “Distributed”
- No mild steel

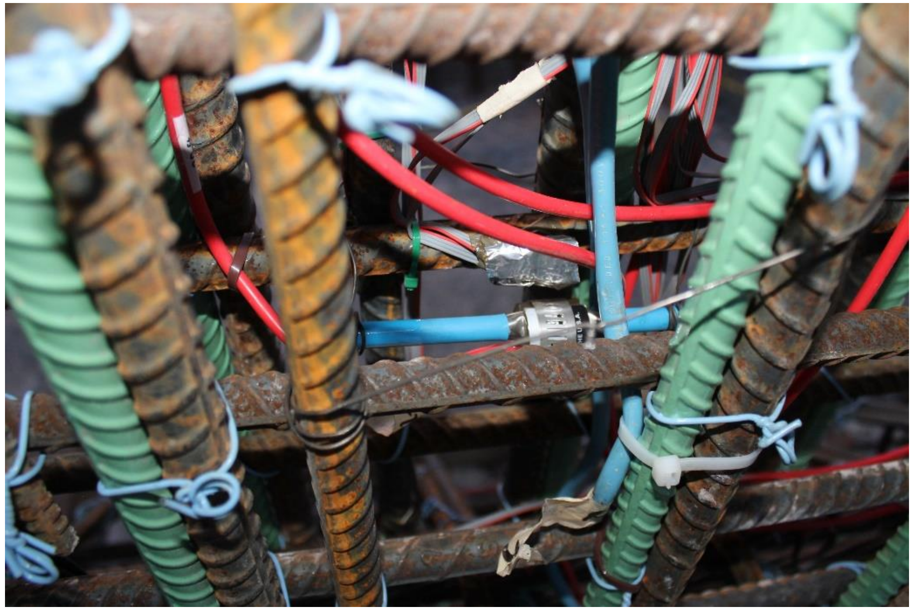
- “Distributed”
- (4) #7 bars

Design, Build and Demonstrate Instrumentation and Data Systems to Perform Structural Monitoring



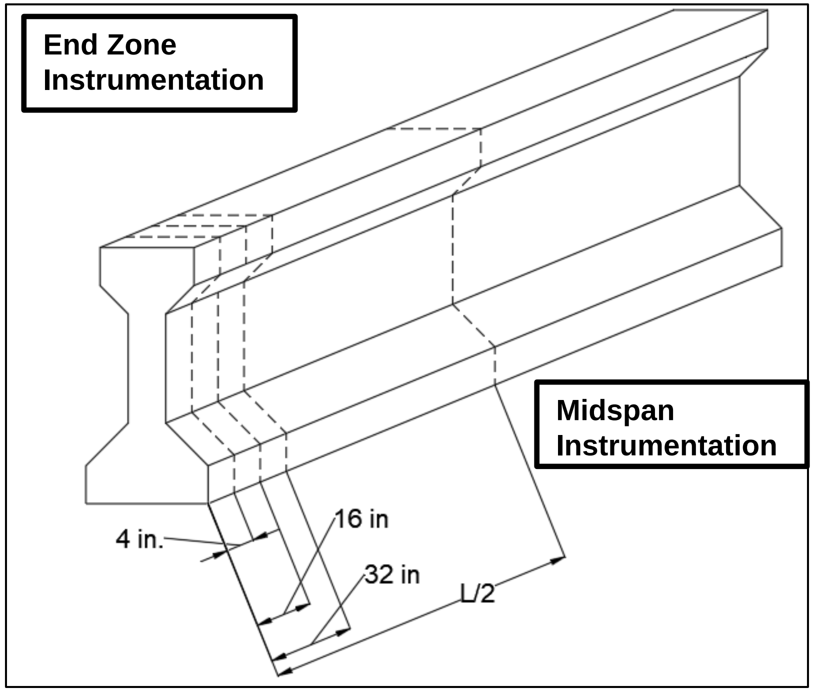


SH 4 – Prestressed Concrete Bridge – N. Canadian River – 1500 ft (450 m span)

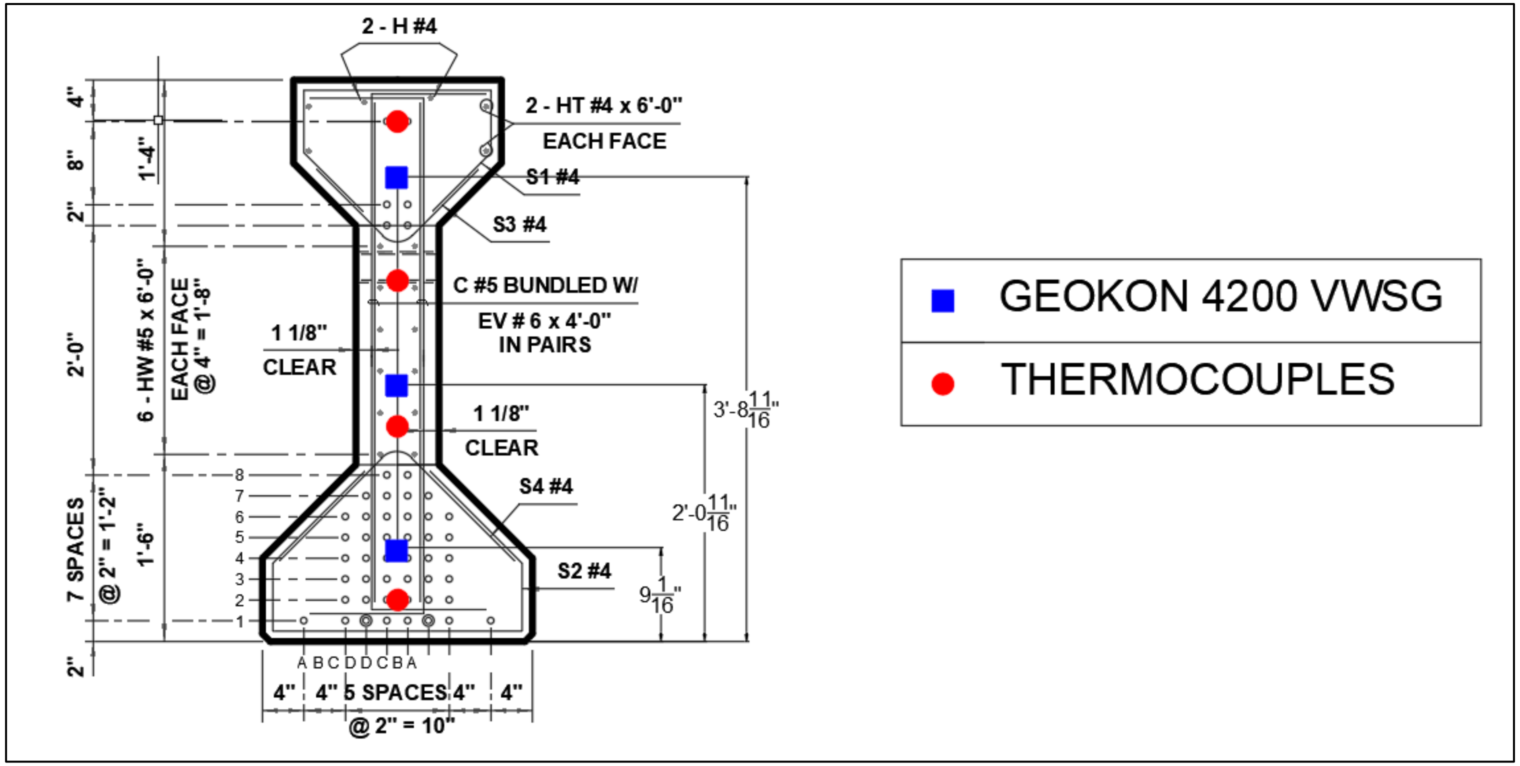


Instrumentation

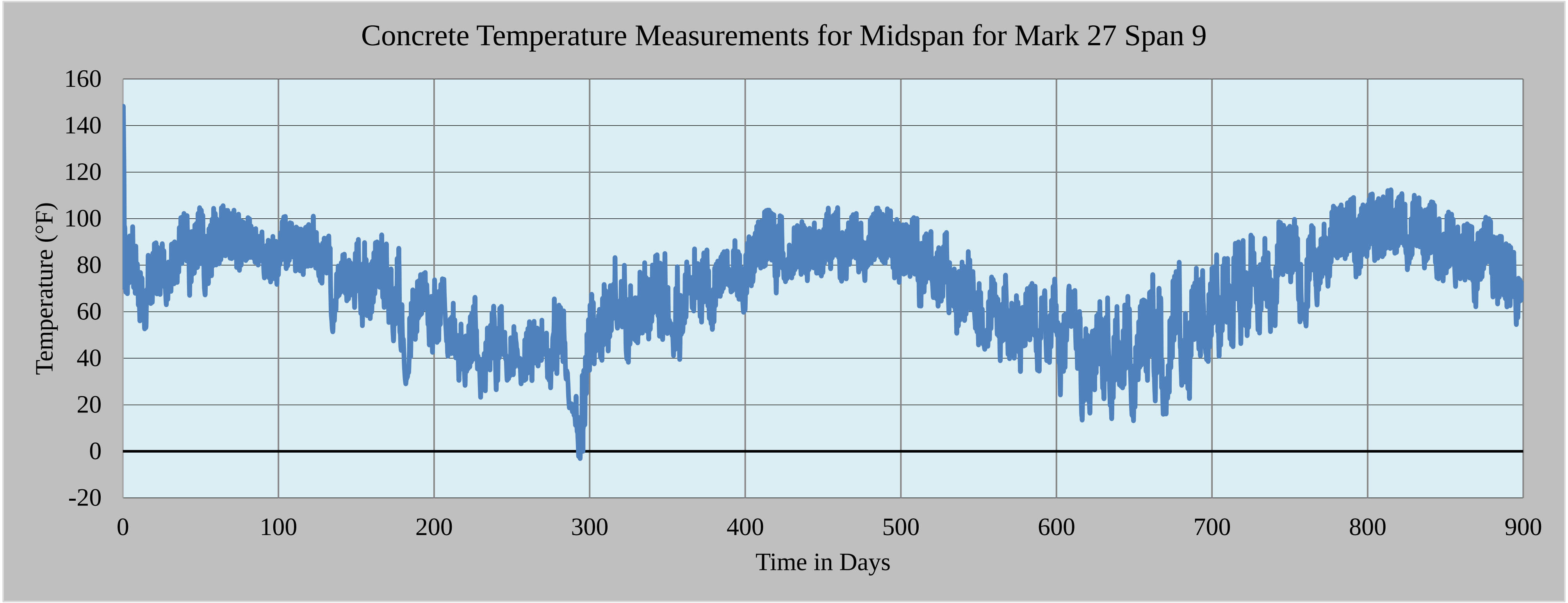
- The two girders that were selected for structural monitoring:
  - Mark 27, Span 9 (Case B)
  - Mark 42, Span 14 (Case C)
- Both girders are external and placed on the Westernmost side of the span.
- Instrumentation:
  - Vibrating wire gauges – strain
  - Thermocouples – temperature
- Strain readings can be used to measure prestress loss.
- Measurements started at casting and continue to this day.



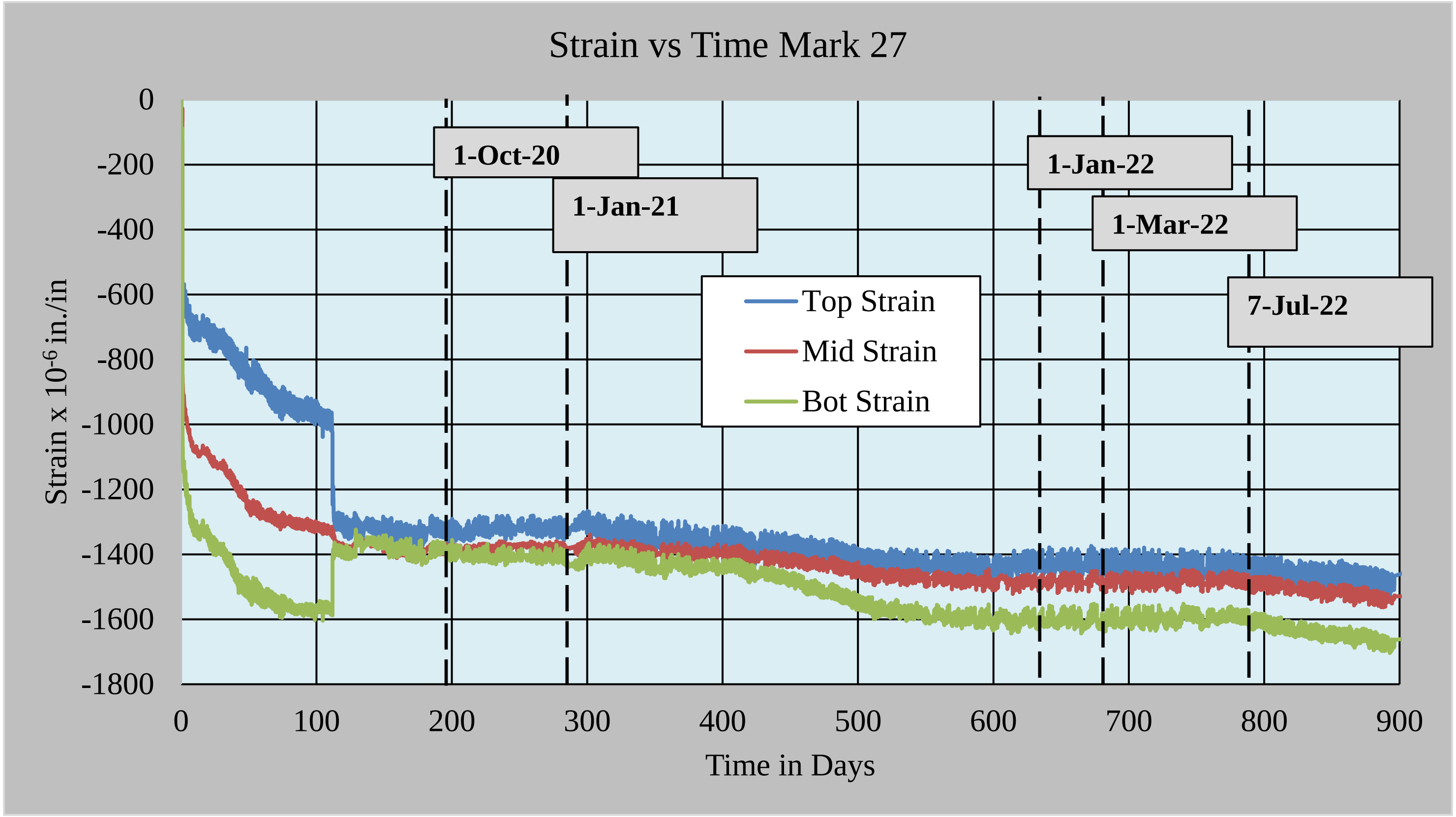
Sensor Locations



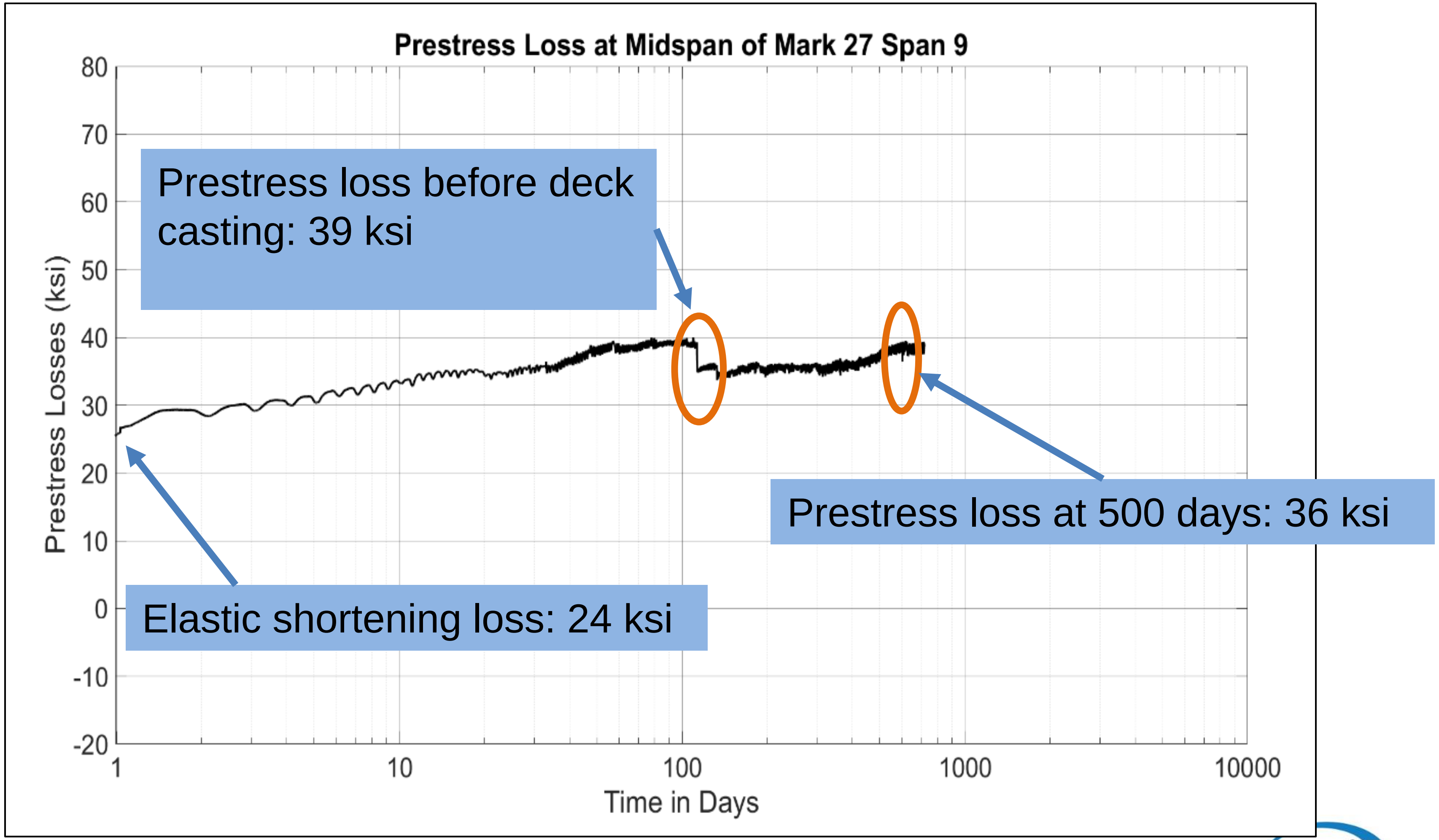
Measured Concrete Temperatures



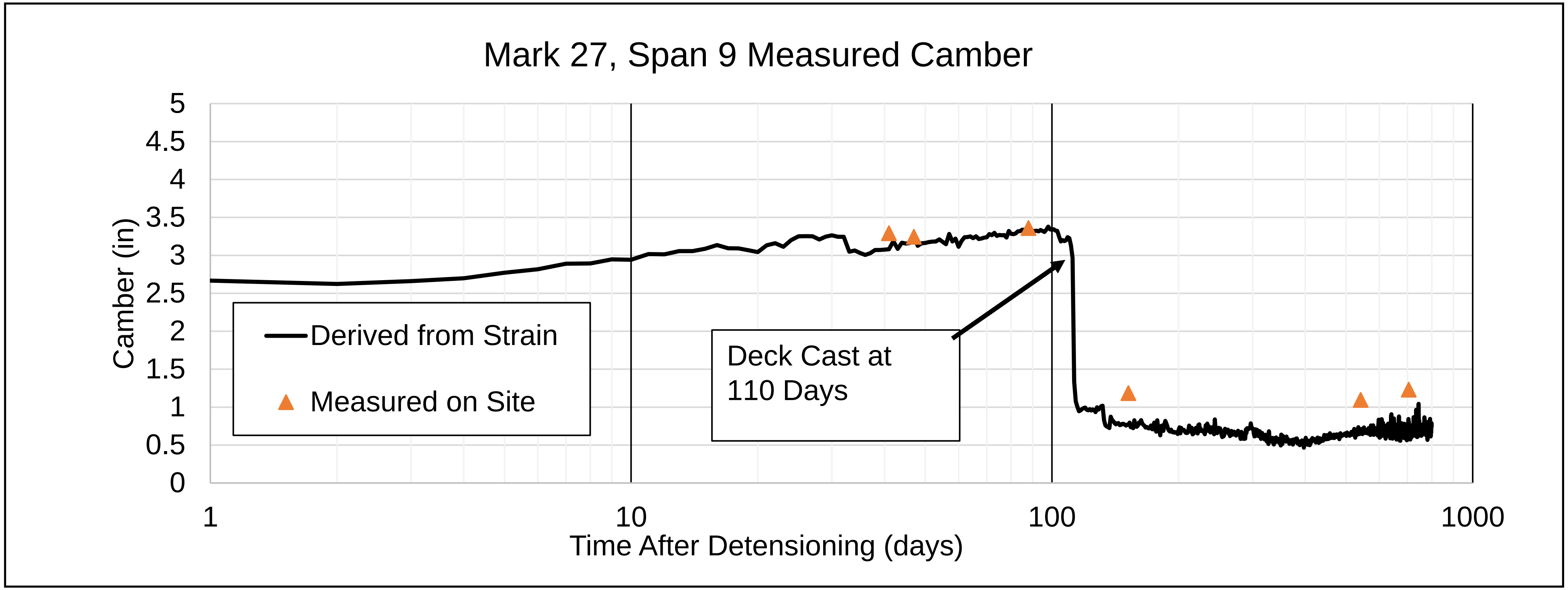
Measured Concrete Strains



Measured Prestress Losses



Comparison of Physically Measured Camber & Camber Derived From Strains



SUMMARY & CONCLUSIONS

- The structural monitoring program implemented in this research combines sensors from diverse technologies into a seamless system using a single database and user interface systems
- Dataloggers and interface systems used in this research are proven to be reliable data retrieval and monitoring system for both short term and long-term monitoring of bridges.
- Continuous monitoring of remote bridge structures can be made possible through interfacing with local network and remote cellular modem

THANK YOU