Structural Monitoring of PC Beams in the SH 4 Bridge over N. Canadian River and Recommendations for Improving Designs

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Oklahoma Department of Transportation

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.

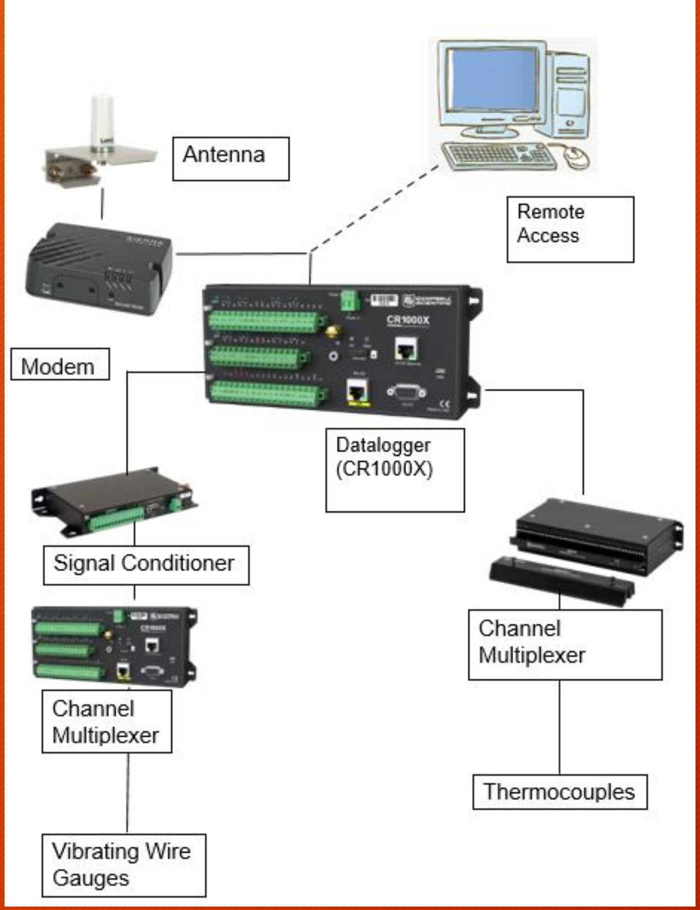
Objectives of the SH 4 PC Bridge Beam Instrumentation Project

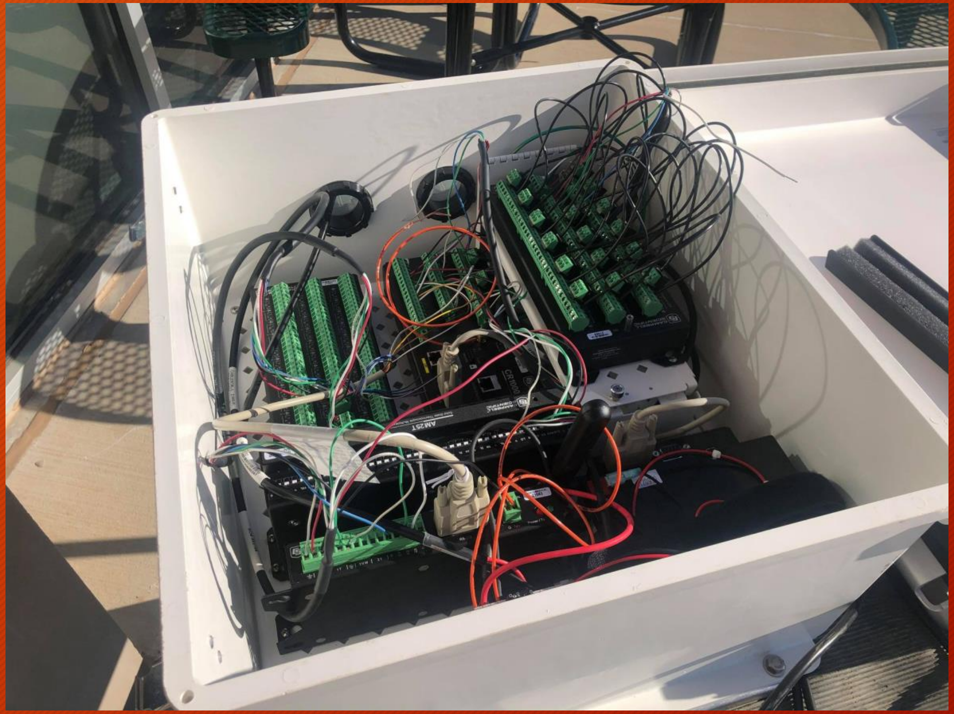
1. To Design, Build and Demonstrate the Instrumentation and Data Acquisition Systems that can achieve Structural Monitoring of Bridges Continuously 24/7/365.
2. To Investigate Variations in Reinforcing Details (both Prestressed Reinforcement and Mild Reinforcement) for effectiveness in mitigating cracking in End Regions of PC Beams.
3. To Evaluate Variations in Reinforcement Details and Assess Their Effectiveness in Reducing Cambers and Prestress Losses.
4. To Measure Concrete Strains in End Regions and at Mid-spans beginning with PC Beam Fabrication and continuing through storage and handling, transportation and erection, bridge construction and finally through In-Service Life of the Bridge.
5. To Measure Concrete Temperatures Continuously for the purpose of improving means and methods during PC Beam fabrication and to monitor temperature effects through Life In-Service.
6. Provide Recommendations for Design Improvements and Direction.

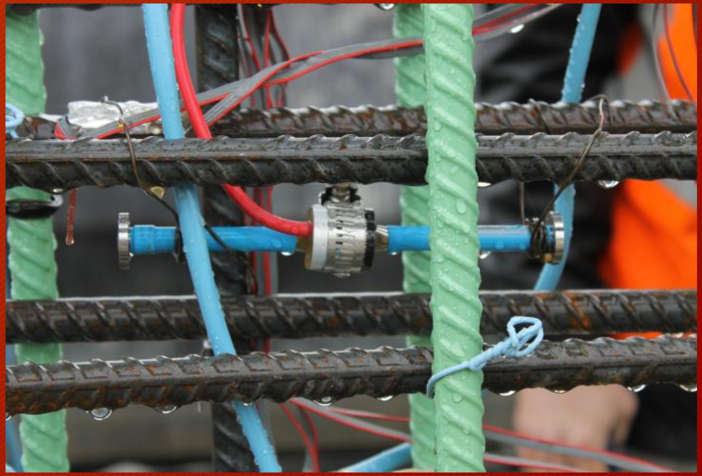
Aerial View of SH 4 Bridge Location

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

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







Control or Mitigate Cracking in End Regions of PC Beams

Control Cambers in PC Beams with variations in Reinforcement Details

Controlling or Reducing Cambers:

- Eases Construction
  - Reduces the Haunch Depth
  - Reduces Camber Variations between Adjacent PC Beams
  - Easier formwork placement
  - Eases Elevation Controls (Screeds)

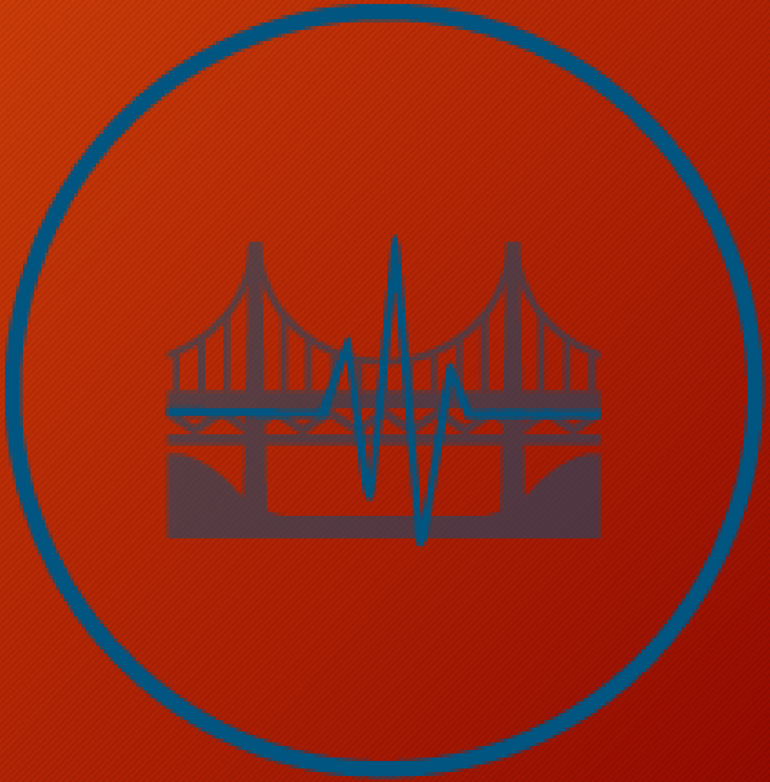
Reduce Prestress Losses

Reducing Prestress Losses will:

- Reduce the Total Number of Strands Required
- Reduce Cambers
- Easier to Control Stresses in End Regions
- Reduce the Need for Debonding
- Reduce total volume change in concrete (creep)

Structural Monitoring, or Structural Health Monitoring

- Observation and Analysis in REAL-TIME
- Periodically sampled measurements to MONITOR CHANGES to the STRUCTURE.
- ALERTS the Management Systems to POTENTIAL PROBLEMS, including changes in material properties or changes in Structural Response to Loads.
- Structural Monitoring Systems should be designed to work Hand-in-Glove with ASSET MANAGEMENT.
- Assist with Maintenance Decisions and Capital Allocation



Structural Monitoring, or Structural Health Monitoring

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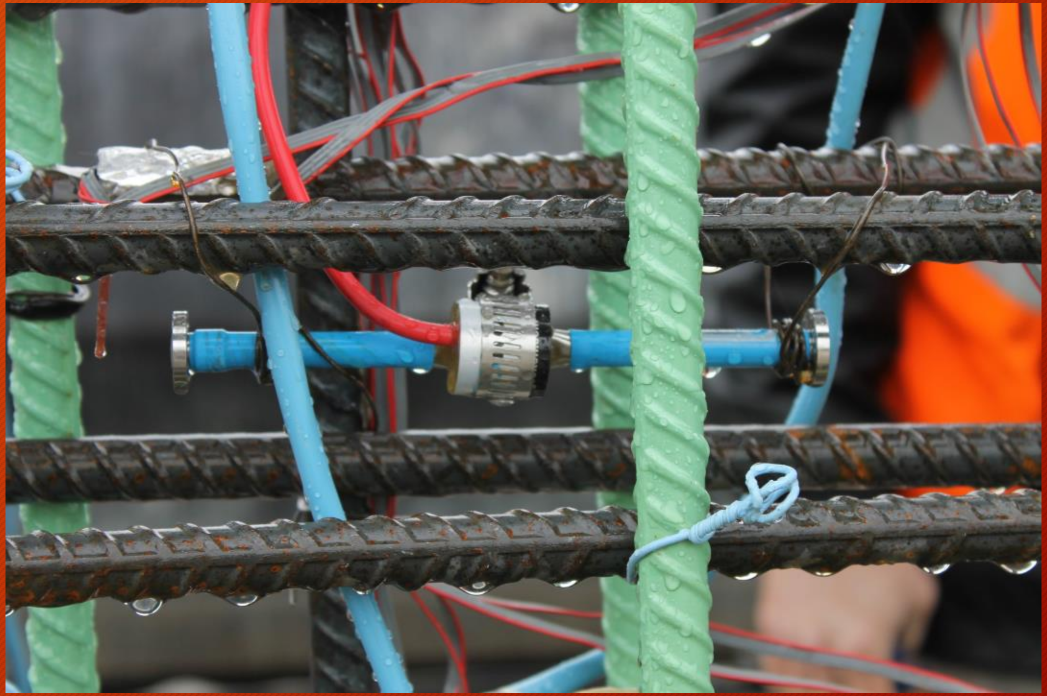
SPECIFICS TO SH 4 Bridge

- Two Bridge Beams were Instrumented:
  - Mark 27, Span 9
  - Mark 42, Span 14
- Thermocouples to Measure Temperatures
- Strain Gages in End Regions
  - Measure Prestress Losses
  - End Zone Stresses
  - High Tensile Stresses
- Strain Gages at Mid-span
  - Assess Prestress Losses
  - Measure PC Beam Cambers (indirectly)



Vibrating Wire Strain Gage near End Region of Mark 27 at CGC

Structural Monitoring, or Structural Health Monitoring

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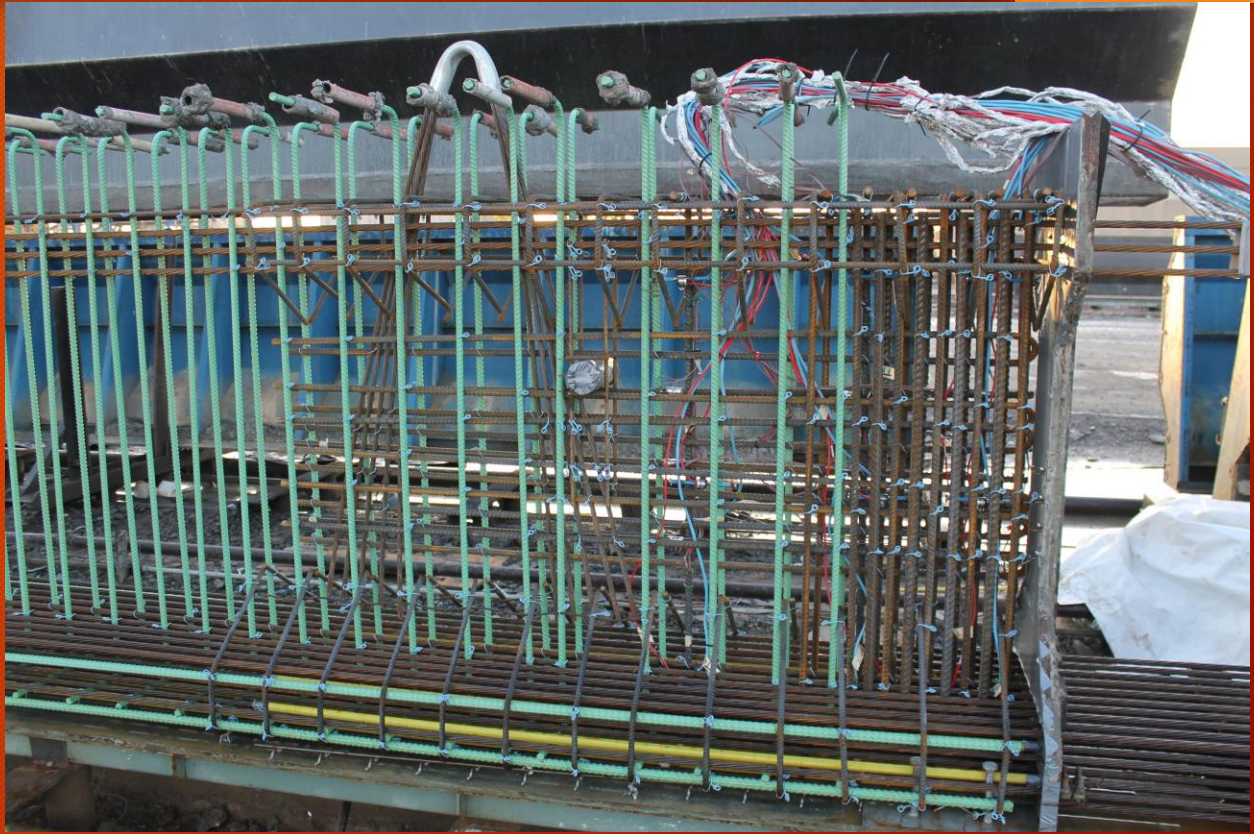
Vibrating Wire Strain Gages at Midspan of Mark 27 installed at three heights within the beam. Thermocouples measure temperatures.



North End Reinforcement and Instrumentation of PC Beam, Mark 27. Instrumentation includes Strain Gages and Thermocouples.

Project Scope

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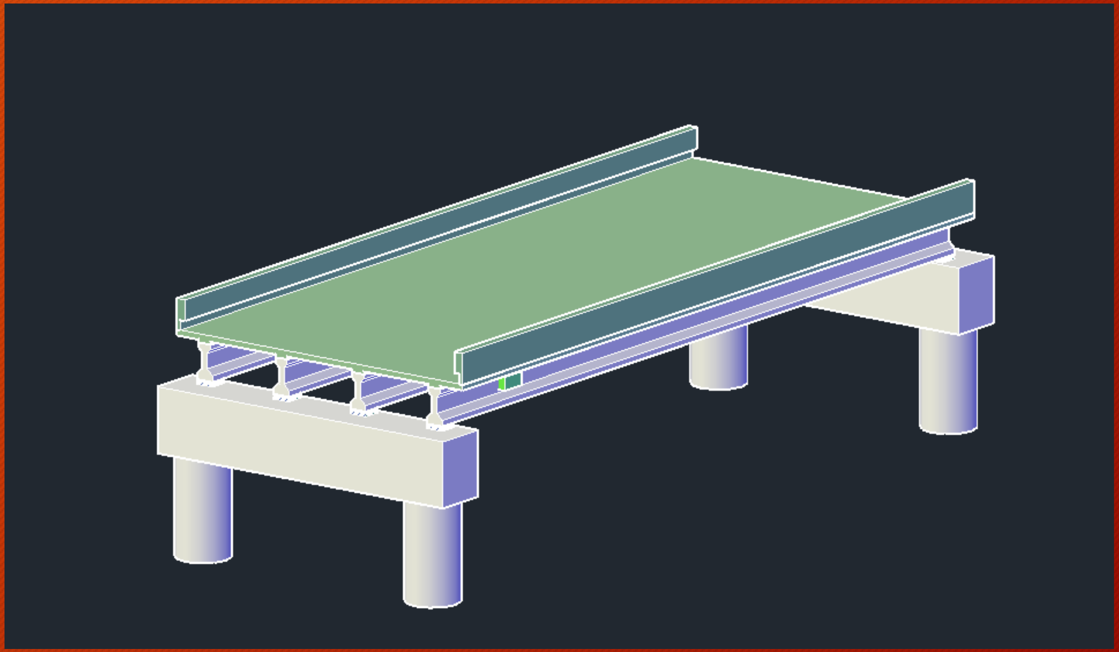
These are the Activities of the Project:

1. Design and Install Instrumentation in End Regions and Midspans of Two PC Bridge Beams
2. Design and Build Solar-Powered Data Acquisition Systems that operate remotely and transmit data via cellular technology.
3. Measure Strains and Temperatures in End Regions and Midspans of Two PC Bridge Beams.
4. Work with ODOT and ODOT Consultants on Designs for variations in Reinforcing Details, both prestressed and mild reinforcement in efforts to: a) Mitigate End Region Cracking; b) Reduce Cambers; c) Reduce Prestress Losses.
5. To Measure Cambers of the PC Bridge Beams in the Field
6. To Measures Cambers indirectly through the Instrumentation installed in PC Beams
7. To Measure prestress Losses through the instrumentation installed in PC Beams
8. To Assess the effectiveness of mild reinforcement included in the midspan regions, and within the "pre-compressed tensile zones" of the PC Beams.

Schematic of a Single Span

- SH 4 Bridge has 15 spans each approximately 100 ft. in length.
- The bridge is 40’-0 clear roadway width for two traffic lanes and two shoulders.
- Each span is supported by four (4) AASTHO-Type IV girders
- Two AASHTO Type IV girders were instrumented during fabrication.



Span by Span Variations in PC Beam Design,

VARIABLES:

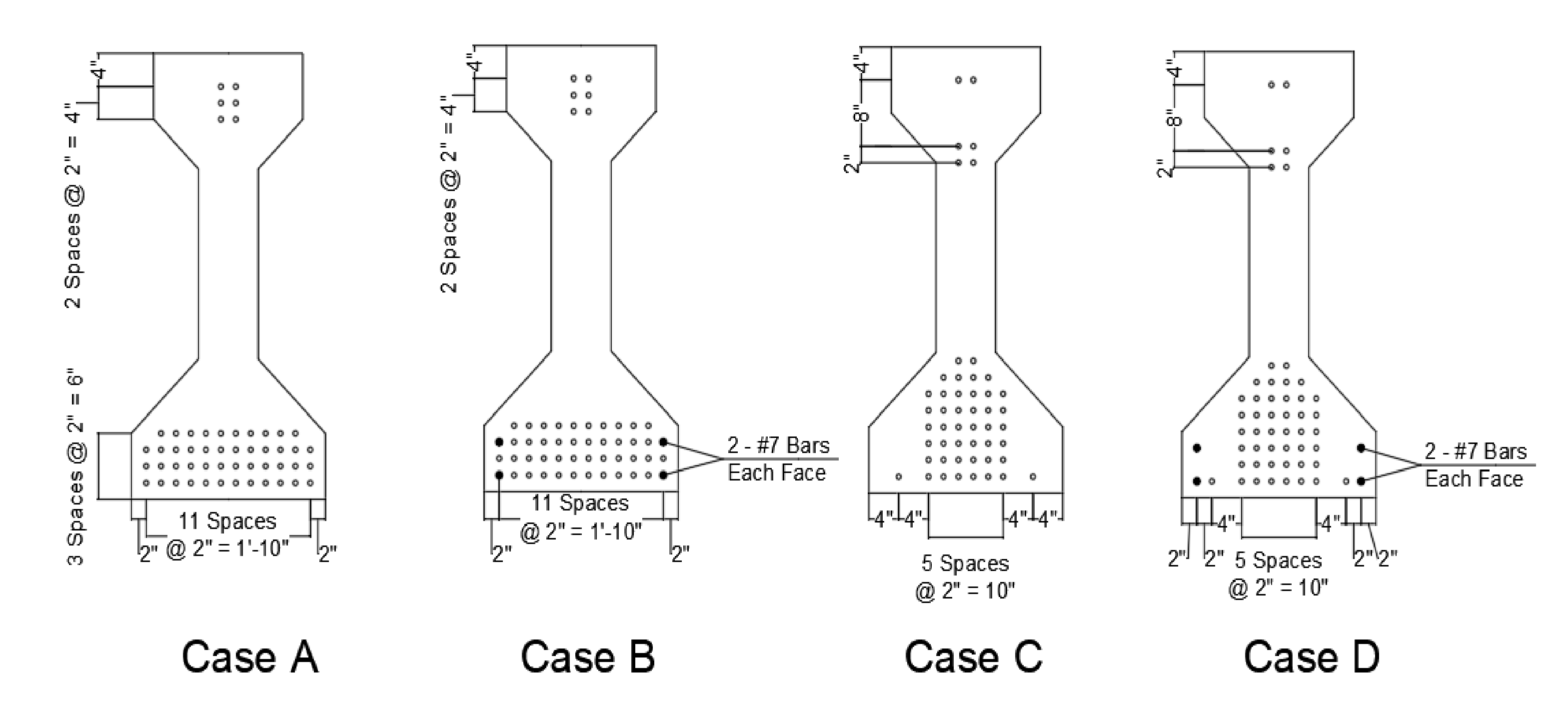
- Strand Pattern
  - No. of Strands
  - Distributed Prestress (Y or N)

    (effectively raises the c.g.s. of the prestressing steel, decreasing eccentricity).
- End Zone Reinforcement Variations:
  - Bundled Verticals
  - L-Bar
- Mild Reinforcement within the "Pre-compressed tensile zones".

	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

Design Variations of Longitudinal Reinforcement – 15 Spans with Four Basic Configurations

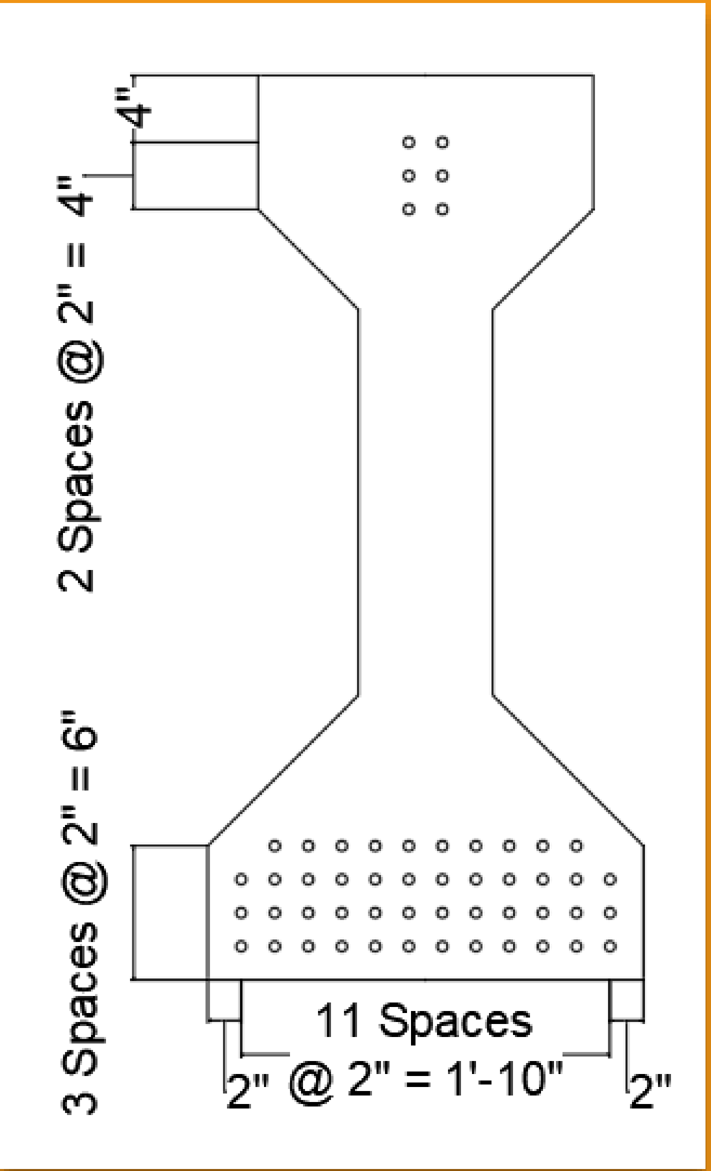
Case	"Distributed Strand Pattern"	(4) #7's Long. Rebar
A	No	No
B	No	Yes
C	Yes	No
D	Yes	Yes



Mark 27, Span 9 – Case B
Mark 42, Span 14 – Case C

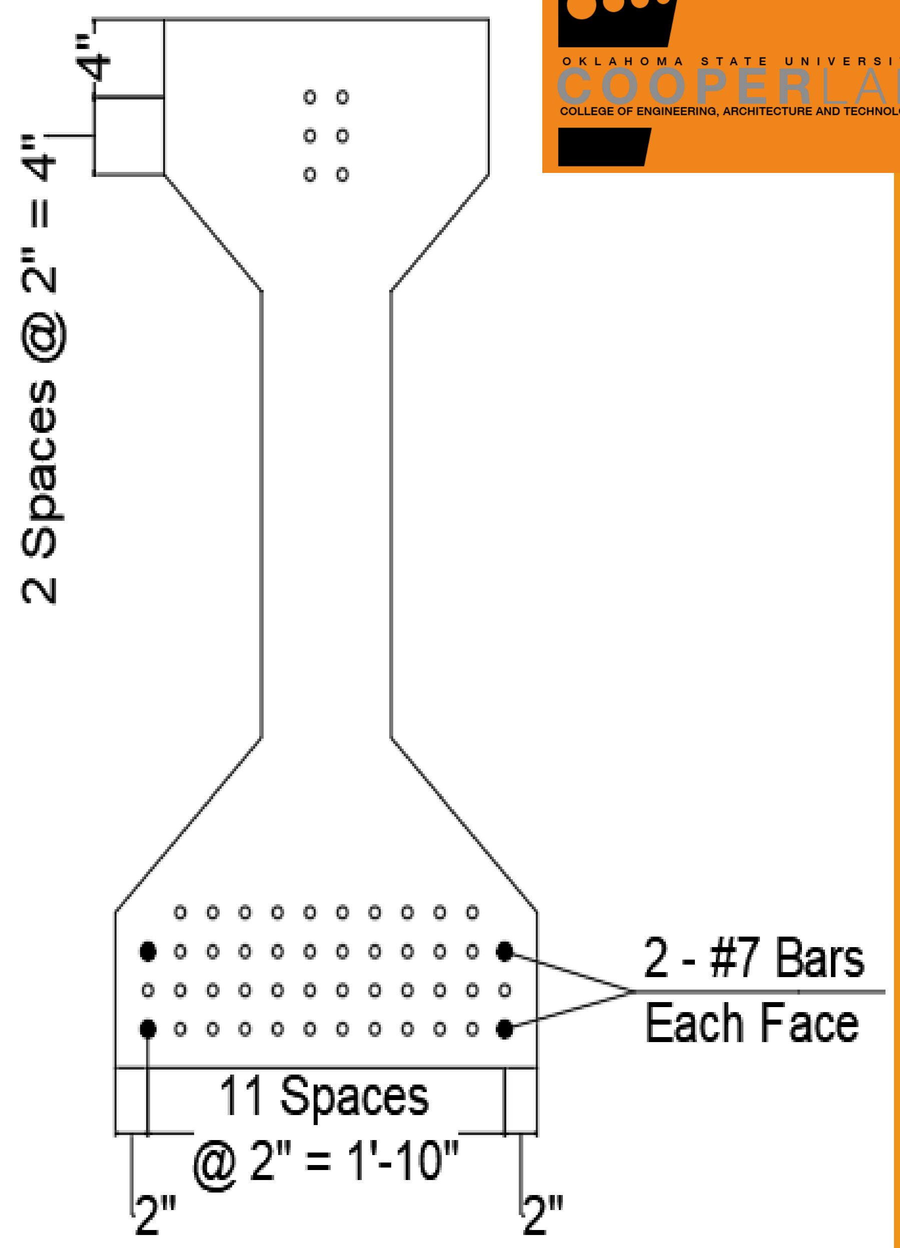
Case A: Prestressed Reinforcement @ Midspan – Spans 3, 4, 12 & 13

- Straight Strand Pattern is based on standard Oklahoma Designs (since 1997) using Fully Tensioned Top Strands
- All Strands 0.6 in. Diameter, Lo-Lax, Gr. 270
- Total No. Strands = 50
- No. Debonded Strands (@ Ends) = 12
- Prestress Eccentricity = 14.90 in.
- No Longitudinal Mild Reinforcement in Bottom Flange



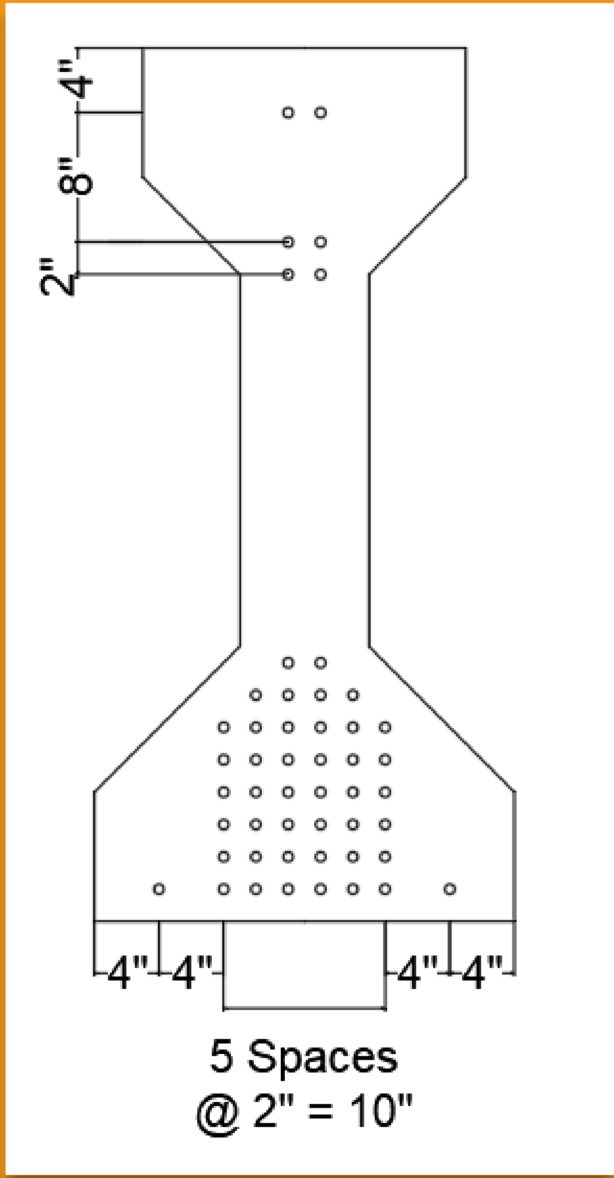
Case B: Prestressed Reinforcement @ Midspan – Spans 8 & 9

- Straight Strand Pattern is based on standard Oklahoma Designs (since 1997) using Fully Tensioned Top Strands
- All Strands 0.6 in. Diameter, Lo-Lax, Gr. 270
- Total No. Strands = 48
- No. Debonded Strands (@ Ends) = 8
- Prestress Eccentricity = 14.90 in.
- (4) #7's Mild Reinforcement in Bottom Flange
- Beam Mark 27 is located in Span 9



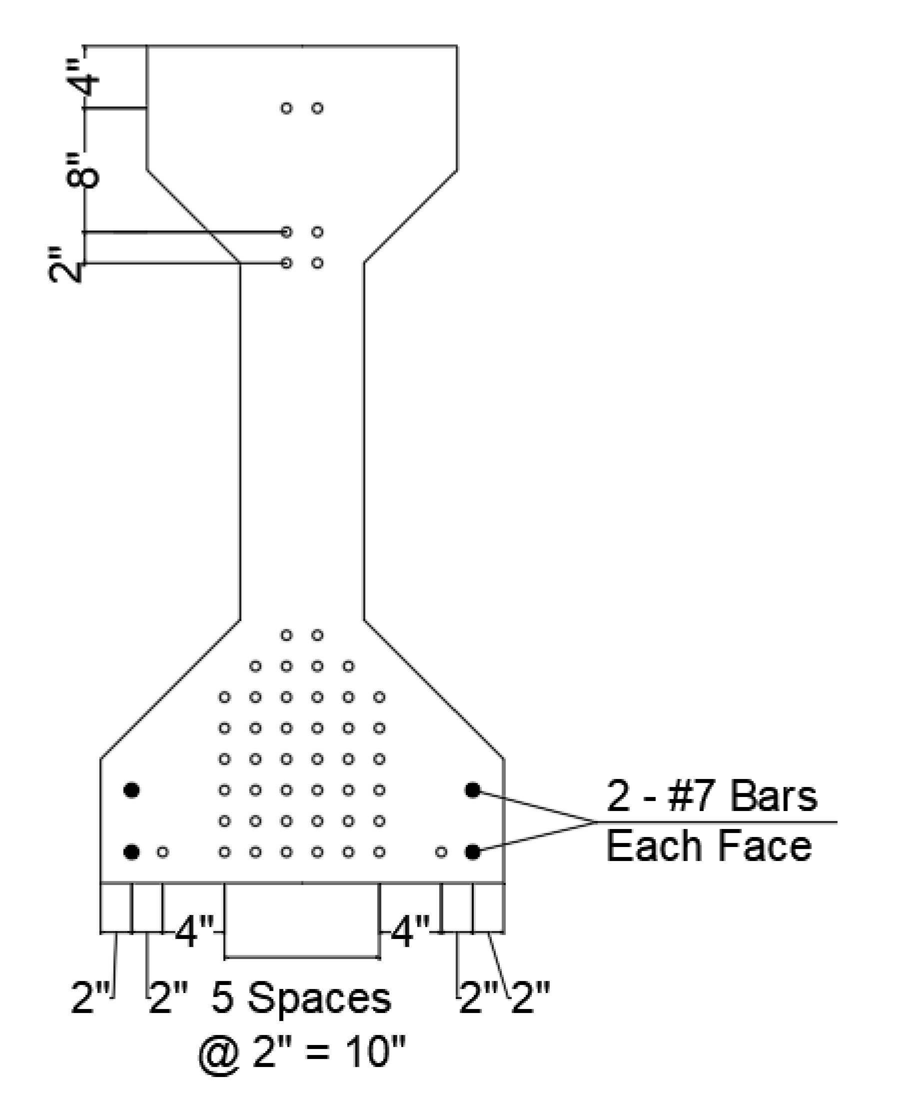
Case C: Prestressed Reinforcement @ Midspan – Spans 1, 2, 4, 5, 11, 14 & 15

- Straight Strand Pattern using Fully Tensioned Top Strands
- “Distributed Prestressing Pattern” raises CGS and reduces Prestress Eccentricity
- All Strands 0.6 in. Diameter, Lo-Lax, Gr. 270
- Total No. Strands = 50
- No. Debonded Strands (@ Ends) = 2
- Prestress Eccentricity = 12.25 in.
- No Longitudinal Mild Reinforcement in Bottom Flange
- Beam Mark 42 is in Span 14



Case D: Prestressed Reinforcement @ Midspan – Spans 6 & 7

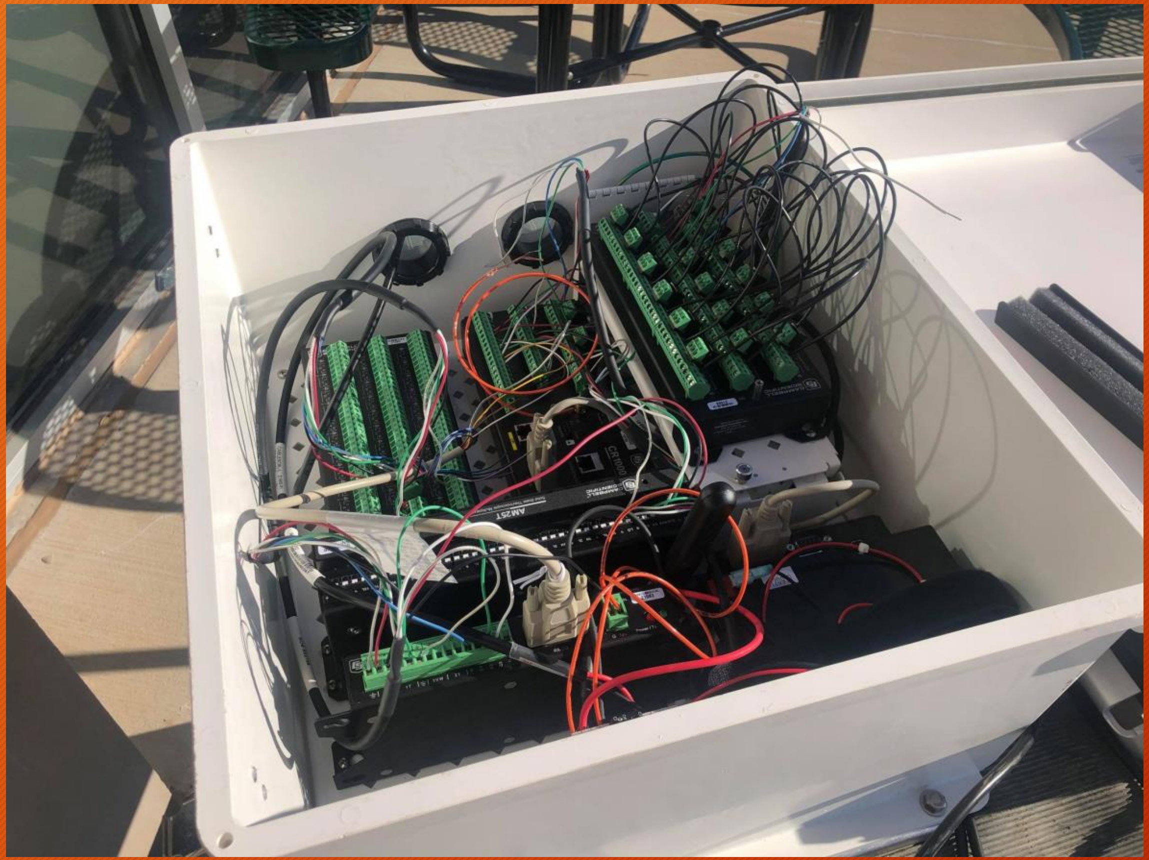
- Straight Strand Pattern using Fully Tensioned Top Strands
- “Distributed Prestressing Pattern” raises CGS and reduces Prestress Eccentricity
- All Strands 0.6 in. Diameter, Lo-Lax, Gr. 270
- Total No. Strands = 50
- No. Debonded Strands (@ Ends) = 2
- Prestress Eccentricity = 12.25 in.
- (4) #7’s Mild Reinforcement in Bottom Flange

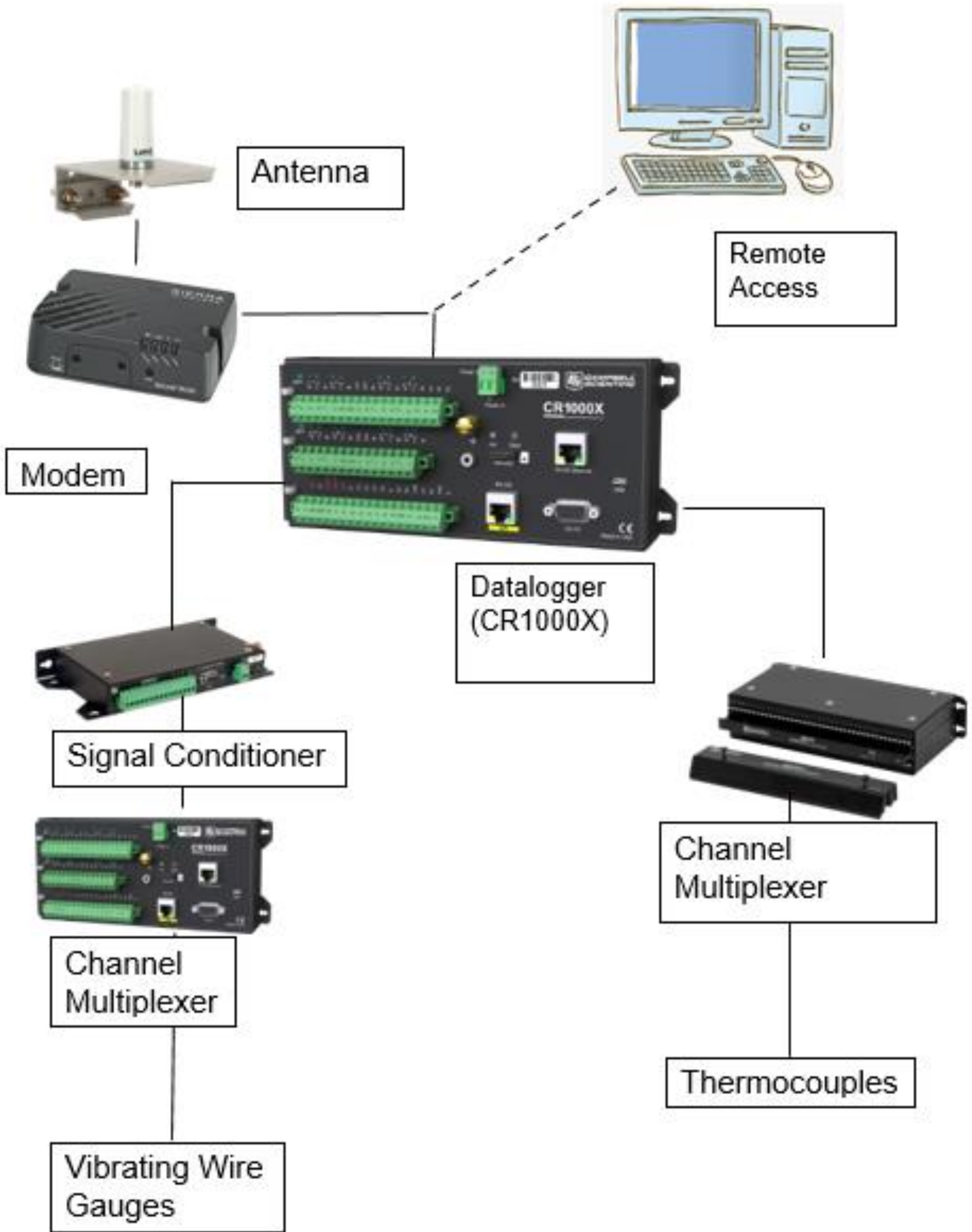


Cross Section Properties of Instrumented Beams

Cross-Section Properties									
	Type IV Gross Properties		Mark 27 Span 9 (Case B)			Mark 42 Span 14 (Case B)			
A (area)	789	in^2	N	48		N	50		
h	54	in	e	14.40	in	e	12.57	in	
y_b	24.67	in	A_s	2.4	in^2	A_s	0	in^2	
I_{xx} (Gross)	260,730	in^4	A_{tr}	881	in^2	A_{tr}	833	in^2	
f'_c	10.0	ksi	$(y_b)_{tr}$	23.56	in	$(y_b)_{tr}$	23.57	in	
f_{ci}	7.5	ksi	I_{tr}	273,760	in^4	I_{tr}	268,510	in^4	
E_p	28,500	ksi							

Data Acquisition Summary:





Data Acquisition System - Summary

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- Solar Panel charges the battery during daylight hours.
- The enclosure box contains the data logger, battery, power supply, signal conditioners and multiplexers.
- The wireless antennae is contained within the enclosure box.
- Instrumentation is connected through wiring to the multiplexers.
- The instrumentation and data systems are robust and demonstrate that the capability to instrument PC Bridge Beams, and to remotely and continuously monitor performance in real-time.
- Sampling frequency is every 2 min.
- Data is transmitted continuously via cellphone technology.

Photographs of the Bridge

View looking East at Pier 14 and the Solar Panel. Span 15 is over an overflow creek. The data logger and wiring for instrumentation is visible on Span 14.

View looking North along the west side of SH 4 Bridge. Span 8 is over the main river channel.

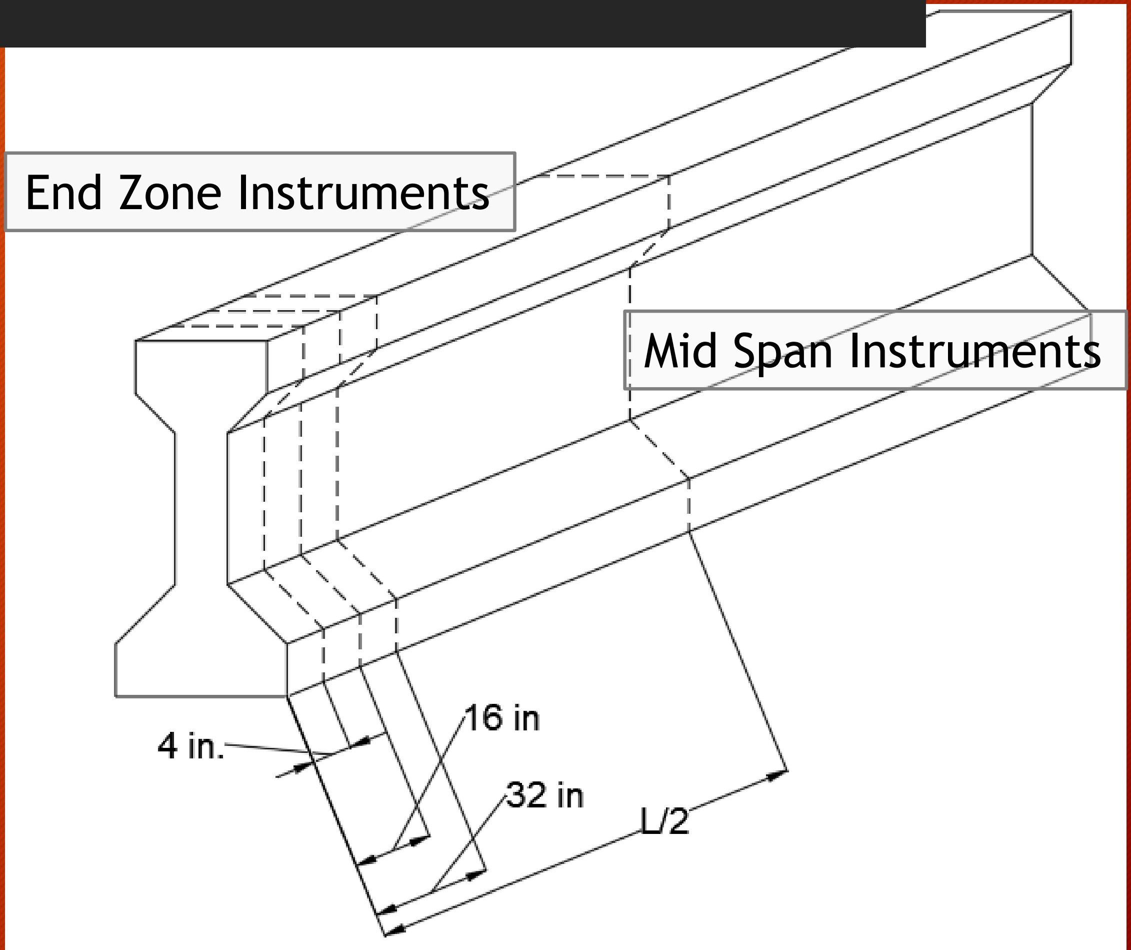
Remote Data Acquisition

- Instrumentation connects to a solar panel powered data logger that transmits data 24/7/365.
- Data has been collected continuously from instruments installed 24 hrs. in advance of PC Beam casting, and through beam fabrication, form removal, strand de-tensioning, lifting and storage at the PC plant, transportation, erection, bridge construction, and through life in-service.
- Data is available for analysis for strains, stresses, temperature variations, variations in camber, and very soon, analysis understatic and moving loads.

Sensor Locations:

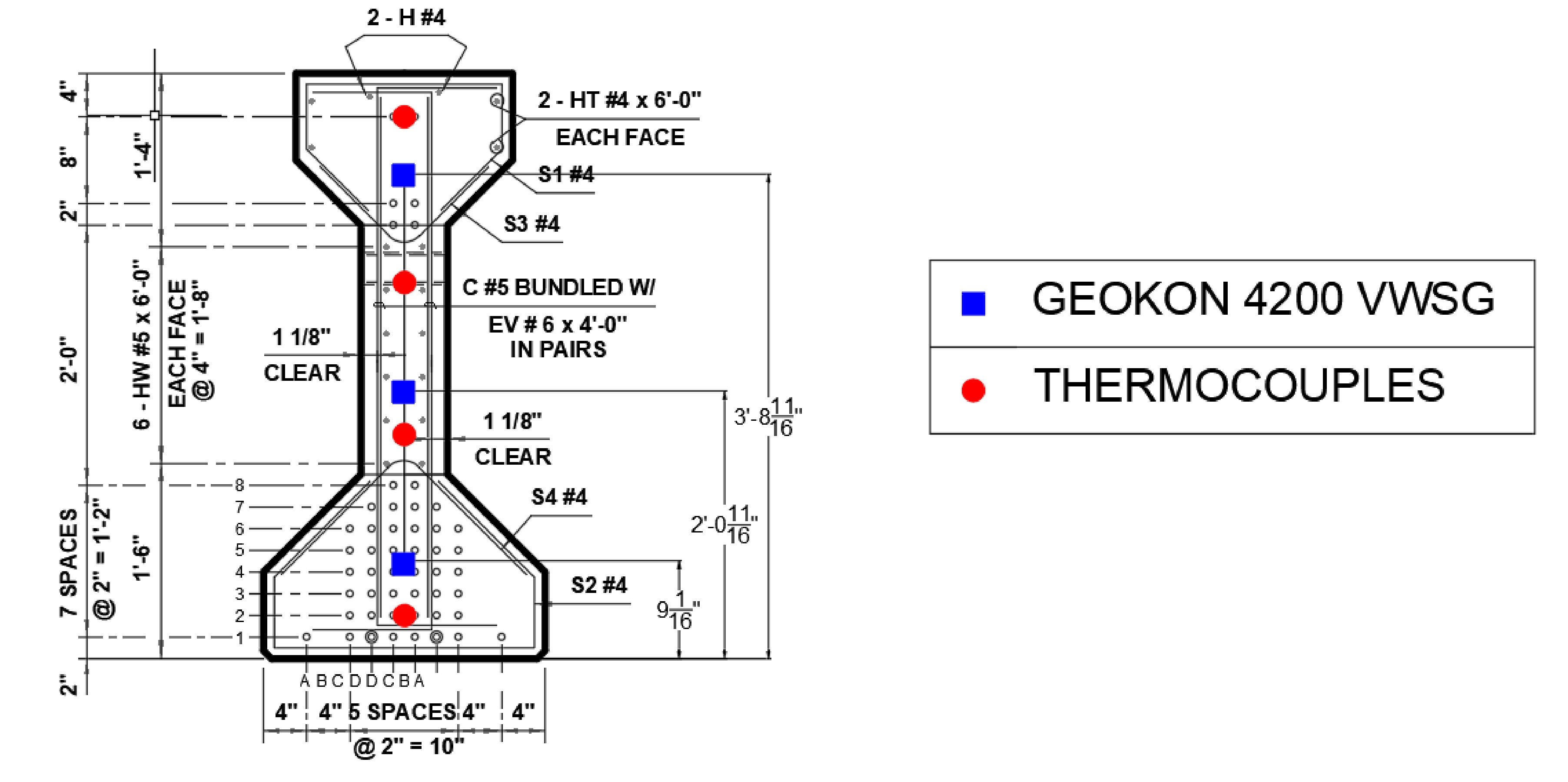
Sensors include strain gages for steel and concrete, thermocouples and strand-o-meter to measure strains directly in steel prestressing strands.

- Sensors were installed in 4 Different locations:
  - @ 4.0 in. from the end region.
  - @ 16.0 in. from the end region.
  - @ 32.0 in. from the end region.
  - @ midspan of the girder.



Instrumentation Layout – Cross Section Elevation

- **4 Thermocouples**:
  - Top flange
  - Top web
  - Bottom web
  - Bottom flange
- **3 Vibrating Wire Gages**:
  - Concrete stains in the top flange
  - Concrete strains in the CGS.
  - Concrete strains in the bottom flange.



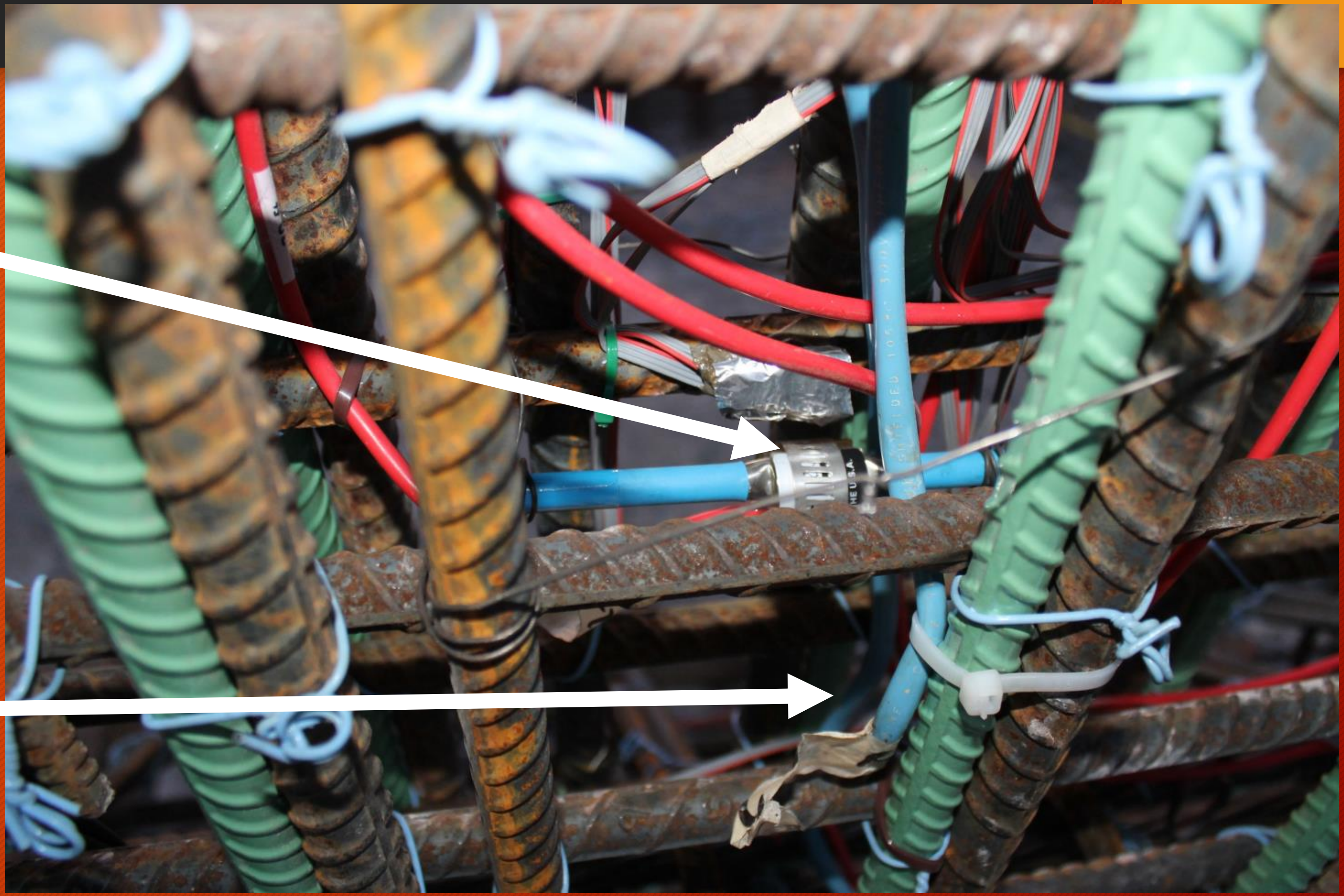
Beam Fabrication - Installation of Instruments

The photograph shows the installation of the sensors in Mark 27 (Span 9).

Beam Fabrication – Install Instrumentatation

- Vibrating wire gauges installed in the web in the end region for Mark 42 Span 14.

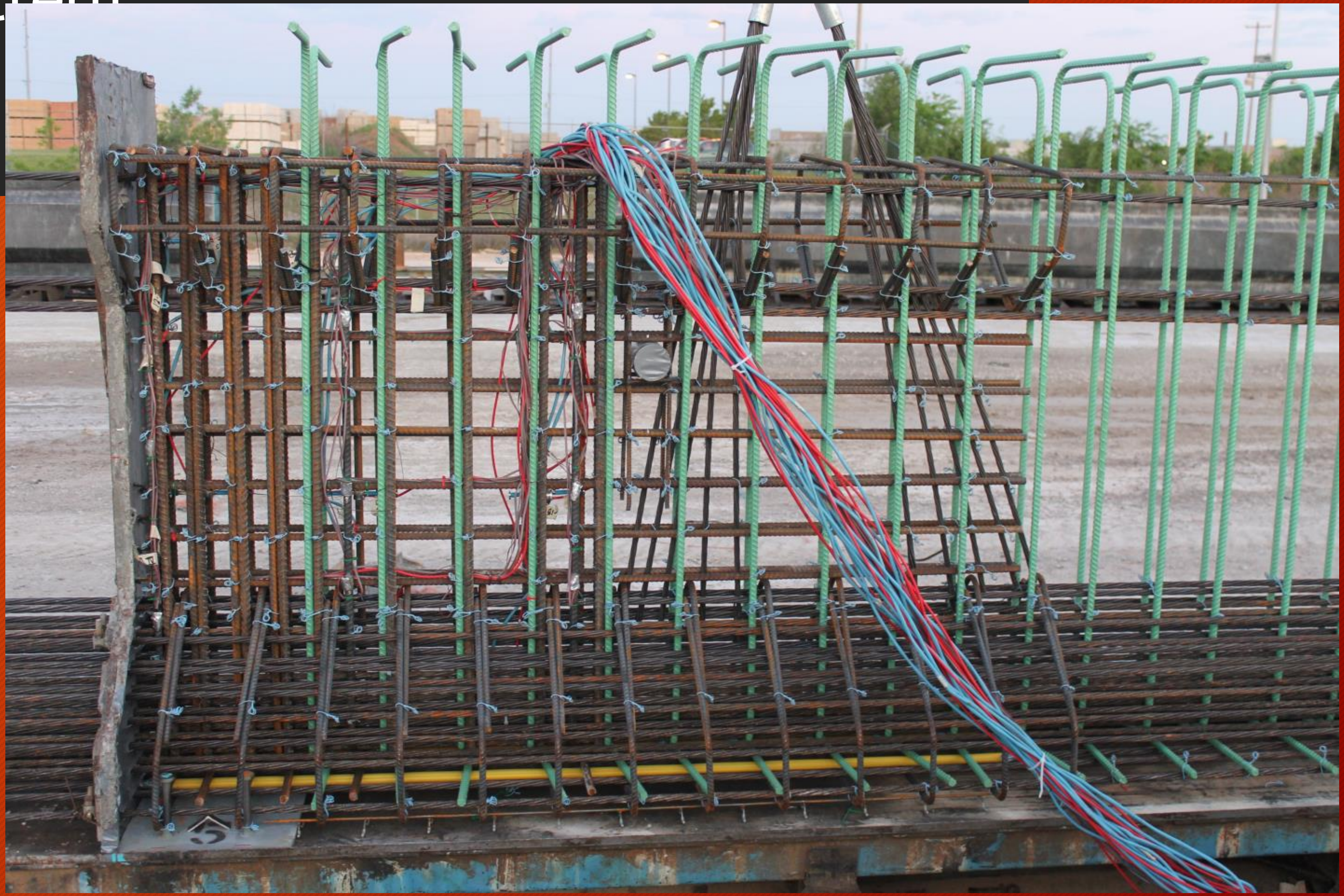
- Thermocouple installed prior concrete casting



Beam Fabrication – Mark 42 (Span 14)

North End of Beam Mark 42, Features include:

- "Distributed" Prestressing Strand Pattern
- Bundled Vertical Reinforcement
- Horizontal Web Reinforcement



- All the sensors were installed and attached prior girder casting.
- The sensors started collecting data 24 h before girder cast.

Handling, Storage, Transportation, Erection, Bridge Construction

- Solar panel (transportation only)
- Wire Sensors
- Enclosure Box that contains the Data Acquisition system
- Mark 27 Span 9

Handling, Storage, Transportation, Erection, Bridge Construction

Monitoring – Short Term

Temperature & Strains & Prestress Losses

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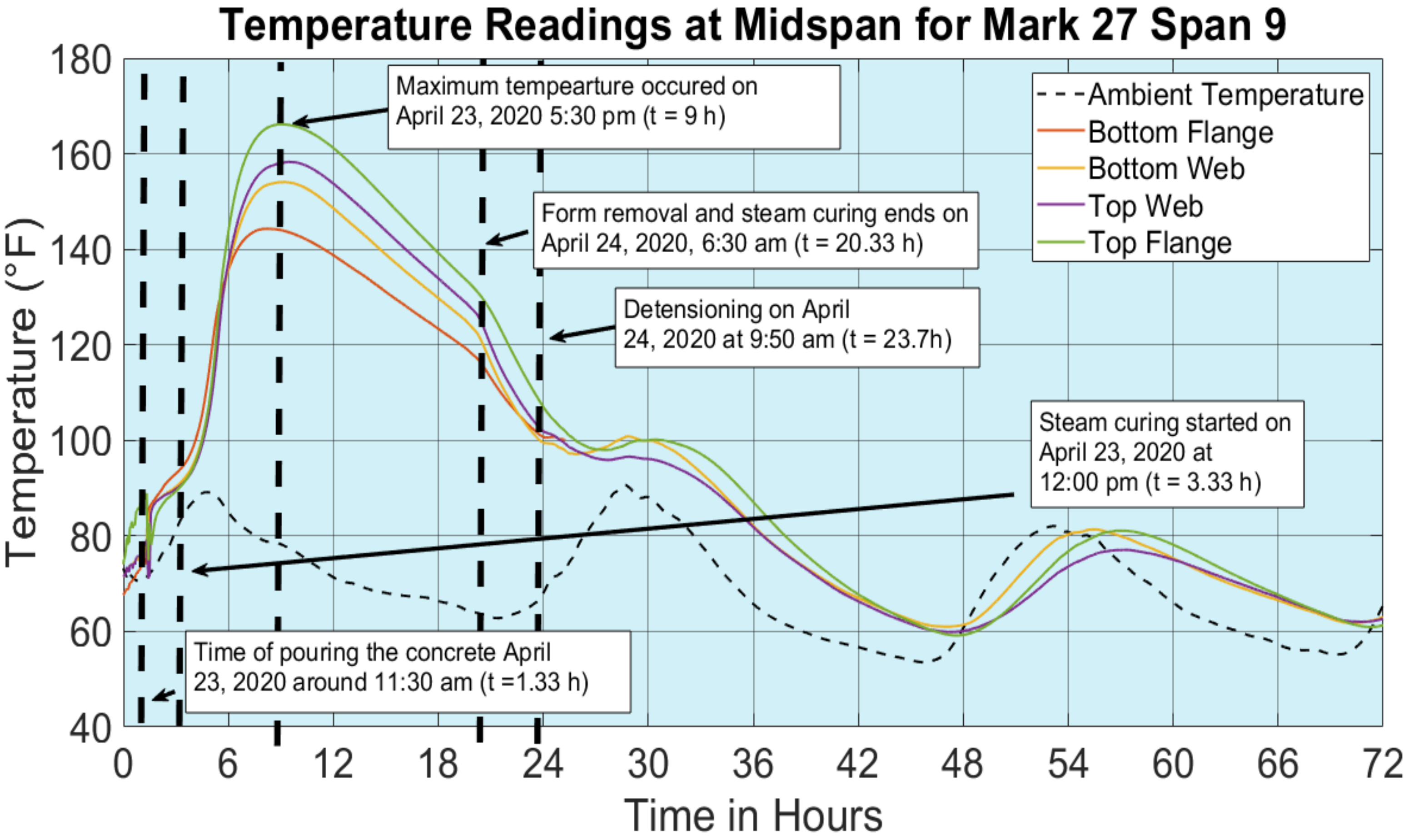
Temperature Data during Fabrication (Early Age Temperature Mark 27 Span 9)

- Concrete Cast = April 23, 2020 @ 11:30 am.
- Maximum temperature was measured in the top flange, ***T_{max} = 168°F***
- Maximum temperature @ 5:30 pm, 6 hrs. after concrete casting
- Temperature differential is 20°F from Top to Bottom Flange
- Cooling accelerates after form removal.
- Cracking occurs in top flanges after form removal prior to de-tensioning.



Temperature Data during Fabrication (Early Age Temperature Mark 42 Span 14)

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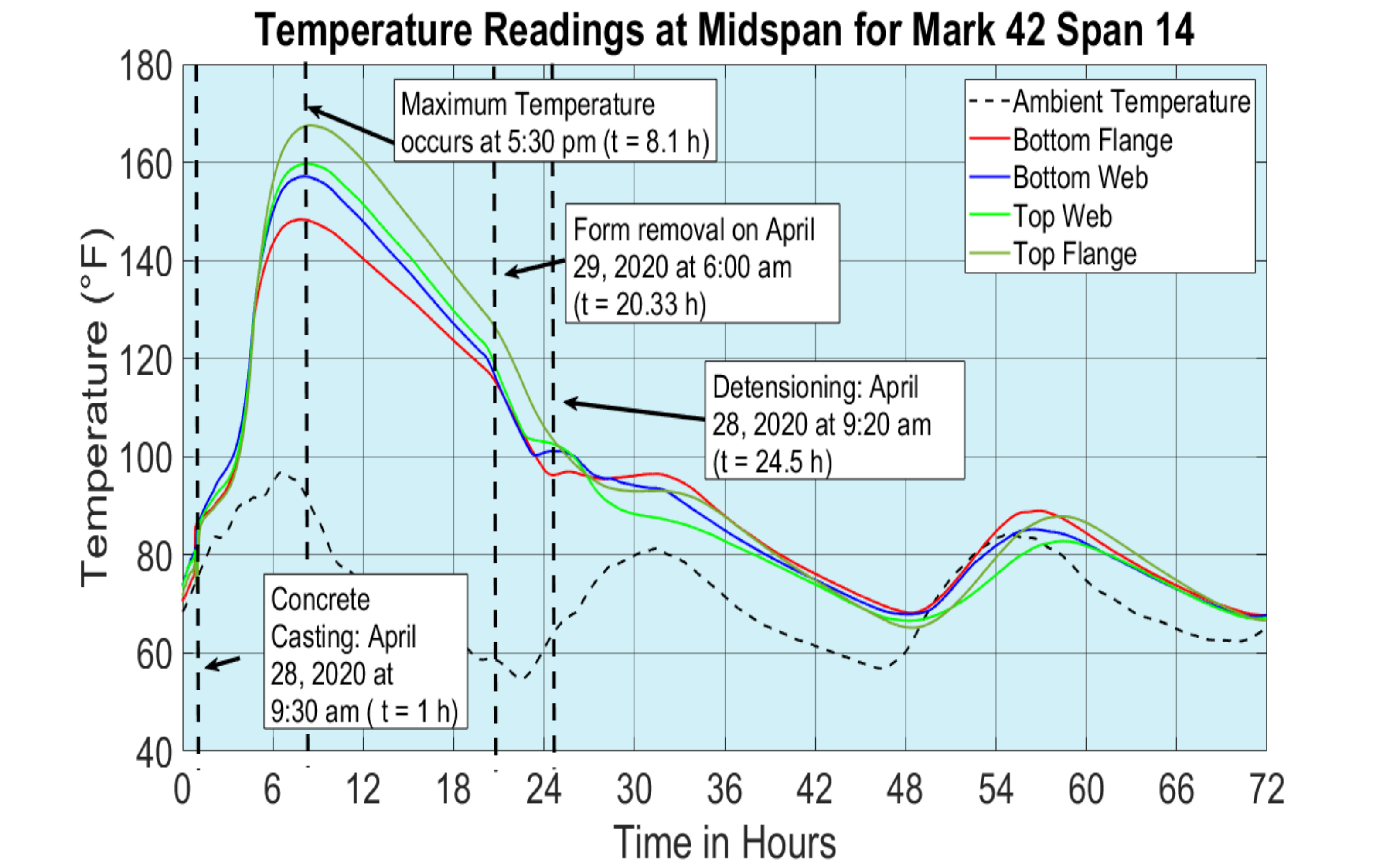
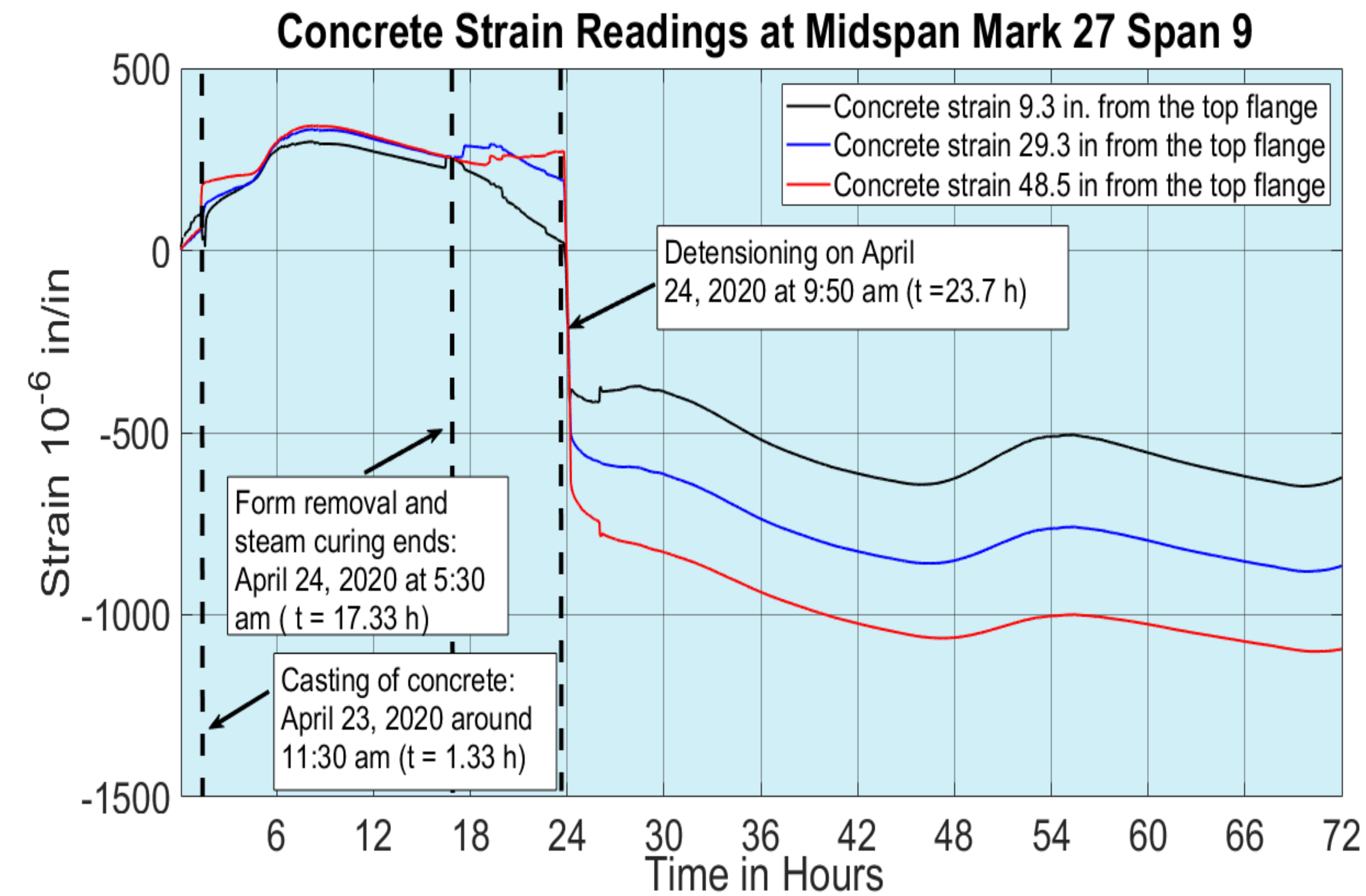
- Concrete Cast = April 23, 2020 @ 9:30 am.
- Maximum temperature was measured in the top flange, T_{max} = 168°F
- Maximum temperature @ 5:30 pm, 8.1 hrs. after concrete casting
- Temperature differential is 20˚F from Top to Bottom Flange
- Cooling accelerates after form removal.
- Cracking occurs in top flanges after form removal prior to de-tensioning.



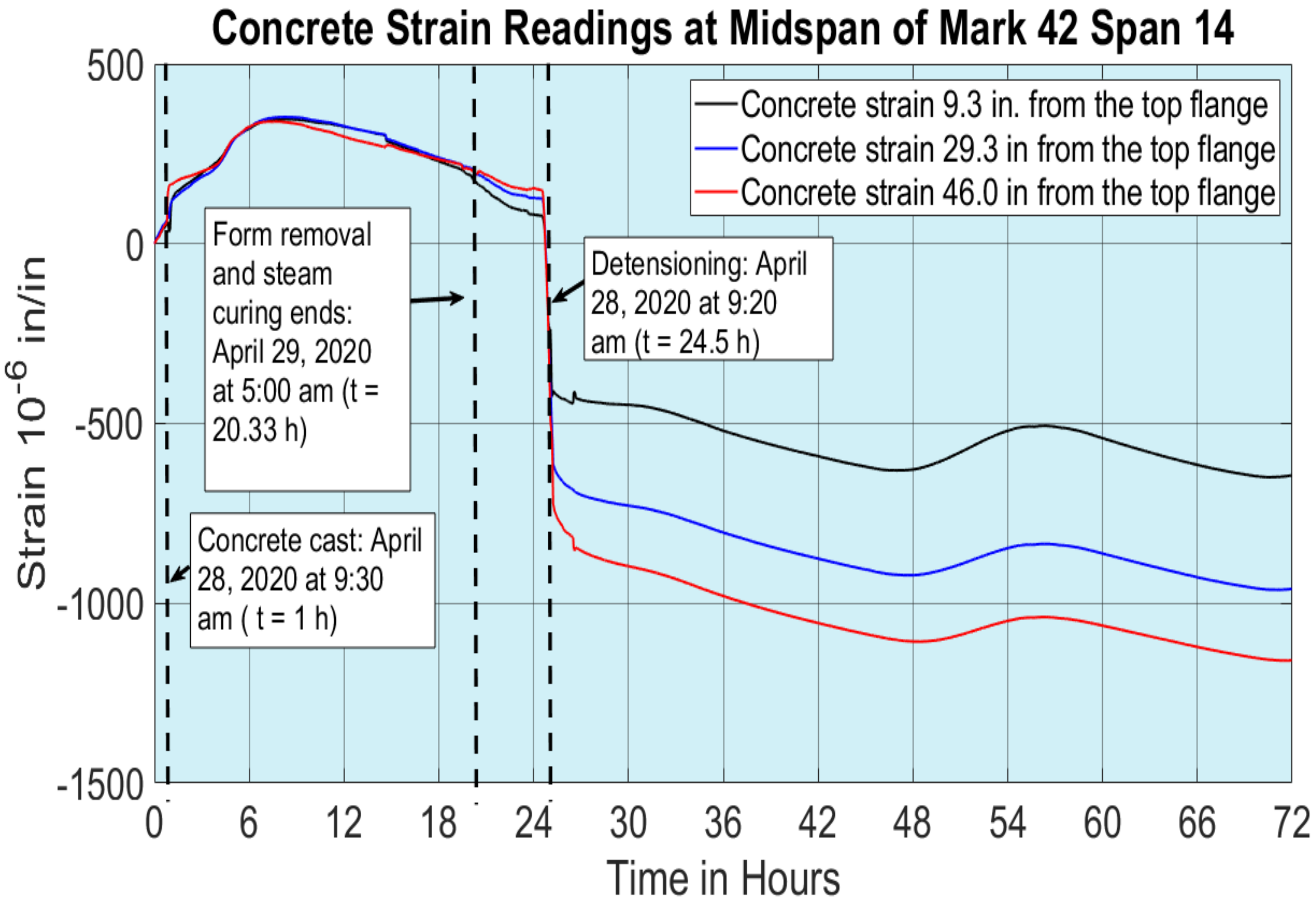
Concrete Strains at Midspan - (0 to 72 hrs. Mark 27 Span 9)

- Concrete Lengthens (strains increase) during concrete hydration.
- Concrete Strains do not decrease (shorten) commensurate with temperature change - this builds residual tension stress.
- Greater shortening occurs in top flange prior to de-tensioning.
- Concrete Shortens (strains decrease) with de-tensioning
- Elastic Shortening Loss, ES ≈ 1070 με.
- Larger compression strains occur in the bottom flange

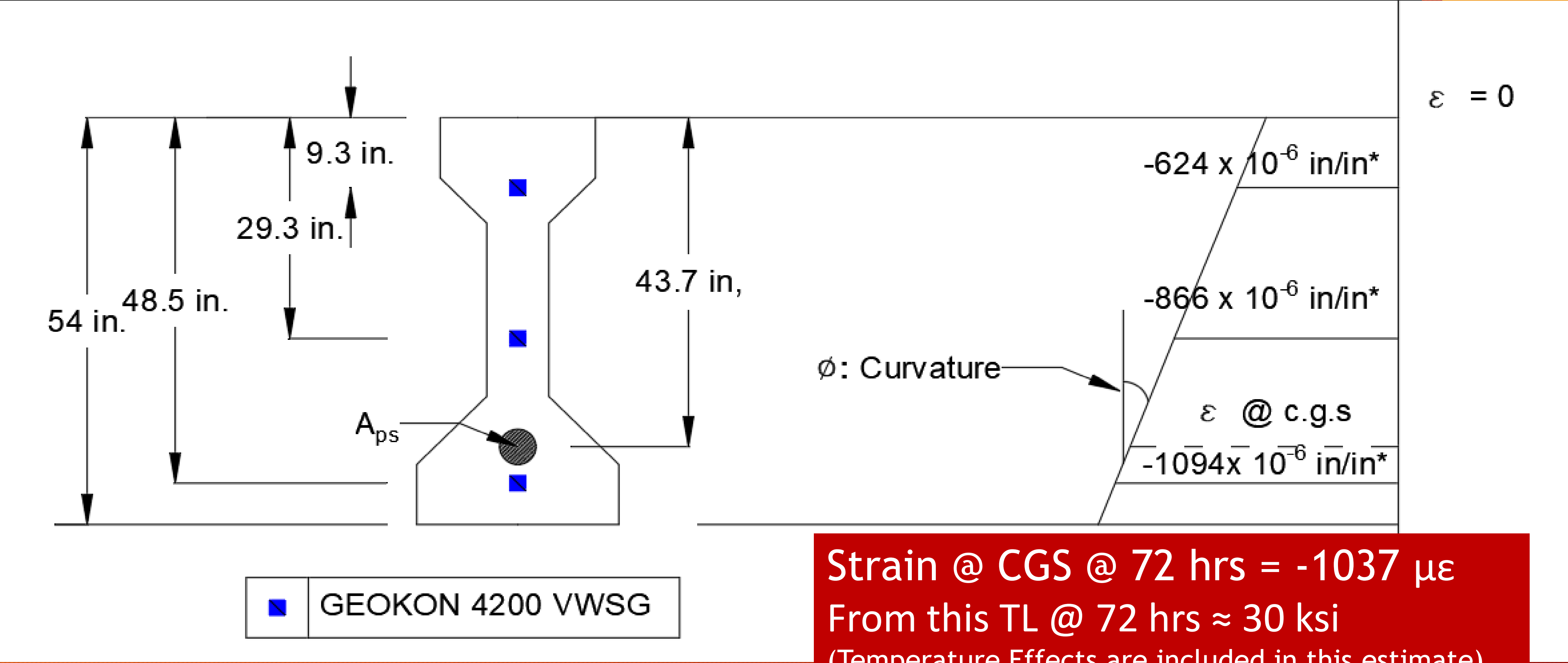


Concrete Strains at Midspan -
(Early Ages 0 to 72 hrs., Mark 42 Span 14)

- **<u>Steam Curing was NOT done on Mark 42</u>**
- **Concrete Lengthens (strains increase) during concrete hydration.**
- **Concrete Strains do not decrease (shorten) commensurate with temperature change - this builds residual tension stress.**
- **Concrete Shortens (strains decrease) with de-tensioning**
- **Elastic Shortening Loss, ES ≈ 1000 με.**



Strain Diagram for Mark 27 Span 9 @ 72 hours @ Midspan



Strain @ CGS @ 72 hrs = -1037 με

From this TL @ 72 hrs ≈ 30 ksi

(Temperature Effects are included in this estimate).

Beam Curvature, Camber and Prestress Losses Computation:

- Beam Curvature can be computed directly from the measured strains.

$$\phi = \frac{Top\ Strain - Bottom\ Strain}{48.5 - 9.3}\ rad/in$$

- At 72 hrs., Mark 27:

$$\phi = \frac{(-424\ \mu\varepsilon - (-1094\mu\varepsilon))}{48.5in. - 9.3in.}$$ = 17.09 x 10^{-6} rad/in.

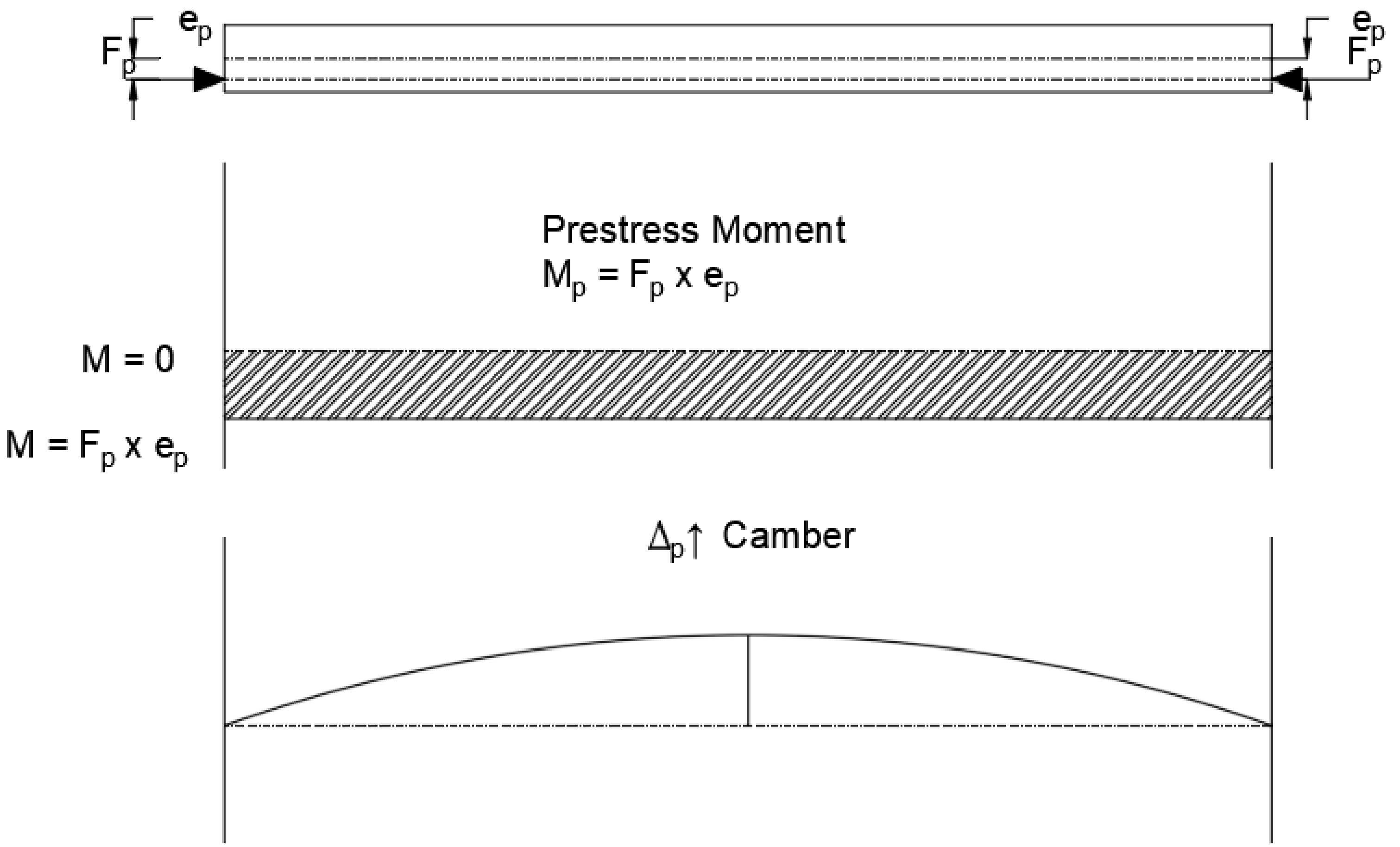
- The curvature at midspan can, in turn, be used to compute cambers
- Strain data at midspan can be used to continuously monitor beam cambers

Camber computation

- The deflection due to the prestress forces can be computed using the following equation:

$$\Delta_p \uparrow = \frac{1}{8} \emptyset L^2$$

- Where, $\emptyset$ is the computed curvature.
- Self Weight moments from the beam must be considered and the computation for camber accounts for the self weight moment.



Measured Losses:

- Measured Prestress Losses are derived from the strain measurements.
- Total losses are computed by interpolating the strain data and findings the strains at the C.G.S of the presstressing Strands.
- The Loss calculation was used using this formula:

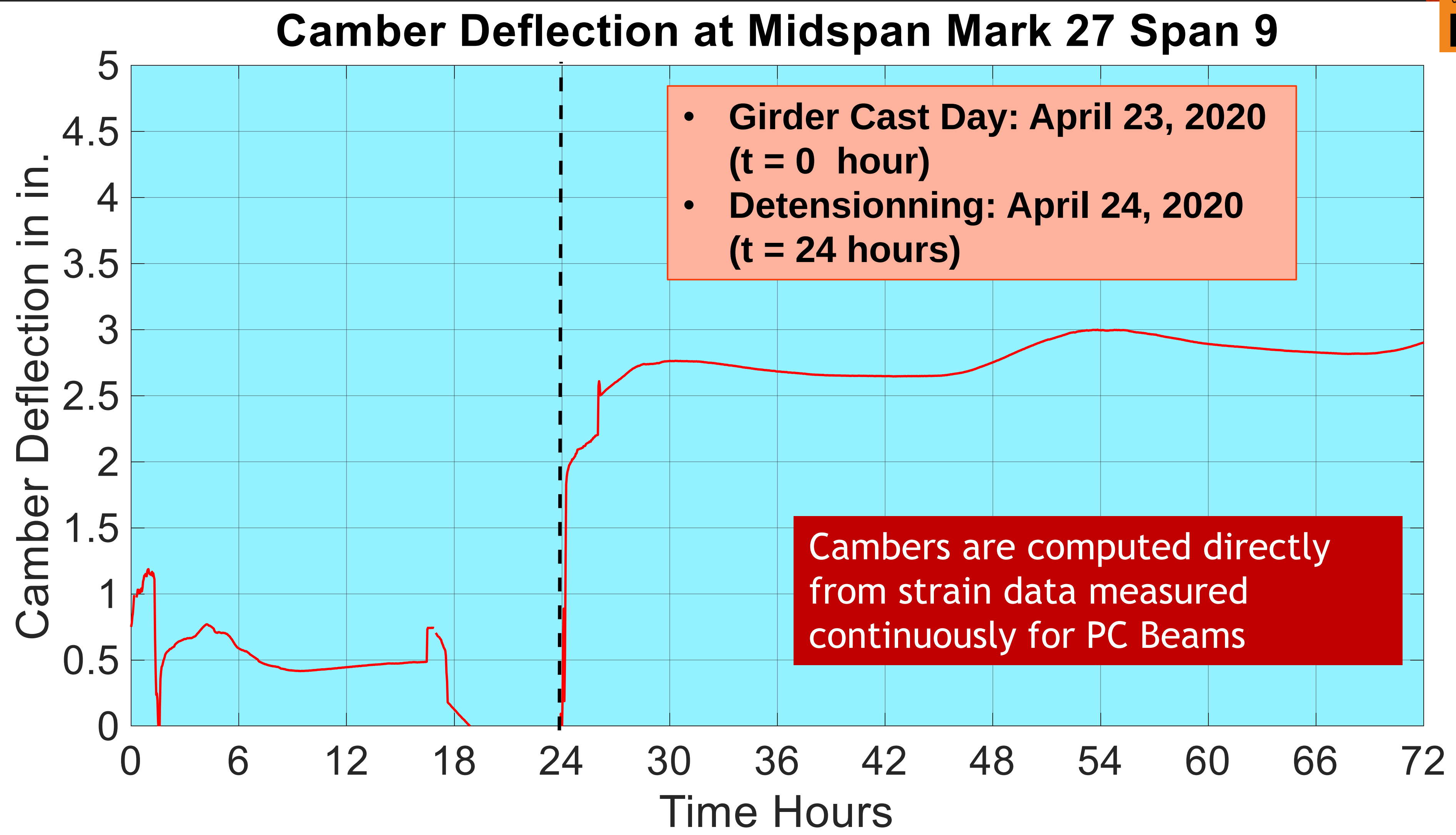
$$TL = \left(Top\ Strain + \frac{y_{tp} - 9.3}{48.5 - 9.3} \times (Bottom\ Strain\ - Top\ Strain)\right) \times E_p$$

Where:

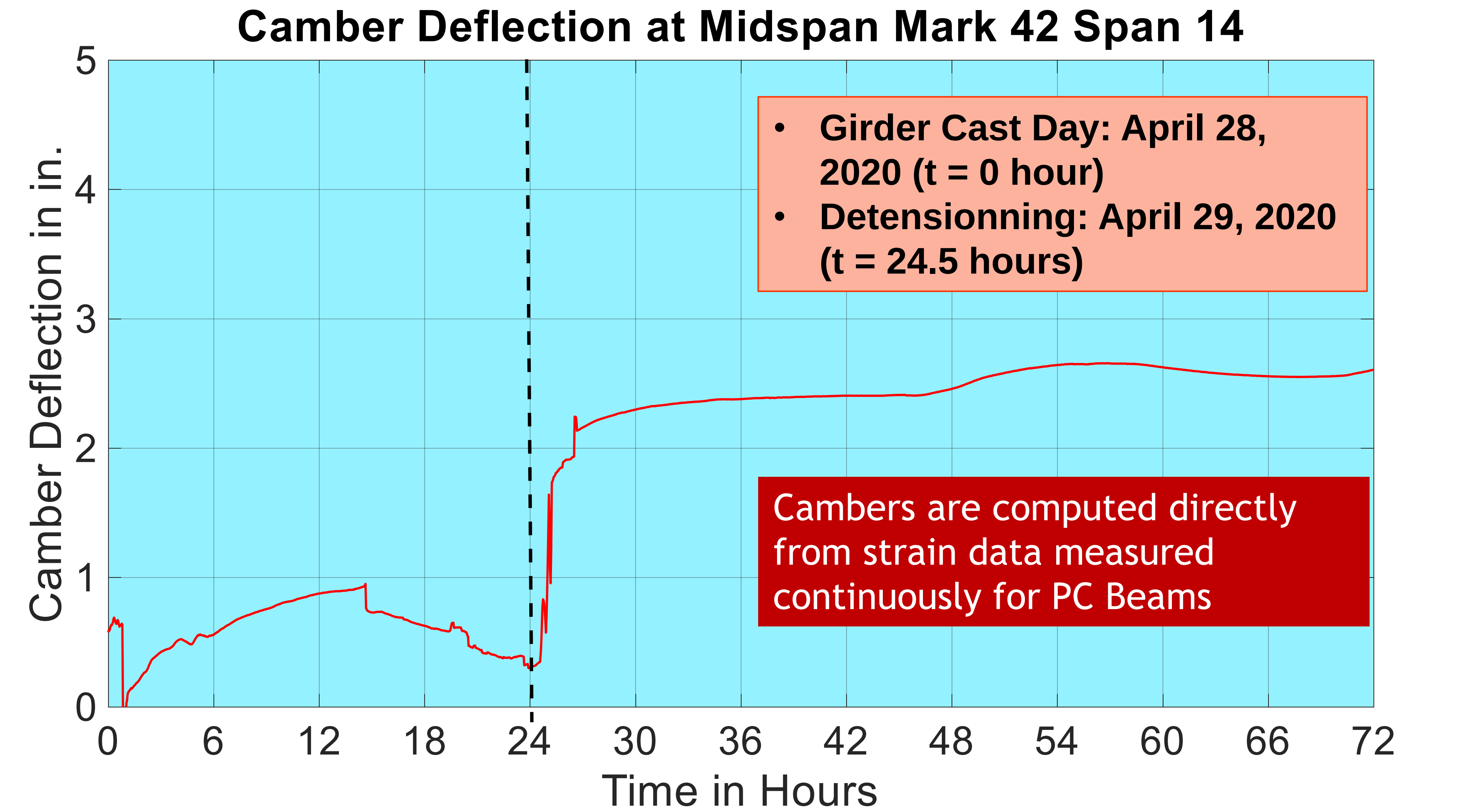
y_t: $Distance\ from\ top\ fiber\ of\ the\ girder\ to\ C.D.G\ of\ the\ strands$

E_p: $Modulus\ of\ Elasticity\ of\ the\ Prestressing\ Strands\ (28500\ ksi)$

Short-term Camber Mark 27 Span 9

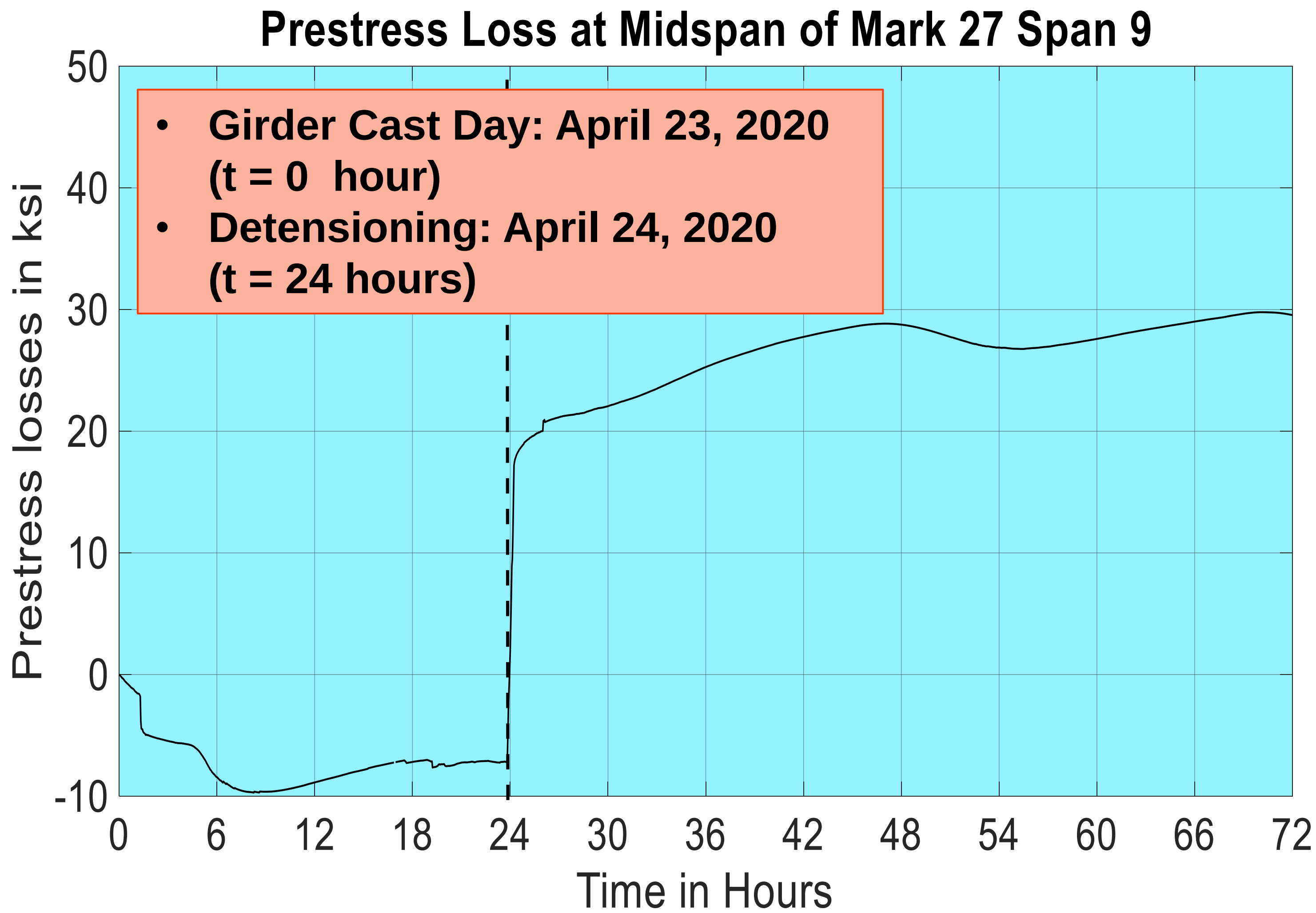


Short-term Camber Mark 42 Span 14



Short-term Midspan Prestressed Losses for Mark 27 Span 9

- Prestress Losses are computed directly from measured strains.
- AASHTO loss calculations do not include the effects of temperature variations in the 1st 24 hours.
- Other methods for loss calculations do not include initial temperature effects
- TL @ 72 hrs ≈ 30 ksi



Short-term Midspan Prestressed Losses for Mark 42 Span 14 (“Distributed” Prestress)

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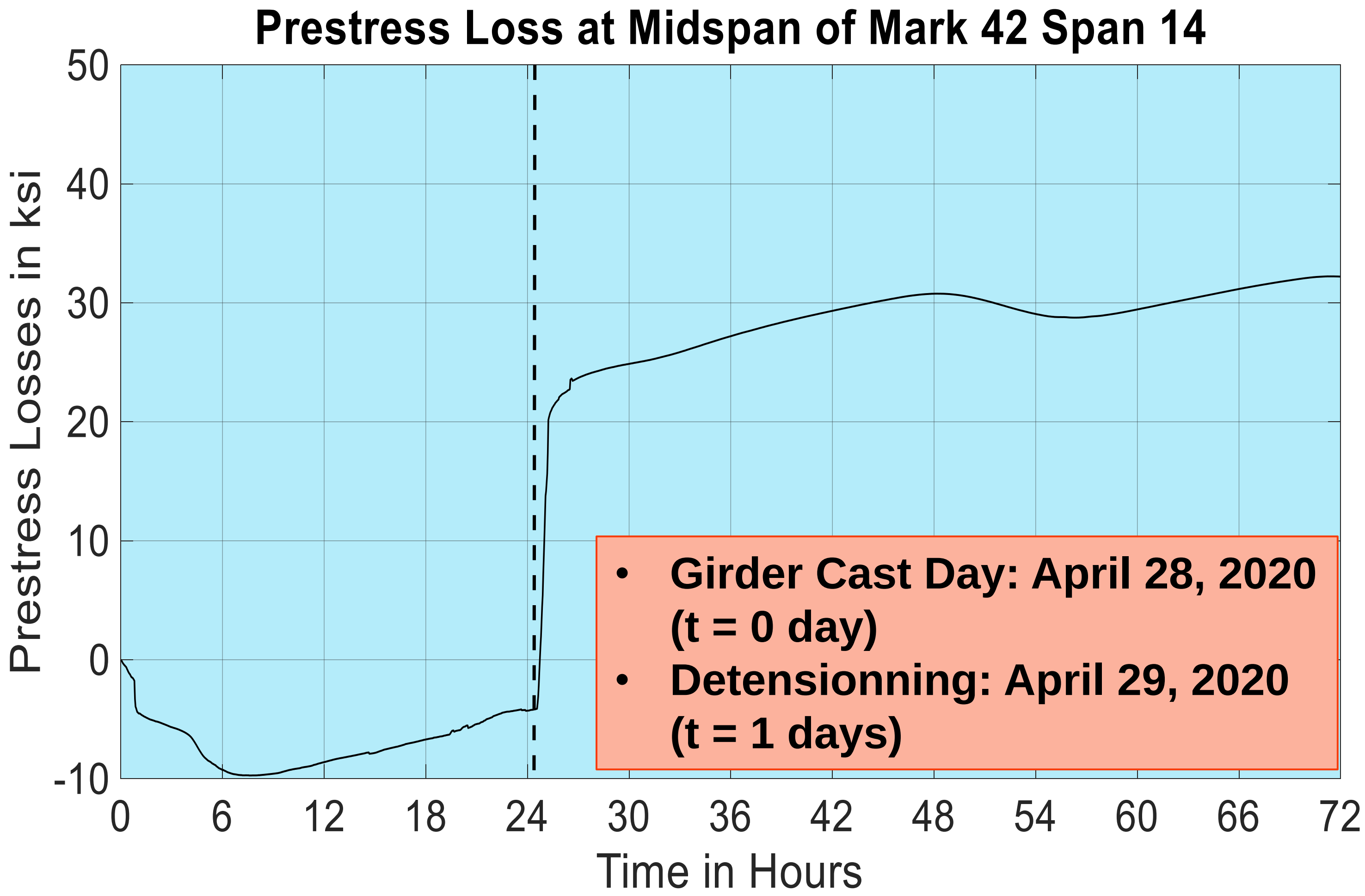
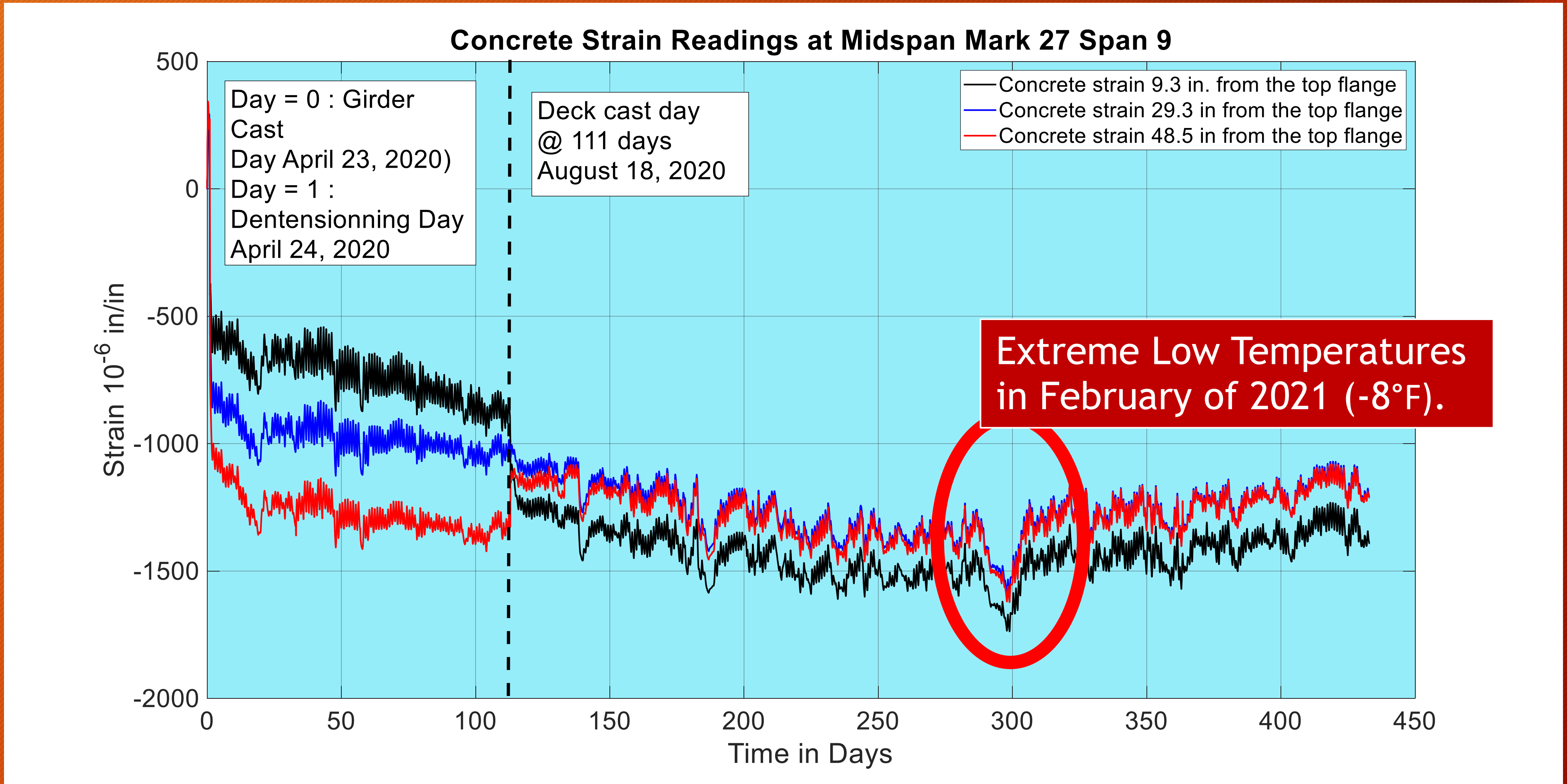
- Prestress Losses are computed directly from measured strains.
- AASHTO loss calculations do not include the effects of temperature variations in the 1st 24 hours.
- Other methods for loss calculations do not include initial temperature effects
- TL @ 72 hrs ≈ 30 ksi



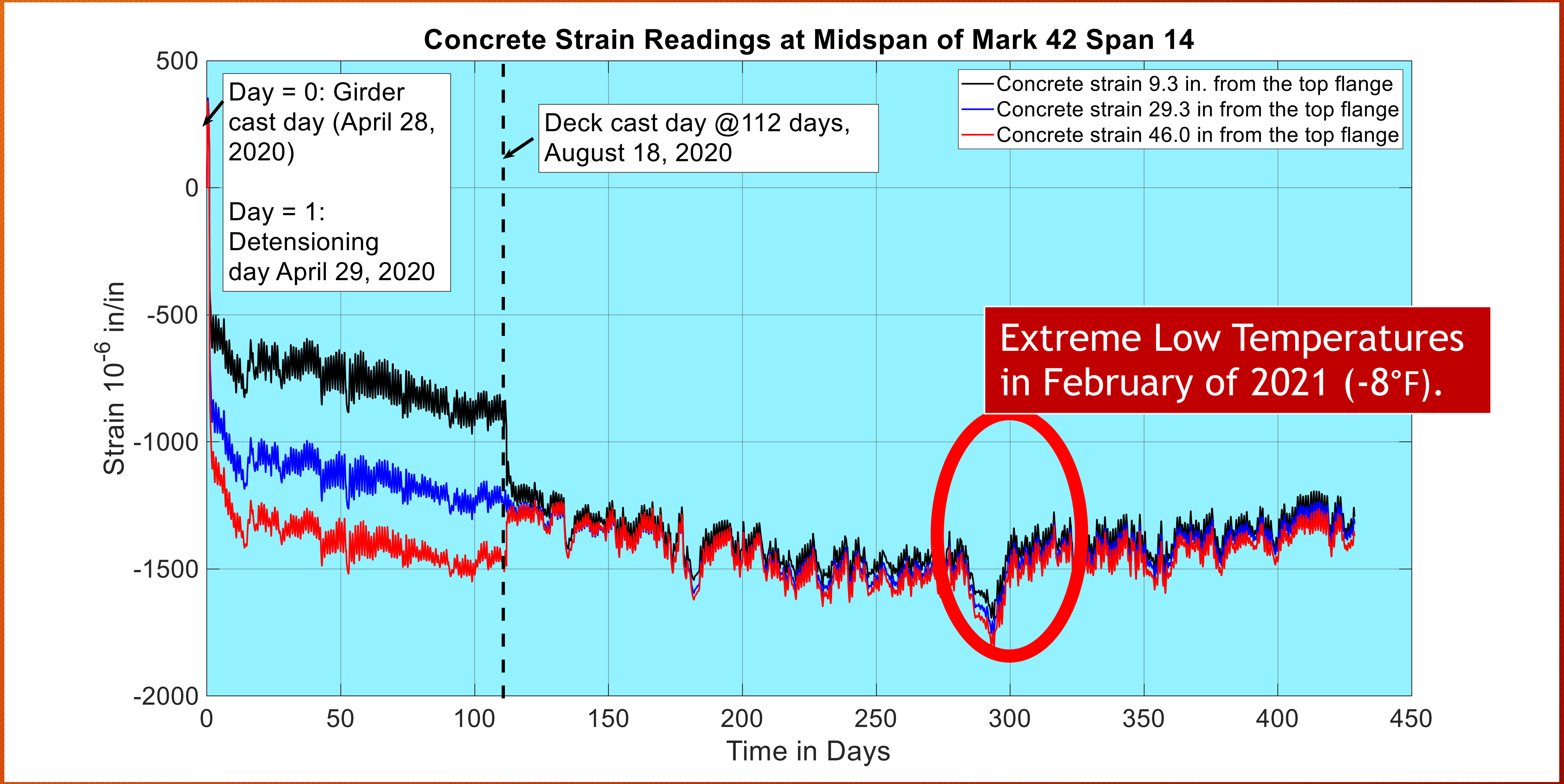
Long Term Monitoring:

Temperature & Strains & Prestress Losses

Long-term Strain Mark 27 Span 9

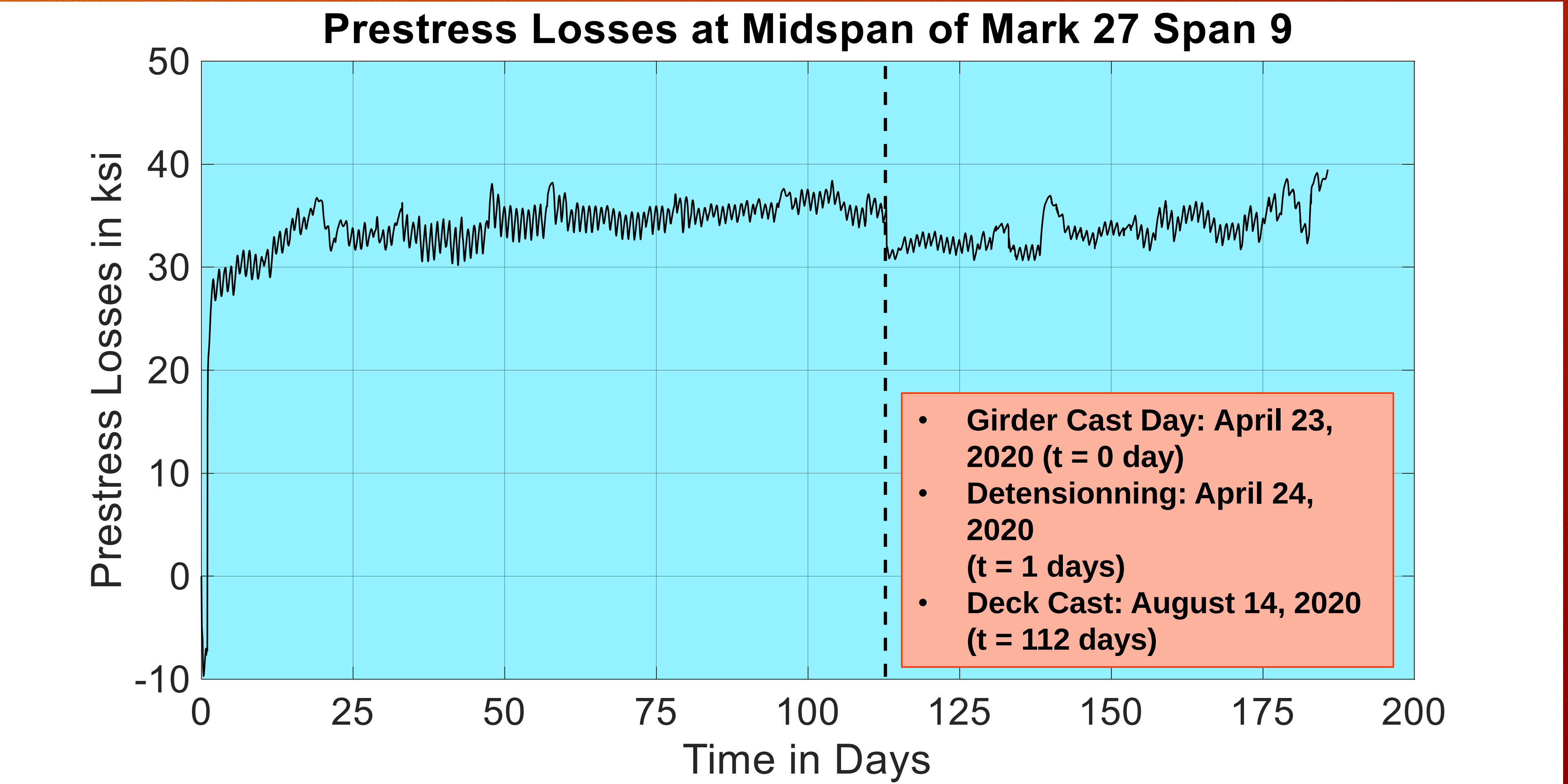


Long-term Strain Mark 42 Span 14



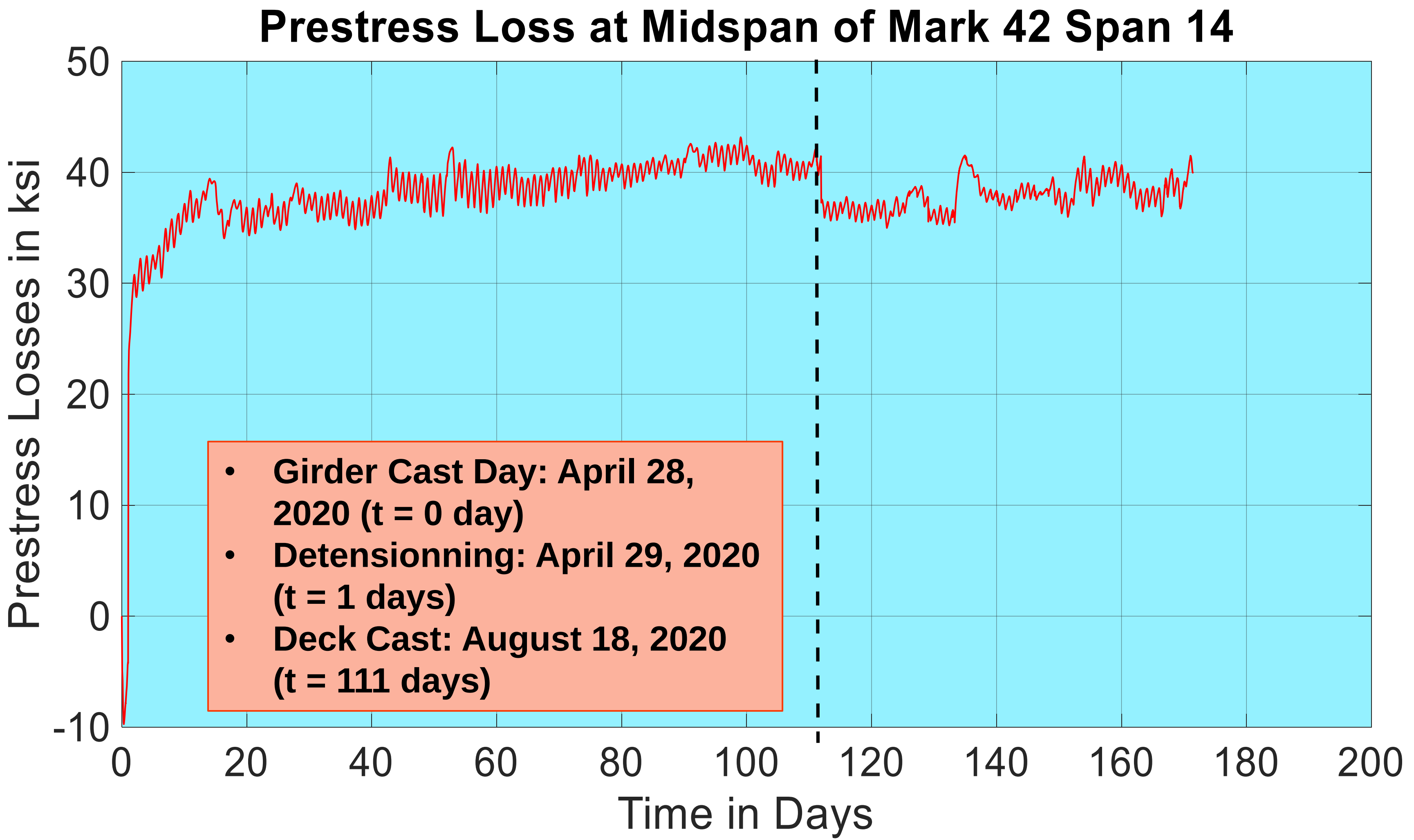
Total Prestress Losses (TL) – Long-Term Mark 27 Span 9

- Prestress Losses are computed directly from measured strains.
- Prior to Slab Casting, TL @ 111 days ≈ 35 ksi
- After Slab Casting, TL @ 112 days ≈ 31 ksi
- On September 30, 2020, TL @ 190 days ≈ 35 ksi



Long-Term Losses Mark 42 Span 14

- Prestress Losses are computed directly from measured strains.
- Prior to Slab Casting, TL @ 110 days ≈ 40 ksi
- After Slab Casting, TL @ 112 days ≈ 36 ksi
- On September 30, 2020, TL @ 190 days ≈ 40 ksi



Measured Camber with Traditional Surveying Equipment (Engineering Level and Phila. Rod)

Numerous site visits were made by the Research Team. Camber readings were measured using traditional surveying equipment on different days prior to casting of all bridge decks.

Measurements Days				
		Mark 27 Span 09	Mark 42 Span 14	Measurement taken?
Girder Cast		4/23/2020	4/28/2020	N
	6/11/2020	49	44	Y
	6/18/2020	56	51	Y
	7/29/2020	97	92	Y
	7/29/2020	97	92	Y
Deck Cast per span	8/14/2020	113*		N
	8/18/2020		112*	N
	10/1/2020	161	156	Y
Note				
Camber measurements were taken once the girders were installed in the bridge site				
Camber Measurements were taken for all spans except for the girders in span 8.				
Span 8 is located over the Canadian river, the research team had difficulty to access it				
On 6/11/2020 the girders for span 14 and for span 15 were not installed in the bridge yet				

Camber Measurements Results

MEASURED CAMBERS (IN.) – SPAN BY SPAN

	Dstrbtd?	Mild Steel?	Ave. Camber (in.) 7/9/20	Case A (No-No)	Case B (Yes-No)	Case C (No-Yes)	Case D (Yes-Yes)
Span 1	1	0	2.535		2.535		
Span 2	1	0	2.640		2.640		
Span 3	0	0	3.660	3.660			
Span 4	0	0	4.125	4.125			
Span 5	1	0	3.120		3.120		
Span 6	1	1	2.775				2.775
Span 7	1	1	2.775				2.775
Span 8	0	1	2.685			2.685	
Span 9	0	1	3.225			3.225	
Span 10	0	0	3.420	3.420			
Span 11	1	0	3.180		3.180		
Span 12	0	0	3.945	3.945			
Span 13	0	0	4.050	4.050			
Span 14	1	0	2.925		2.925		
Span 15	1	0	3.270		3.270		
N =	**8**	**4**	**N =**	**5**	**6**	**2**	**2**
			Average =	**3.84**	**2.95**	**2.96**	**2.78**
			Median =	**3.95**	**3.02**	**2.96**	**2.78**
			S =	**0.29**	**0.30**	**0.38**	**0.00**

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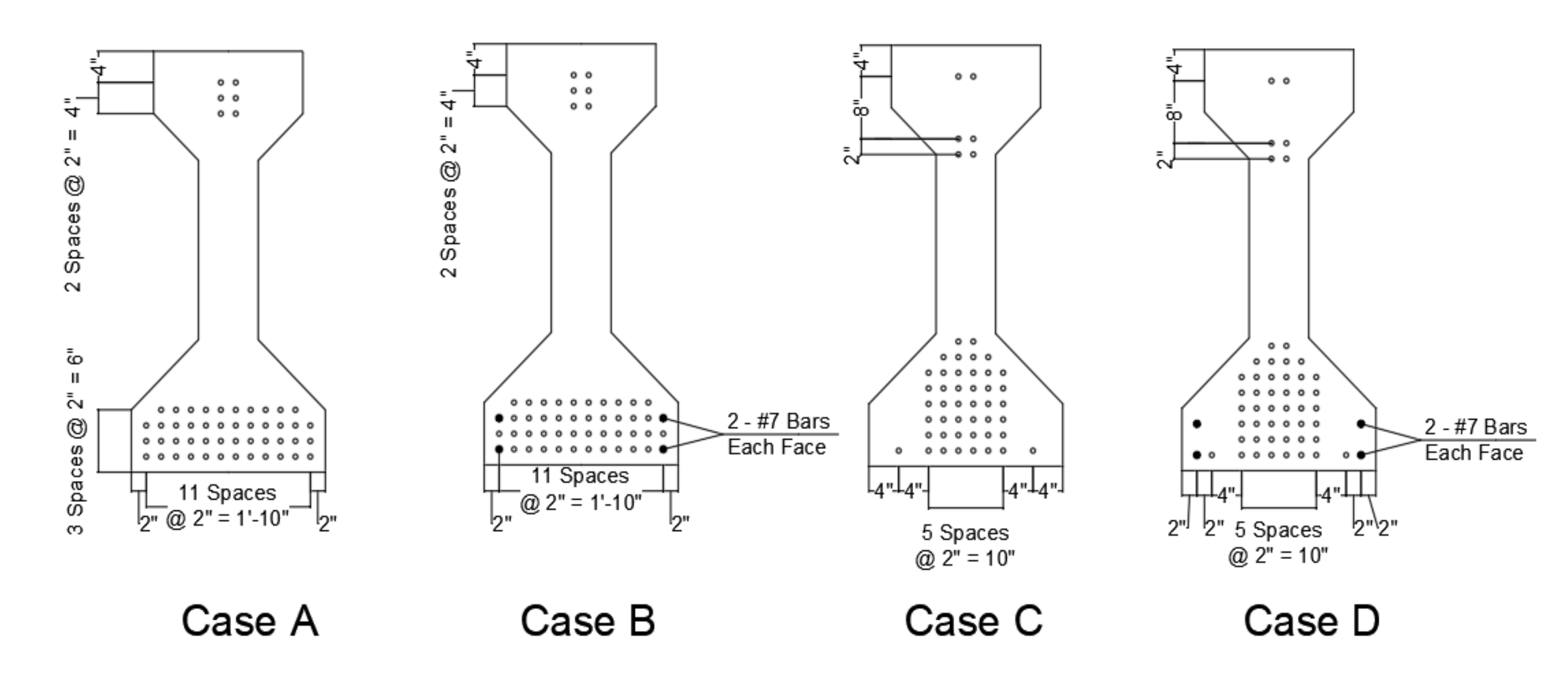
Camber Measurements Results.

- The data shows that the design that has the least camber is the Case D Design.
- The data also indicates that Case B and Case C have almost similar camber
- Note that Mark 42 Span 14 corresponds to case D, and Mark 27 Span 9 corresponds to Case C.



Camber Measurements Results - Summary

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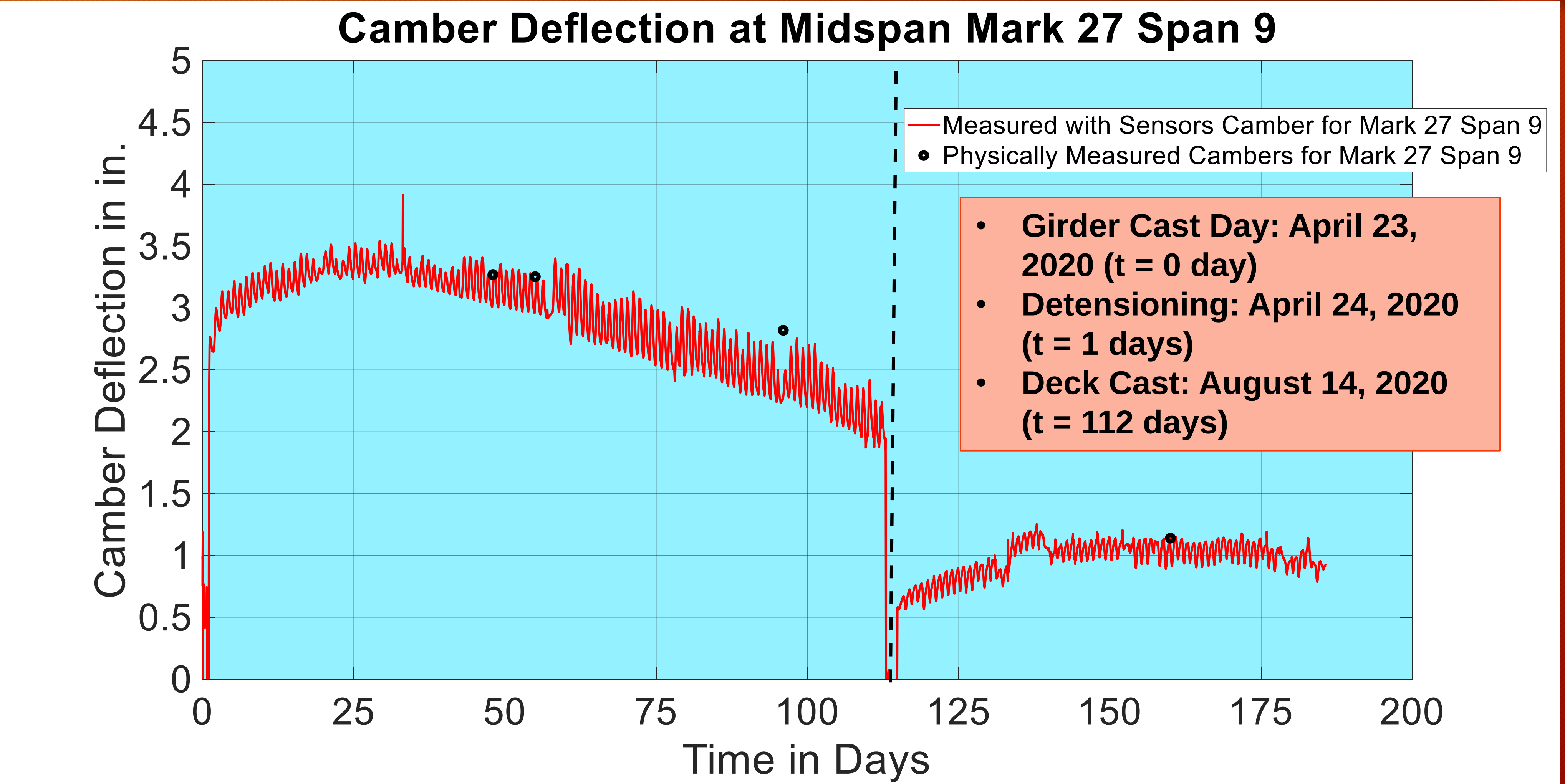
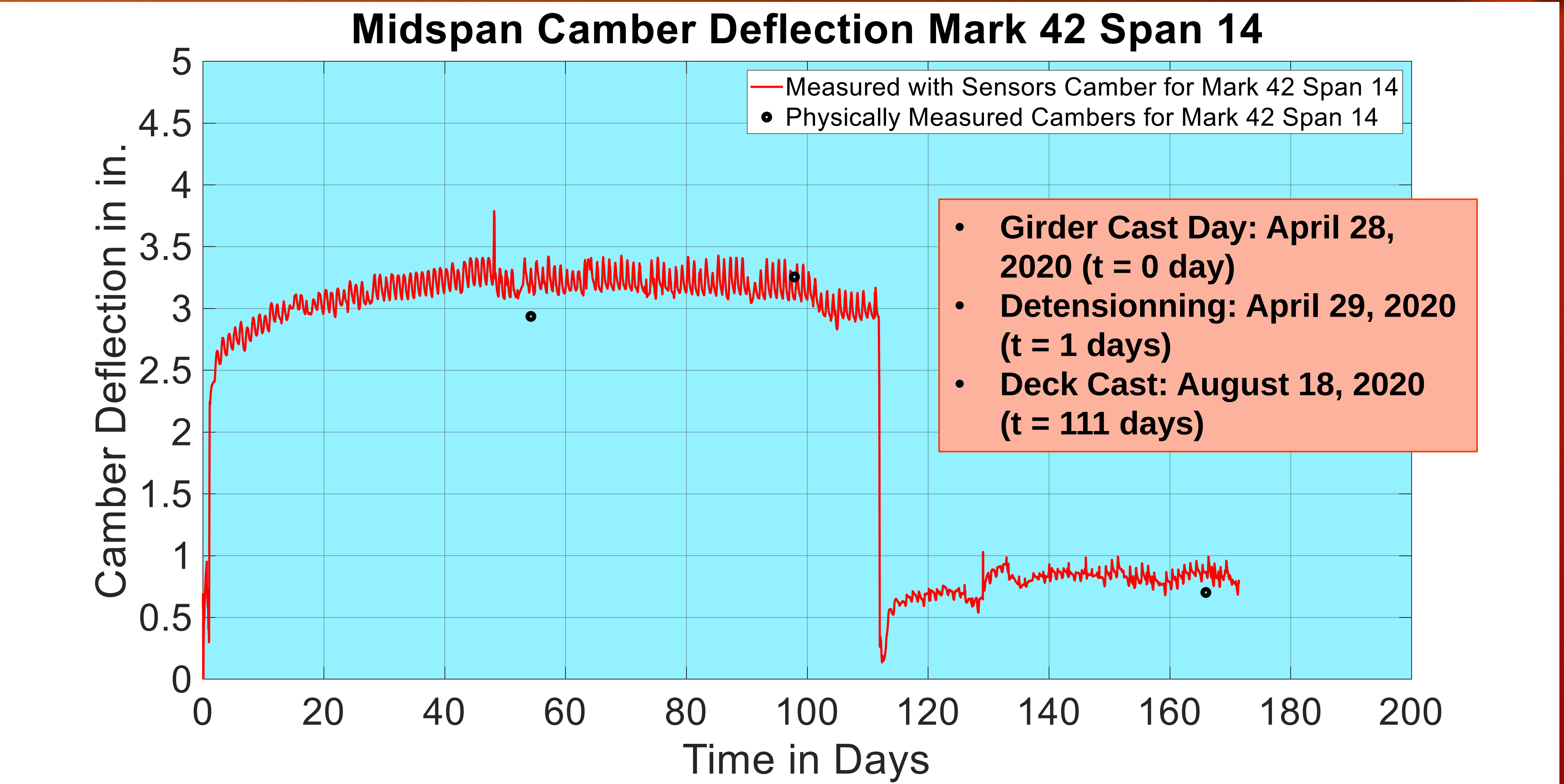
Cambers (in.) on July 29,2020 (Prior to Deck Casting)				
	Cambers(in.) w/o Distributed w/o Mild Steel	Cambers(in.) w/o Distributed w/ Mild Steel	Cambers(in.) w/ Distributed w/o Mild Steel	Cambers(in.) w/ Distributed w/ Mild Steel
N=	5	2	6	2
Average=	3.84	2.96	2.95	2.78
Median=	3.95	2.96	3.02	2.78
S=	0.26	0.27	0.28	0

Long-Term Camber Mark 27 Span 9



Long-Term Camber Mark 42 Span 14



- **Girder Cast Day: April 28, 2020 (t = 0 day)**
- **Detensionning: April 29, 2020 (t = 1 days)**
- **Deck Cast: August 18, 2020 (t = 111 days)**

Conclusions:

1. We can successfully apply instrumentation to acquire concrete temperatures, and concrete and steel strains during PC Bridge Beam Fabrication, and that these data are useful for structural monitoring in both the short-term period (during fabrication, storage, handling, transportation, erection and bridge construction), and in the long-term (post-construction and in-service conditions).
2. We can successfully acquire the strain and temperature data in real-time and use the data for analyses of overall bridge beam behavior including evaluations of our design methods, our design choices, and our construction processes,
3. Temperature fluctuations during fabrication (heat of hydration and steam curing followed by form removal) create significant concrete strains at early ages during fabrication. These variations are not accounted for in computing prestress losses.
4. The instrumentation and data acquisition systems enable the direct measurement of prestress losses.

Conclusions:

5. The systems enable the direct computation of PC Bridge Beam cambers during fabrication, storage, transportation, erection, bridge construction and throughout life in-service; these computations are correlated with direct physical measurements of camber.
6. The camber of a PC bridge girder is directly tied to the parameter that is best described as the "PRESTRESSED MOMENT" which is the total prestressing force times its eccentricity, i.e. Fp*ep. Therefore, the use of fully-tensioned top prestressing strands reduces prestress losses by reducing the eccentricity of the prestressing force. Additionally, other prestressing patterns that raise the center of gravity of the prestressing force (cgs) work in the same manner to reduce prestress losses and reduce beam cambers.
7. The use of longitudinal mild steel at midspan regions reduces prestress losses at midspan, and reduces camber.

Conclusions:

8) We found that other variations of end-zone reinforcement do not appear to affect end-region cracking. However, it appears that moving the diaphragm location toward the interior of the beams can lessen the width of cracking that runs through the diaphragm detail. Our recommendations would include rationalizing and reducing some of the vertical steel in end regions to reduce the congestion in end regions; and that this may be more effective in reducing cracking than in adding steel. We note that ODOT designs, at least those that follow guidelines put in place in the late 1990’s when using details authored by the PI, are probably sufficient mitigate cracking width and length.

9) It was also observed that the de-tensioning processes for PC Bridge Beams during fabrication creates impact forces directly upon the end regions of the girder, and that these impacts cause both movement of the girders, and cracking in unexpected and undesirable locations.

Recommendations and Implementation

1. PC Bridge Beam Designs should continue to feature fully tensioned top strands. This design feature raises the CGS of the prestressing forces and lower its eccentricity. The technique is effective in helping to reduce prestress losses, and reduce cambers, when compared to traditional designs where top strands are not in use or are not fully-tensioned. We note that there is not a national standard in this regard, and many other states do not employ fully tensioned top strands.
2. Mild Steel should be included in the bottom flanges of PC Beams near midspan. Camber data show that the mild steel helps reduce cambers in PC Beams. The reduced camber found in measurement is supported by theoretical calculation that show mild steel is effective to reduce prestress losses and help control camber.
3. Additional PC Beams should be instrumented for strains and temperatures during fabrication. Measurements can focus on short term cracking in end regions, large temperature swings during fabrication (that may be contributing to cracking in end regions), and also be useful for supporting long-term structural monitoring of bridges that are built using the PC Beams.

Recommendations and Implementation

4. The ODOT should consider the regular instrumentation of PC Beams in all ODOT Bridge Projects. The data is useful to improving designs, improving the life span of our bridges, and in providing an effective means for structural monitoring that can supplement our current inspection programs and assist our Asset Management Initiatives.

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Thank you – Questions

Additional slides

Instrumentation: Devices

Datalogger (CR1000X):

A data logger is an electronic device that records data over time or in relation to location either with a built-in instrument or sensor or via external instruments and sensors.

Instrumentation: Devices

Multiplexer (AM16/32 and AM25T):

multiplexers significantly increase the number of sensors that you can measure with a Campbell Scientific data logger. It interfaces with the data logger and adds terminals so that you can wire additional sensors of almost any type.

AM25T Multiplexer

AM16/32 Multiplexer

Instrumentation: Devices

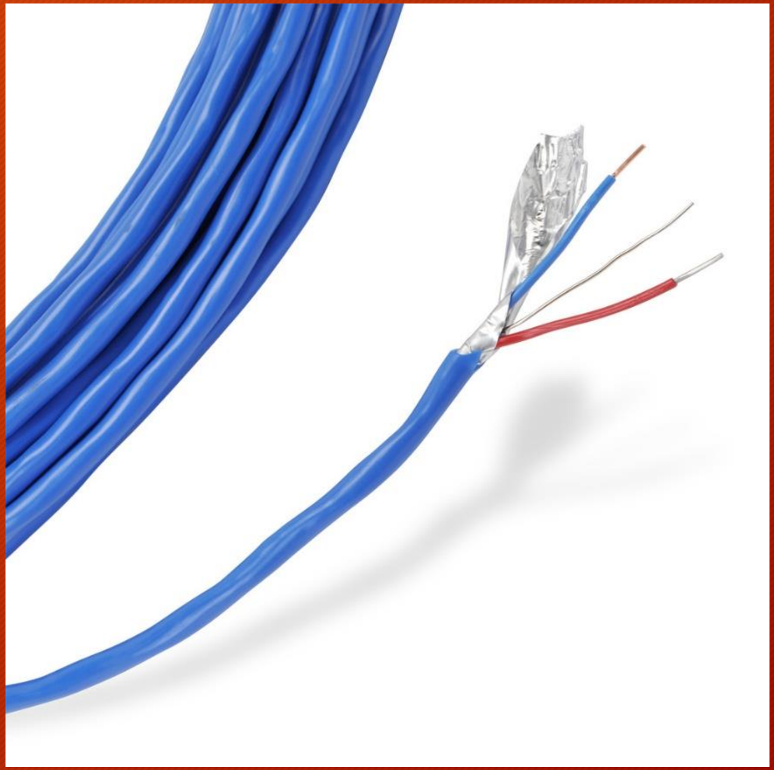
- **Signal Conditioner (AVW200):**
- The AVW200 uses vibrating-wire spectral-analysis technology (VSPECT™). VSPECT observes the incoming sensor signal, performs a Fourier transform and a spectral analysis (transforming the time series into individual sinusoidal components in the frequency spectrum), and determines the sensor frequency by identifying the largest signal in the acceptable range while filtering out environmental and electrical noise.

AVW200
Multiplexer

Instrumentation (Sensors):

Thermocouple:

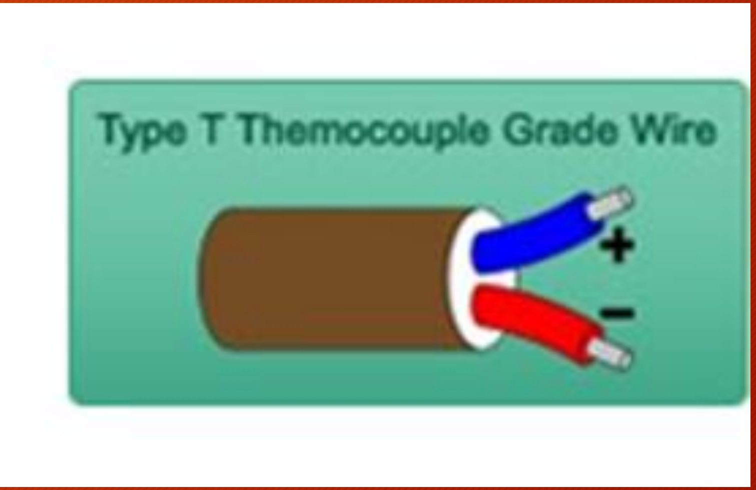
A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor.

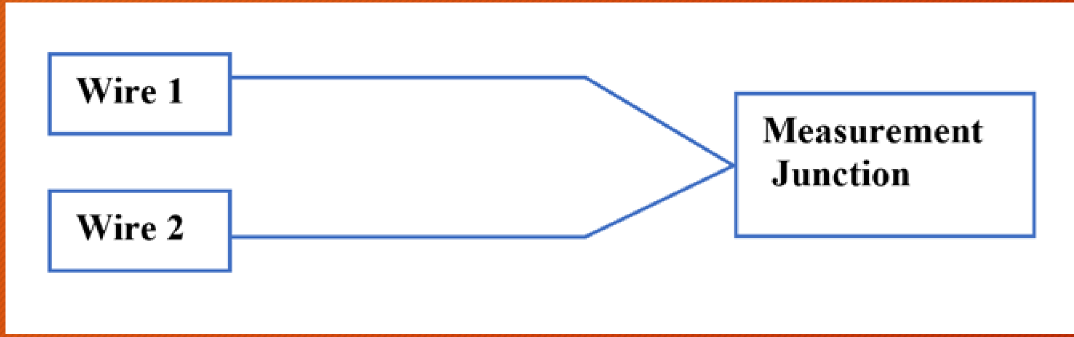


Instrumentation (Sensors): (continued)

Specification of the Thermocouple:

- Type T (Copper Constantan).
- Temperature Range is] -32F to 392F[
- Accuracy about 0.18 F





Instrumentation (Sensors): (continued)

Advantages

- Inexpensive, durable and easy to install
- Provide accurate results
- Robust and can measure over a wide range of temperatures

Limitations

- may have to be protected from solar radiation

Instrumentation (Sensors):

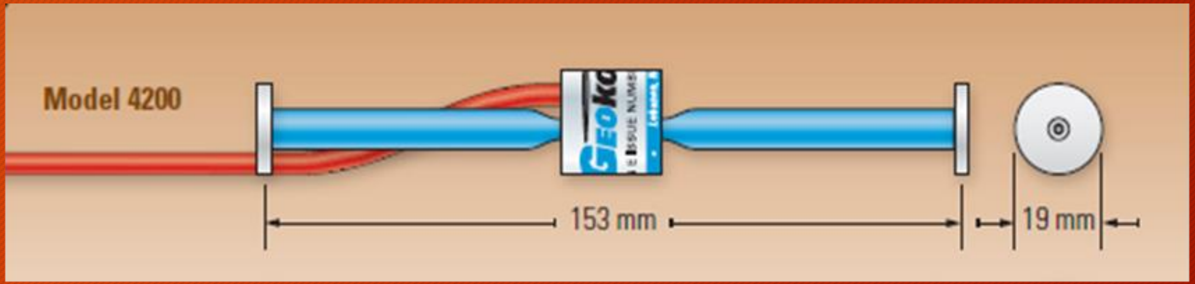
Vibrating Wire Gauges:

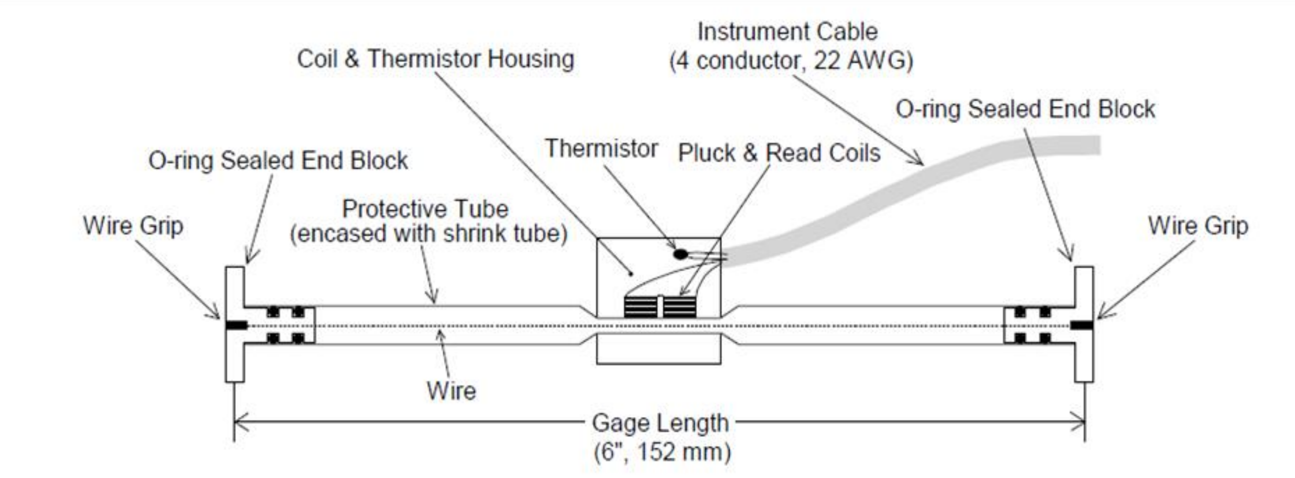
The vibrating wire strain gauge operates on the principle that a tensioned wire, when plucked, vibrates at a frequency that is proportional to the strain in the wire. The gauge is constructed so that a wire is held in tension between two end flanges.

Instrumentation (Sensors): (continued)

- Embedded in concrete and measures concrete strain and temperature (Thermistor)
- Actual strain in concrete

  $\mu_{actual} = (R_1-R_0)+(T_1-T_0)*C_1$
- Range= 3000 με, w/ resolution = ±0.1με





Instrumentation (Sensors): (continued)

- Advantages
  - Long –term stability and easy to install
  - Waterproof and corrosion resistant
  - Frequency output is stable for transmissions over long cable lengths
  - Immune to electrical noises, designed to withstand rigors of concrete placement
- Limitations
  - Expensive
  - Require temperature correction