Extending Application of Folded Steel Plate Girder Bridge (FSPGB) System, to Longer Span Lengths

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Presentation Outline

1- What is Folded Steel Plate Girder Bridge (FSPGB) system
2- Brief overview of FSPGB with 60 ft. length
3- Examples of FSPGB in service
4- Details used to extend FSPGB to longer length
5- Overview of research leading to longer FSPGB system
6- How designers could implement FSPGB in their practice
7- Future plans
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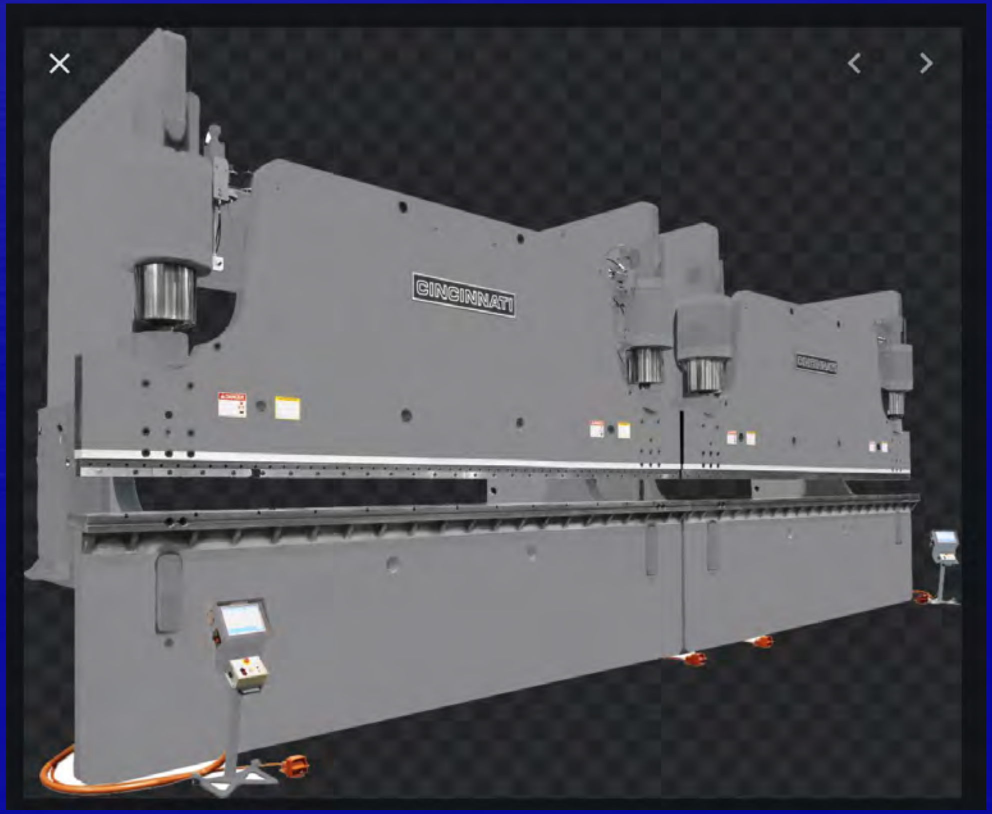
Folded Plate Girders are made by bending flat plate into a C shape by using press break

Plate thicknesses used are 3/8 inches or ½ inches

Currently Maximum length of the folded plate girder is limited to 60 ft., which is the reflection of the longest press brakes that are available.



Stable Shape During Casting Deck

No need for internal cross frames

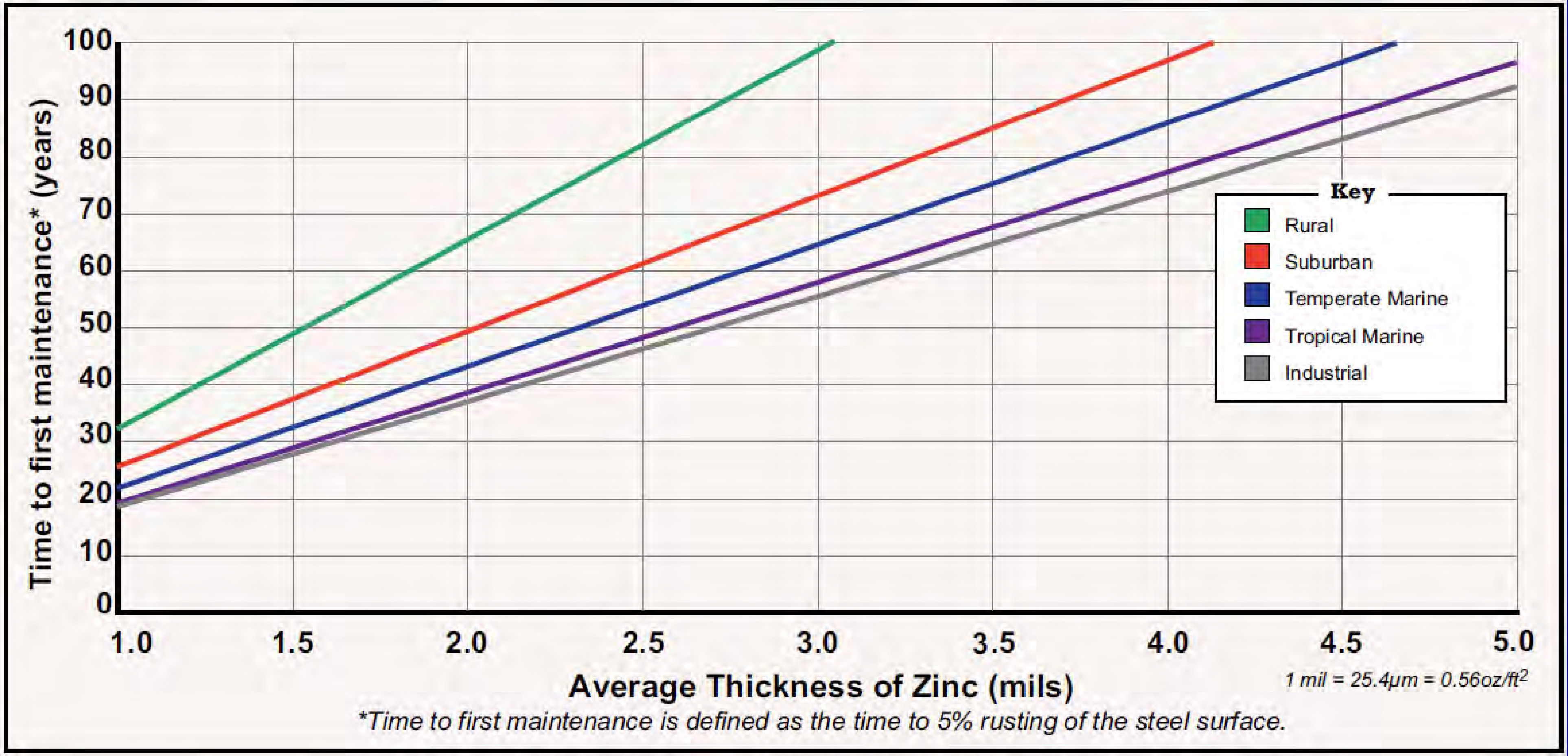
No need for external cross frames

No fatigue prone details

Lowest fatigue category detail is B

Open bottom allows easy Inspection

1- Galvanizing
2- Weathering steel option
3- Coating



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Initial Development of Folded Plate Bridge System for ABC application involved conducting more than seven years of research

Part of the research included fatigue test by subjecting the test specimen to more than 7.5 million cycles of loading

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Nebraska

Montana

Michigan

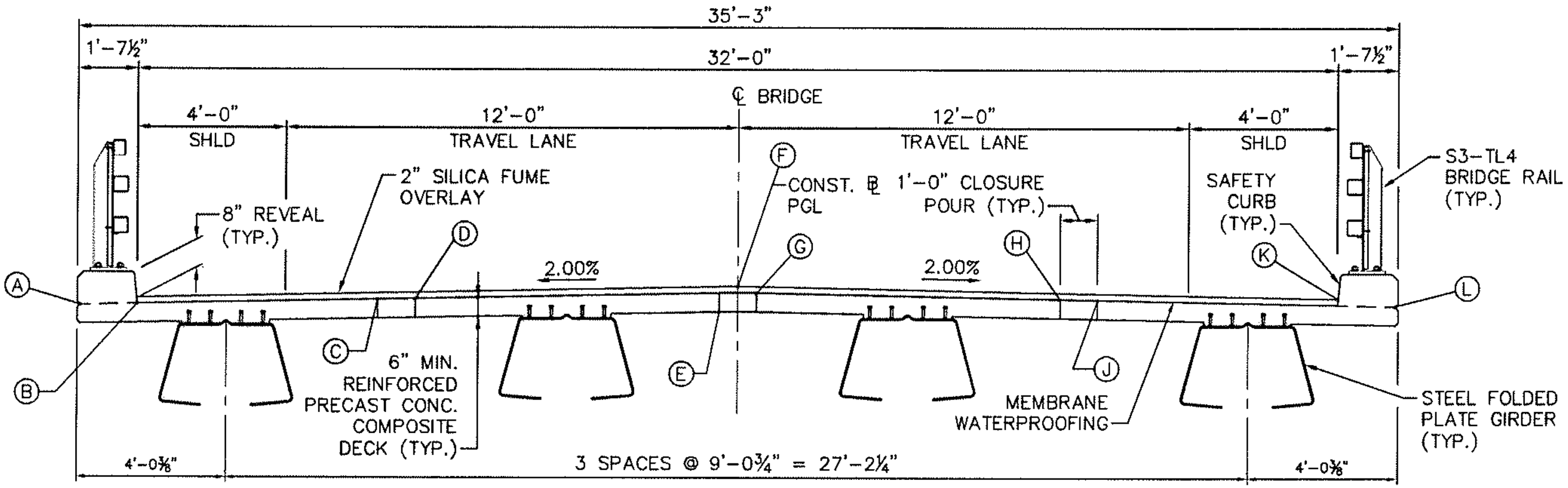
Massachusetts

Pennsylvania (7) 217-2018 Contractor selected based on economy over other alternatives

States with Folded Steel Plate Girder Bridge system in service

Existing bridge
Uxbridge Massachusetts

New Bridge was designed to be wider
Two 12.0 ft. lanes with two 4.0 ft. shoulders
Span length 46 ft.



TYPICAL SECTION
SCALE: ⅜"=1'–0"

Design was based on AASHTO LRFD Bridge Design Specification

using HL93 Loads

Strength

- Moment
  - Demand 29000 Kip-in
  - Resistance 35000 Kip-in

- Shear
  - Demand 220 Kips
  - Resistance 580 Kips

Service Limit States

- Deflection
  - 2 HS20 Trucks = 0.28 in.
  - Span/800 = 0.69 in.
- Stress in top flange
  - Demand 7 ksi
  - Resistance 47 ksi
- Stress in Bottom Flange
  - Demand 39 ksi
  - Resistance 47 ksi

Fatigue Detail Design and Categories

- Lowest Fatigue Category

  Lowest fatigue category detail is B

  which is at the Bottom Flange at the Tie Plate location

After galvanizing , all four girders were transferred to the precast plant

For ABC application, the formwork is simple. For Uxbridge the contractor built the formwork over pre-stressing bed and placed the folded plate in between the formwork

Design was based on girder being supported at two ends while casting the deck, However, during Construction, girders were supported over the entire length (shored construction)

Casting Deck- Note use of headed shear studs for closure pour. There are better details that we can use

Pre-top folded plate units were placed over trailers, following casting and curing deck

The shipping width of completed module were 10’-2”. Including 11” headed rebar

All four units were ready for shipping by August 2011

Units shipped to job site on October 2011

All four units were shipped to the job site on a same day

Truck delivering a completed pre-top folded plate girder

Placing Girder Unit over abutments

Placing Girder Unit

From Below

Finished Structure

Finished Roadway – November 2011


GROVE
GROVE.
OVERSIZE LOAD

Girder Delivery

Deck Placement

Completed Deck Placement

Loading Deck Units

Placing Deck Units

Placing Deck Units

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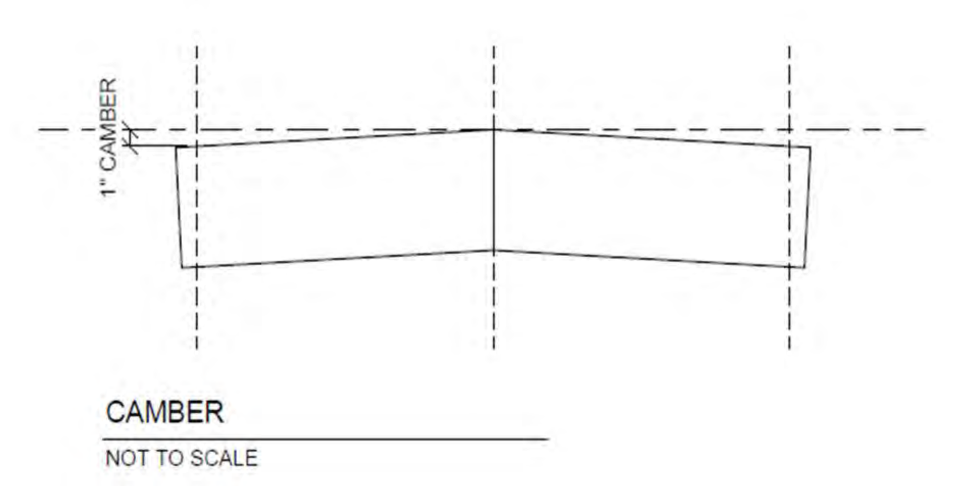
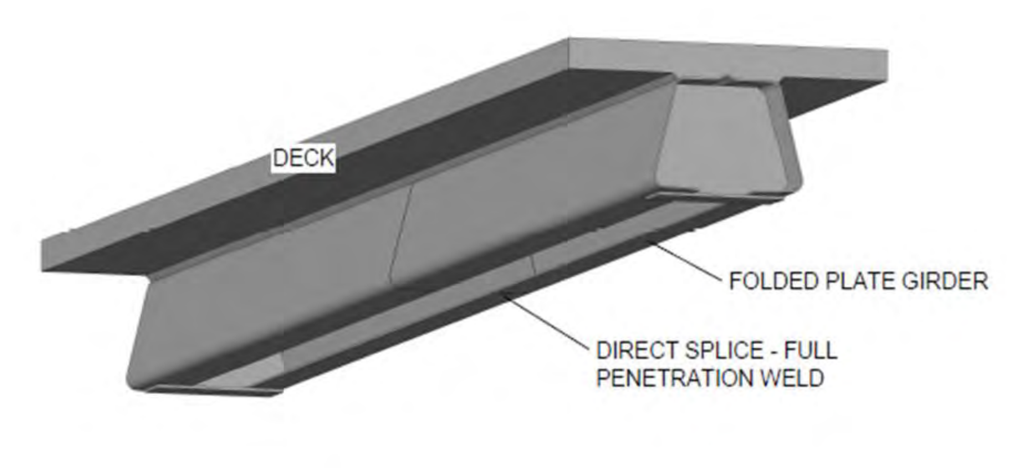
For now it is recommended to use direct welding of two sections to develop longer folded plate.

We are also looking at bolting options





The cost of welding the two segment, according to fabricator is about $5,000

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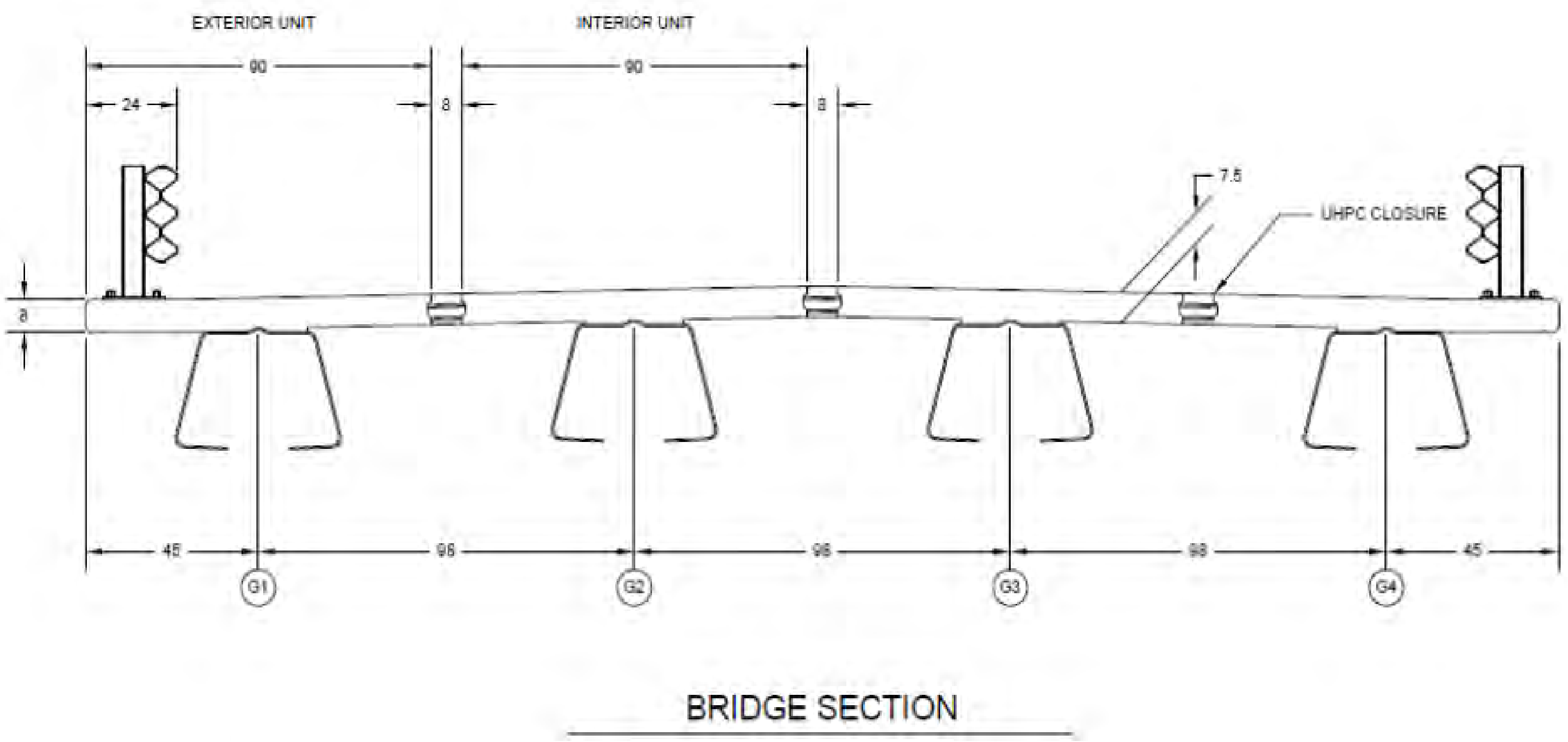
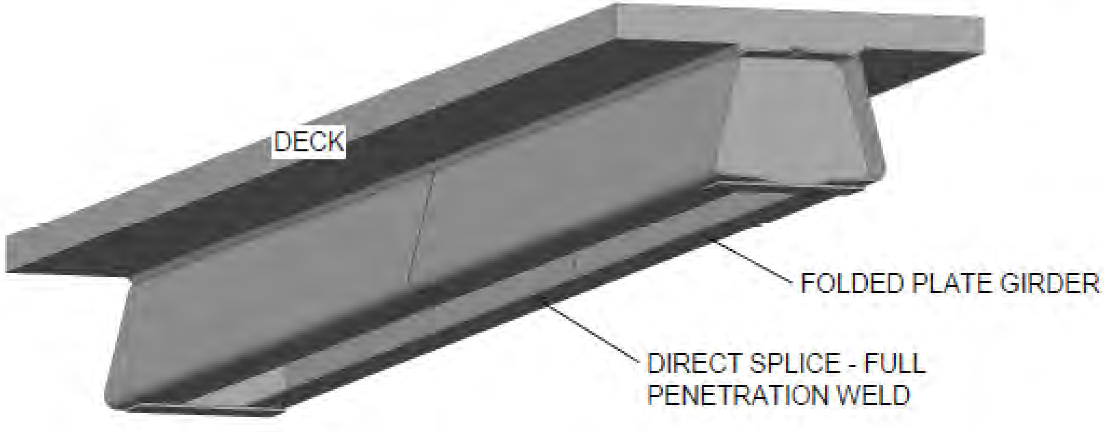
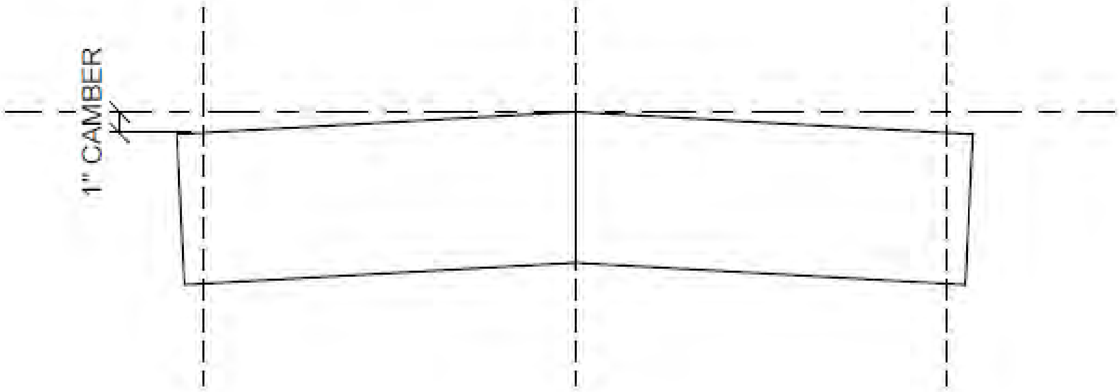
Prototype Structure



Welded Splice Specimen

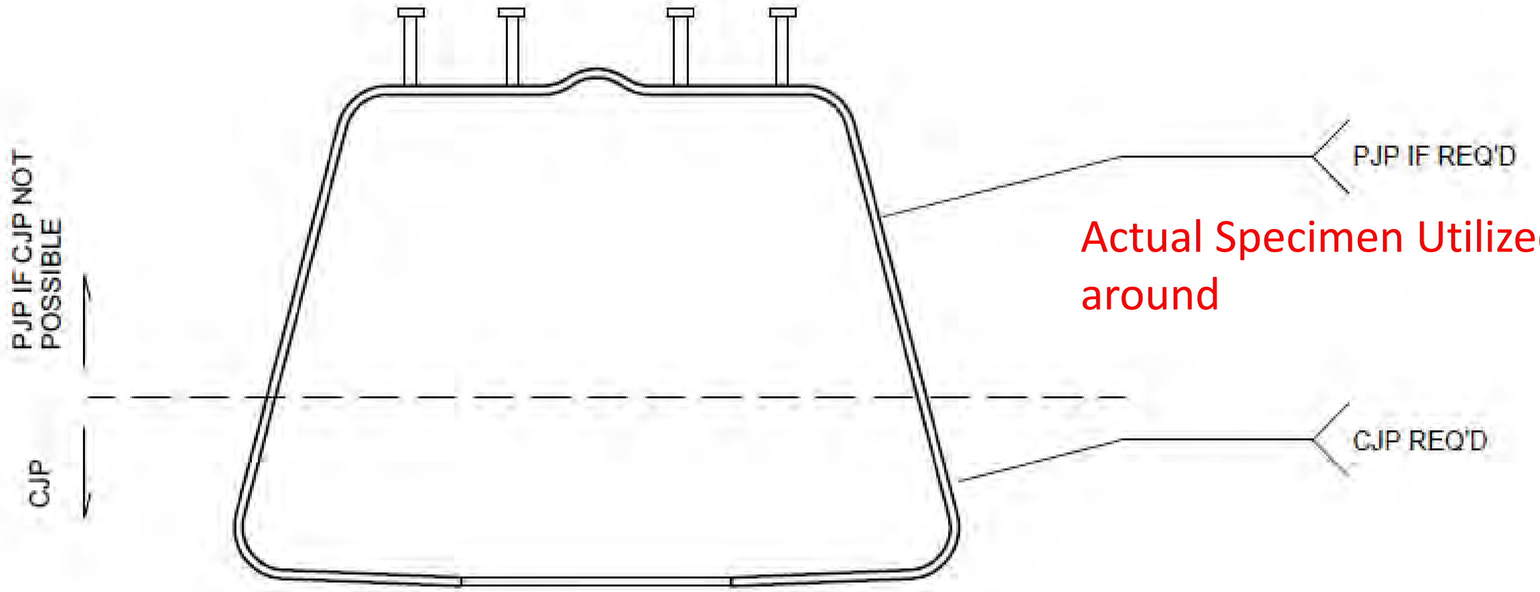




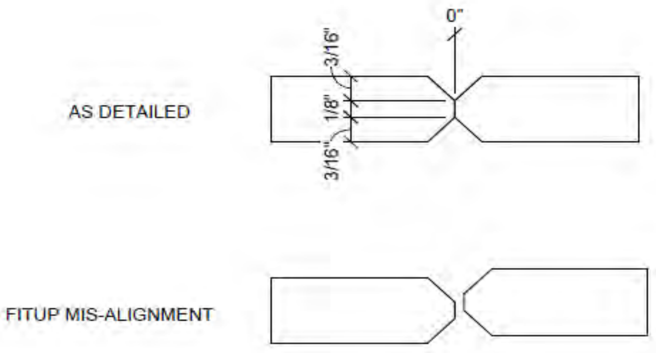
CAMBER

NOT TO SCALE

Specimen Weld



Actual Specimen Utilized CJP all around



Hold Alignment as Detailed at Bottom Flange
- Complete Joint Penetration Weld

Partial Joint Penetration allowed at Upper Flange
- Deck can assist compression transfer

CONSTRUCTION SEQUENCE OF TEST SETUP

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Equation for S-N Curve – Any point on S-N curve correspond to failure

$$(\Delta F)_n = \left(\frac{A}{N}\right)^{\frac{1}{3}} \qquad (6.6.1.2.5\text{-}2)$$

in which:

$$N = (365)(75)n(ADTT)_{SL} \qquad (6.6.1.2.5\text{-}3)$$

where:

A	=	constant taken from Table 6.6.1.2.5-1 (ksi^3)
n	=	number of stress range cycles per truck passage taken from Table 6.6.1.2.5-2
$(ADTT)_{SL}$	=	single-lane $ADTT$ as specified in Article 3.6.1.4
$(\Delta F)_{TH}$	=	constant-amplitude fatigue threshold taken from Table 6.6.1.2.5-3 (ksi)

A typical bridge will be subjected to millions of cycles of truck loading. As an example using following equation the number of times that trucks would pass over a bridge during its 75 years design life would be 219,000,000.

N=365x75xnxrx20,000

N=365x75x2x0.2x20000 = 219,000,000

However applying 219,000,000 would take a very long time.

To shorten the cyclic test period and at the same time simulate the effect of truck traffic over 75 years of design life, the following relationship can be used. Derivation of this equation will be shown in next slide.

$$\frac{M1}{M2} = \left(\frac{N2}{N1}\right)^{1/3}$$

Relationship that can be used to shorten the testing time.

$$(\Delta F1)^3 * N1 = A$$

$$(\Delta F2)^3 * N2 = A$$

$$(\Delta F1)^3 * N1 = (\Delta F2)^3 * N2$$

$$\Delta F1 = M1 * y/I \;\&\; \Delta F2 = M2 * y/I$$

$$(M1)^3 * N1 = (M2)^3 * N2$$

Where:
M1= Moment Produced by Design Truck
N1= Number of Fatigue Cycles Induced Over the Period of Design life of Bridge
N2= Number of Cycles to be Induced in Lab i.e. 5 Million in this study
M2= The Bending Moment Required to be Produced in Specimen to Simulate AASHTO Design Truck for N2 Number of Cycles.

$$\frac{M1}{M2} = \left(\frac{N2}{N1}\right)^{1/3}$$

Using the relationship develop in the previous slide, we applied 5,000,000 cycles and able to simulate the effect of 75 years of heavy truck traffic.

This was achieved by applying higher loads at lower number of cycles, vs, 219,000,000 cycles at much less load

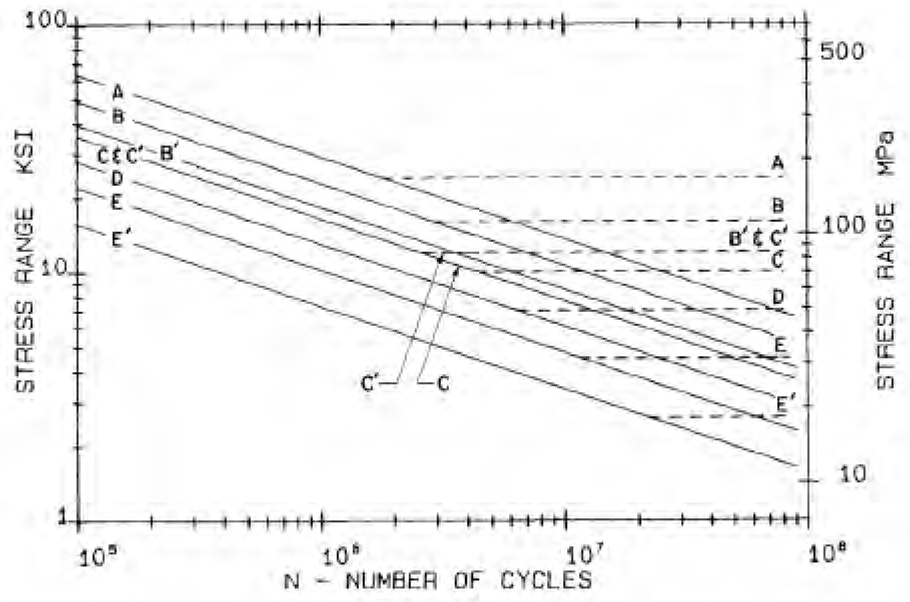
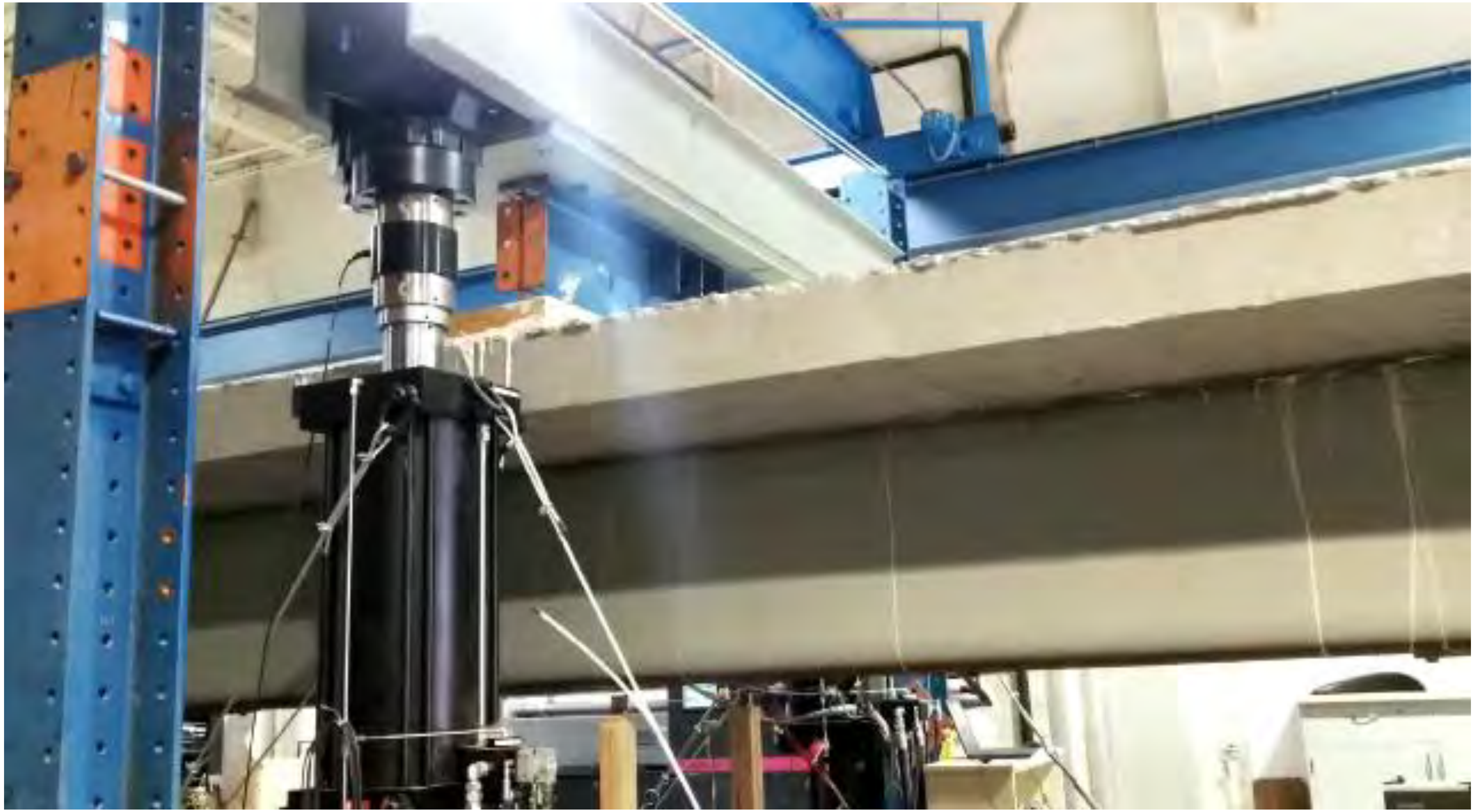


Figure C6.6.1.2.5-1 Stress Range Versus Number of Cycles.

5,000,000 cycles at about 10 ksi tensile stress in bottom flange
And
219,000,000 cycles at about 2.5 ksi tensile stress in bottom flange
Are on same S-N curve

THE EXPERIMENT

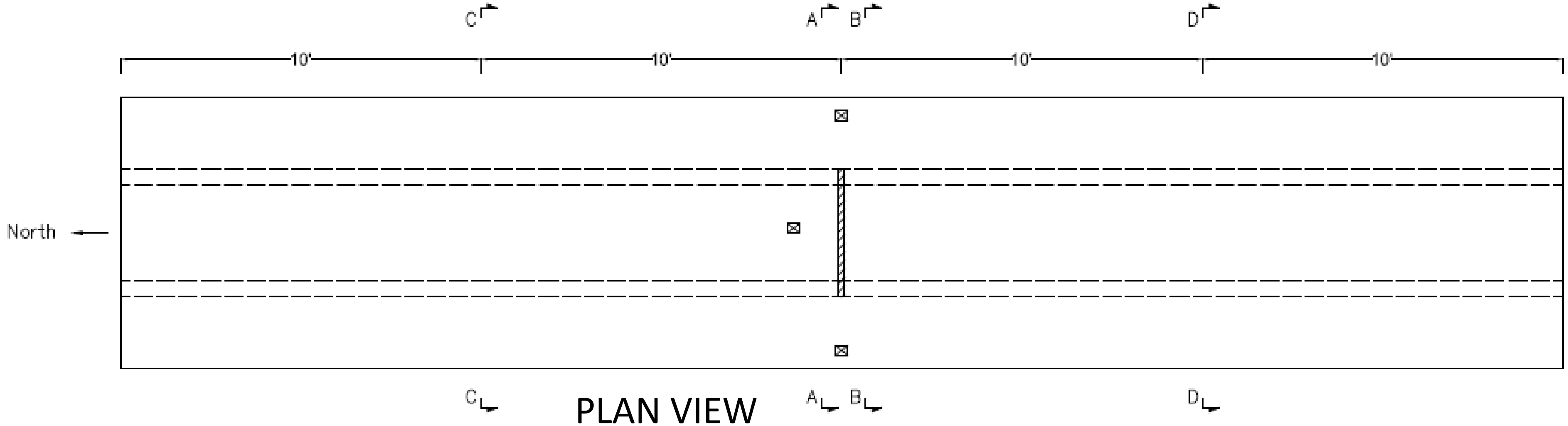
Cyclic test started on September 12th, 2019 Continuous 1.4 Hz.
Cyclic Test ended - October 21, 2019

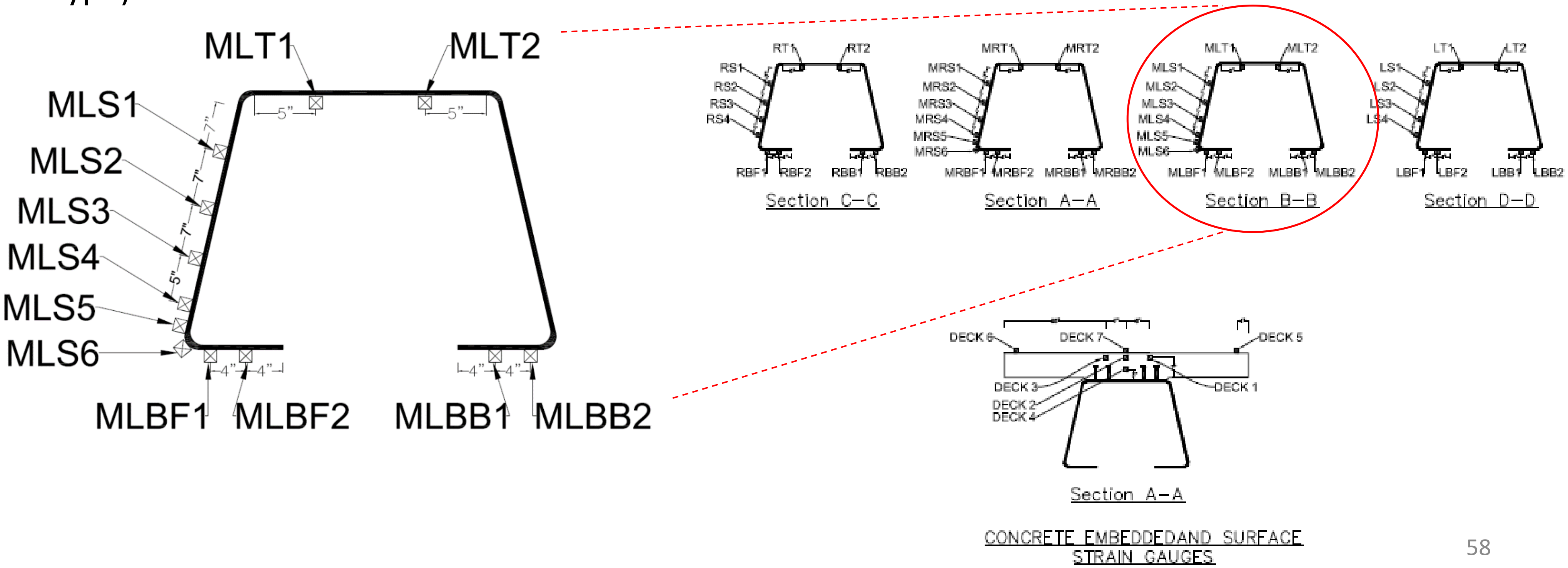


INSTRUMENTATION LAYOUT-STRAIN GAUGES

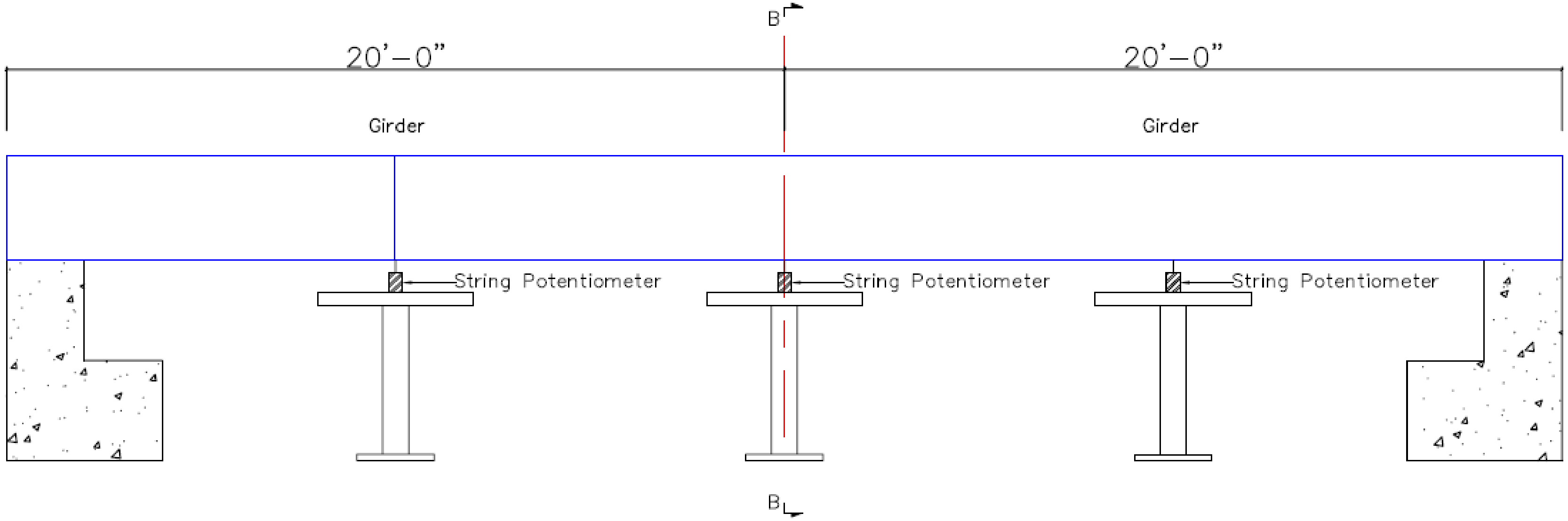
- Steel Strain Gauges
  - Midspan
  - Quarter Span
  - 44 Total (See Figure)

- Concrete Gauges
  - Midspan
  - 4 Emedded (VWType)
  - 3 Surface





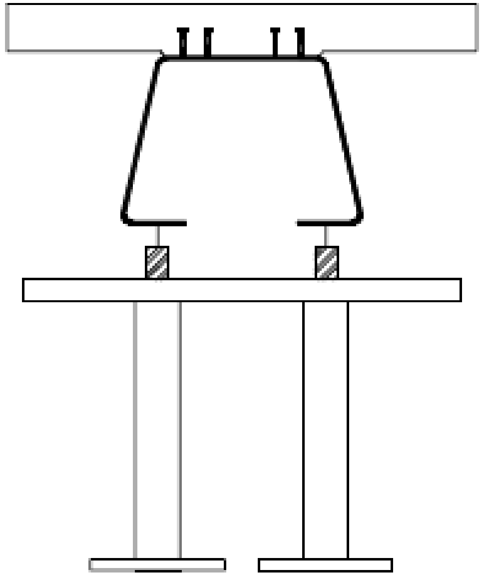
INSTRUMENTATION LAYOUT- POTENTIOMETERS



ELEVATION VIEW

- Vertical Displacement
  - Midspan
  - Quarter Span

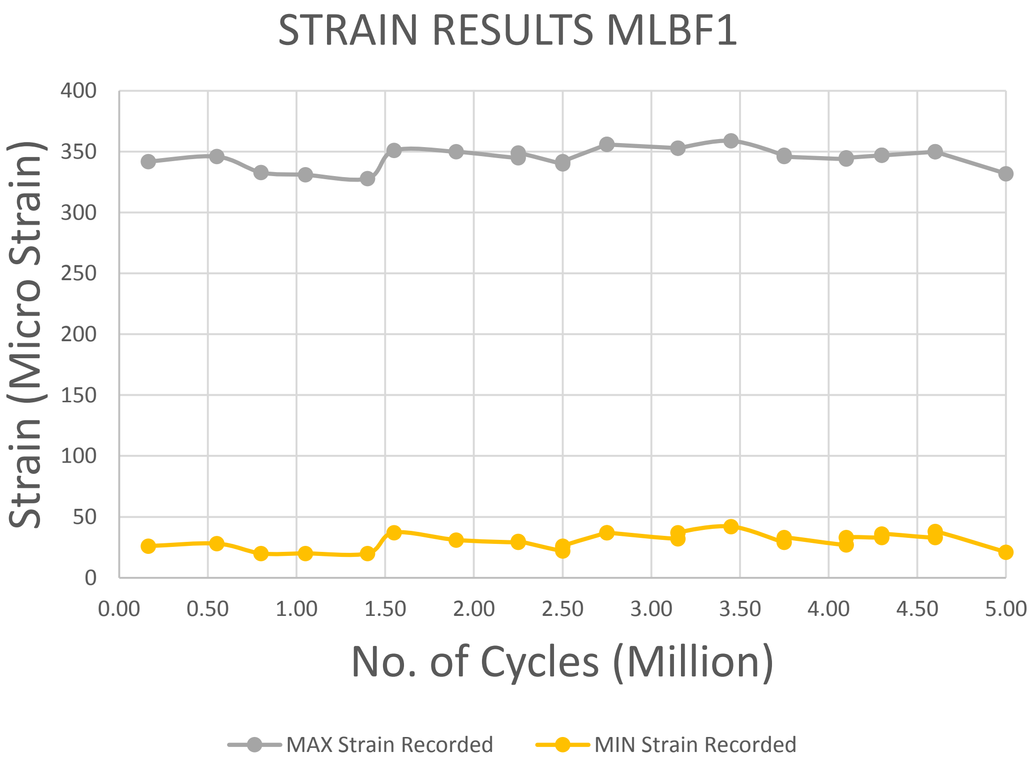
  - 2 Each Location

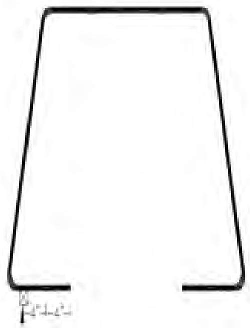


SECTION B-B

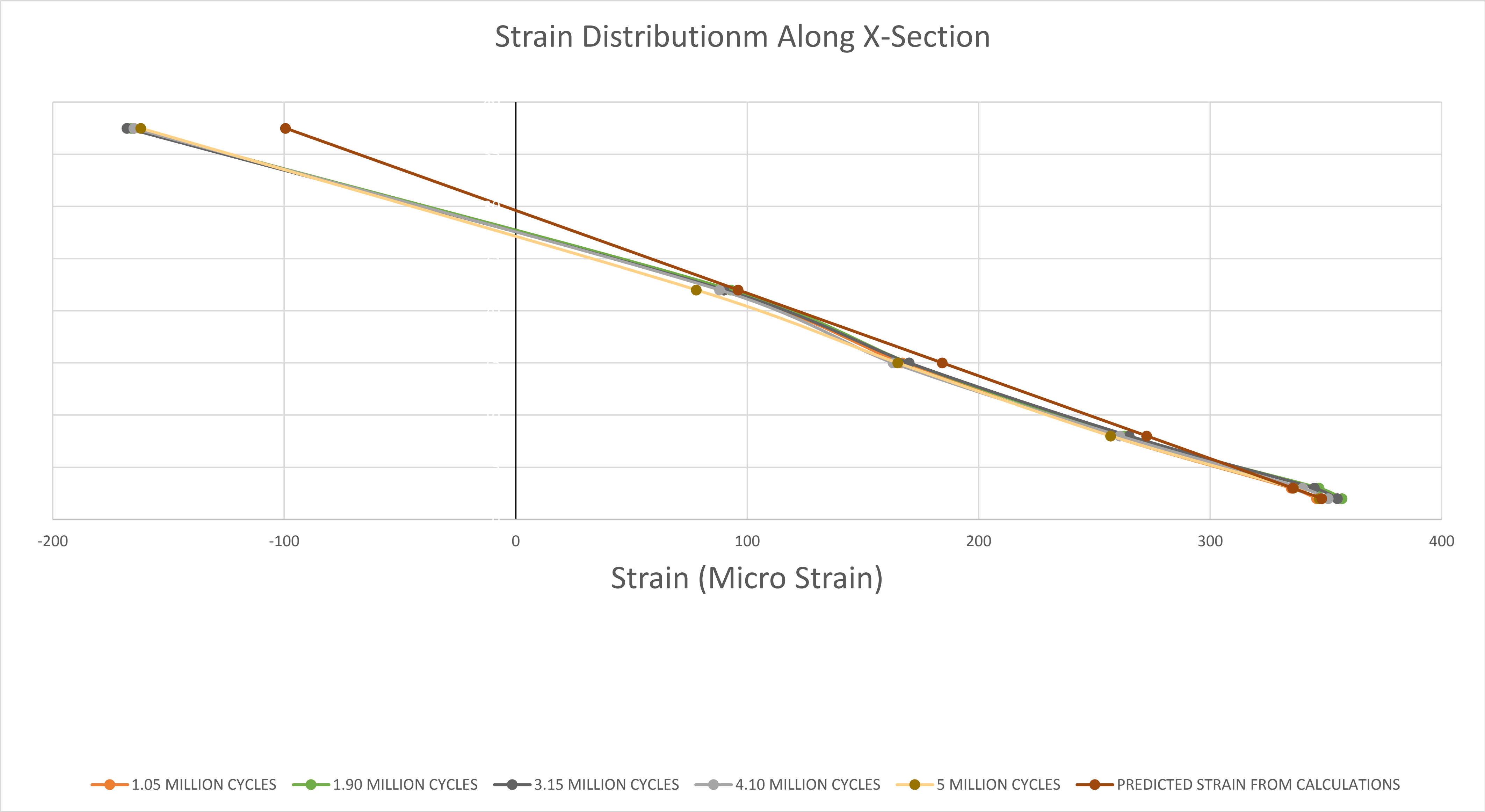
Typical Cyclic Test Result

- Table Shows Range of Strains Against Range of Force Applied Along The Course of Experiment.
- The Results Corresponds to Sensor MLBF1 Which is Also Shown with a Figure Alongside.



LOCATION OF SENSOR	NO. OF CYCLES (M)	RECORD	RANGE OF LOAD (KIP)			EXPECTED STRAIN DIFFERENTIAL	RANGE OF STRAIN (με)			% DIFF-STR EXPECTED-STR
			MIN	MAX	DIFF		MIN	MAX	DIFF	%
 MLBF1	0.17	AFTER	6.3	81.0	74.7	316.0	26	342	316	0.00%
	0.55	AFTER	6.6	81.0	74.4	314.7	28	346	318	1.04%
	0.80	AFTER	5.3	76.0	70.8	299.3	20	333	313	4.58%
	1.05	AFTER	5.1	76.8	71.7	303.3	20	331	311	2.54%
	1.40	AFTER	4.2	75.0	70.8	299.5	20	328	308	2.84%
	1.55	AFTER	6.5	79.5	73.0	308.8	37	351	314	1.68%
	1.90	AFTER	7.3	80.0	72.7	307.5	31	350	319	3.73%
	2.25	BEFORE	7.0	79.0	72.0	304.6	29	345	316	3.75%
		AFTER	6.5	81.0	74.5	315.2	30	349	319	1.22%
	2.50	BEFORE	5.0	78.0	73.0	308.8	22	340	318	2.98%
	2.50	AFTER	6.0	78.0	72.0	304.6	26	342	316	3.75%
	2.75	BEFORE	6.5	79.0	72.5	306.7	37	356	319	4.01%
	2.75	AFTER	7.0	79.0	72.0	304.6	37	356	319	4.73%
	3.15	BEFORE	6.0	78.0	72.0	304.6	32	353	321	5.39%
	3.15	AFTER	6.7	78.0	71.3	301.6	37	353	316	4.77%
	3.45	AFTER	7.0	78.0	71.0	300.3	42	359	317	5.54%
	3.75	BEFORE	5.0	77.0	72.0	304.6	29	347	318	4.41%
		AFTER	5.5	76.5	71.0	300.3	33	346	313	4.21%
	4.10	BEFORE	5.0	76.7	71.7	303.3	27	344	317	4.51%
		AFTER	5.5	76.5	71.0	300.3	33	345	312	3.88%
	4.30	BEFORE	5.0	75.5	70.5	298.2	33	347	314	5.29%
		AFTER	5.0	75.5	70.5	298.2	36	347	311	4.28%
	4.60	BEFORE	5.0	75.5	70.5	298.2	33	350	317	6.29%
		AFTER	5.0	76.0	71.0	300.3	38	350	312	3.88%
	5.00	BEFORE	3.7	74.0	70.3	297.4	21	332	311	4.58%

THE RESULTS- SRAIN ACROSS SECTION



Summary

The full penetration weld used to connect two FPG segment and result in longer length was able to resist 5,000,000 cycles of high applied load, simulating 75 years, passage of heavy truck traffic, without sustaining any damages.

Therefore the recommendation is to use full penetration weld to connect two segments for achieving longer FPG lengths. This detail is category C detail if weld reinforcement is not removed and Category B if weld reinforcement is removed.

Making longer folded plate system using shorter segments allows more fabricators to be able to fabricate the girders

There is not many 60 ft long press breaks

However, there are many fabricators that have 40 ft long press breaks

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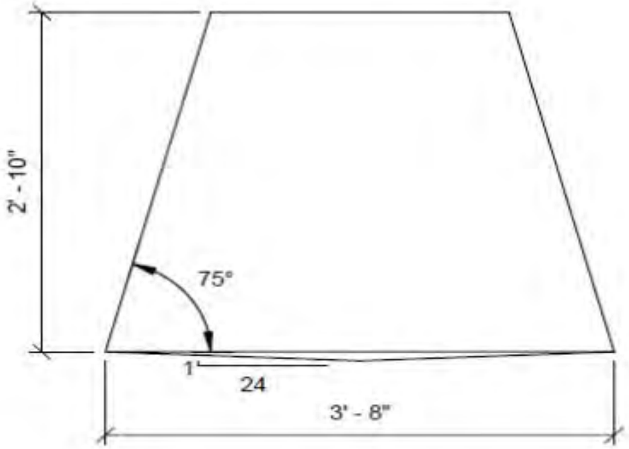
Plate Width 119 Inches

	Span	Thickness	Yield	Pos Str	Service	Fatigue	Defl
	90	0.5	50	0.86	1.17	0.81	1.15
	85	0.5	50	0.79	1.08	0.76	1
80	80	0.5	50	0.73	0.99	0.71	0.92
	75	0.5	50				
	65	0.5	50				
95 Alt	95	0.5	70	0.73	0.9	0.86	1.29
90	90	0.5	70	0.67	0.84	0.81	1.15
	85	0.5	70				
	75	0.5	70				
	65	0.5	70				

	Span	Thickness	Yield	Pos Str	Service	Fatigue	Defl
	105	0.75	50	0.85	1.11	0.7	1.13
95	95	0.75	50	0.74	0.96	0.63	0.93
	85	0.75	50				
	75	0.75	50				
105	105	0.75	70	0.65	0.79	0.7	1.13
	95	0.75	70				
	85	0.75	70				
	75	0.75	70				

Cross Section for Longer Span Lengths



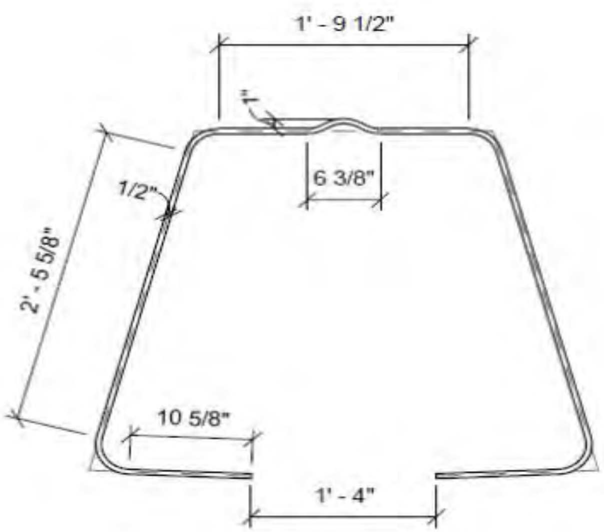


Plate (Flat) Width = 119"

Height about 32 inches

Maximum Span (Feet)

	50 KSI	70 KSI
1/2"	80	90
3/4"	95	105

For 80 ft span
Span/depth = 30

For 90 ft span
Span/depth = 34

For 105 ft span
Span/depth = 40

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Future Plans

- Using rolling operation for making Folded Plate Steel Girder
- Developing orthotropic deck system option
- Completing the bolted options

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Development of the Folded Steel Plate Girder System with longer length is part of research activities at ABC-UTC

One of our objectives is to commercialize results of our research

Many Folded Steel Plate Girder Bridge Systems are in service with excellent performances and having maximum length of less than 60 ft.

System with length approaching 100 ft. is ready for field application We are looking for partners to use longer length

States with Folded Steel Plate Girder Bridge system in service

We are very interested in commercialization of the system

Contact Dr. Atorod Azizinamini at

aazizina@fiu.edu

402-770-6210

If interested in using Folded Plate Girder Steel Bridge System