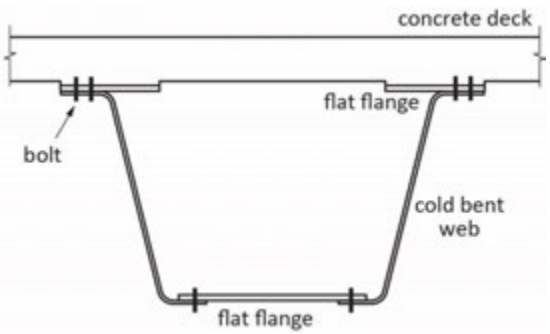
UNIVERSITY OF NOTRE DAME

HNTB

Built-up Press-brake Formed Tub Girders



Research Need Statement

- Accelerated bridge construction has evolved significantly, with a focus on minimizing traffic disruption
- Little research in advancing rapid fabrication
- Fabrication of simple steel bridges takes tens of weeks
- Prestressed concrete girders dominate short-span market, but are heavy, often requiring large cranes and special trucking and permits

Not just ABC but ABF

Accelerated Bridge Construction (ABC)

- Dramatic reduction in traffic disruption
- Modest overall time savings

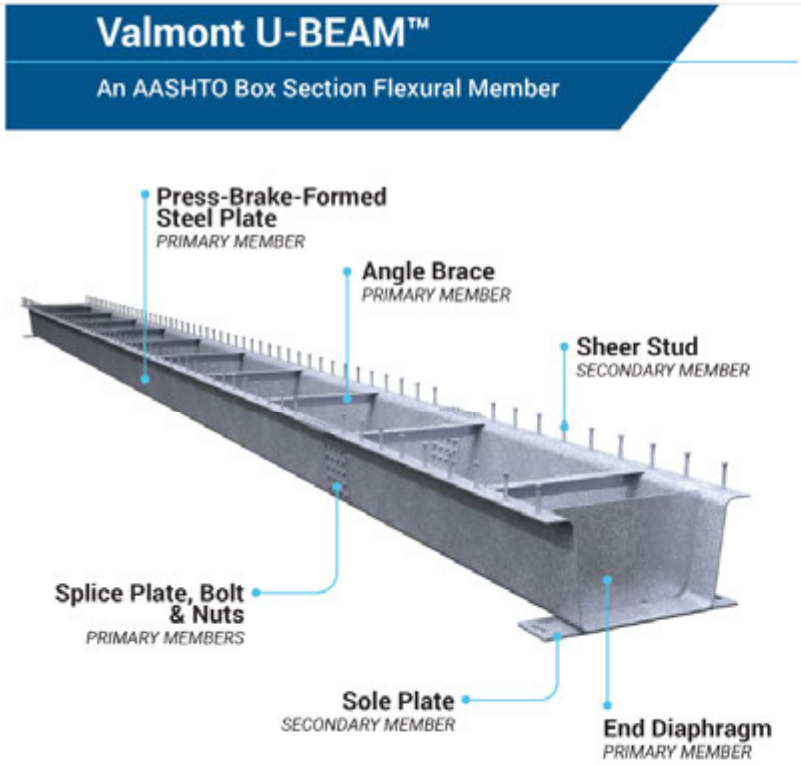
What about Accelerated Bridge Fabrication (ABF)?

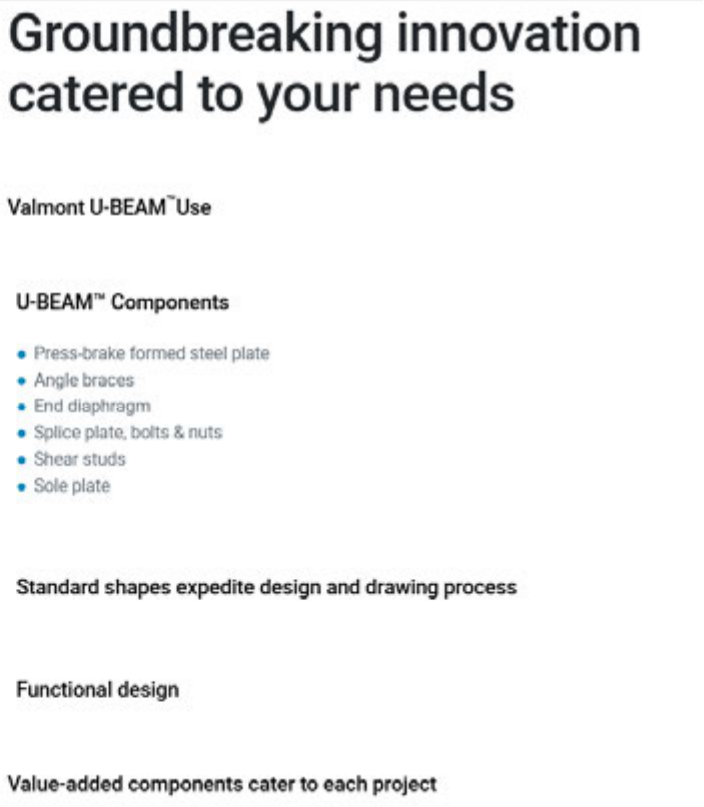
- From months to days?

Kit of Parts

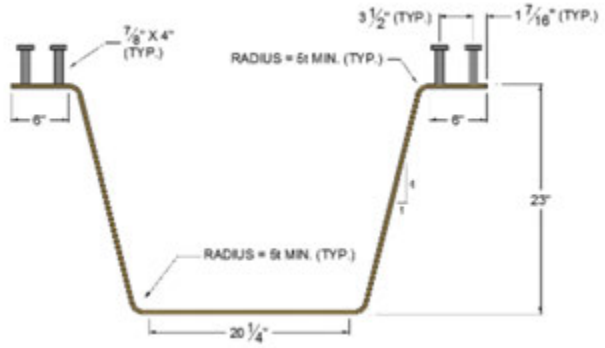
- Minimize time for design, shop drawings, and fabrication

Existing Short-Span Steel Solutions

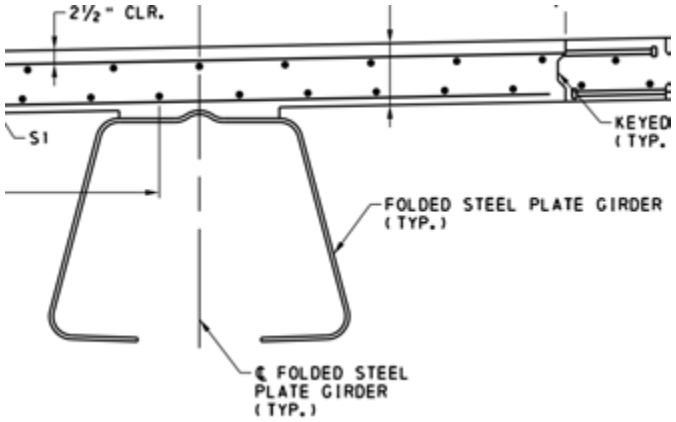




Press-Brake-Formed Tub Girders



Folded Steel Plate Girder



Images courtesy of Short Span Steel Bridge Alliance and CDR

Valmont & Investment in PBTG

Valmont Workflows

#1 AASHTO STEEL PLATE MATERIAL

AASHTO 11.3.1.2
AASHTO M270. **Made in the USA**. Steel Plates and Structural Shapes shall conform to ASTM A709/A709M.

#2 AASHTO FORMING

AASHTO 11.4.3.3 - Bent Plates
Fracture-critical and Non-fracture critical plates and bars shall be cold bent.

#3 AASHTO CAMBERING

AASHTO 11.4.12.2.7
Cold cambering is a customary means of achieving camber… to avoid impact damage to the steel, it's appropriate to introduce bending pressure in a controlled fashion.

#4 AASHTO WELDING AND SHEAR STUDS

AASHTO 11.3.3
Certified Welders and welded stud shear connectors shall satisfy all requirements of the AASHTO/AWS D1.5M/D1.5 Bridge Welding Code related to material, manufacturing, physical properties, certification, and welding.

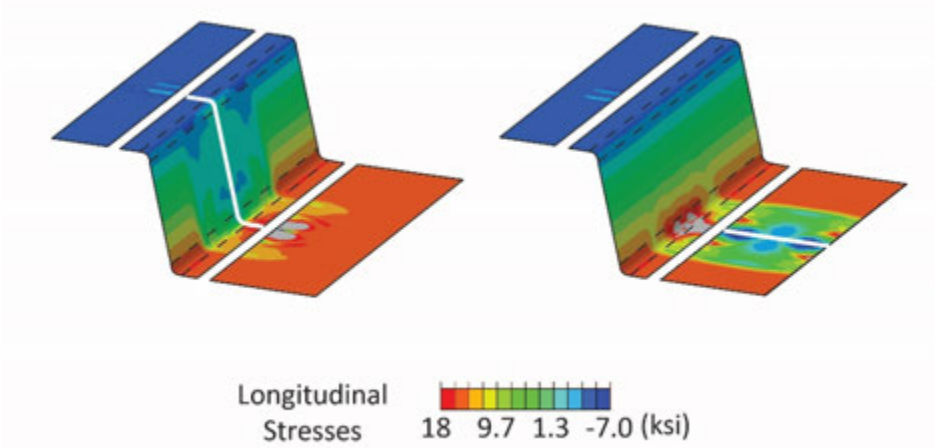
#5 AASHTO PROTECTIVE COATING

AASHTO 11.3.7
Galvanizing shall be in accordance with AASHTO M 111M/M 111 (ASTM A123/A123M)

Built-up Press-brake Formed Tub Girders

Distinct Form:

- Web is the only press brake formed component
- Virtually any tub shape and long spans possible
- No Welding
- Bolted Up Form is internally redundant
- Can be transported loose (webs stack like pringles)
- Transmission Pole Manufacturing Workflows



System Redundancy – Twin Box Girder Bridges

UT Austin Tests on Twin Box Girders

- Blast induced Bottom Flange Fracture = 1” deflection under HS20
- Full Web Fracture & Explosive Release from Temp Support = 7” deflection
- Final Static Load Test – Applied Load of 363 kips >5x legal limit

FSEL Test Bridge

Figure 1.7: Second bridge fracture test

Incremental loading

Collapsed bridge

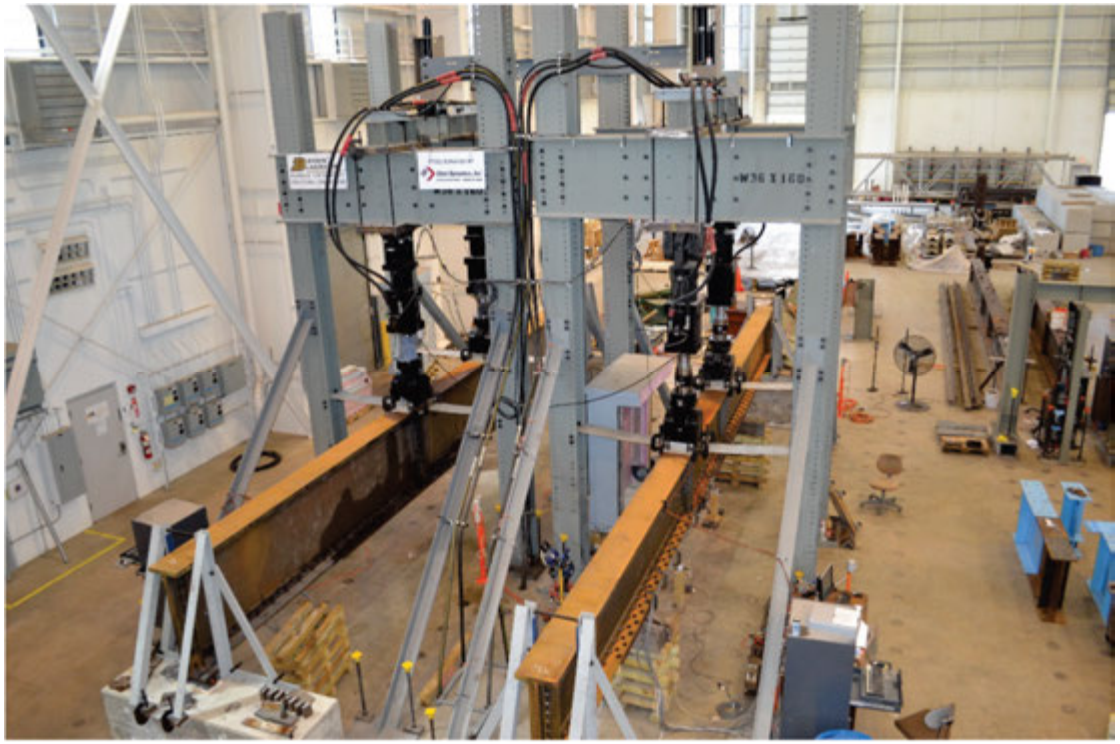
Explosively Induced Fracture & Support Loss

Barnard et al. 2010, Modeling and Response of Fracture Critical Steel Box Girder Bridges

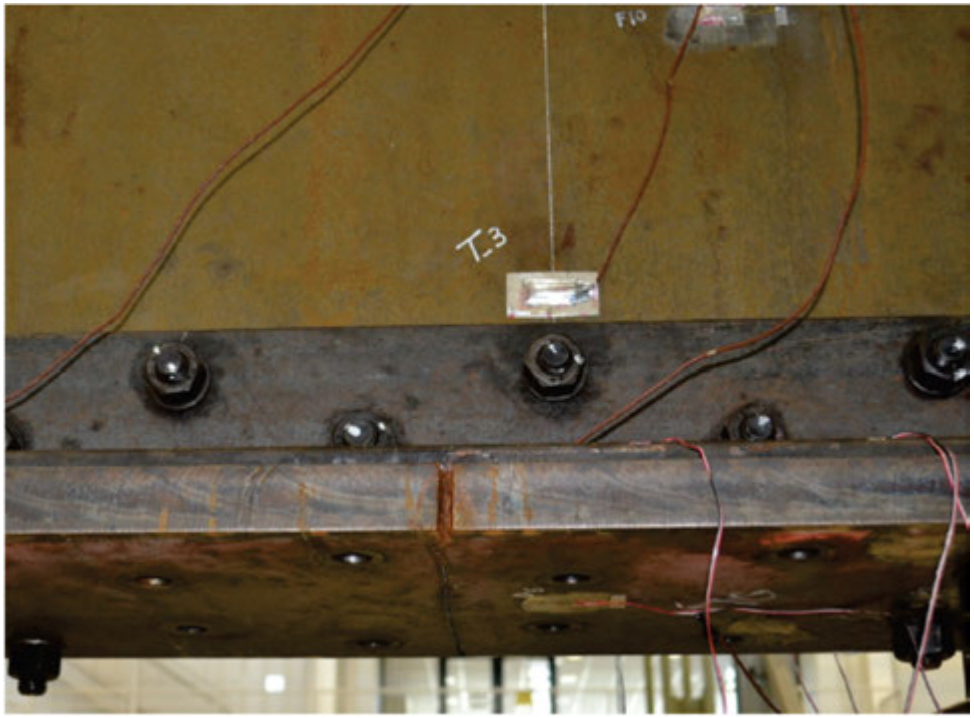
Internal Redundancy – Rob Connor's Work

Purdue Research Girders Subjected to Flexure

- Built-up sections prevent crack propagation to adjacent
- Cooled to -83°F (lower shelf)
- Driving wedges to force cover plate crack propagation
- No propagation into any component



Test Setup for Fatigue and Strength



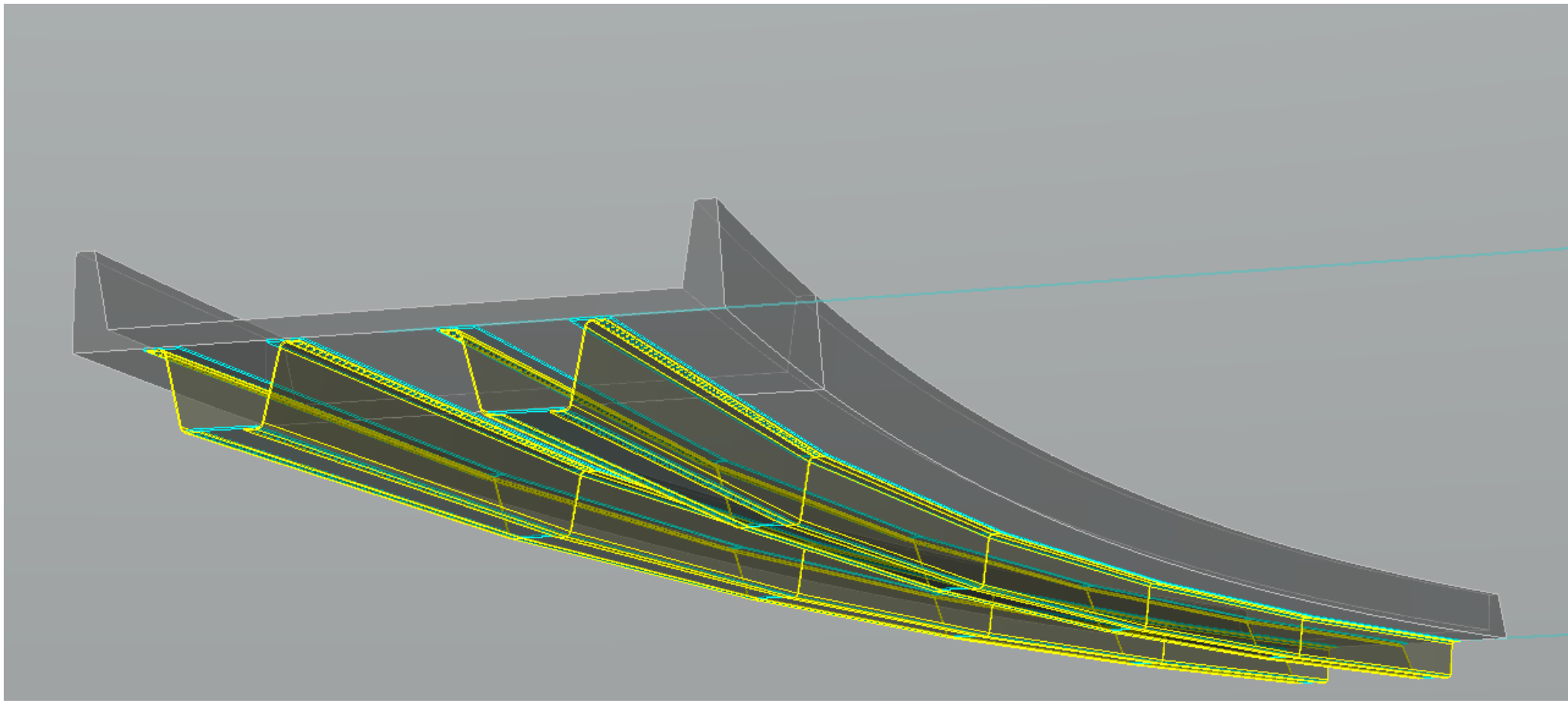
Cover Plate Crack Induced by Wedges

Hebdon, Connor et al. 2015, Member Level Redundancy of Girders Subjected to Flexure

Internal Redundancy - Stacked FB’s & Through Stringers

Built-up Press-brake Formed Tub Girders

- Piece-wise straight: Camber & Curvature through kinked splices



Research Project

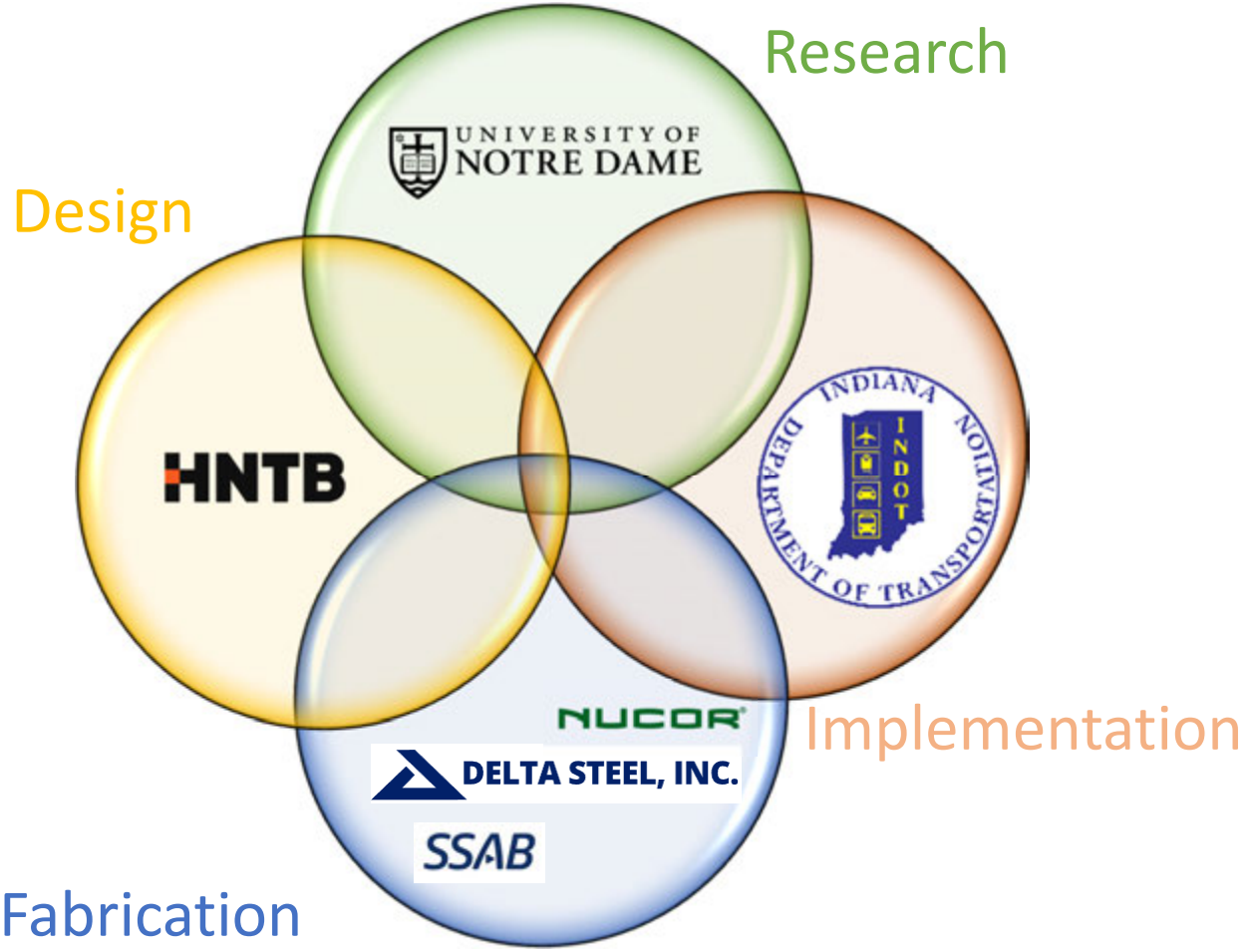
Objectives:

1) Design and build 2 demonstration bridges

2) Measure behavior of demonstration bridges

3) Develop and optimize a kit-of-parts system

Collaboration:



DELTA STEEL, INC.

INFRA-METALS

- Bringing new fabrication capabilities to accelerate project delivery

DELTA STEEL, INC.

INFRA-METALS

- Steel on the Ground (No Mill Order Step)
- Fabrication on-demand or prefabricated stockpile

Photo credit: Delta Steel Inc

Two Demonstration Bridges

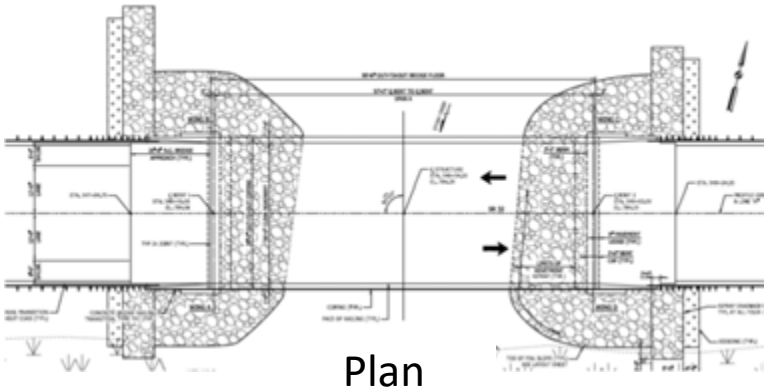
Simple Span: 97 ft

Two-span Continuous:
105 ft – 86 ft

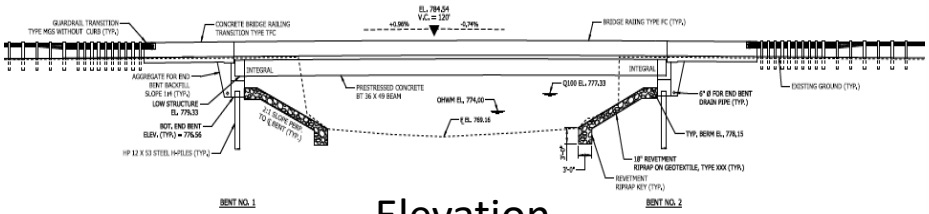
Existing Bridges

Simple Span (97 ft)

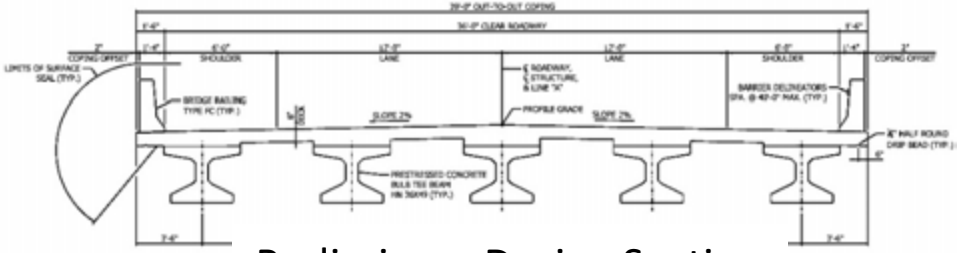
Built-up Press-Brake Formed Tub Girder Design



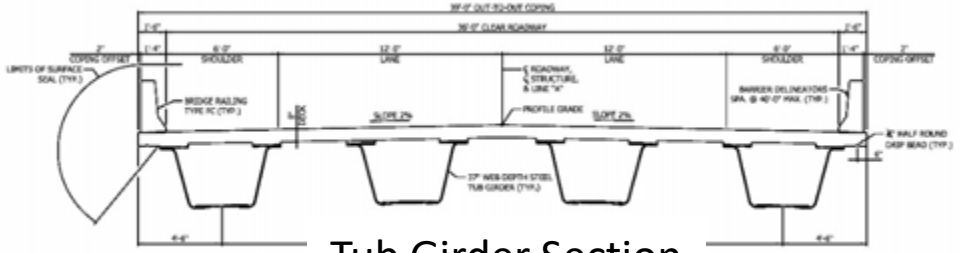
Plan



Elevation



Preliminary Design Section

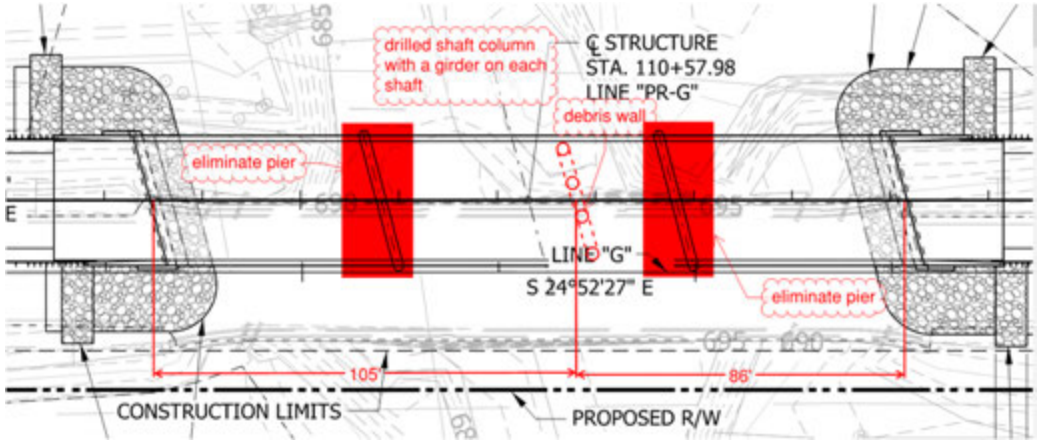


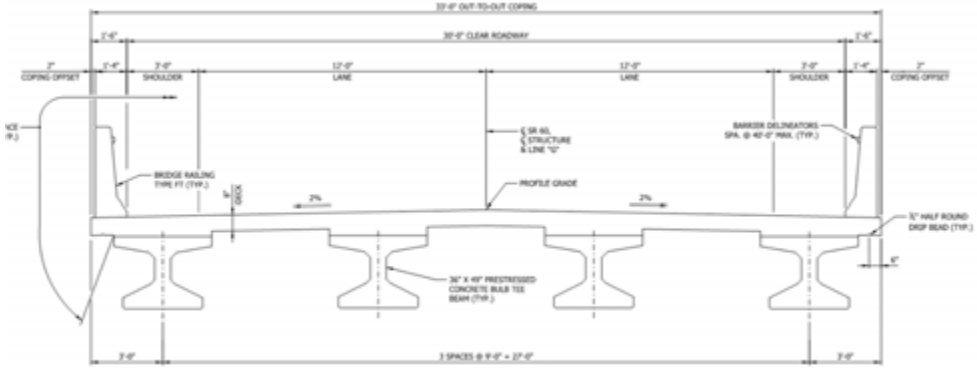
Tub Girder Section

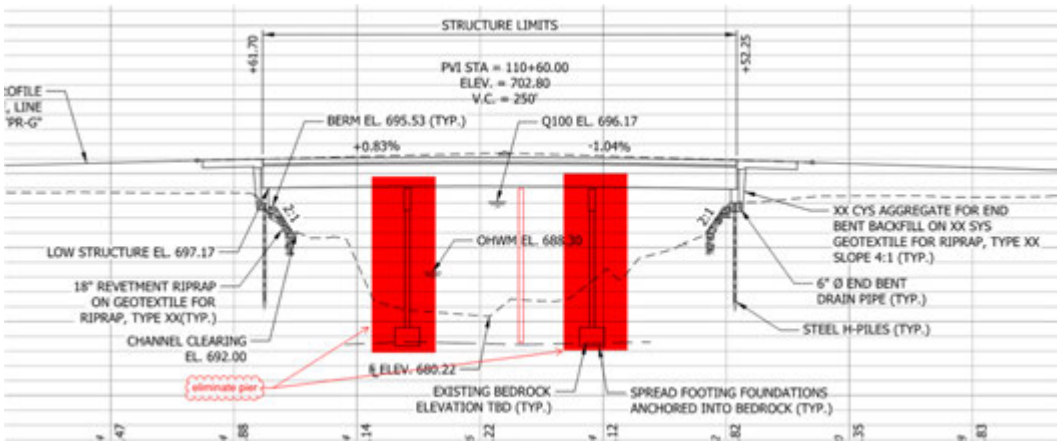
- Tub girders are ½ the weight of prestressed concrete girders
- One less girder line

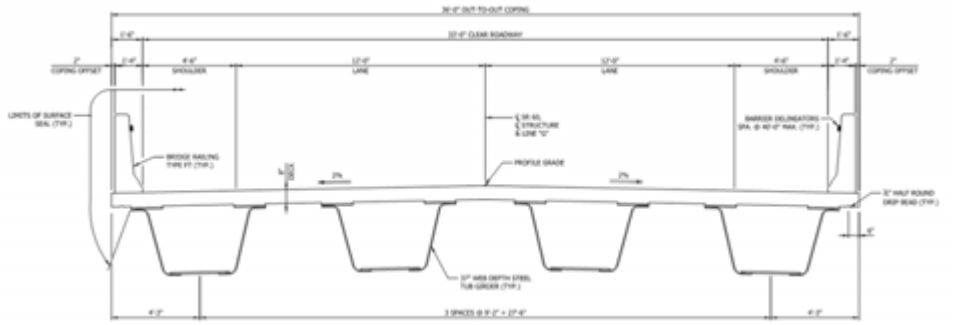
Two-Span Continuous (105 ft – 86 ft)

Built-up Press-Brake Formed Tub Girder Design





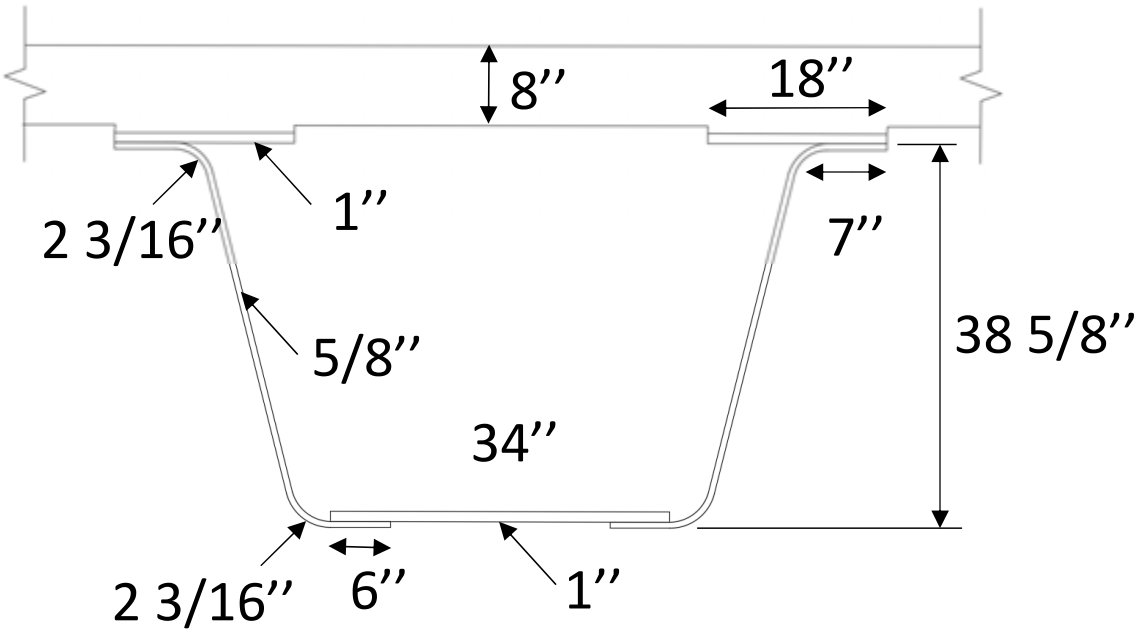




Tub Girder Section

For Both Demonstration Bridges:

Cross-section:



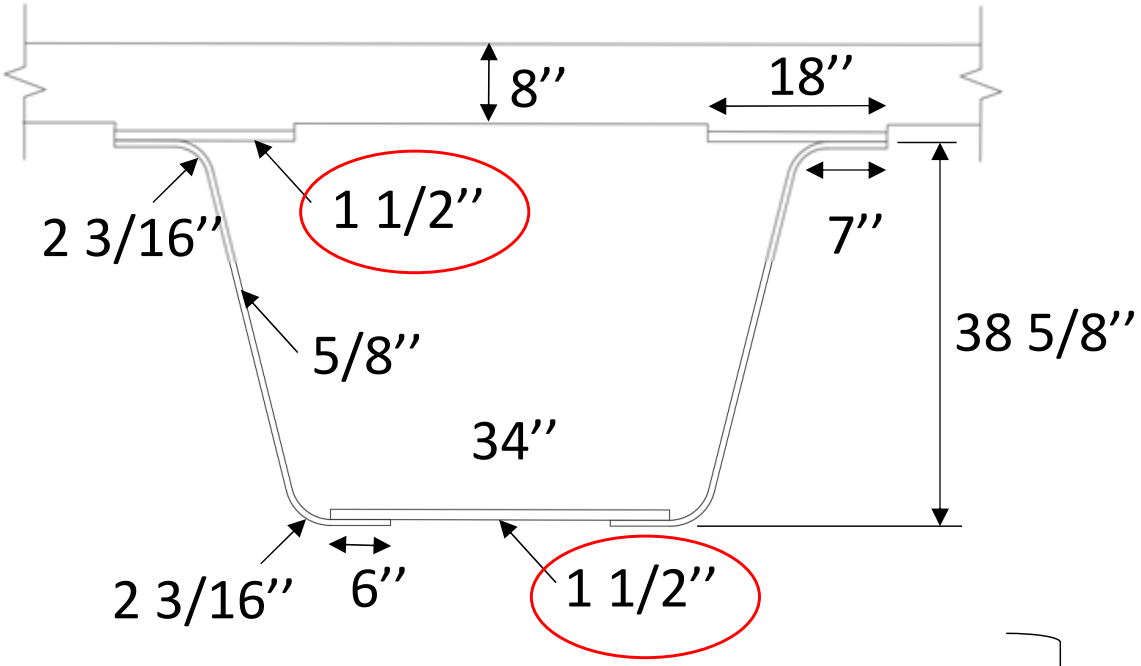
Simple Span and
Two-Span Continuous in
Positive Moment Region

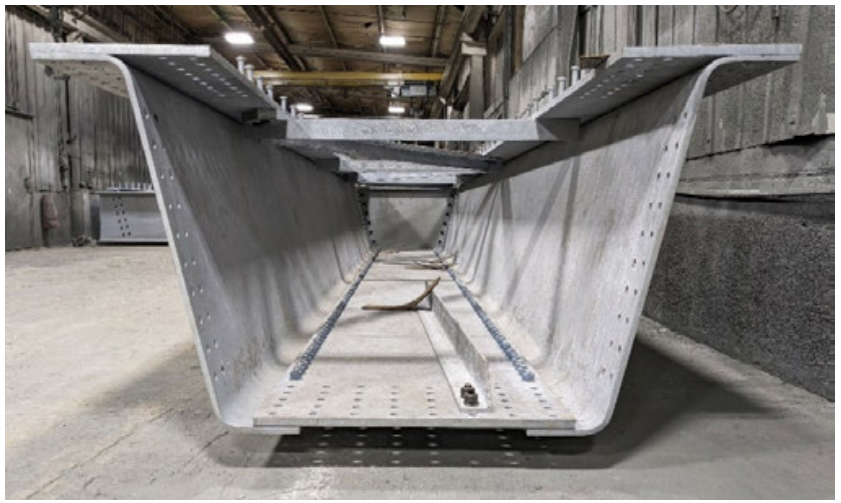
Same Sections for
Both Bridges:

Kit-of-Parts

For Both Demonstration Bridges:

Cross-section:





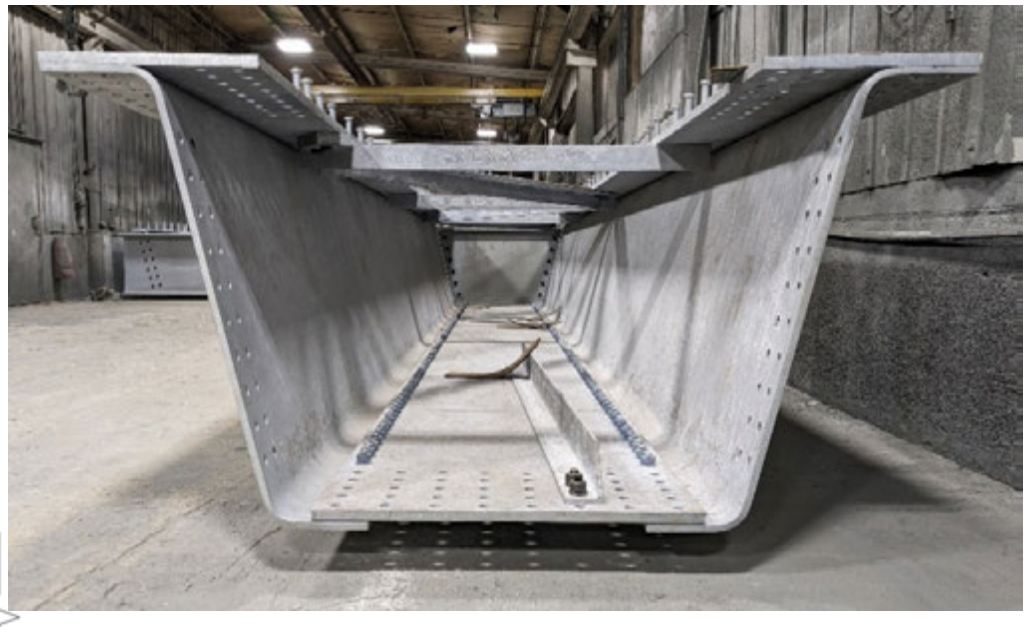
Two-Span Continuous in Negative Moment Region

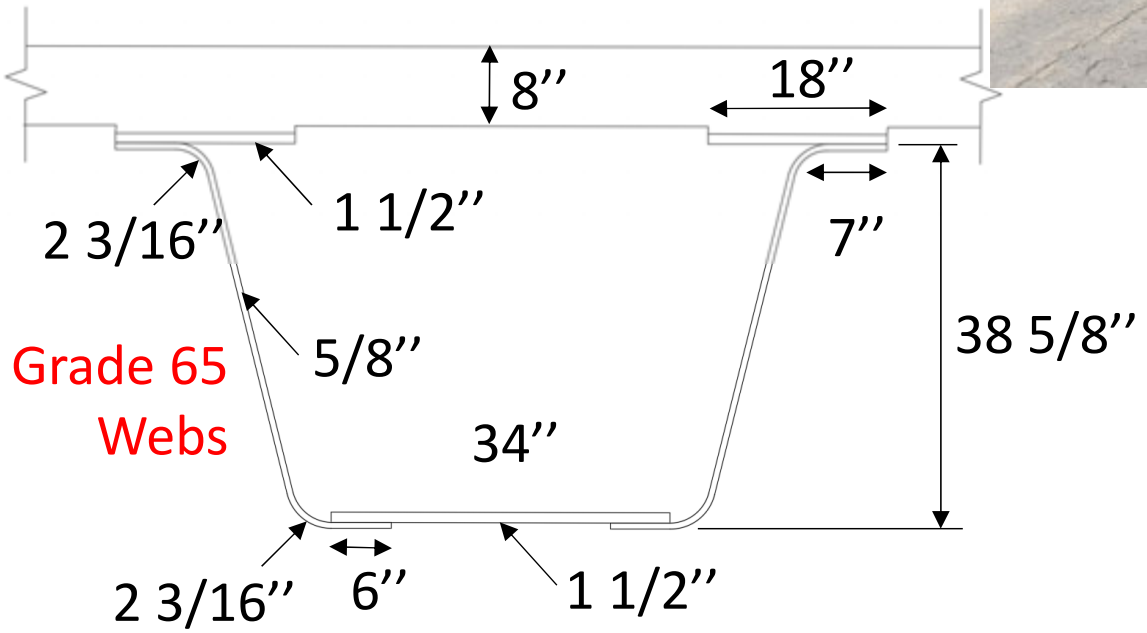
Same Sections for Both Bridges:

Kit-of-Parts

For Both Demonstration Bridges:

Cross-section:

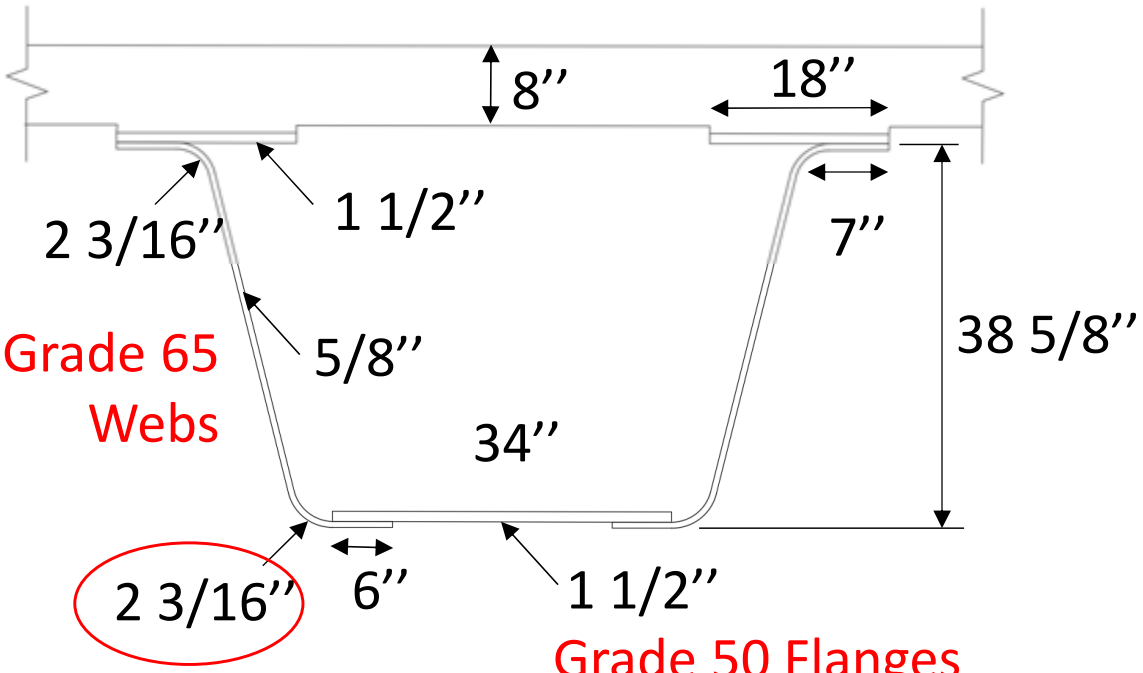




Grade 50 Flanges

For Both Demonstration Bridges:

Cross-section:



Press-brake:

transmission pole manufacturers

ASTM A572 Grade 65 /
ASTM A871 Grade 65

CVN's 15 ft-lb @ -20 °F

Photo credit: Delta steel Inc

NUCOR®
PLATE MILL GROUP

P.O.Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report

Page 1

1505 River Rd
Cofield, NC 27922
(252) 356-3700

Issuing Date : 02/07/2022 **B/L No. :** 616175 **Load No. :** 633473 **Our Order No. :** 195404/1 **Cust. Order No. :** DFT-67689

Vehicle No: TTPX 80287

Specification: 0.6250" x 120.000" x 300.000"
ASTM A572 Grade 65-21e1 Modified Quench and Tempered

Sold To: DELTA STEEL
7335 ROUNDHOUSE LN
HOUSTON,TX 77078

Ship To: DELTA STEEL INC-FT WORTH SO FRWY
PRIMARY STOCK
9217 S FREEWAY
UP RR SPOT #0275400
FT WORTH,TX 76161

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	Ceq	Pcm
2600561	0.16	1.26	0.008	0.002	0.19	0.10	0.06	0.04	0.01	0.024	0.043	0.002	0.001		0.0013	0.0000	0.008	0.40	0.25

			Tensile Test					Heat Treat			
Plate Serial No	Pieces	Tons	Dir.	Yield (psi)	Tensile (psi)	Elong. % in 2"	Elong. % in 8"	Quench (°F)	Time (min)	Temper (°F)	Time (min)
2600561-03-4	1	3.19	H-T	89,100	99,900	36.5		1665	27	1250	34

			Charpy Impacts																	
			--------Absorbed Energy (Ft-lbs)--------					------Lateral Expansion (in.)---------					----------Shear (%)----------						
Plate Serial No	Pieces	Tons	Dir.	(ft-lbs) 1	(ft-lbs) 2	(ft-lbs) 3	(ft-lbs) Ave	Min	(in.) 1	(in.) 2	(in.) 3	(in.) Ave	(in.) Min	(%) 1	(%) 2	(%) 3	(%) Ave	Min	Temp (°F)	Size
2600561-03-4	1	3.19	H-L	180.1	171.1	176.1	175.8	15											-20	10mm

175.8 ft-lb @ -20 °F

SSAB

12400 Highway 43 North, Axis, Alabama 36505, US

Test Certificate

⚠ **WARNING:** This product can expose you to chemicals including nickel and nickel compounds, which are known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Form TC1: Revision 4: Date 6 Feb 2019

Customer:
INTERNAL USE MOBILE
12400 HWY 43 NORTH

AXIS
AL 36505

Customer P.O.No.: DFT-71999 **Mill Order No.** 41-674785-05 **Shipping Manifest:** AT356856

Product Description: ASTM A572(21) 65/M450
CVNL 15 FT.LBS @ -20DEG F/A673-H

Ship Date: 15 May 22 **Cert No:** 081046415
Cert Date: 15 May 22 (Page 1 of 1)

Size: 0.625 X 112.0 X 532.0 (IN)

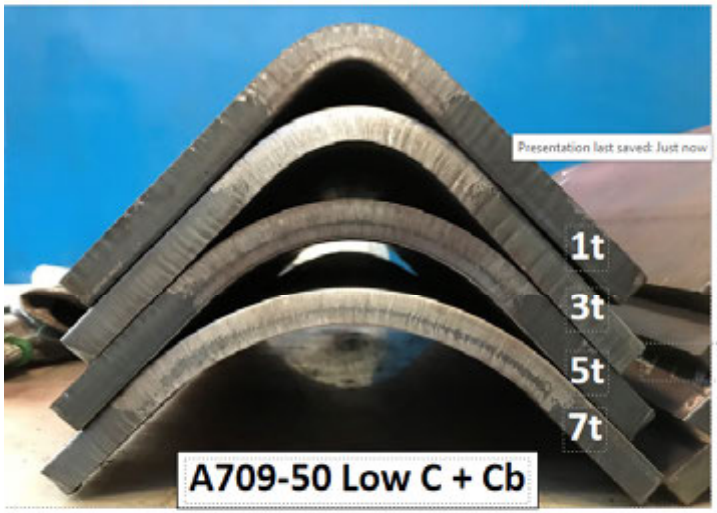
Tested Pieces:				Tensiles:						Charpy Impact Tests								
Heat Id	Piece Id	Tested Thickness	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
E2E127	B15	0.625 (DISCRT)	L	75	87		33	T							
			T	67	83		30	T							
E2E127	B16	0.625 (DISCRT)	L	74	87		36	T							
			T	72	86		35	T							
E2E127	B14	0.624 (DISCRT)	L							127 106 96 110		-22F	L	10.	

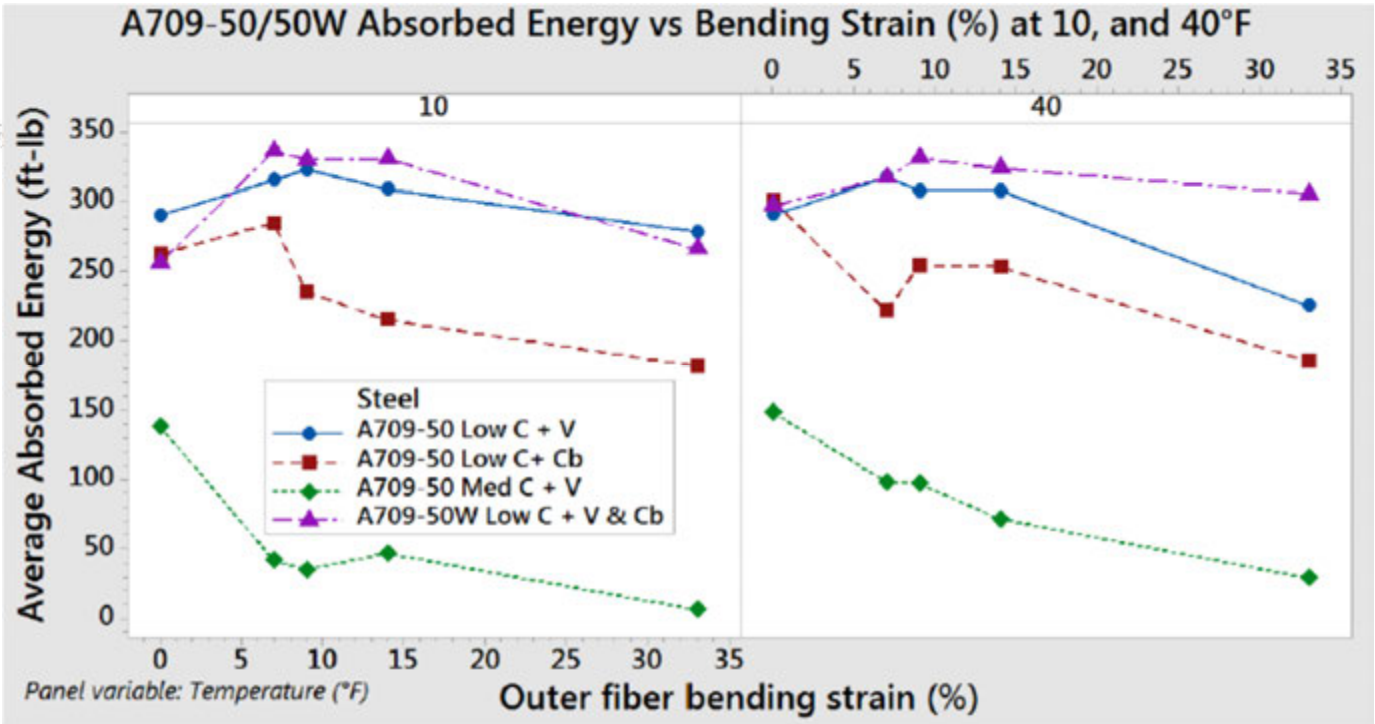
Chemical Analysis																
Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	ORGN
E2E127	.15	1.19	.009	.002	.03	.028	.23	.13	.16	.02	.026	.056	.007	.0001	.0090	USA

110 ft-lb @ -22 °F

SSAB (Stoddard's work on cold forming)

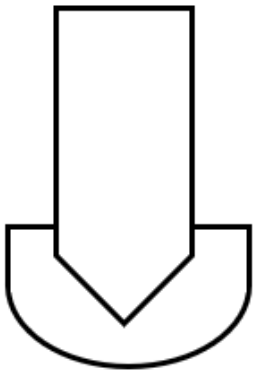
A709-50/50W specimens formed with 7t, 5t, 3t and 1t bend radii





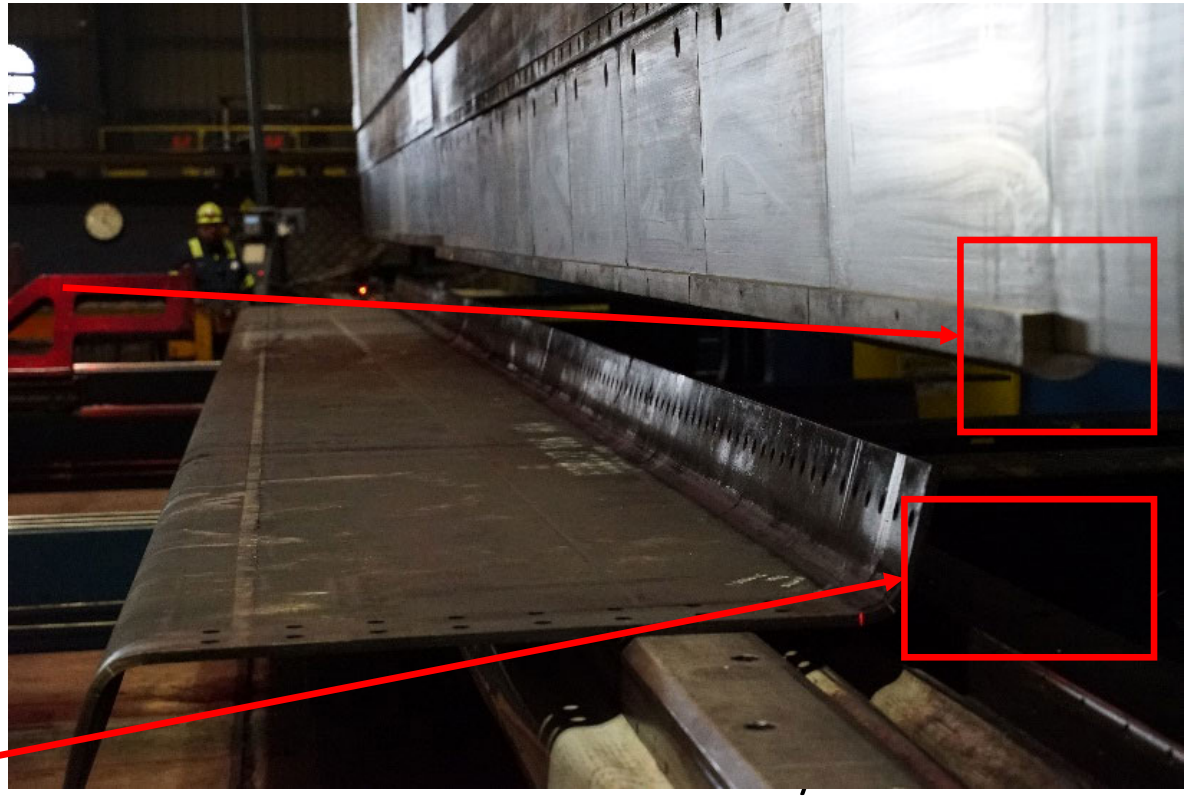
For Both Demonstration Bridges:

Cross-section:



Bull nose R = 2 3/16”

Airgap

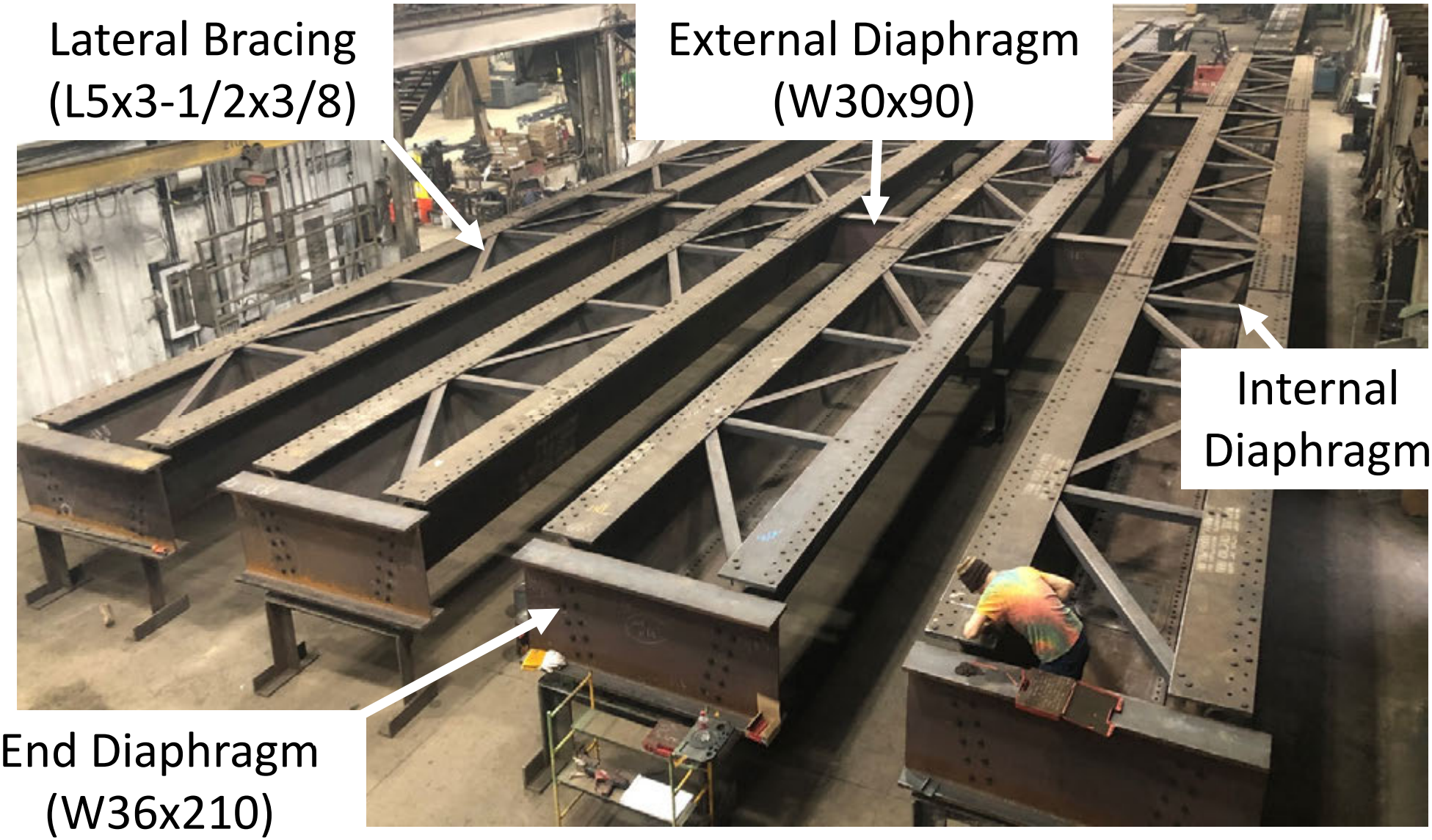


ASTM A871 Grade 65

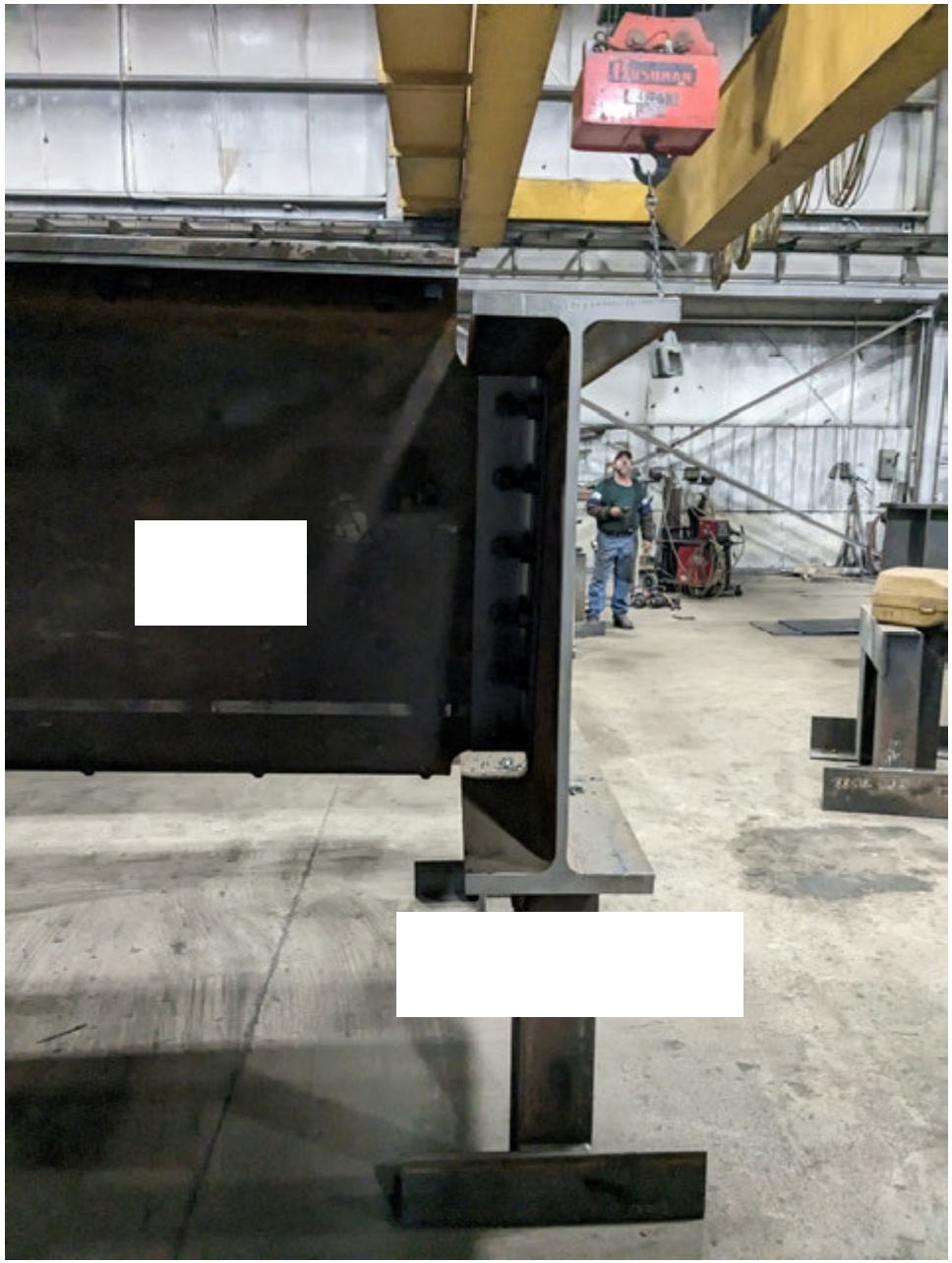
CVN’s 15 ft-lb @ -20 °F

Photo credit: Delta steel Inc

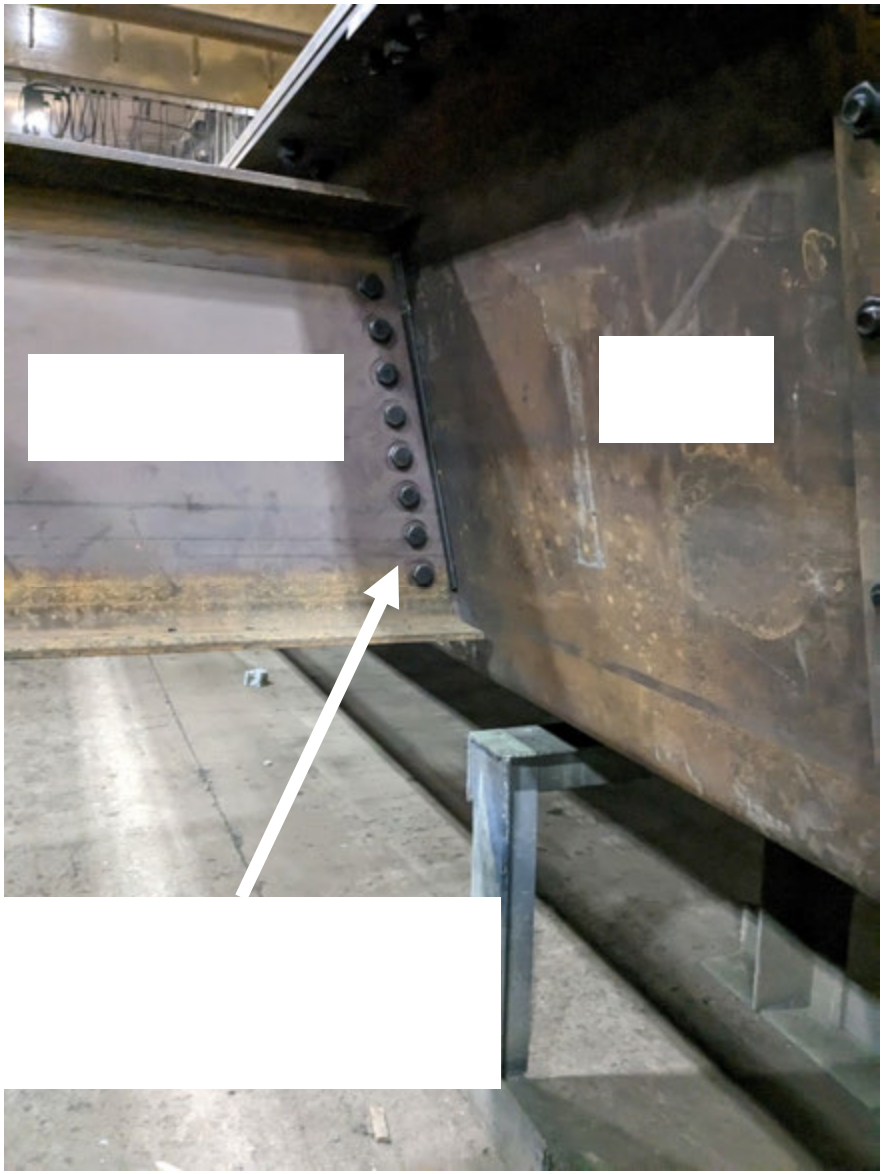
Bridge Details



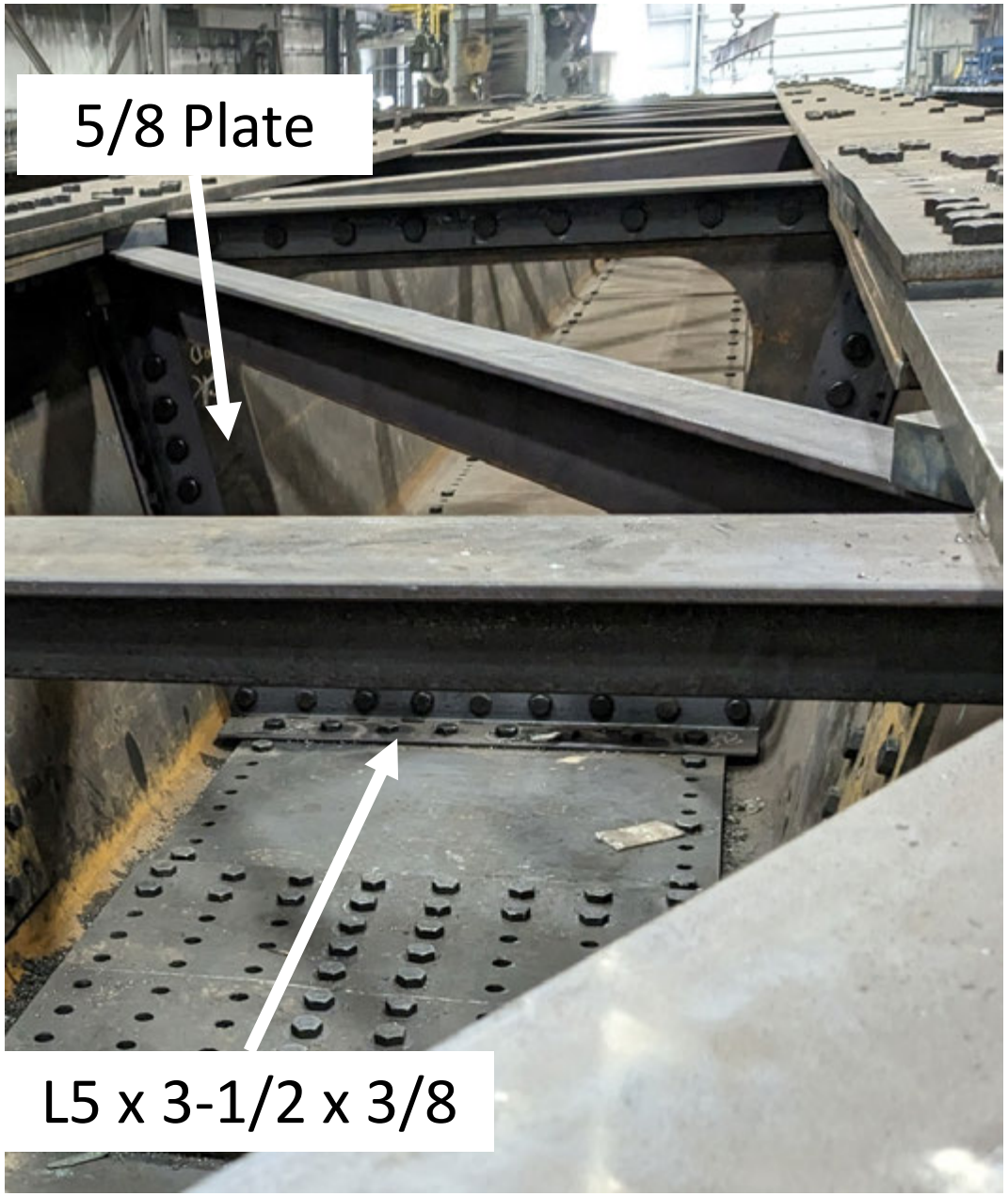
End Diaphragm: W36 x 120

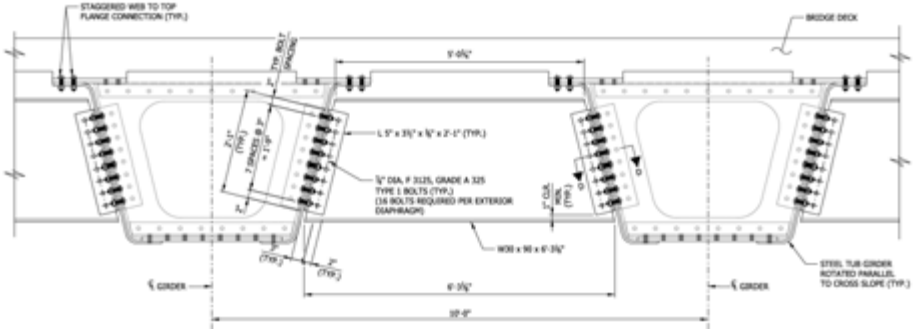


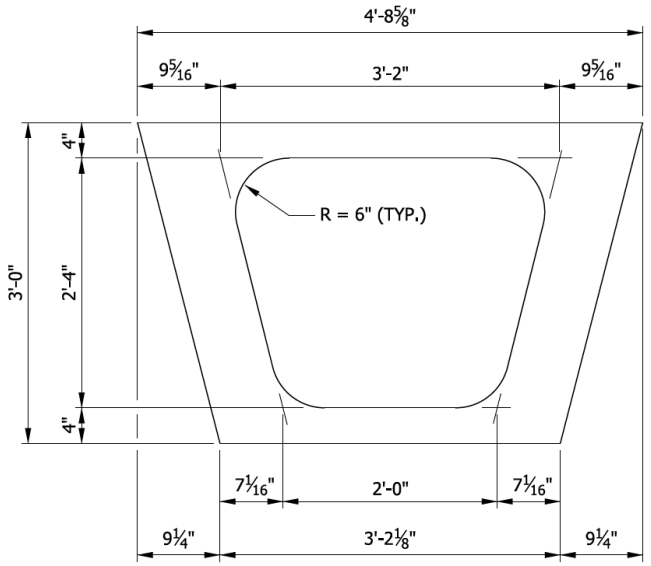
External Diaphragm: W30 x 90

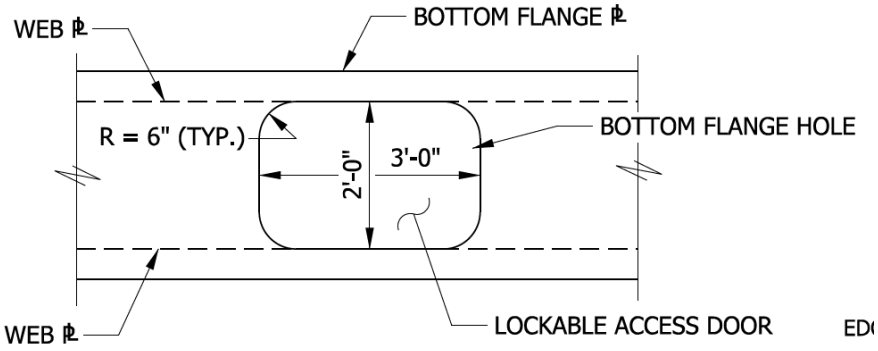


Internal Diaphragm: 5/8 Plate

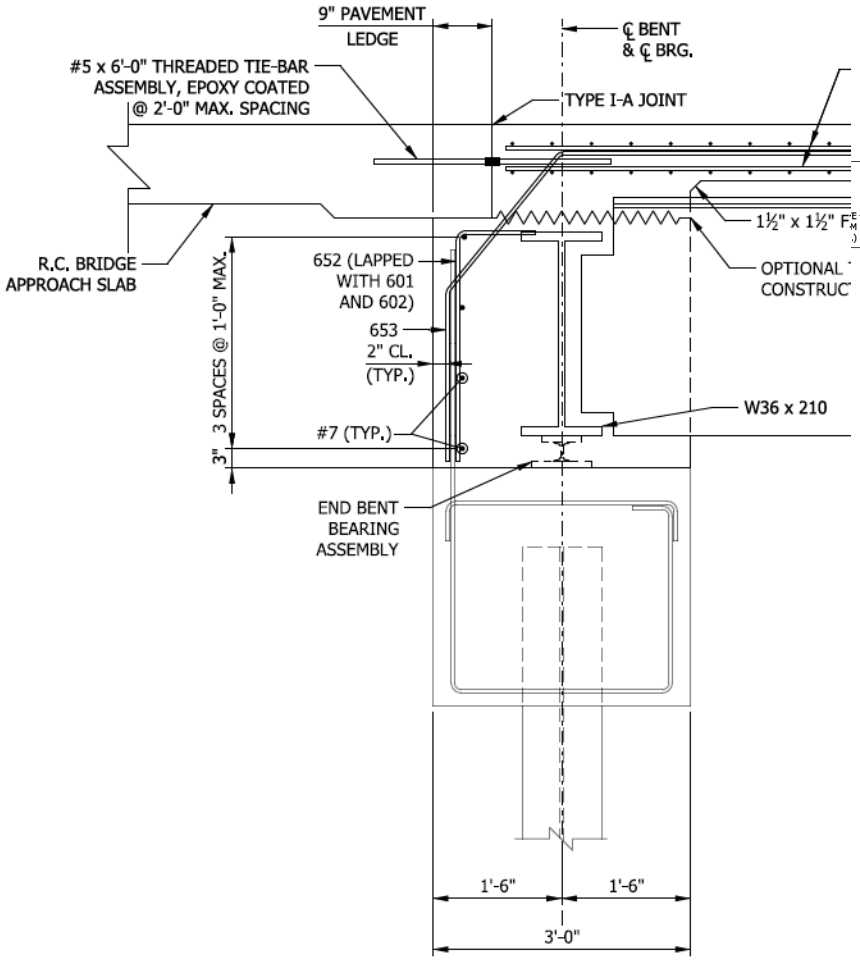


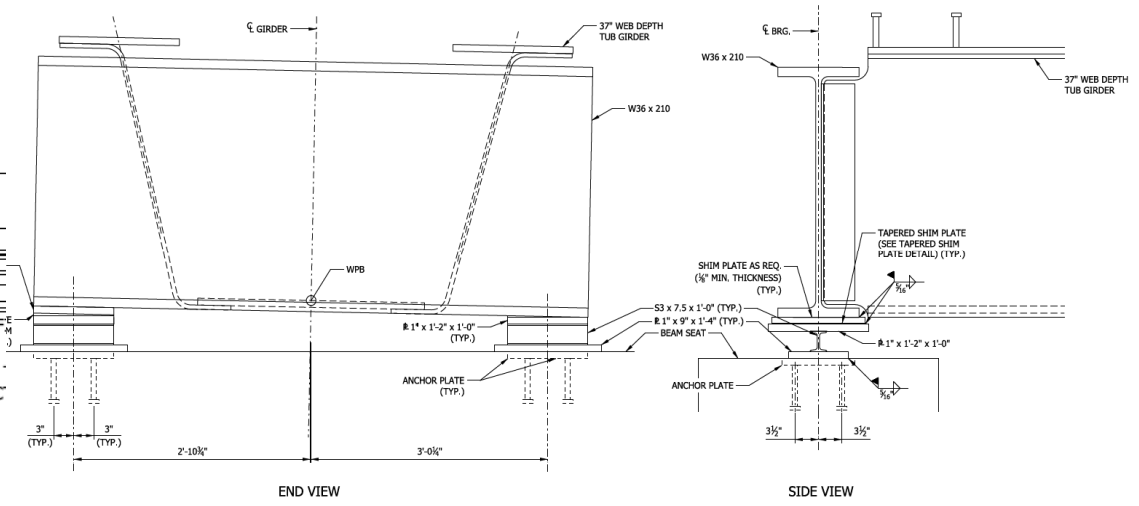




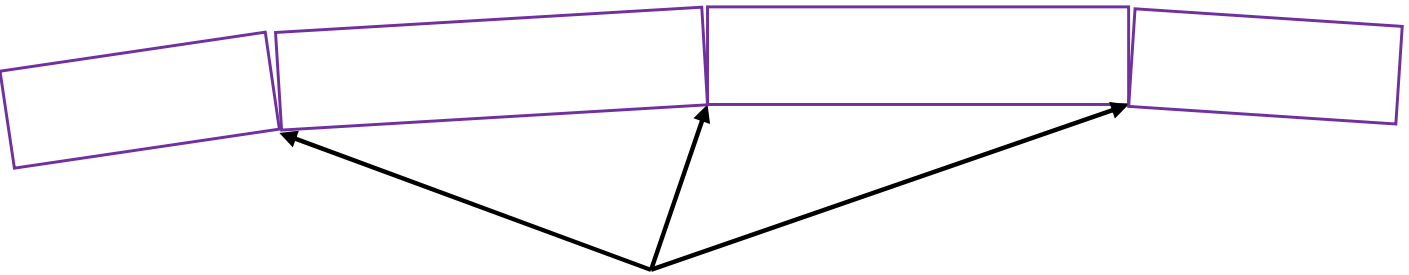


Integral Abutments

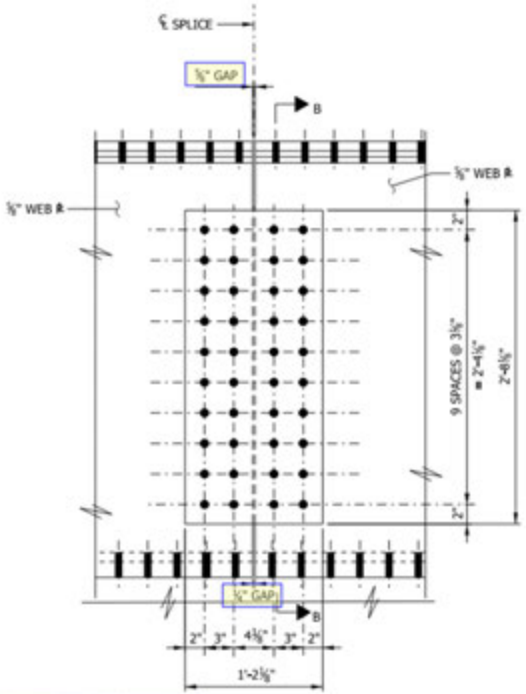




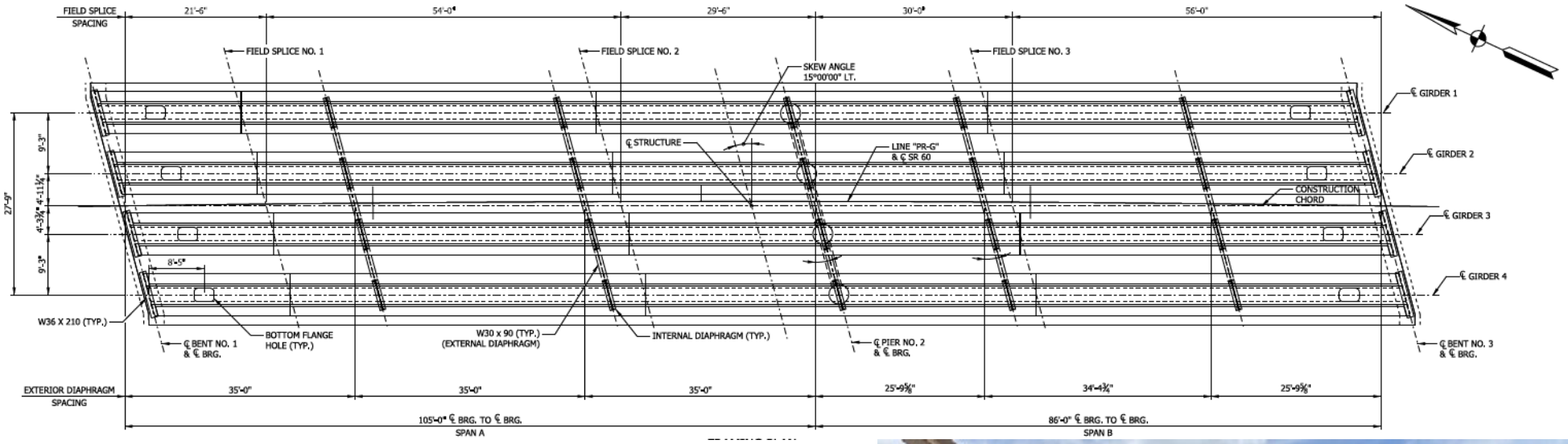
Camber: Kinked Splices

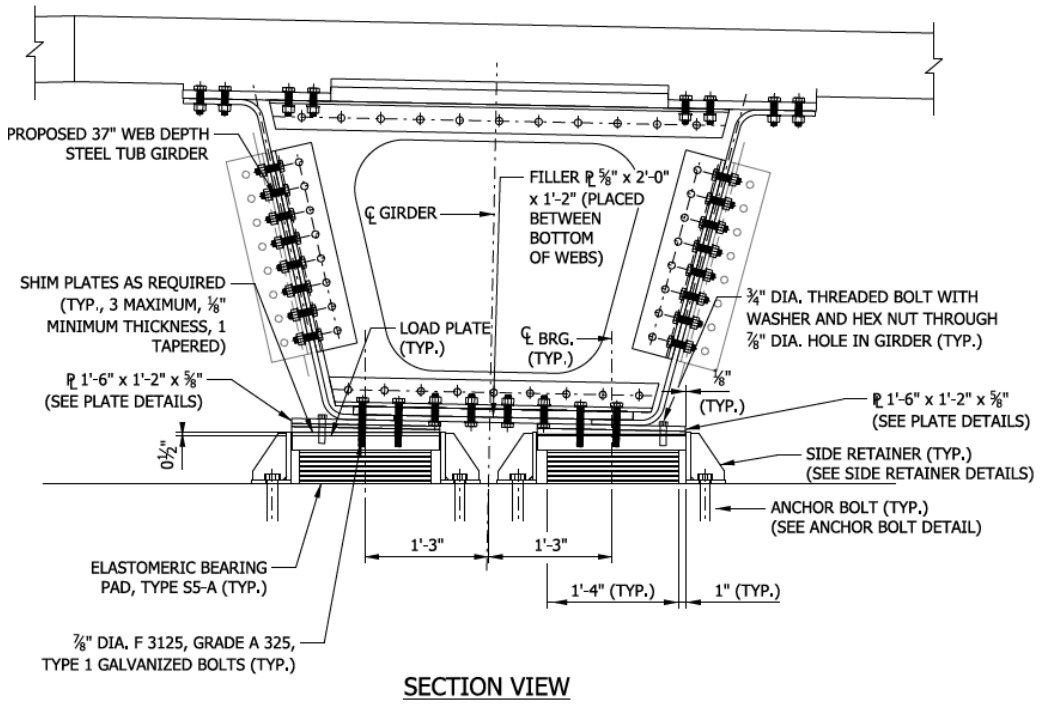


Kink Points



Two-Span Continuous: Skewed Diaphragms





SECTION VIEW

DELTA STEEL, INC.

INFRA-METALS

Press-Brake Formed Webs

Photo credit: Delta Steel Inc

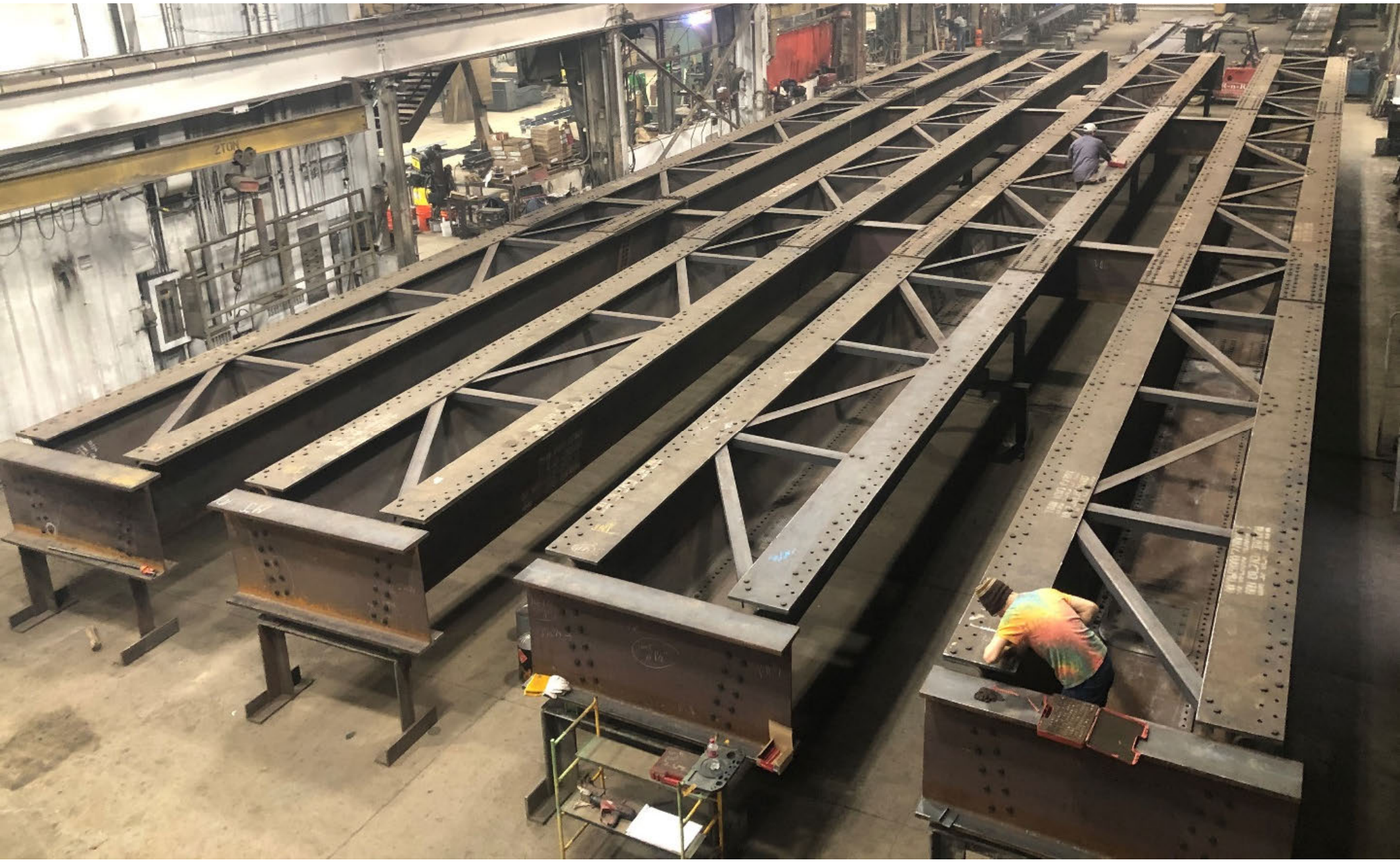
DELTA STEEL, INC.

INFRA-METALS

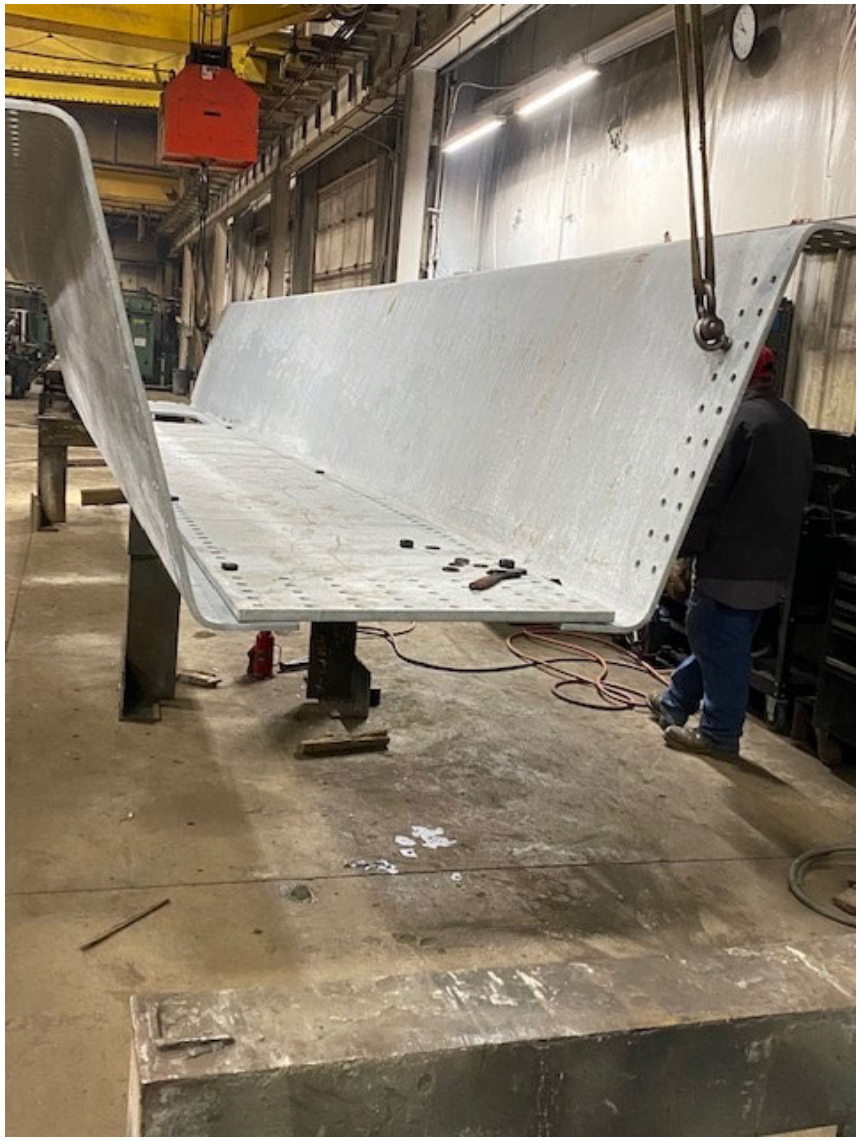
Press-Brake Formed Webs

Delta Steel Inc

Full Shop Assembly



Galvanized and Bolted-up at Shop



Transported to Site Fully Bolted Up

Girders Set on Site

Simple Span: Completed July 2023

Two-span Continuous: Completed July 2024

Phase 1 Construction

Lessons Learned & Future Improvements

- Stock material for webs selected based on material certifications to validate bend radii
- For skewed bridges, avoid skewed internal diaphragms
- Further development to limit the number of different pieces
- Optimize Top Lateral Bracing, focus on end regions

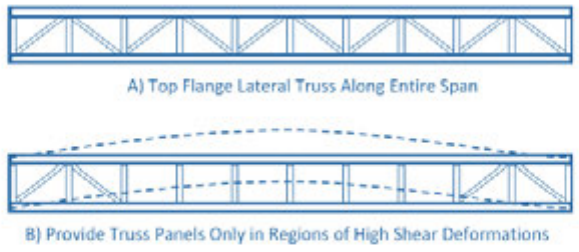


Figure 1-12 - a) Usual Top Lateral Bracing (TLB) Layout, b) Optimized TLB Layout (Proposed)

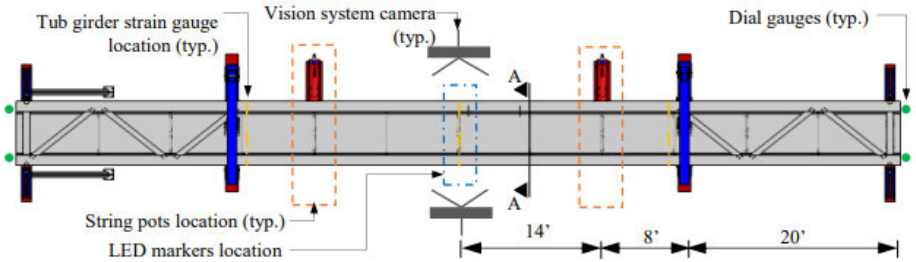


Figure 3-21 - Instrumentation Layout - Plan View

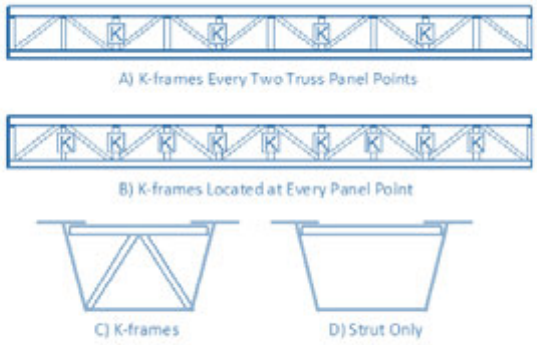


Figure 1-13 -Internal K-frame Details

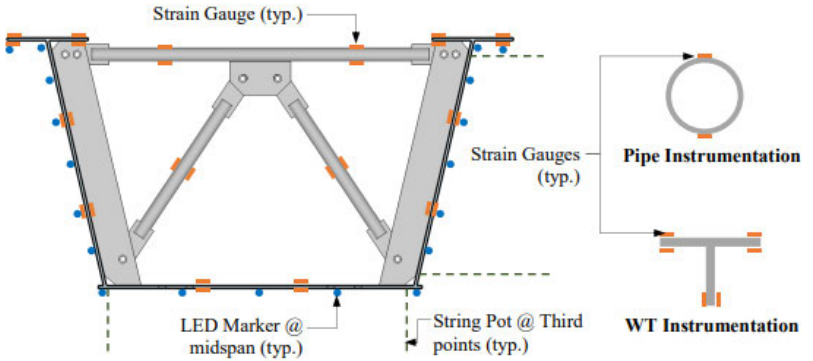


Figure 3-22 - Instrumentation Layout - Section A-A

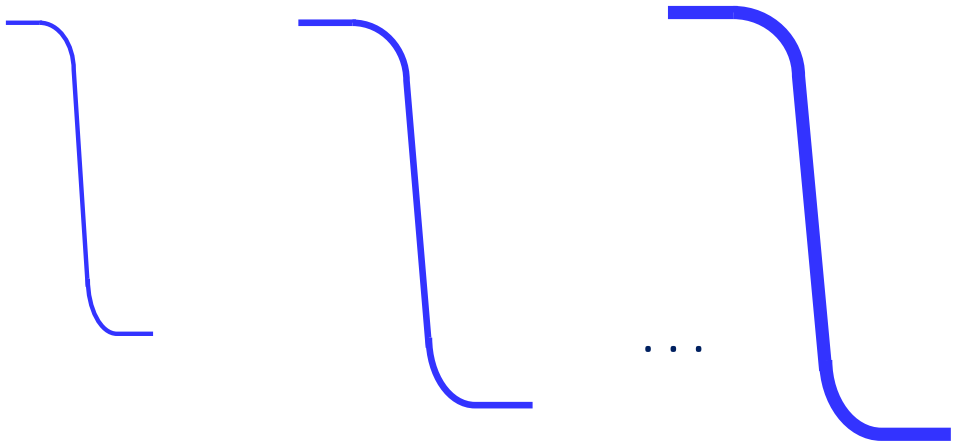
Kit-of-Parts

Options for web products:

- Web thickness: 0.5”, 0.625”, 0.75”
- Web depth: 36” up to 108” in 6” increments
- Bend radius: fixed at 2 3/16”

Available flange thicknesses:

- Flat plates: 1”, 1.25”, 1.5”, 1.75”, 2”



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