

2018 ABCD

# PennDOT's Bridge Initiatives

Presentation to the  
Susquehanna Chapter of ABCD

By Tom Macioce, P.E.  
September 4, 2018

# OUTLINE

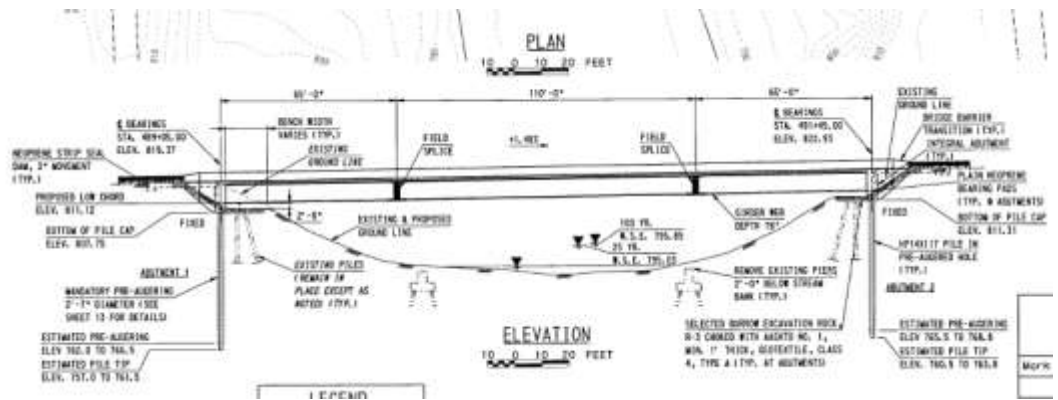
1. Steel
  - a) Global Stability
  - b) Variable Depth Girders
2. Concrete
  - a) Coplay Spliced I-Girder
3. MASH
4. 3D Bridge Design

# AASHTO STEEL CROSS FRAMES

1. NCHRP Report 725 – Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges - Level of structural analysis sufficient for the construction engineering of curved and skewed steel I- and tub-girder bridges; 1D, 2D vs 3D
2. NCHRP 20-07 Task 355 GUIDELINES FOR RELIABLE FIT-UP OF STEEL I-GIRDER BRIDGES - Simplified methods of accounting for SDLF and TDLF detailing effects are provided
3. NCHRP Project 12-113 Fatigue loading on cross frames and bracing stiffness requirements, underway

# Global Stability

<b>Bridge Properties</b>	
<b>Span Length</b>	240 ft.
<b>Girder Spacing</b>	7 ft.
<b>Number of Girders</b>	
Stage 1	3
Stage 2	4
Final Condition	7
<b>Girder Depth</b>	72 inch
<b><math>I_x</math></b>	256258 in <sup>4</sup>



Due to the large span length and relatively shallow beam depth this bridge had the potential for Global Stability issues through all stages of construction (even the in a full section re-decking scenario).





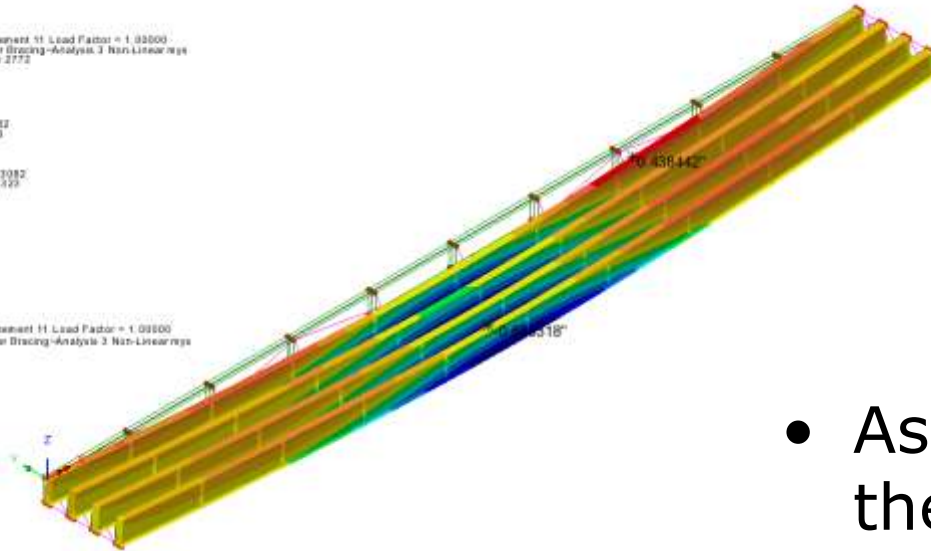
# Global Stability

## Non-Linear Model of Stage 2

Lateral Deflection (inch) With Bracing

Scale: 1.22139  
Zoom: 100.0  
Eye: (-4.3782°, -6.9282°, 6.9282°)  
Nonlinear analysis  
Analysis: Analysis 3 Non-Linear  
Loadcase: 11 Wet Concrete (Copy 2), Increment 11 Load Factor = 1.0000  
Results File: Staged Construction - 4 Global Bracing-Analysis 3 Non-Linear.rpt  
Maximum displacement 3' 4.1386" at node 2772  
Distortion: exaggeration: 5.0  
Contour style: Displacement  
Contour component: DY (Units: ft)  
Number of contours: 9  
Contour interval: 0.0151074  
Contour maximum: 0.438442" at node 13082  
Contour minimum: -0.655318" at node 1323  
Postvalue entry: Displacement  
Postvalue component: DY (Units: ft)  
Peak range for: 0.14:0  
Postvalue maximum: 0.438442" at node 13082  
Postvalue minimum: -0.655318" at node 1323

Analysis: Analysis 3 Non-Linear  
Loadcase: 11 Wet Concrete (Copy 2), Increment 11 Load Factor = 1.0000  
Results File: Staged Construction - 4 Global Bracing-Analysis 3 Non-Linear.rpt  
Entry: Displacement  
Component: DY (Units: ft)  
0.607842"  
0.489118"  
0.364587"  
0.240358"  
0.121529"  
0  
0.121529"  
0.240358"  
0.364587"  
Maximum: 0.438442" at node 13082  
Minimum: -0.655318" at node 1323



- Multiple Bracing configurations where analyzed

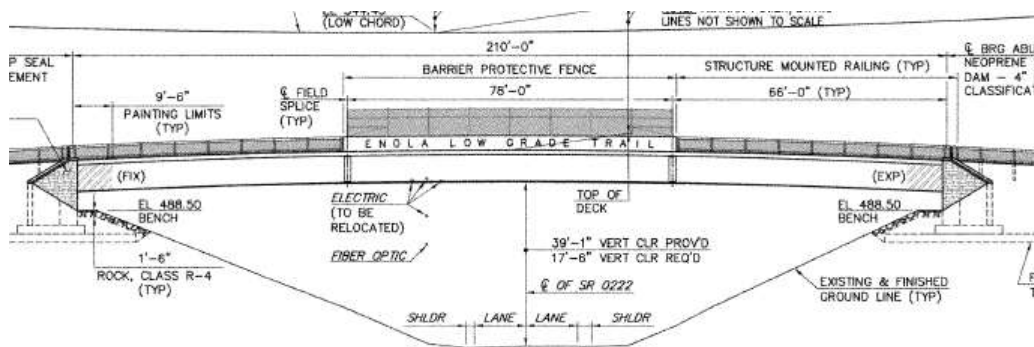
- As the results show the bracing pattern that was used significantly

# Global Stability

## Bridge Properties

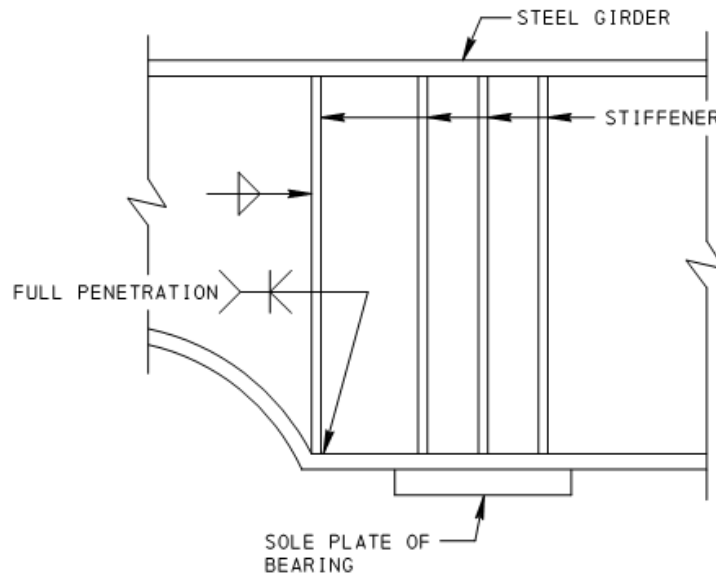
<b>Span Length</b>	210 ft.
<b>Girder Spacing</b>	8 ft.
<b>Number of Girders</b>	2
<b>Girder Depth</b>	76 inch
<b><math>I_x</math></b>	239912.9 in <sup>4</sup>

- Lateral Bracing needed to be added in the first bay at the abutment to stabilize the system.





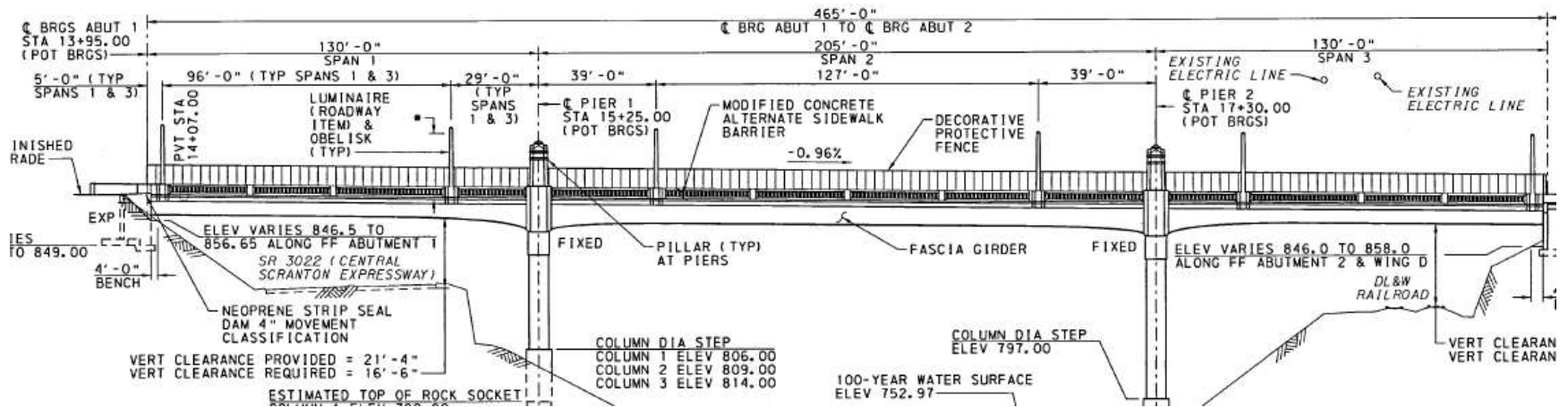
# Haunch Girder Stiffener



GIRDER HAUNCH STIFFENER DETAIL

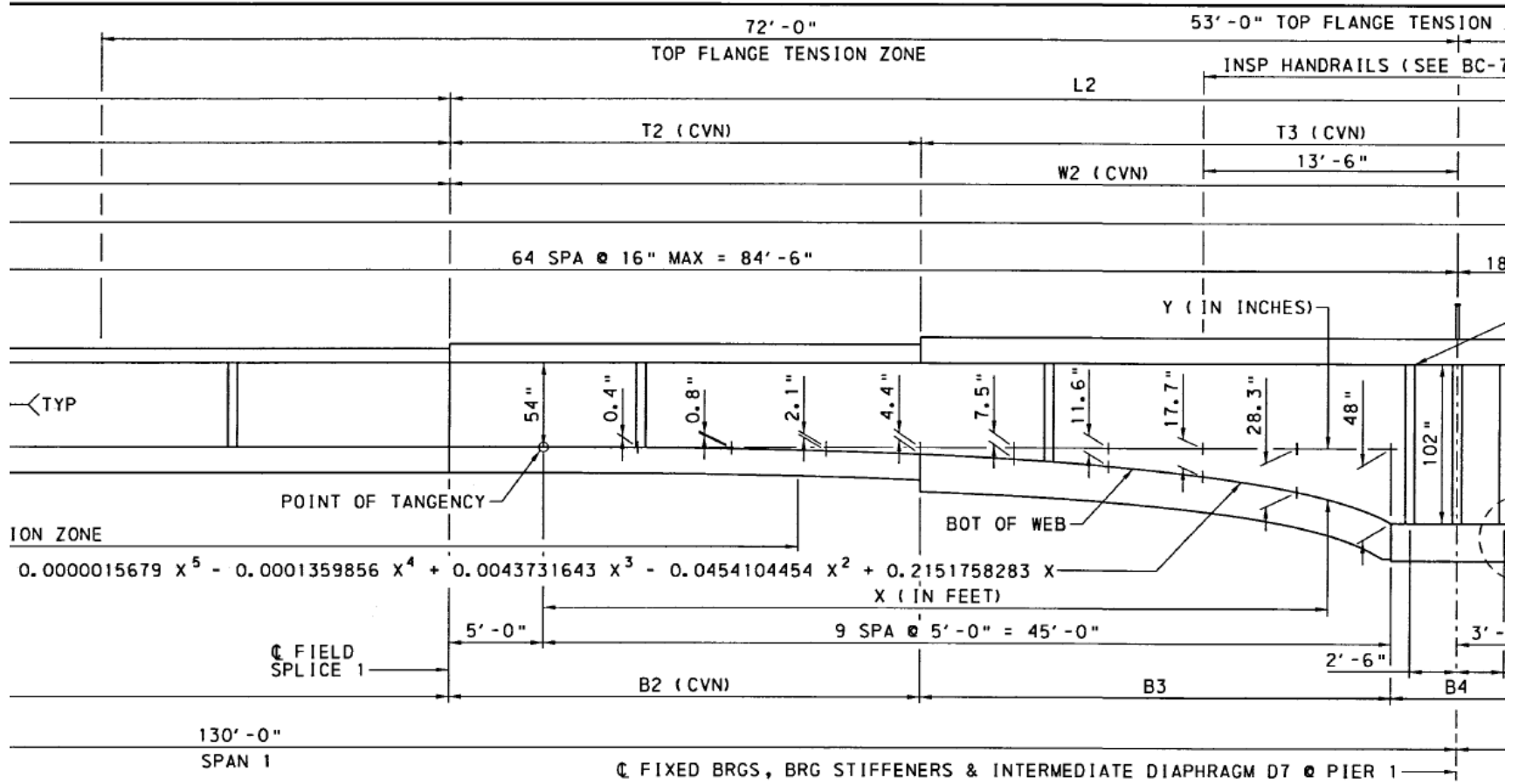
# Haunch Girder Stiffener

## Harrison Avenue



# Haunch Girder Stiffener

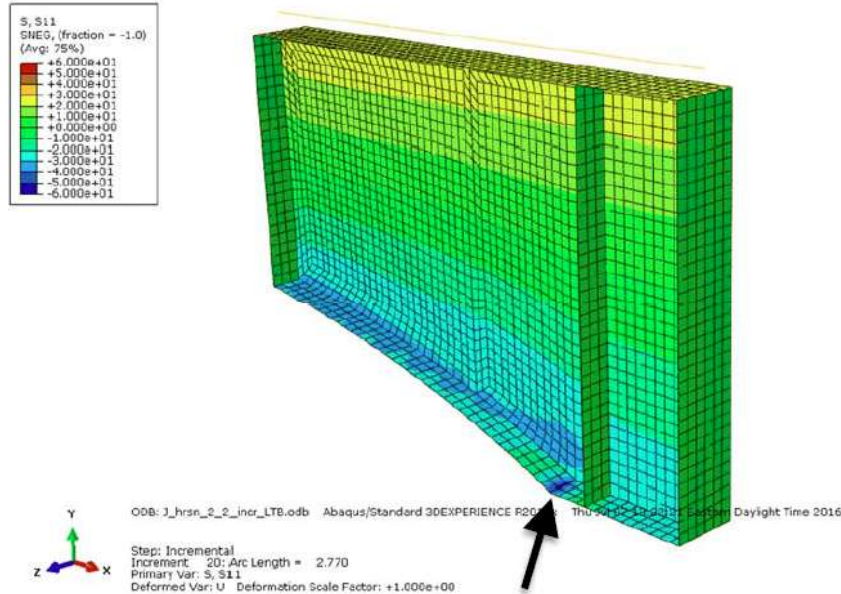
## Harrison Avenue – Span 1 Haunch Section



GIRDER ELEVATION - SPAN 1

### NOTES

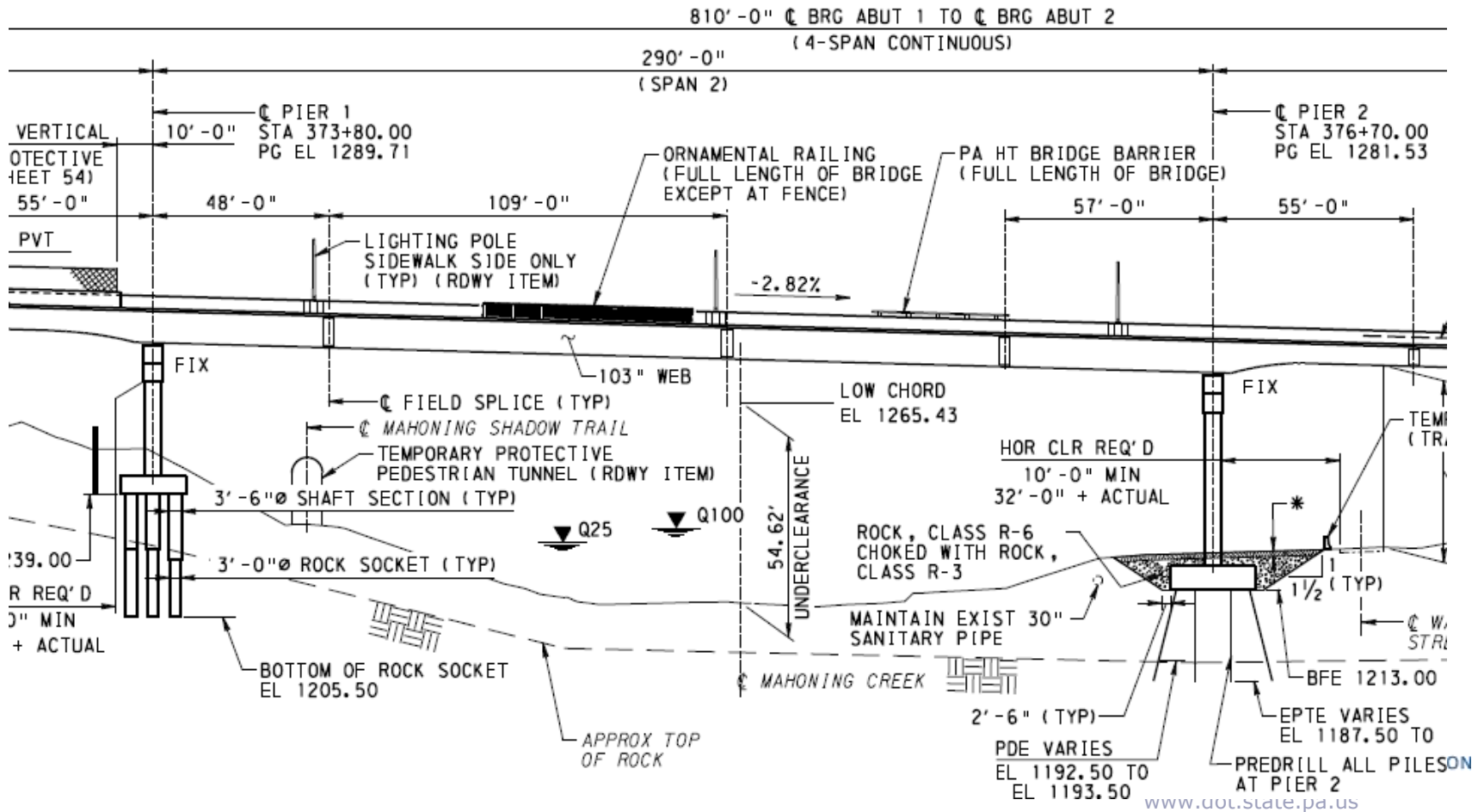
# Haunch Girder Stiffener



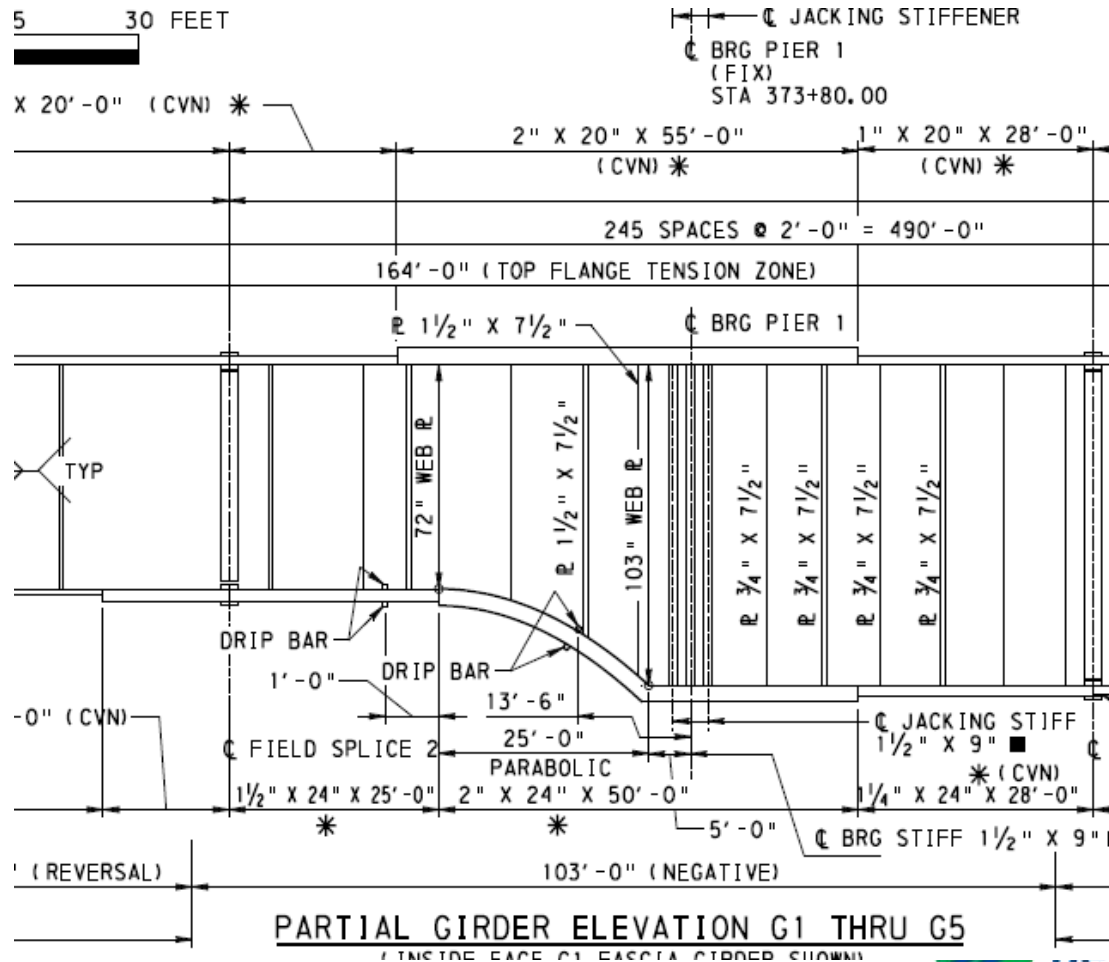
**Figure 12. Segment 2.2 nonlinear static analysis – Contour plot of longitudinal stresses (S<sub>xx</sub>) at a LPF of 0.66 showing yielding at bottom flange kink**

- iv. Segment 2.2 contains a bottom flange discontinuity, termed the flange bend line, where the sloped flange of the haunched girder meets a horizontal flange segment at the pier. Nonlinear static FEA showed local yielding in the web at this flange bend line at an early stage (65% of the full factored Strength I load), due to the discontinuity of the flange and the lack of vertical stiffeners which could resist the vertical component of flange force at the bend line (such a web stiffener is present at the bend line on the Hulton Street Bridge and is connected to the bottom flange with a full-penetration weld).

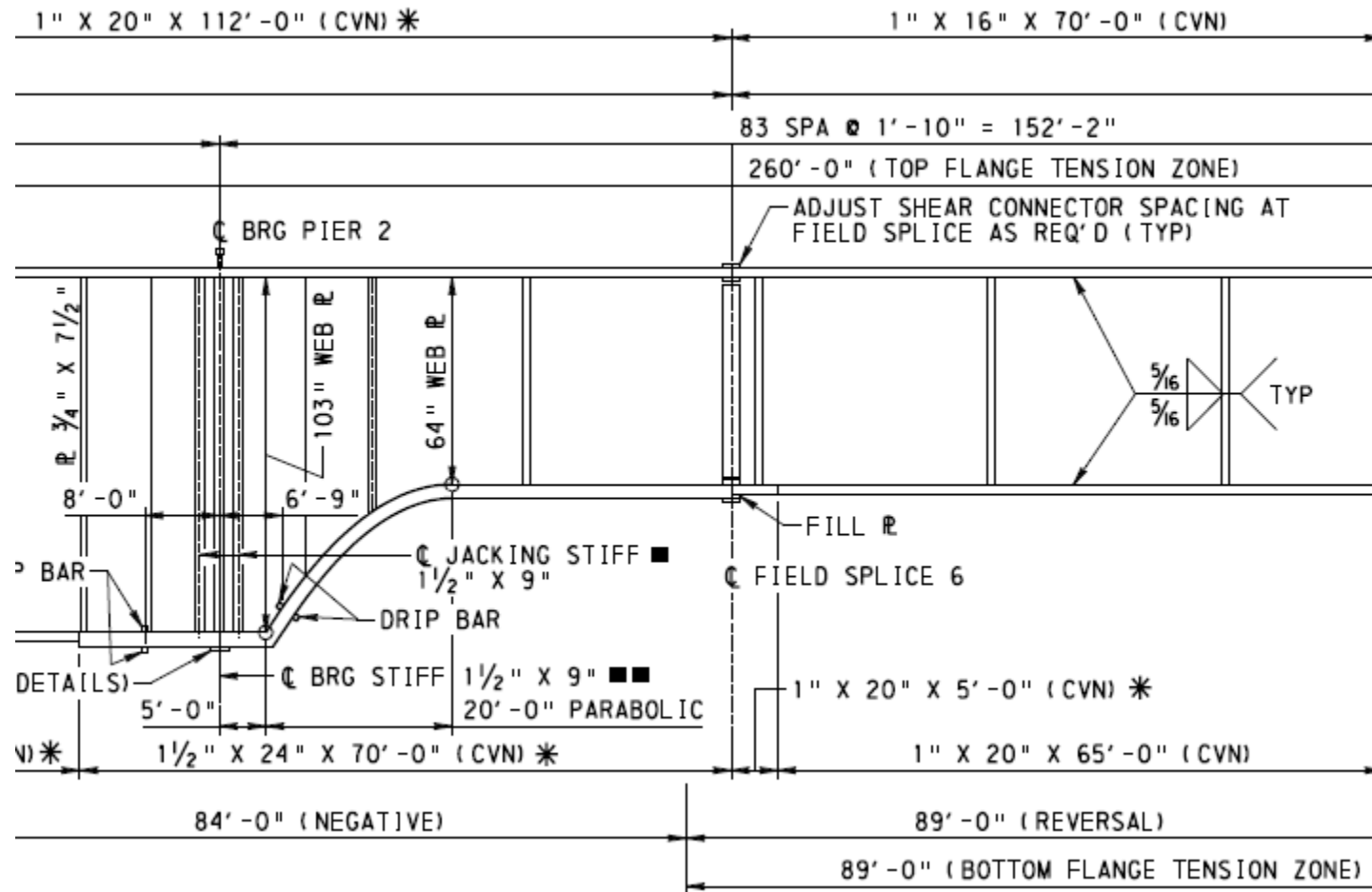
# Haunch Girder Stiffener



# Haunch Girder Stiffener



# T-14 Haunch Girders Stiffener

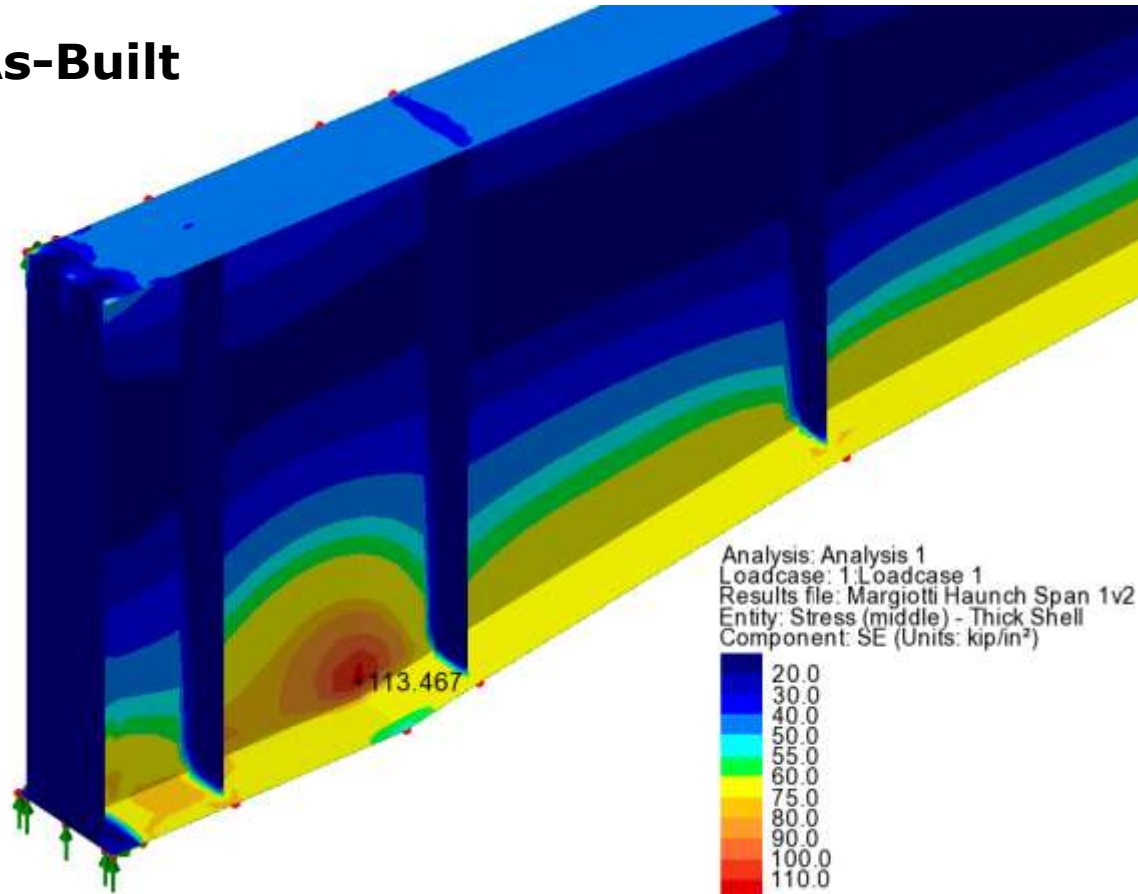


# Haunch Girder Stiffener

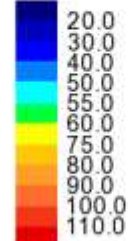


# Haunch Girder Stiffener

## Span 1 As-Built



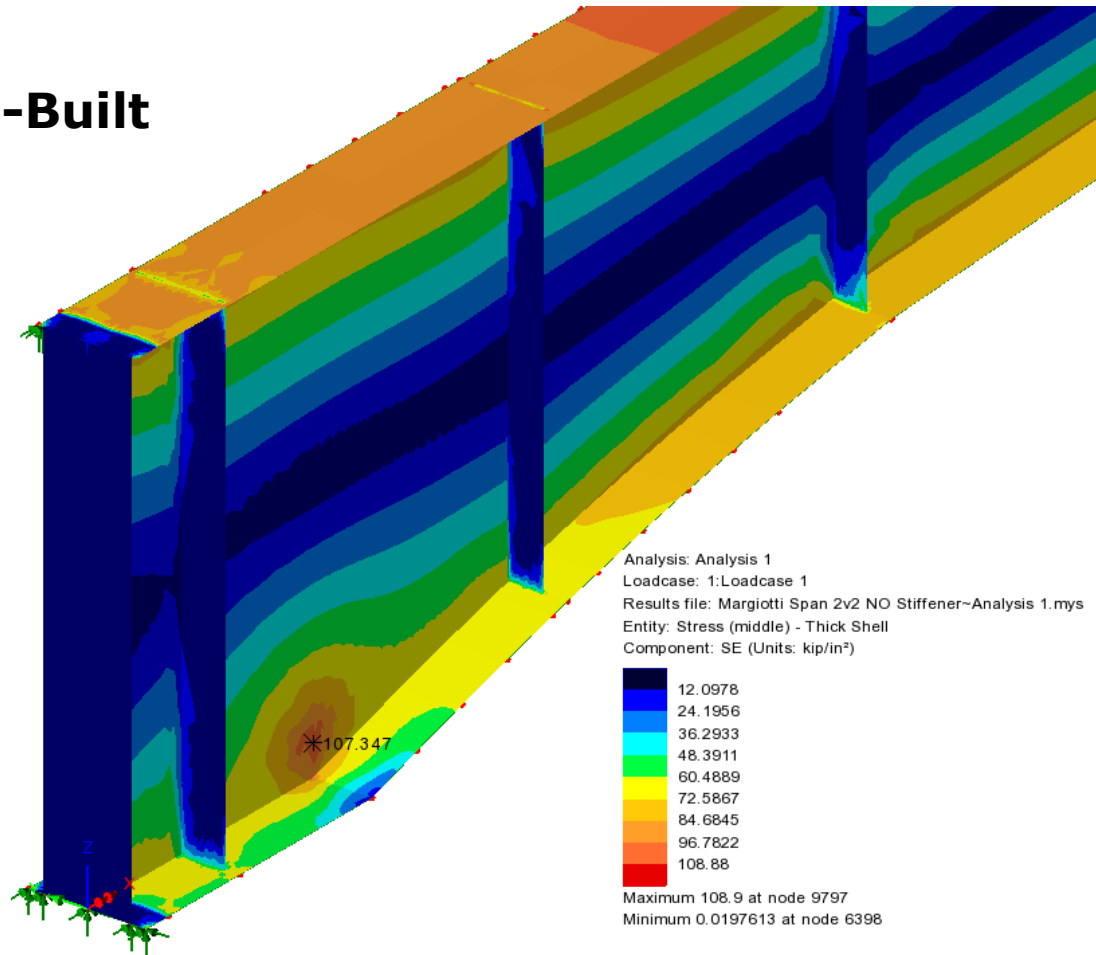
Analysis: Analysis 1  
Loadcase: 1: Loadcase 1  
Results file: Margiotti Haunch Span 1v2  
Entity: Stress (middle) - Thick Shell  
Component: SE (Units: kip/in<sup>2</sup>)



Maximum 113.467 at node 672  
Minimum 0.0395314 at node 3546

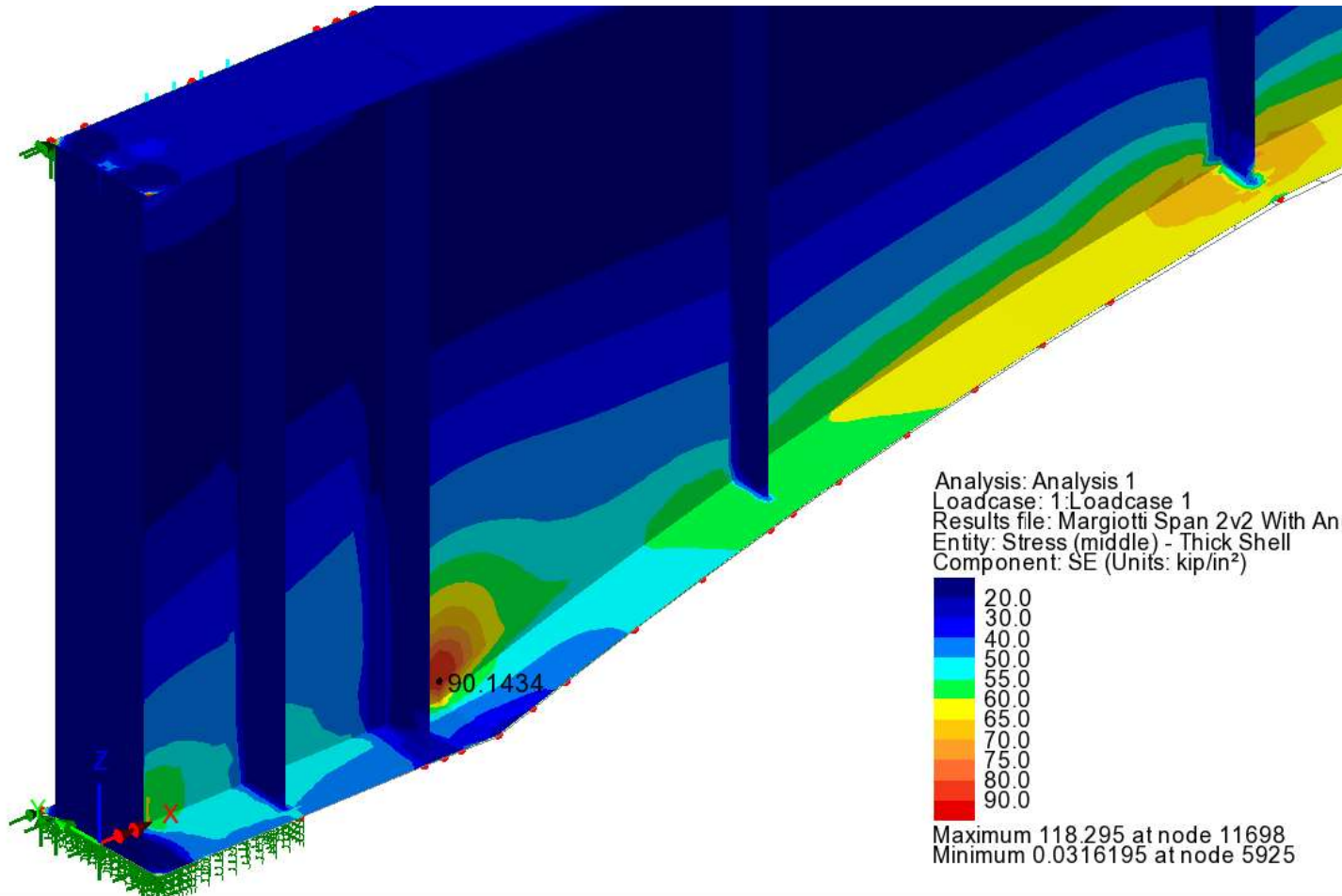
# Haunch Girder Stiffener

## Span 3 As-Built



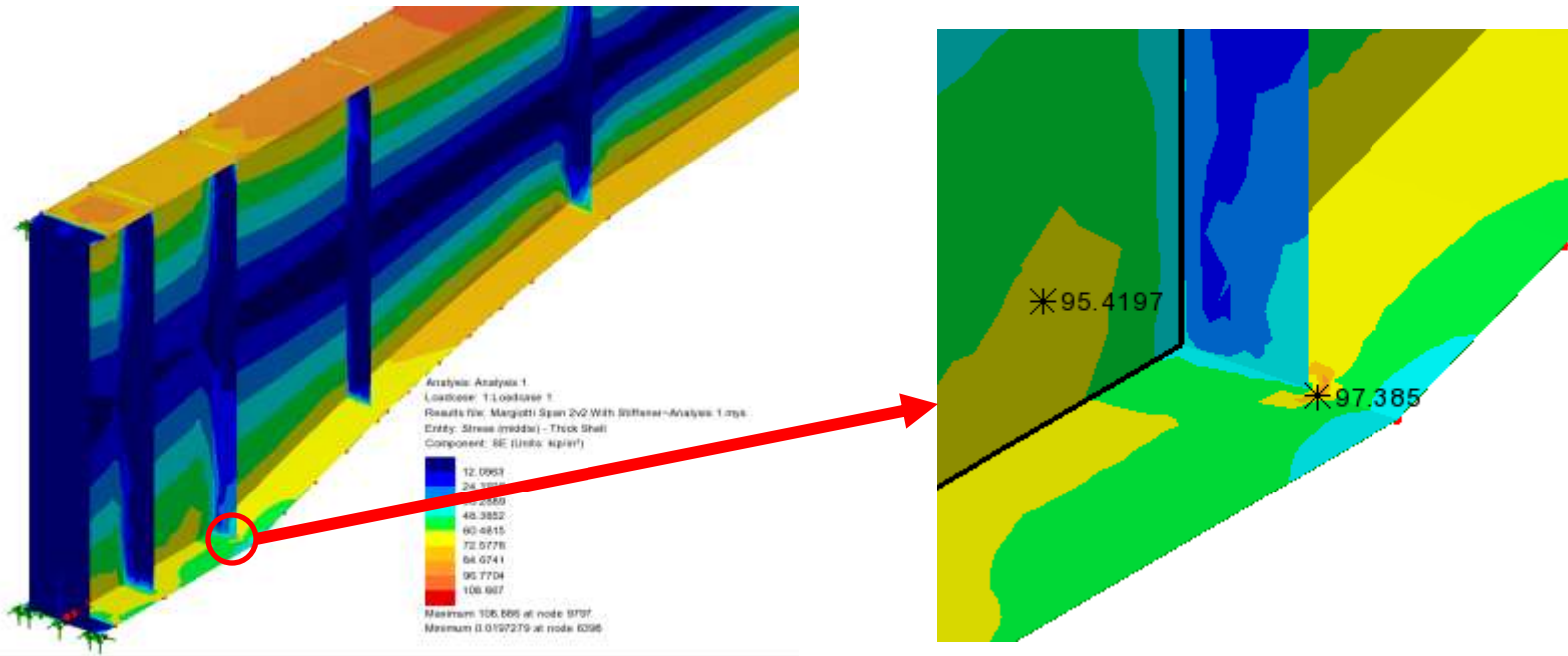
# Haunch Girder Stiffener

## Span 3 Angle Retrofit 6" off Transition (haunch to flat flange)



# Haunch Girder Stiffener

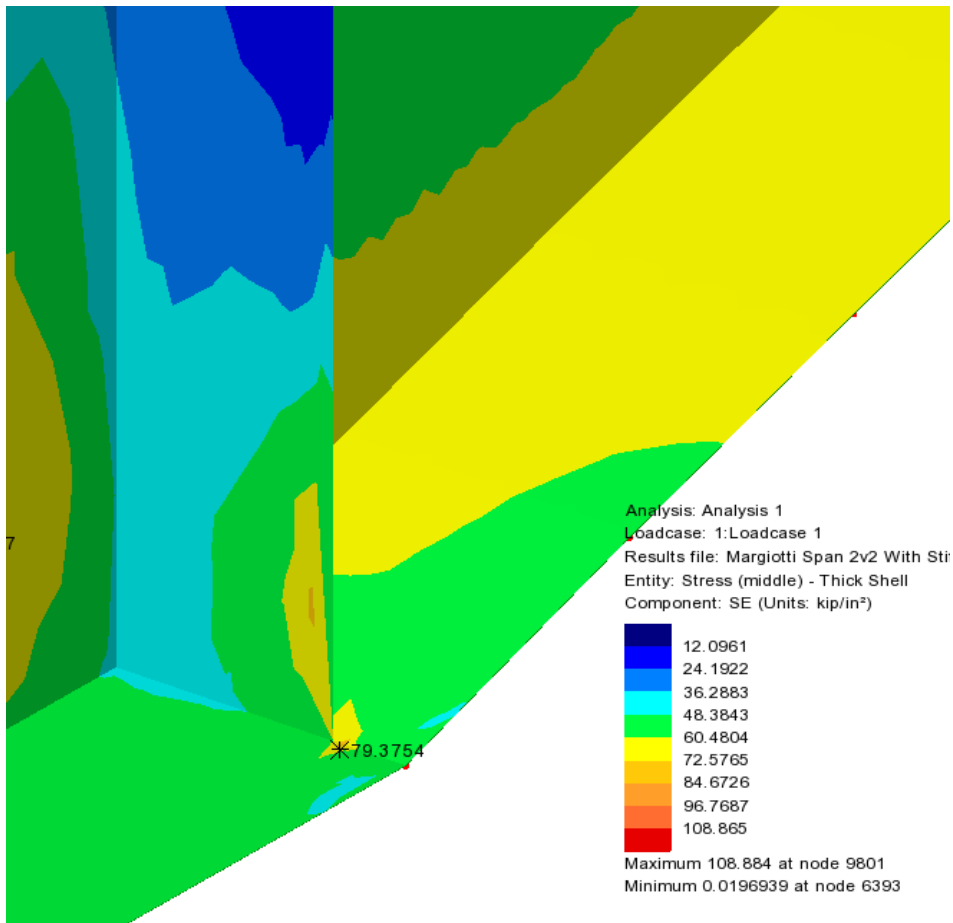
## Span 3 Retrofit Directly on Transition (haunch to flat flange) 1.5" x 7" Stiffener added



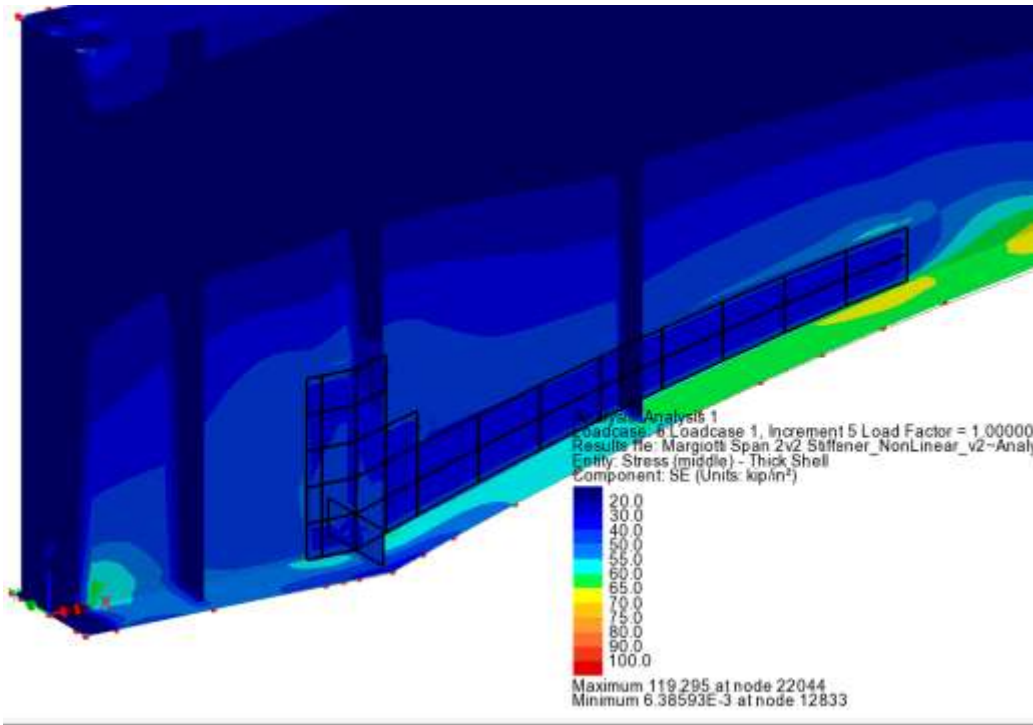
The size of stiffener added did impact stress results

# Haunch Girder Stiffener

## Span 3 Retrofit Directly on Transition (haunch to flat flange) Best Result 0.5" x 9" Stiffener



# Haunch Girder Stiffener

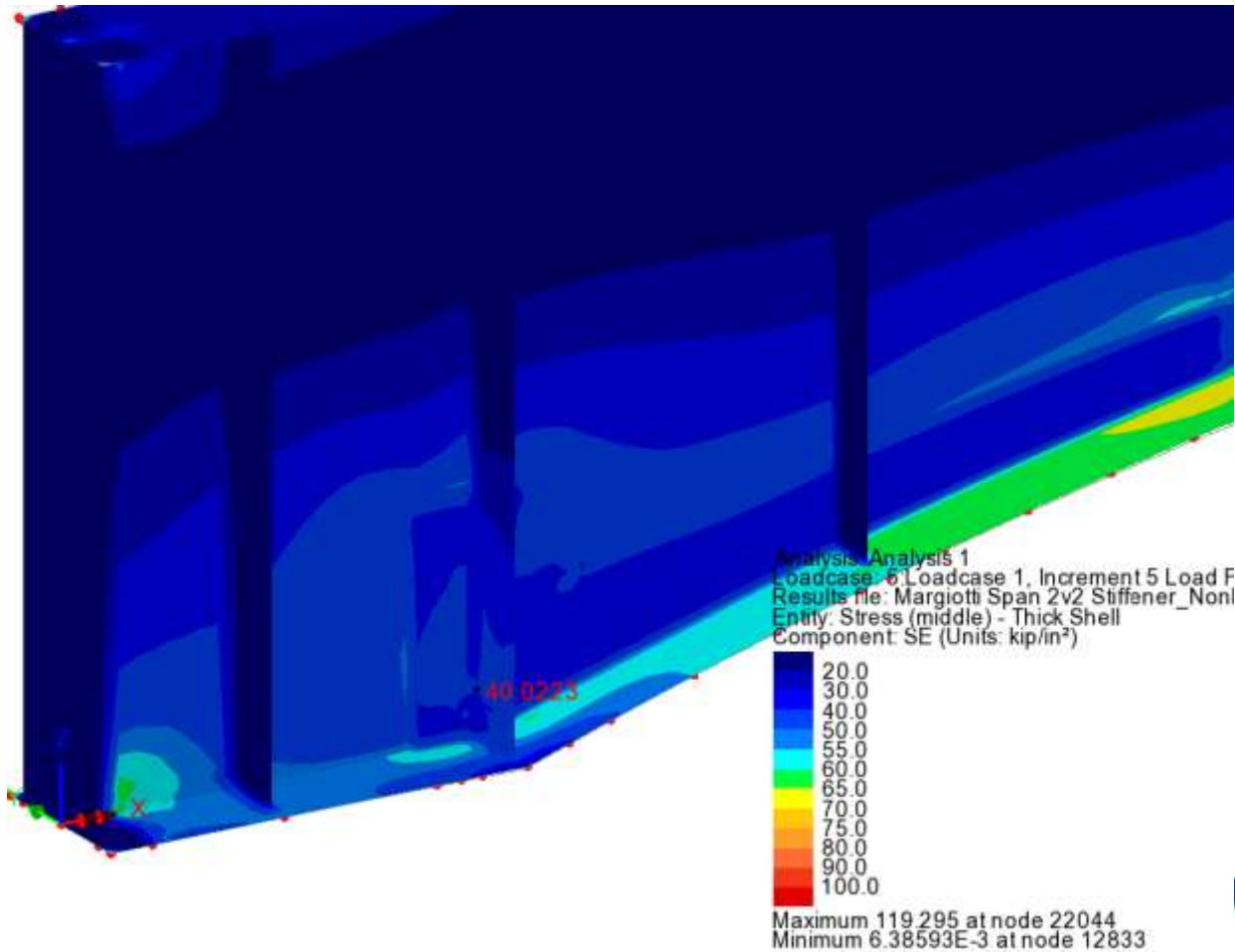


## Span 3 W/Stiffener NonLinear Material Properties

Plastic sections are selected

# Haunch Girder Stiffener

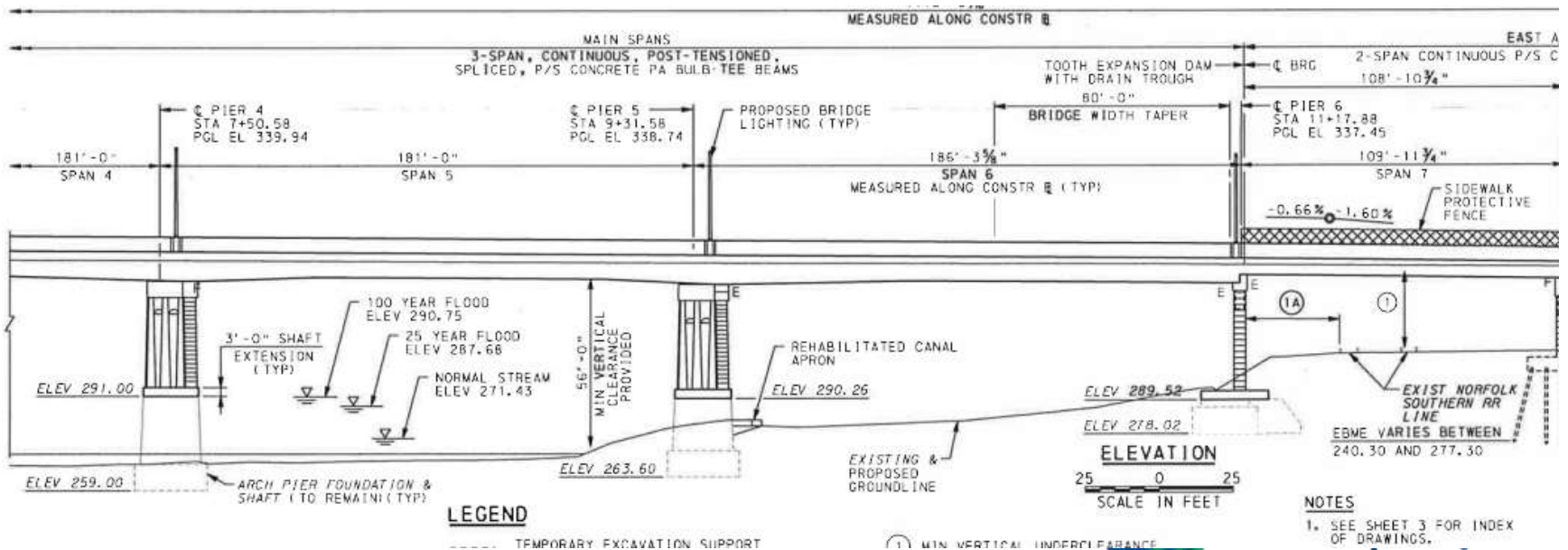
## Span 3 W/Stiffener NonLinear Material Properties



A nonlinear analysis show truer stress results

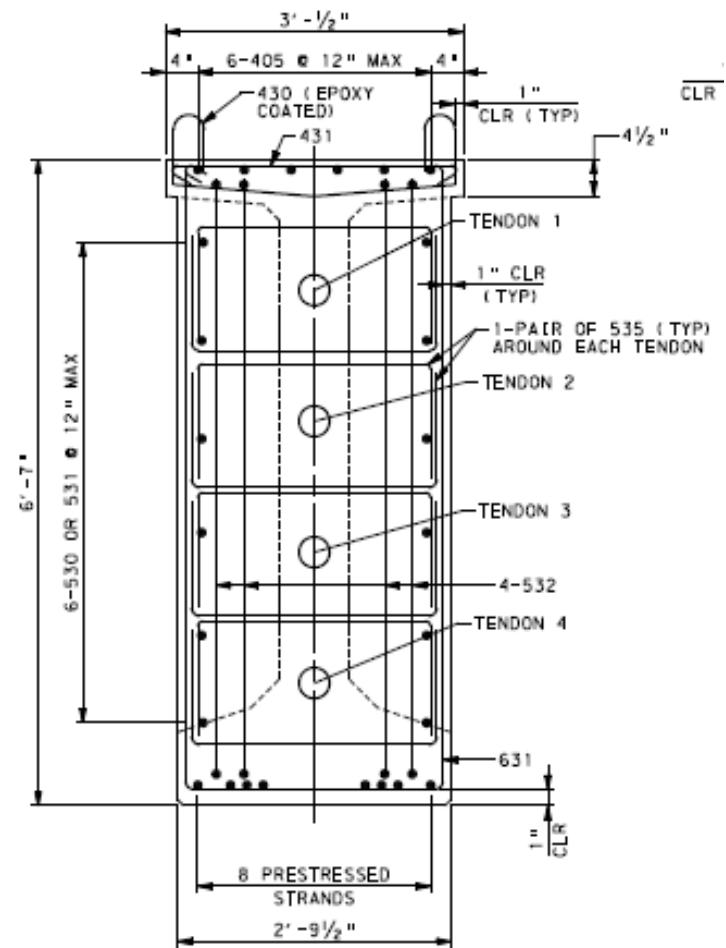
# Coplay EIT

- Spans 4-6 are to be post tensioned with 4 tendons per girder



# Coplay EIT

- Five girder continuous pre-stressed concrete PA Bulb Tee



# Coplay EIT

- Technology used in Europe
- First use in the United States



# Coplay EIT

- Plastic Duct



- Plastic Duct with supplemental protection sleeve  $\frac{3}{4}$  enclosure



# Coplay EIT

- General View of PT tendons



- Close-up of protective sleeve



# Coplay EIT

- General View of PT tendons



- Close-up of protective sleeve



# Coplay EIT

- Trumpet: EIT on Right, conventional on Left
- EIT Trumpet – Plastic ducts extends through steel anchorage head sleeve



# Coplay EIT Plastic Ducts

- Conventional Trumpet: top photo. Hole on right of trumpet is for grouting
- EIT Trumpet lower photo



# Coplay EIT

- Trumpet and reinforcing
- Conventional on left, EIT on right
- No difference in the spiral confinement reinforcement



# Coplay EIT

EIT Isolated Anchorage head



Non-Isolated Anchorage Head

# Coplay EIT



# Coplay EIT



# Coplay EIT



# Coplay EIT

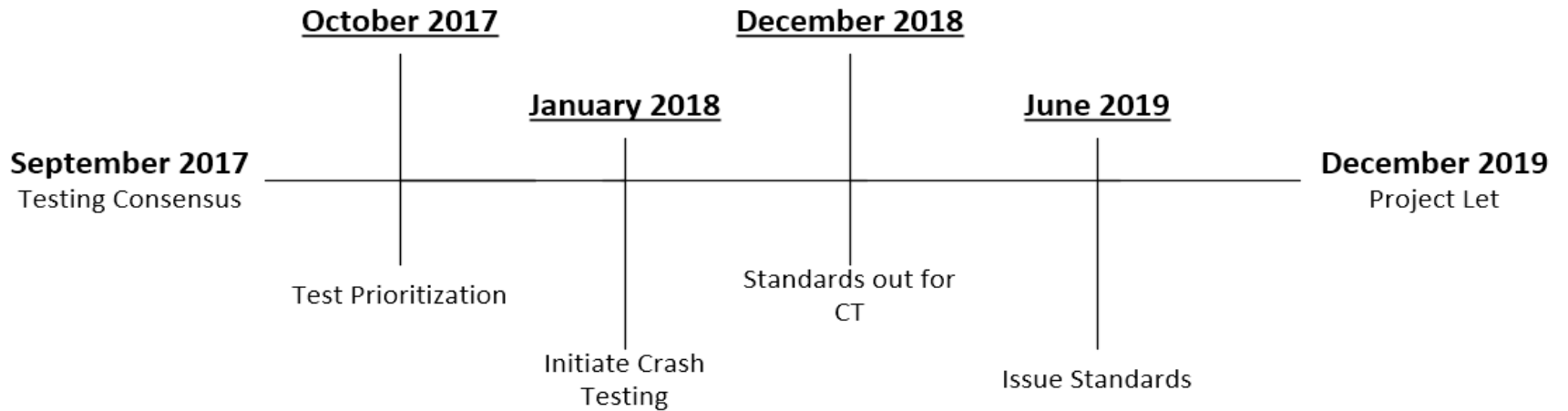


**Efforts now, the changes will be easier in  
future**

**First step in bridge design – pick the right  
barrier**

- **December 31, 2019:** bridge rails, transitions, all other longitudinal barriers (including portable barriers installed permanently), all other terminals, sign supports, and all other breakaway hardware

# MASH



# MASH

## Draft Policy

- a) Interstate BPN 1, limited access highways and major bridges TL-5 45 inches
- b) NHS. BPN 2 TL- 5. 42 inches
- c) Non-NHS ADTT > 2000. BPN 3 TL-5 42 inches
- d) BPN 4. TL 5 42 inch barrier, except
  - a) Allow TL-4 or TL-3 based on sight distance need but must provide calculations to support lower TL.
  - b) allow TL 3 32 inch barrier structure mounted guiderail on culverts and conspan type structures
- e) Locals - TL-5 42" min exceptions similar to BPN 4
- f) TL-5 42 inches as standard for all roadways (lower heights per design exception)
- NOTE: TL-5 42 inch tall barrier if a future overlay is provided will not meet current MASH TL-5 requirements. Issue to be addressed at time of overlay placement.

# MASH - Draft

## Effects to District Bridge Designs

Barrier	Revisions	Update needed for planned projects	
45 inch F shape	3 inch increase in height for future wearing surface, slight increase in dead load, evaluate sight distance	Yes	No change to width, no change to reinforcement. Interstate, limited access highways and major bridges only.
PA 10M Barrier	Increase in total height by 4 inches, increase concrete curb height from 13 inches to 17 inches, two more anchor bolts, change from anchor bar to a plate, increase in dead load, evaluate sight distance.	Yes	Conceptual design study has been performed for this modification. Crash test will be performed
PA Bridge Barrier	Change from anchor bars to a plate, updated BC-713M	No	Crashed test has been completed and is successful.
PA Structure Mounted Guiderail	No change anticipated	No	WO of Crash test has been created.
PA HT bridge barrier	To be eliminated	Yes	No crash test for this.
42 inch F shape	No change	No	TL-5 minimum height is 42 inch.
32 inch alternate	No change	No	TL-3 minimum height is 29 inch
Transition	No change in details. BC-739M will be eliminated and details to be on RC-50M. Update list of supplemental drawings	No	Crash tested. WO has been created for condensing the standards.
42 inch vertical wall	No change	No	TL-5 minimum height is 42 inch
32 inch vertical wall alternate	No change	No	TL-3 minimum height is 29 inch

# Current Status –Guiderail and Bridge Std. Changes

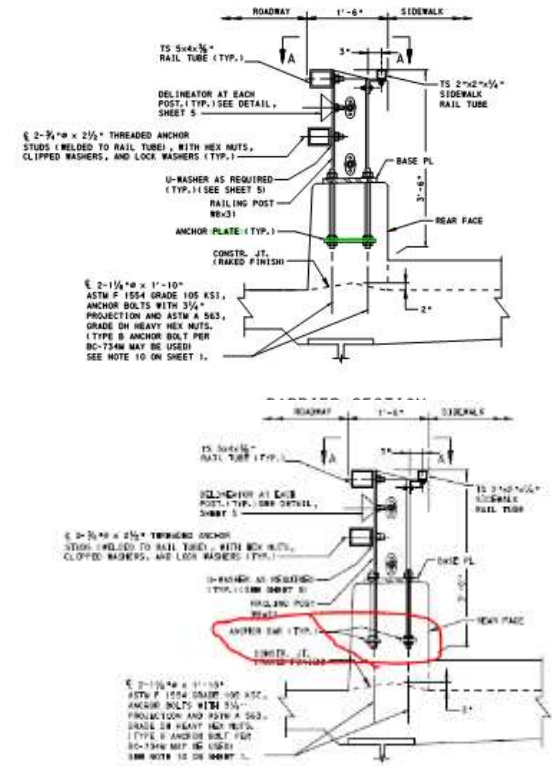
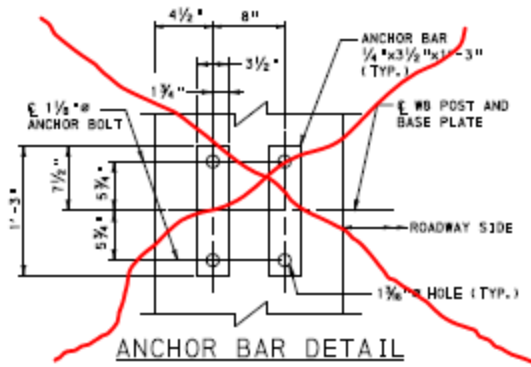
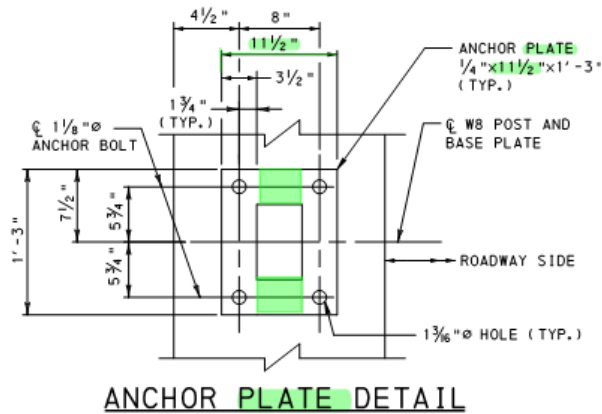
August (2017): Issued the following on Change to include:

- DM-2, Chapters 1 and 12.
- RC's: 50M, 51M(new), 52M(removed), 53M, 54M, 58M.
- BD's (30 sheets) and BC's (16 sheets).
- Pub. 408, Section 620. Special provisions until next change.  
11 new (MASH) guide rail item #s in ECMS.
- Other pubs (DM-1C, ITS standards: on separate SOL's).

- Pending Changes for MASH
- BC – 713M out on CT B18-006 (Comments Due 9/4/2018)
- BC –706M structure mounted Guiderail and BC-709M PA 10M pending crash test
- BC -739M to be deleted. The single transition which has been crash tested will be added to RC-50M. Connection details for each barrier type will be added to RC-50M.
  - Thrie - beam connections will be eliminated because crash test **for pick-up truck** without curb **failed**.

# MASH

- Proposed Change to BC – 713M
  - Use of anchor plate instead of 2 anchor bars



# PA Bridge Barrier (car Test 2018)



# PA Bridge Barrier (pick-up truck)



# PA Bridge Barrier (Tractor Trailer)



# PA Bridge Barrier (Tractor Trailer)



# AASHTO definitions of TL-5, TL-4, TL-3

## 13.7.2—Test Level Selection Criteria

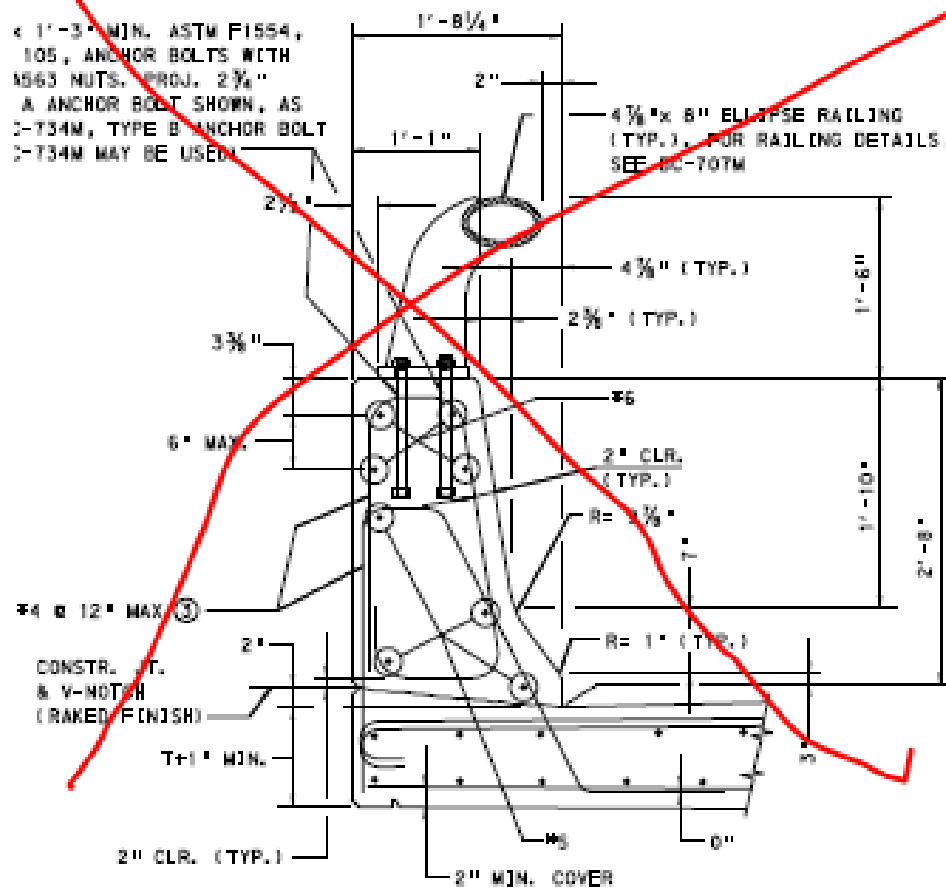
- TL-3—Test Level Three—taken to be generally acceptable for a wide range of high-speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions;
- TL-4—Test Level Four—taken to be generally acceptable for the majority of applications on high speed highways, freeways, expressways, and Interstate highways with a mixture of trucks and heavy vehicles;
- TL-5—Test Level Five—taken to be generally acceptable for the same applications as TL-4 and where large trucks make up a significant portion of the average daily traffic or when unfavorable site conditions justify a higher level of rail resistance; and



FHWA

# PA HT – No longer available after Dec 2019.

## TYPICAL PA HT BRIDGE BARRIER



# MASH

- Bridge Transition-W-Beam-(Typical Concrete Bridge Barrier RC-50M)
- ✓ Current transition is MASH (TL-3) Compliant based on NCHRP web only document #157
- ✓ New work order is in place to revised BC, BD and RC for the new bridge barrier connections



# MASH

- Bridge Transition-Thrie-Beam-(without curb RC-50M)
  - ✓ MASH Test 3-21(Pick-up) fail based on TTI Test report.
  - ✓ With curb test is not in future.



# MASH


- Bridge Transition-Thrie-Beam - will be removed from Standards



# MASH

- 1981 NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances.
- 1993 NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features
- 2009 and 2016 *Manual for Assessing Safety Hardware*, MASH
- NEXT Version 2025??

# Change in Vehicle for TL-4 Test level

<b>Vehicle Class</b>	<b>NCHRP 350</b>	<b>MASH – 2009/16</b>
Single Unit Truck 	Weight: 17,636 lb Speed 50 mph Design Impact Force 54K	Weight: 22,000 lb Speed 56 mph Design Impact Force 54K

# MASH – Draft

MASH Test Level	Minimum Height (in.)	Design Impact Force (kip)	Height of Design Impact Force (in.)
TL-3	29	54	29
<b>TL-3</b>	<b>32</b>	<b>54</b>	<b>32</b>
TL-4	36	54	36
<b>TL-4</b>	<b>39**</b>	<b>54</b>	<b>39</b>
TL-5	42	124	42
<b>TL-5</b>	<b>45*</b>	<b>124</b>	<b>45</b>

\*\* 39 inch to account for future overlays

\* 45 inch to provide for future 3 inch overlay. Used on interstates, limited access highways and major bridges

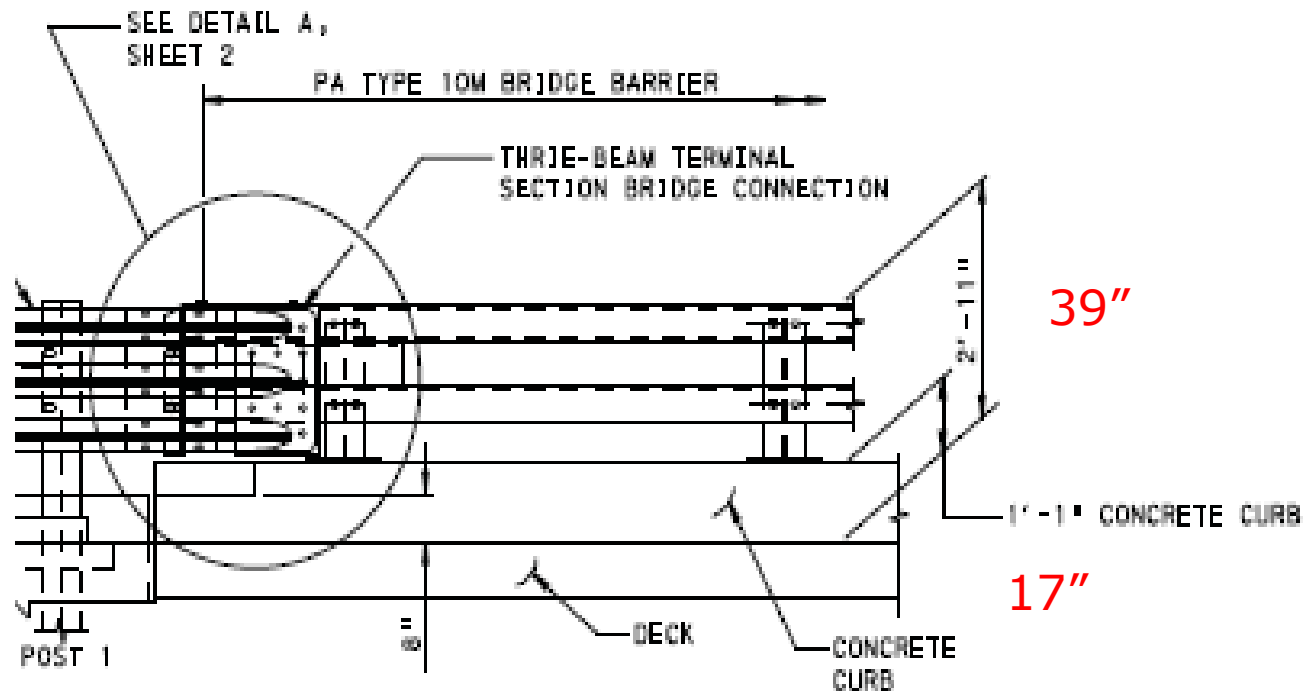
# MASH - Draft

**Table 1. Summary of Potential Modifications to PA Type 10M Bridge Barrier.**

	Design Option 1	Design Option 2	Design Option 3
Sketch			
AASHTO Section 13 Snag Criteria	Satisfactory	Satisfactory	Satisfactory
AASHTO Section 13 Post Setback Criteria	Satisfactory	Satisfactory	Satisfactory
Advantages	<ul style="list-style-type: none"> <li>Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification.</li> <li>Provides simplest retrofit, requiring only replacement of rail posts.</li> </ul>	<ul style="list-style-type: none"> <li>Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification.</li> <li>Increased concrete wall height can help prevent vehicle snagging.</li> </ul>	<ul style="list-style-type: none"> <li>Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification.</li> <li>Increased concrete wall height can help prevent vehicle snagging. However, this benefit is not as significant as for design option 2.</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>Increased rail height and rail spacing increases snagging potential.</li> </ul>	<ul style="list-style-type: none"> <li>Retrofit of existing design would require extensive work to increase concrete wall height.</li> </ul>	<ul style="list-style-type: none"> <li>Most extensive retrofit option. Requires extensive work to increase concrete wall height and also requires post replacement.</li> </ul>
AASHTO Section 13 13.8.1 Clear Opening Criteria	Not Satisfactory	Satisfactory	Not Satisfactory

# MASH - Draft

- PA 10M Bridge Barrier





## MASH

- Barrier-Guard is MASH 2016 TL-3.
  - Compliance issued by FHWA May 17, 2018
  - We have not received an updated submission from Barrier-Guard.
- Zone-guard MASH TL-3 compliant.  
Drawings signed February 22, 2013.
- Temporary steel barriers are NOT TL-4 MASH compliant.
- Some temporary Steel barriers were NCHRP 350 TL-4

## MASH Summary

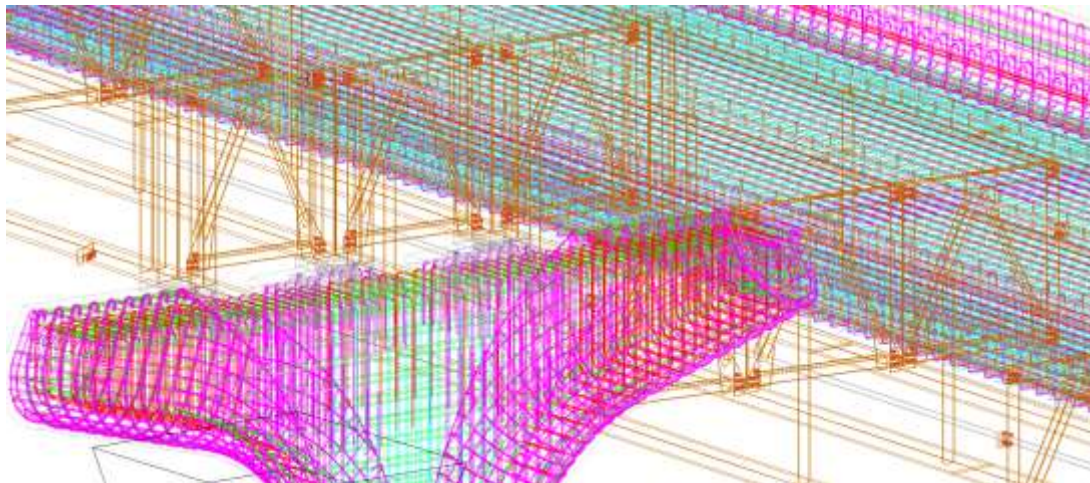
1. Update designs based on use of 45 inch barrier, TL-4 PA 10M barrier.
  - a) Select proper barrier
  - b) Update bridge plans
  - c) Evaluate sight distance
2. Do not specify PA HT barrier for design let after December 31, 2019
3. BC -739M is being deleted, transition details are on RC Standard (RC-50M) – Only one transition; three beam transition is being eliminated.
4. Use of TL-4 or TL-3 bridge barrier based calculations in accordance with NCHRP 22-12(03). To be included in DM2.
5. Temporary Steel barriers are TL-3 MASH compliant

# 3D Bridge Design and Delivery

## Iowa DOT

Eastbound I-80 to Southbound I-380  
Ramp B over Ramp G

Let: July 17, 2018  
Bid as an Electronic 3D Model

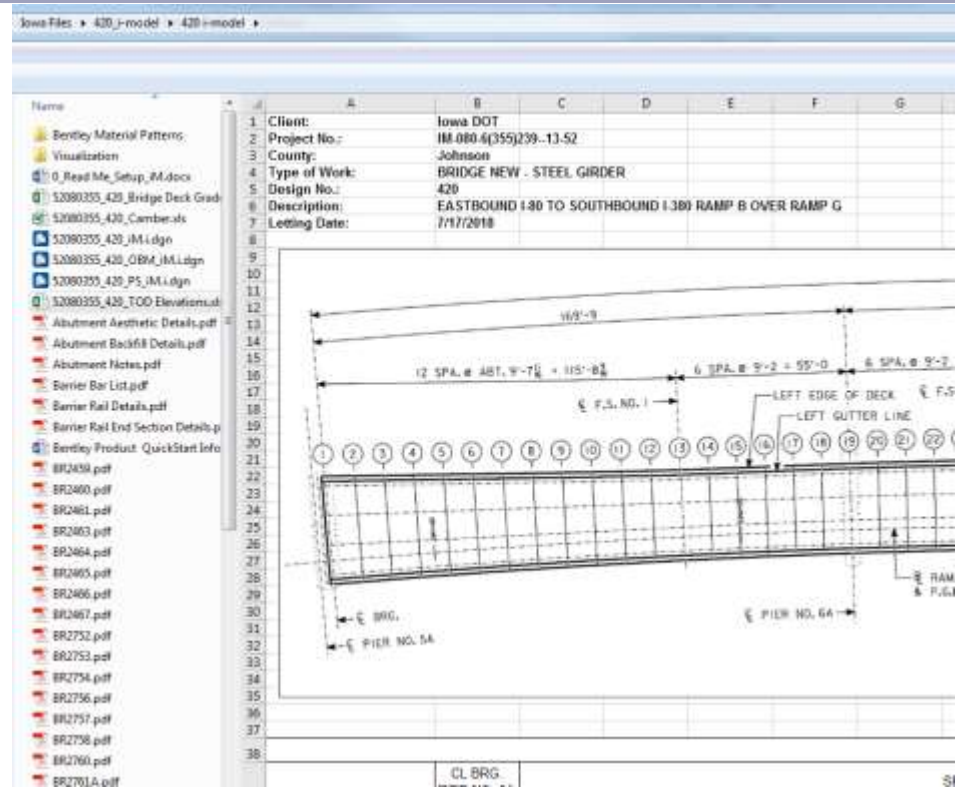


## 3D Bridge Design and Delivery

- Modeled in OpenBridge Modeler
- Designed in LEAP Steel
- Detailed in ProStructures
  
- Bridge Design and Technology Division is investigating the use of this software suite
  - District 9 leading the effort
  - District 1 supporting
  - Preliminary report to Districts in January 2019
  - Possible adoption in September 2019

# 3D Bridge Design and Delivery

- The goal is 3D electronic deliverables
- 3D electronic deliverable does not mean NO plans
- 3D electronic deliverable means:
  - Electronic model is the legal document
  - NO paper bid documents
  - Electronic plan sheets are for information only
- Electronic deliverable MUST support all constructors



# 3D Bridge Design and Delivery

AASHTO Pooled Fund Study: TPF-5(372)

Building Information Modeling (BIM)  
for Bridges and Structures

Running July 2017 through July 2022  
To establish standards for BIM

Members: IA (Lead State), WI (Assist. Lead)

FHWA, CA, DE, IL, KS, MI, MS, NC, NJ, NY, OH, PA, TX, UT

Prime Consultant: HDR Engineering Inc.

Sub Consultants: Fair Cape Consulting,  
AEC3, Trimble,  
BIM Works &  
University of Florida

# 3D Bridge Design and Delivery

## AASHTO Pooled Fund Study: TPF-5(372)

### Building Information Modeling (BIM) for Bridges and Structures

#### Primary focus:

- Industry Foundation Class (IFC) as the data repository
  - Collaborate with buildingSmart International
- Model View Definition (MVD) as the translator between software and data repository and back to software
  - Develop the initial (most critical) set of MVDs
- Documentation and training

# 3D Bridge Design and Delivery

## BIM for Bridges and Structures – Milestones

2018 – Validate process map / Begin MVD development

2019 – IFC 4.2 Release / Coordinate with bSI

2020 – IFC 5.0 release / Begin ROI analysis

2021 – Create data storage / Create data dictionary

2022 – Develop educational materials

2023 – Launch education & training / Project assessment

# Tybot - Advanced Construction Robotics Device For Tying Rebar

Advanced Construction Robotics – Used on bridge in D11.



# Tybot - Advanced Construction Robotics Device For Tying Rebar

Advanced Construction Robotics – Used on bridge in D3.



# Tybot - Advanced Construction Robotics Device For Tying Rebar

Advanced Construction Robotics – Used on bridge in D3.



- Any Questions