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

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).

<table>
<thead>
<tr>
<th>Bridge Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Span Length</td>
<td>240 ft.</td>
</tr>
<tr>
<td>Girder Spacing</td>
<td>7 ft.</td>
</tr>
<tr>
<td>Number of Girders</td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>3</td>
</tr>
<tr>
<td>Stage 2</td>
<td>4</td>
</tr>
<tr>
<td>Final Condition</td>
<td>7</td>
</tr>
<tr>
<td>Girder Depth</td>
<td>72 inch</td>
</tr>
<tr>
<td>$I_x$</td>
<td>256258 in$^4$</td>
</tr>
</tbody>
</table>
Global Stability

Stage 1

Stage 2
Global Stability

Non-Linear Model of Stage 2
Lateral Deflection (inch) Shown for As Designed

Bracing Configuration Solution
Global Stability

Non-Linear Model of Stage 2
Lateral Deflection (inch) With Bracing

- Multiple Bracing configurations where analyzed
- As the results show the bracing pattern that was used significantly
Global Stability

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

<table>
<thead>
<tr>
<th>Bridge Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Span Length</td>
<td>210 ft.</td>
</tr>
<tr>
<td>Girder Spacing</td>
<td>8 ft.</td>
</tr>
<tr>
<td>Number of Girders</td>
<td>2</td>
</tr>
<tr>
<td>Girder Depth</td>
<td>76 inch</td>
</tr>
<tr>
<td>$I_x$</td>
<td>239912.9 in$^4$</td>
</tr>
</tbody>
</table>
Haunch Girder Stiffener

GIRDER HAUNCH STIFFENER DETAIL
Haunch Girder Stiffener

Harrison Avenue
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).

Figure 12. Segment 2.2 nonlinear static analysis – Contour plot of longitudinal stresses (Sxx) at a LPF of 0.66 showing yielding at bottom flange kink
T-14 Haunch Girder Stiffener
Haunch Girder Stiffener
Haunch Girder Stiffener

Span 1 As-Built
Haunch Girder Stiffener

Span 3 As-Built
Span 3 Angle Retrofit 6” off Transition (haunch to flat flange)
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 showed truer stress results.
• 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 ¾ 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

www.dot.state.pa.us
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

September 2017
Testing Consensus

Test Prioritization

October 2017

January 2018
Initiate Crash Testing

December 2018

Standards out for CT

June 2019

Issue Standards

December 2019
Project Let
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.
<table>
<thead>
<tr>
<th>Barrier</th>
<th>Revisions</th>
<th>Update needed for planned projects</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 inch F shape</td>
<td>3 inch increase in height for future wearing surface, slight increase in dead load, evaluate sight distance</td>
<td>Yes</td>
<td>No change to width, no change to reinforcement. Interstate, limited access highways and major bridges only.</td>
</tr>
<tr>
<td>PA 10M Barrier</td>
<td>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.</td>
<td>Yes</td>
<td>Conceptual design study has been performed for this modification. Crash test will be performed</td>
</tr>
<tr>
<td>PA Bridge Barrier</td>
<td>Change from anchor bars to a plate, updated BC-713M</td>
<td>No</td>
<td>Crashed test has been completed and is successful.</td>
</tr>
<tr>
<td>PA Structure Mounted Guiderail</td>
<td>No change anticipated</td>
<td>No</td>
<td>WO of Crash test has been created.</td>
</tr>
<tr>
<td>PA HT bridge barrier</td>
<td>To be eliminated</td>
<td>Yes</td>
<td>No crash test for this.</td>
</tr>
<tr>
<td>42 inch F shape</td>
<td>No change</td>
<td>No</td>
<td>TL-5 minimum height is 42 inch.</td>
</tr>
<tr>
<td>32 inch alternate</td>
<td>No change</td>
<td>No</td>
<td>TL-3 minimum height is 29 inch</td>
</tr>
<tr>
<td>Transition</td>
<td>No change in details. BC-739M will be eliminated and details to be on RC-50M. Update list of supplemental drawings</td>
<td>No</td>
<td>Crash tested. WO has been created for condensing the standards.</td>
</tr>
<tr>
<td>42 inch vertical wall</td>
<td>No change</td>
<td>No</td>
<td>TL-5 minimum height is 42 inch.</td>
</tr>
<tr>
<td>32 inch vertical wall</td>
<td>No change</td>
<td>No</td>
<td>TL-3 minimum height is 29 inch.</td>
</tr>
</tbody>
</table>
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.
• 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
PA HT – No longer available after Dec 2019.
• 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
• 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
• 2009 and 2016 *Manual for Assessing Safety Hardware*, MASH
• NEXT Version 2025??
## Change in Vehicle for TL-4 Test level

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

![Single Unit Truck Image]
## MASH – Draft

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

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

<table>
<thead>
<tr>
<th></th>
<th>Design Option 1</th>
<th>Design Option 2</th>
<th>Design Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch</td>
<td><img src="image1.png" alt="Sketch 1" /></td>
<td><img src="image2.png" alt="Sketch 2" /></td>
<td><img src="image3.png" alt="Sketch 3" /></td>
</tr>
<tr>
<td>AASHTO Section 13 Snag Criteria</td>
<td>Satisfactory</td>
<td>Satisfactory</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>AASHTO Section 13 Post Setback Criteria</td>
<td>Satisfactory</td>
<td>Satisfactory</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Advantages</td>
<td>• Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification. &lt;br&gt; • Provides simplest retrofit, requiring only replacement of rail posts.</td>
<td>• Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification. &lt;br&gt; • Increased concrete wall height can help prevent vehicle snagging.</td>
<td>• Satisfactory according the geometric criteria of Section 13 of the AASHTO LRFD Bridge Specification. &lt;br&gt; • Increased concrete wall height can help prevent vehicle snagging. &lt;br&gt; • Most extensive retrofit option. Requires extensive work to increase concrete wall height and also requires post replacement.</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>• Increased rail height and rail spacing increases snagging potential.</td>
<td>• Retrofit of existing design would require extensive work to increase concrete wall height.</td>
<td></td>
</tr>
<tr>
<td>AASHTO Section 13 13.8.1 Clear Opening Criteria</td>
<td>Not Satisfactory</td>
<td>Satisfactory</td>
<td>Not Satisfactory</td>
</tr>
</tbody>
</table>
- PA 10M Bridge Barrier

Diagram showing details of PA 10M Bridge Barrier with dimensions 39” and 17”.
45” F-shape Barrier (BC-601M, Typ Weight 650 lb/ft.; New weight 700 lb/ft.)

TYPICAL CONCRETE BARRIER DETAIL
• 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; thrie 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
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
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