Mississippi Steel Bridge Forum

John Hastings, PE

Bridge Steel Specialist, Southeast
John Hastings
Thank You

John Hastings
Thank You

Mississippi Department of Transportation
  Justin Walker
ACEC Mississippi
  Craig Carter
  Jessica Gosa
Structural Engineers Association of Mississippi
  Trish Ballard

Louisiana Department of Transportation
  Jenny Fu
Speakers

Justin Walker, PE – MDOT
Rob Connor, PhD – Purdue University
Sean Peterson, W&W|AFCO Steel
Michael Grubb, PE – MA Grubb and Associates
Chris Garrell, PE – NSBA
Brandon Chavel, PhD, PE – NSBA
Panel Members

Fabricators
Dale Ison – Florida Structural Steel
Tom Leb – Stupp Bridge Company
Kevin Bird – Veritas Steel
Kevin Reynolds, PE – W&W | AFCO Steel

Producers
Martin Francis – ArcelorMittal
Graham Holman – Nucor
David Stoddard – SSAB Americas
## Agenda – September 17, 2020

<table>
<thead>
<tr>
<th>Time*</th>
<th>Topic</th>
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<tbody>
<tr>
<td>11:00am - 11:30am</td>
<td>Introduction and Industry Overview</td>
</tr>
<tr>
<td>11:30am - 12:30pm</td>
<td>Steel I-Girder Fatigue, Details, and Repairs</td>
</tr>
<tr>
<td>12:30pm - 1:00pm</td>
<td>Cost Effective and Efficient Detailing for Fabrication of Steel Girders</td>
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* All times are approximate.
## Agenda – September 22, 2020

<table>
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<tr>
<th>Time*</th>
<th>Topic</th>
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</table>
| 11:00am - 12:00pm | Practical approaches & Tools for the Design of Steel Bridges  
Part 1: Layout, Design, & Simon |
| 12:00pm - 12:30pm | Bolted Connections and Field Splices  
(AASHTO’s Simplified Method) |
| 12:30pm - 1:00pm | Updates to AASHTO 9\(^{th}\) Edition LRFD Bridge Design Specifications |

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<td>11:00am - 12:00pm</td>
<td>Practical approaches &amp; Tools for the Design of Steel Bridges</td>
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<tr>
<td></td>
<td>Part 2: Availability, Constructability, &amp; Resources</td>
</tr>
<tr>
<td>12:00pm - 1:00pm</td>
<td>Producer and Fabricator Panel Discussion</td>
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Who We Are
Meet the NSBA Team
Meet the **NSBA**

**Bridge Steel Specialists**

**Western Market**
Jason Lloyd

**Central Market**
Tony Peterson

**Southeast Market**
John Hastings

**Northeast Market**
Vin Bartucca

**Steel Solutions Center**
Devin Altman ⭐

**Leadership Team**

Director of Market Development
Jeff Carlson ⭐

Director of Market Development
Brandon Chavel ⭐

Chief Bridge Engineer
Chris Garrell ⭐
Who We Are

National Steel Bridge Alliance, a Division of AISC

- Technical Institute & Trade Association

- Not-for-profit: working for the advancement of steel bridge design and construction

- Services: free resources, forums, AASHTO/NSBA collaboration, preliminary design & evaluation tools, continuing education
STEEL SOLUTIONS CENTER

The Steel Solutions Center is your gateway to nearly 100 years of steel knowledge, and it’s just a phone call or email away.

aisc.org/askaisc
solutions@aisc.org
866.ASK.AISC

- answer your technical questions about structural steel design.
- help you understand NSBA’s technical publications.
- help you reduce project risk by connecting decision-makers with AISC bridge-member fabricators for price and schedule information.
- provide conceptual solutions for steel girder and beam bridges, including framing plan and girder spacing concepts, preliminary girder sizes, and steel tonnage estimates.
Upcoming Events
World Steel Bridge Symposium
“If you work in the steel construction industry, this is THE show to attend. Any resource you could ever want is here, all in one place!”

—Hexagon PPM

NASCC: THE STEEL CONFERENCE

World Steel Bridge Symposium | QualityCon | Architecture in Steel
SSRC Annual Stability Conference | NISD Conference on Steel Detailing

Louisville, Kentucky
Kentucky International Convention Center | April 14–16, 2021

aisc.org/nascc
More Information

• National Steel Bridge Alliance
  www.aisc.org/nsba
• Resources for Design and Estimation
  www.aisc.org/nsba/design-and-estimation-resources/
• Steel Bridge Forums
  www.aisc.org/nsba/steel-bridge-forum/
• Bridges to Prosperity
  www.aisc.org/nsba/bridges-to-prosperity/
• Modern Steel Construction
  www.modernsteel.com
John Hastings, P.E.
615.490.6519
hastings@aisc.org
Justin Walker, PE
MDOT Update
BASIC CONCEPTS ON FATIGUE DESIGN
FOR STEEL BRIDGES

ROBERT J. CONNOR
PURDUE UNIVERSITY
JACK AND KAY HOCKEMA PROFESSOR OF CIVIL ENGINEERING

SEPTEMBER 2020
WHAT IS FATIGUE?

• Process by which cracks initiate and grow by cyclic loading
  ▪ “Cyclic loading”
    – E.g. trucks repeatedly passing over a bridge
  ▪ Clearly loading is time dependent (not static)

• The stress/load ranges producing fatigue damage do not need to be large

• Brittle/ductile fracture is a concern in the presence of a crack, especially as it grows

• Fracture at a crack is NOT the same as a net section strength checks at holes
**CRACK VS NET SECTION (FOR STRENGTH)**

Stress intensity factor (SIF) is infinite at crack tip (theory)

Max stress concentration factor (SCF) is $3.0 \times S_{NOM}$

Dia. = a
FATIGUE LIFE

• Generally refers to interval of time during which no significant cracking is expected
  ▪ Significant cracking is based on laboratory testing and is not a unique value
    – Could be ½” crack, or 5% of member strength, etc.
    – Does not mean member fractures
    – Would generally be detectable at room temperature
  ▪ Fatigue life is measured in number of stress cycles
  ▪ Based on probabilities of cracking found from laboratory testing
FATIGUE LIFE CONT.

• Two regions of fatigue life:
  ▪ **Infinite life**
    – Significant cracking (i.e. failure) never expected to occur
  ▪ **Finite life**
    – Based on stress range ($S_r$), # cycles ($N$), and detail category
• Constant-Amplitude Fatigue Limit (CAFL): Boundary between finite and infinite life
FATIGUE LIFE BASED ON S-N CURVES

![Graph showing S-N curves and CAFL with log-log scales.](image)
FATIGUE LIFE BASED ON S-N CURVES

S-N Curve: Category C

DESIGN/EVALUATION FAILS: DESIGN FATIGUE LIFE

FINITE LIFE REGION

INFINITE LIFE REGION
THREE MOST IMPORTANT PARAMETERS INFLUENCING THE LIKELIHOOD OF FATIGUE DAMAGE ARE:

• Stress range \( (S_r) \)

• Number of cycles \( (N) \)

• Detail classification \( (A, B, C, \text{ etc.}) \)
DEGREE OF DAMAGE (CRACKING) IS A FUNCTION OF TWO PARAMETERS

• Magnitude of load ($S_r$)
  ▪ How large is the stress range?
  ▪ Stress range = $S_r$

• Frequency of occurrence (N)
  ▪ How often are cycles applied?
  ▪ ADTT

• *Above parameters define load or stress-range spectrum*
SUMMARY OF FATIGUE

• Trucks produce damage
  ▪ Cars & light trucks not much of an issue
• More trucks = more cycles
• Some details more susceptible to cracking
  ▪ Today, we can selected “good” details quite easily
    – “Good” = Category C and better
    – Avoid E and E’ details in tension applications as much as practical
FATIGUE VS. FRACTURE

• Fatigue
  ▪ Slow stable crack growth over time.
  ▪ If loading stops, growth stops
  ▪ Crack growth is independent of material properties
  ▪ You can inspect for fatigue damage

• Fracture
  ▪ Brittle or explosive instantaneous cracking
  ▪ Potential for fracture is influence by material properties
  ▪ Can still occur even without live load
  ▪ Generally, you find fractures after they occur
SOME GUIDANCE ON USING THE AASHTO DETAIL CATEGORIES
First, consider title of the table?  
- “Detail Categories for Load-Induced Fatigue”

What does this mean?  

Sort of confusing, as all fatigue is “load” induced  

Really means “live loads that produce stress ranges we calculate”
- Includes Mc/I & P/A
- “Nominal Stresses”
Second, what loading (i.e., stress range) is not considered?
- Out-of-plane distortion
- Secondary stresses
- etc.

We don’t calculate these stresses

These stresses also are very complex and local in nature
- Details based on nominal stress, not local stress
Third, must understand what defects are not included in the details

- Categories don’t include specific defects
  - Existing cracks
  - Gouges
  - Corrosion
  - Impact damage
- Thus, if a member is cracked, details/categories in the table don’t apply
  - Need to use fracture mechanics
INFO. INCLUDED IN THE TABLE

• Illustration of “typical” detail
  ▪ Trick is mapping your detail to an illustration
• Orientation of nominal stress range that is being checked
• Specific information regarding detail constants and CAFL
  ▪ For life calculations
• Location where cracking is expected
  ▪ Useful when mapping your detail to illustration
STEPS TO USING TABLE

• Determine the nominal LL stress range orientation in the member

• Compare relative orientation of the detail being evaluated to that of the applied stress range
  ▪ e.g., perpendicular or parallel to the weld toe
STEPS TO USING TABLE

• Attempt to determine where cracks will form
  ▪ Weld toe?
  ▪ Inside of the weld?
  ▪ At rivet hole?
• Maybe more than one location per detail
STEPS TO USING TABLE

• Welded details
  ▪ Determine weld type and length
  ▪ Determine orientation of weld axis

• Determine orientation of weld toe to stress range
  ▪ For welded details, cracking will almost always occur at weld toes oriented perpendicular to applied stress range
  ▪ True even if ground smooth
  ▪ Still must check portion that is parallel, but almost always a better category
• Bolted/riveted details
  ▪ Orientation w.r.t. holes
    – Circles so pretty easy!
    – There is always a stress range tangent to the hole
FOR EXAMPLE

Detail is parallel to stress range in girder, so “longitudinally loaded”

Orientation of stress range due to bending

CJP Weld
Where is weld toe that is perpendicular to applied stress range?

CJP Weld
FOR EXAMPLE

What is expected orientation of cracking?

Orientation of stress range due to bending
FOR EXAMPLE

Detail is parallel to stress range in girder, so “longitudinally loaded”

Orientation of stress range due to bending
RETROFITTING STEEL BRIDGES FOR FATIGUE

- Excellent “FREE” resources available published documents on retrofitting:
  - NCHRP 20-07/Task 387 (2017)
  - FHWA Manual (2013)
- Many “bad” retrofits out there...
  - BE SURE IT WILL WORK
  - TRY PROTOTYPES
QUESTIONS?
Cost Effective and Efficient Detailing for Fabrication of Steel Girders
Agenda

- Raw Material Selection
- Girder Details
- Crossframe Details
Raw Material Selection

- We suggest the use of 50W steel in lieu of grade 50 painted. The cost of grade 50 PRIMER ONLY is approximately the same cost as 50W uncoated.
- Due to recent changes in HPS-70W material pricing it may be economical to explore its use. Contact your local fabricator for additional information.
- Plate availability
  - Webs depths **DO NOT** have to be specified in 3” increments
  - Plates thicknesses are available in 1/16” increments between ¼” to 4”
Raw Material Selection

- Good example of HPS-70W material use
Raw Material Selection

- When possible avoid expensive sections such as W40s and MCs
- Depending on market conditions and schedule, fabricating a plate girder can be less expensive than W40s. In multiple cases we have seen savings of as much as 10% on the total steel package.

THE CONTRACTOR MAY PROPOSE PLATE GIRDERS USING EQUIVALENT SECTION PROPERTIES IN LIEU OF THE ROLLED BEAM SHAPE SHOWN AT NO ADDITIONAL COST TO THE DEPARTMENT. PROVIDE $\frac{5}{8}''$ MINIMUM FILLET WELDS BETWEEN WEB AND FLANGES. NON-DESTRUCTIVE TESTING WILL BE REQUIRED AS APPROPRIATE.
Raw Material Selection

- MC diaphragms can cost up to 60% more than bent plate diaphragms or rolled beams. Especially if tab plates are welded to the MCs.
Girder Details

- What is slab splicing and why does it matter to you?
- Splicing can dictate your delivery schedule.
- Slab splicing is up to 34% more efficient than splicing single flanges.
*FRAMING PLAN
*FRAMING PLAN

*GIRDER ELEVATION
*FRAMING PLAN

*GIRDER ELEVATION

*PURCHASED PLATES
*FRAMING PLAN

*GIRDER ELEVATION

*PURCHASED PLATES

*SPLICED PLATES
* FRAMING PLAN

* GIRDER ELEVATION

* PURCHASED PLATES

* SPliced PLATES

* STRIPPED FLANGES
Girder Details

- Limit flange width transitions to field splice locations.

- Finish to bear in lieu of full pen welded stiffeners can save 10-15% on stiffener fitting/welding cost.
Girder Details

- Limit web to flange welds to AWS D1.5 minimum fillet weld sizes (max 5/16”). Anything beyond a 5/16” fillet will at minimum double web to flange welding cost.

<table>
<thead>
<tr>
<th>Base Metal Thickness of Thicker Part Joined (T)</th>
<th>Minimum Size of Fillet Weld</th>
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<tbody>
<tr>
<td>$T \leq 20 \text{ mm} [3/4 \text{ in}]$</td>
<td>$6 \text{ mm} [1/4 \text{ in}]$</td>
</tr>
<tr>
<td>$T &gt; 20 \text{ mm} [3/4 \text{ in}]$</td>
<td>$8 \text{ mm} [5/16 \text{ in}]$</td>
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- Use the latest splice design criteria and larger bolts up to 1” dia when it reduces the number of holes.
Crossframe Details

- Avoid the use of back to back angles.
- K-frames with all welding on one side eliminates the need to flip crossframes in the shop.
- Please specify minimum weld lap sizes. This allows the fabricator to create non-rectangular gussets and reduce the amount of welding required.
- Use larger bolt diameters to reduce the number of bolt holes in crossframes. 1” dia. A325 bolts are readily available.
NOTE FULL LENGTH WELDS
NOTE PARTIAL LENGTH WELDS
Examples of Clipped Crossframe Gussets
LOOKS INNOCENT ENOUGH
LACK OF INNOCENCE REVEALED
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