

# Unforeseen Effects of Secondary Members



MoDOT Team Conference

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Natalie McCombs, PE, SE







## History

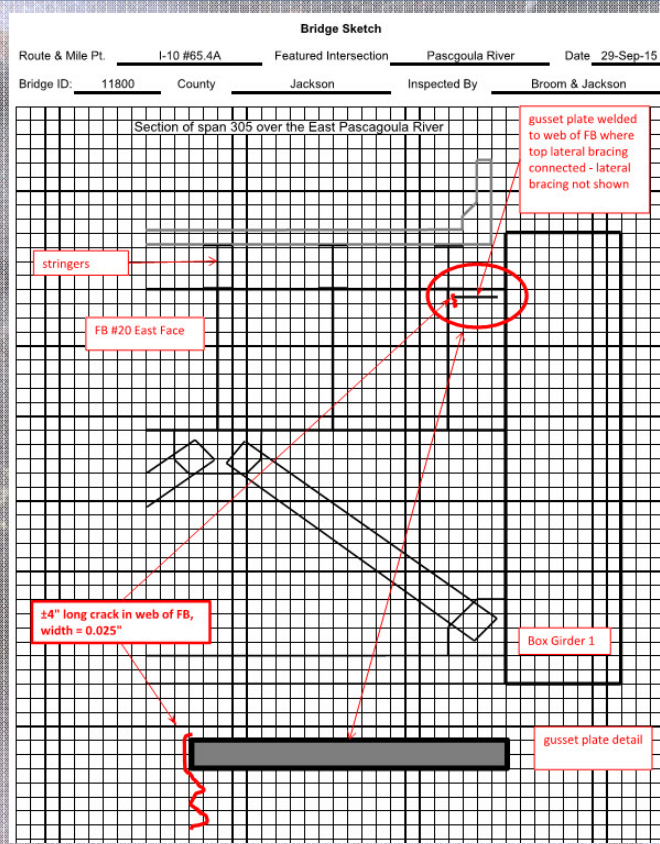
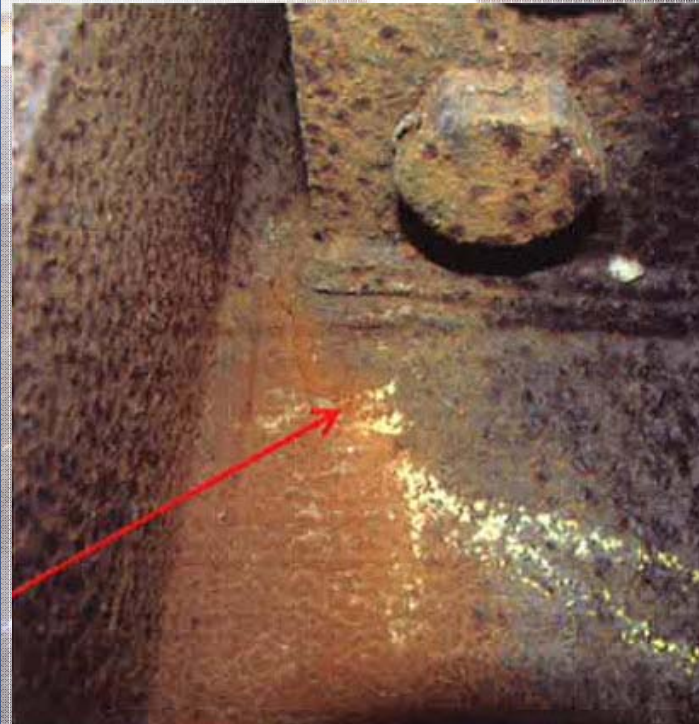
- 5 ¼" open grid deck replaced in 1991 with 7" continuous concrete deck
- Added 1,000 kips of dead load
- Bolts have been intentionally loosened
  - First bay of upper lateral bracing
  - Exterior stringers
- Cracks in floorbeam web were evident in 2013

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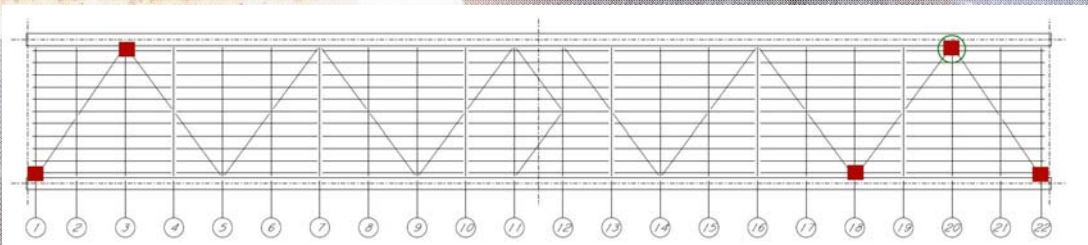
# Crack Location



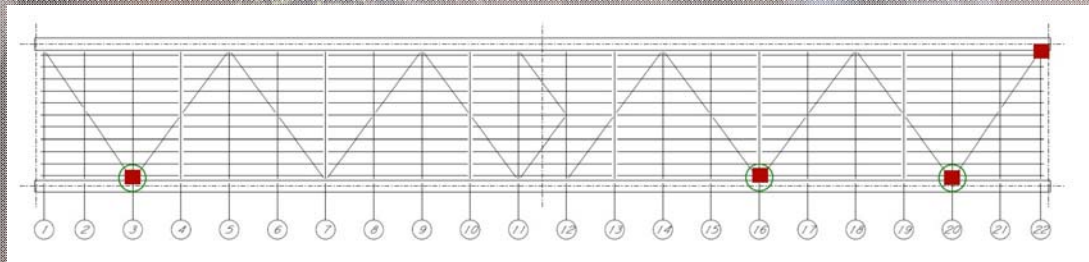
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# Crack Location



Westbound Upper Lateral Bracing Plan



Eastbound Upper Lateral Bracing Plan **HNTB**



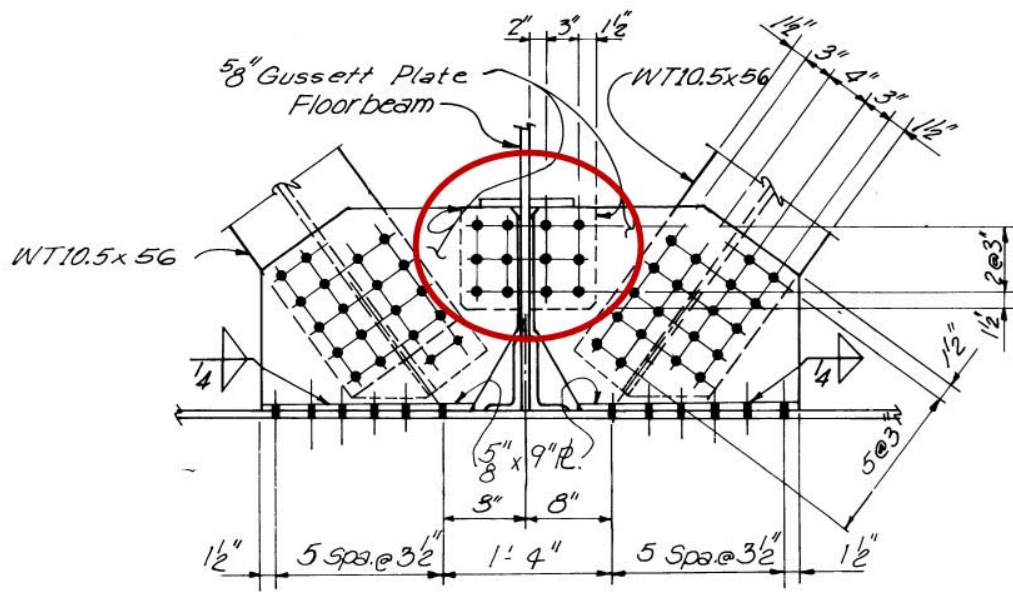
# Crack Location

<b>Westbound - Bridge ID 11800</b>					
Structure Number 65.4A					
Floorbeam	Girder	2014 Inspection		2015 Inspection	
		Crack Length	Crack Tip Location	Crack Length	Crack Tip Location
1	2	+/- 1/2"	toe of weld	+/- 1/2"	toe of weld
3	1	+/- 1/2"	floorbeam web	+/- 1/2"	floorbeam web
18	2	+/- 1/2"	toe of weld	+/- 1/2"	toe of weld
20	1	+/- 2 1/2" to 3"	floorbeam web	+/-4" *	floorbeam web
22	2	+/- 1/2"	toe of weld	+/- 1/2"	toe of weld

<b>Eastbound - Bridge ID 11801</b>					
Structure Number 65.4B					
Floorbeam	Girder	2014 Inspection		2015 Inspection	
		Crack Length	Crack Tip Location	Crack Length	Crack Tip Location
3	2	+/- 2"	floorbeam web	+/- 6" *	floorbeam web
16	2	+/- 1/2"	floorbeam web	+/- 4" *	floorbeam web
20	2	+/- 1/2"	floorbeam web	+/- 4 1/2" *	floorbeam web
22	1	+/- 1/2"	toe of weld	+/- 1/2"	toe of weld

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# Connection As-Designed



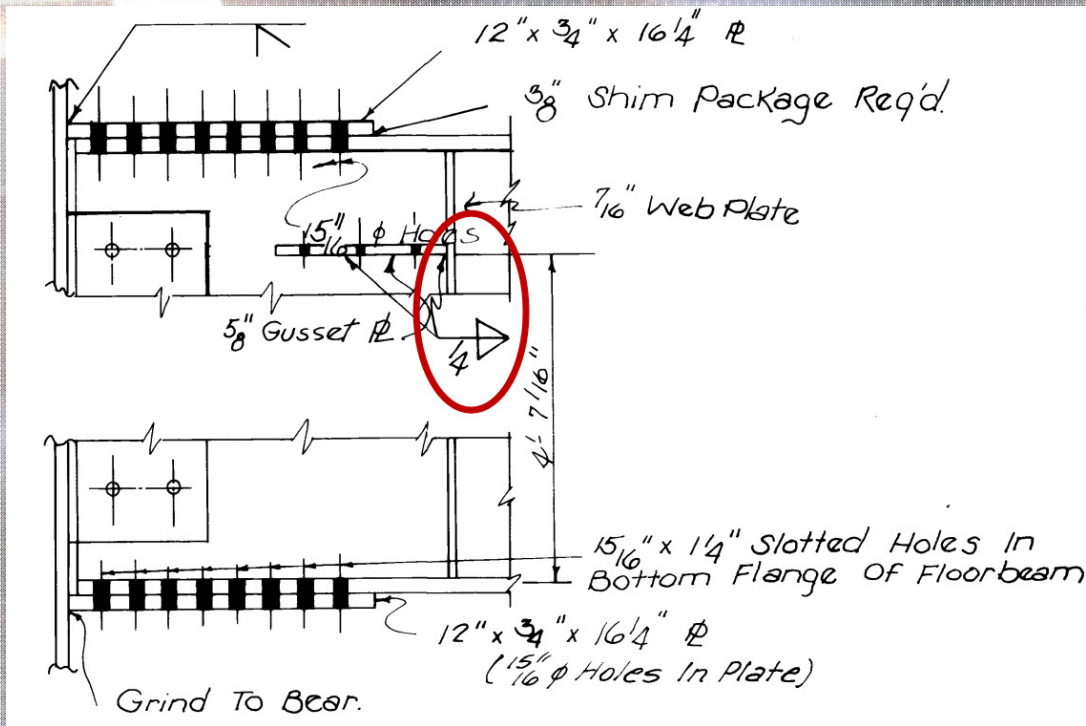
**DETAIL 'C'** ▲

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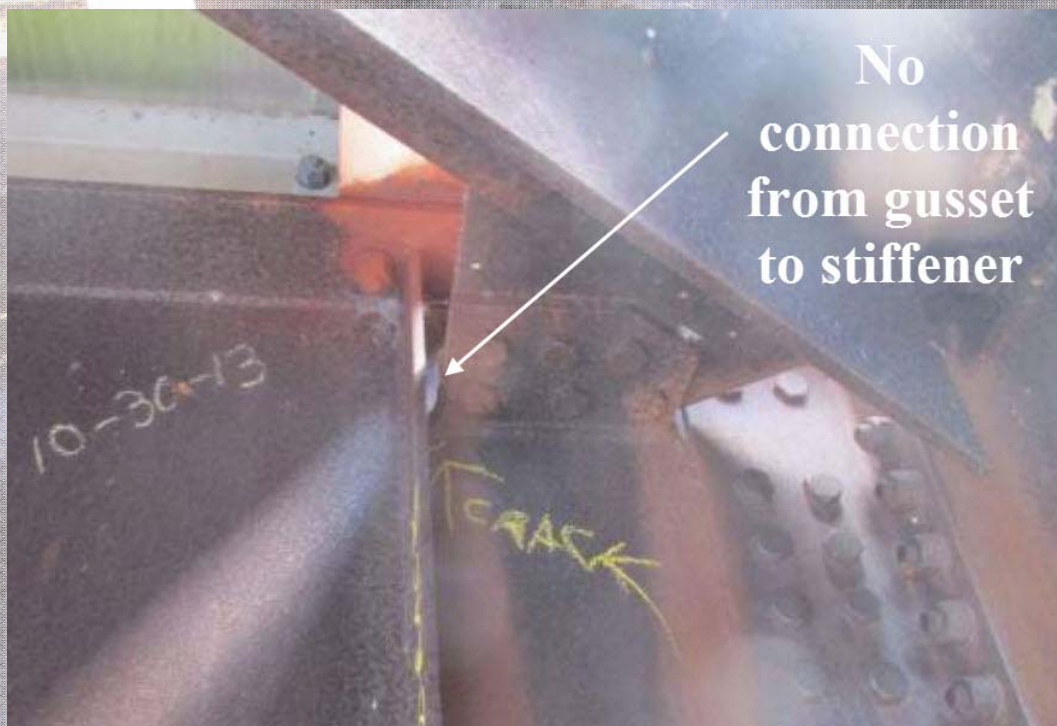


# Connection As-Designed

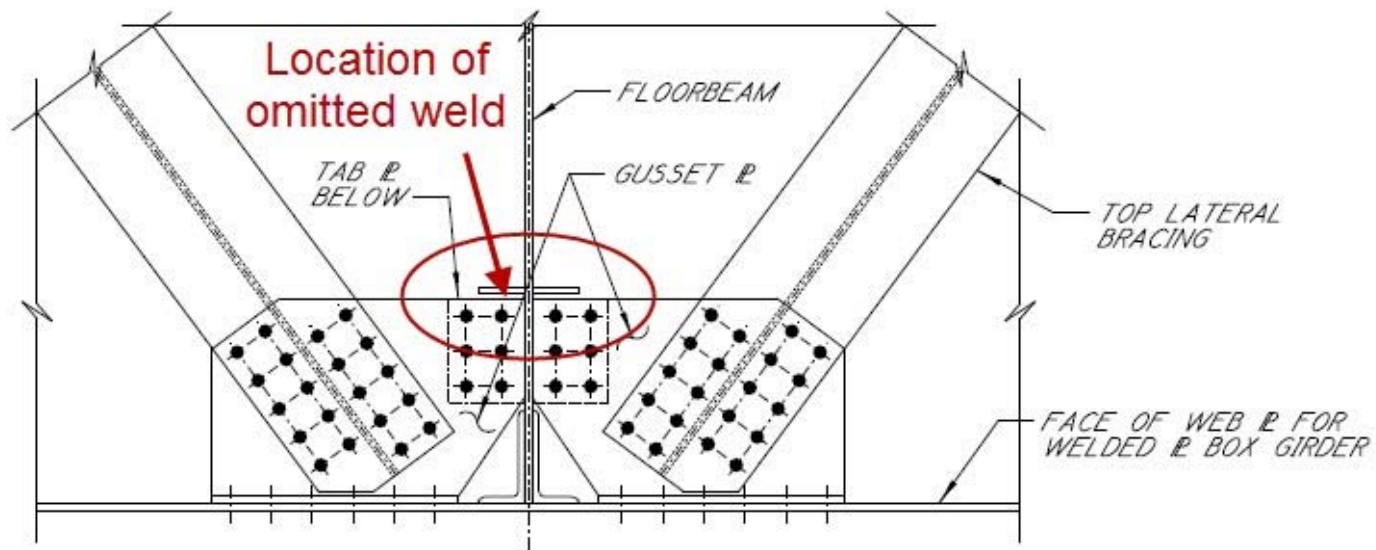




## Connection As-Built

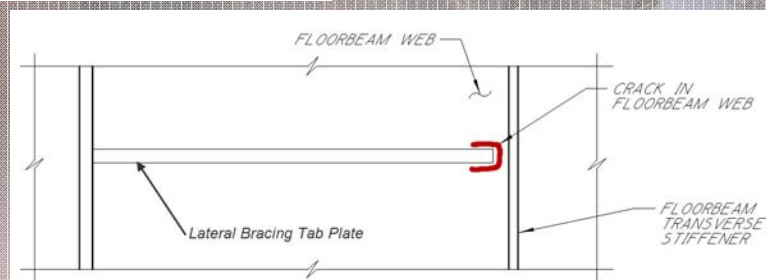
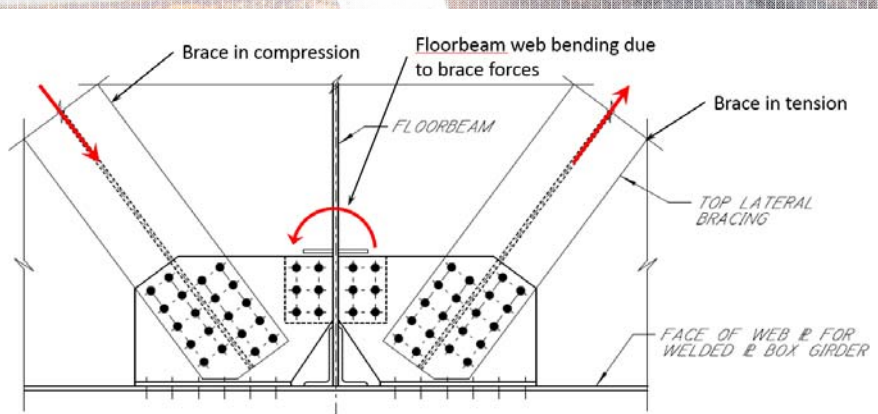


# Connection As-Built





# Force Transfer



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# Fatigue Category

## Section 7—Longitudinally Loaded Welded Attachments

7.1 Base metal in a longitudinally loaded component at a detail with a length  $L$  in the direction of the primary stress and a thickness  $t$  attached by groove or fillet welds parallel or transverse to the direction of primary stress where the detail incorporates no transition radius:

$L < 2$  in.

$2$  in.  $\leq L \leq 12t$  or  $4$  in.

$L > 12t$  or  $4$  in.

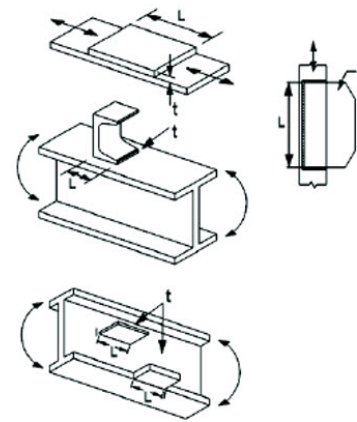
$t < 1.0$  in.

$t \geq 1.0$  in.

(Note: see Condition 7.2 for welded angle or tee section member connections to gusset or connection plates.)

C	$44 \times 10^8$	10
D	$22 \times 10^8$	7
E	$11 \times 10^8$	4.5
E'	$3.9 \times 10^8$	2.6

In the primary member at the end of the weld at the weld toe





## Study Approach

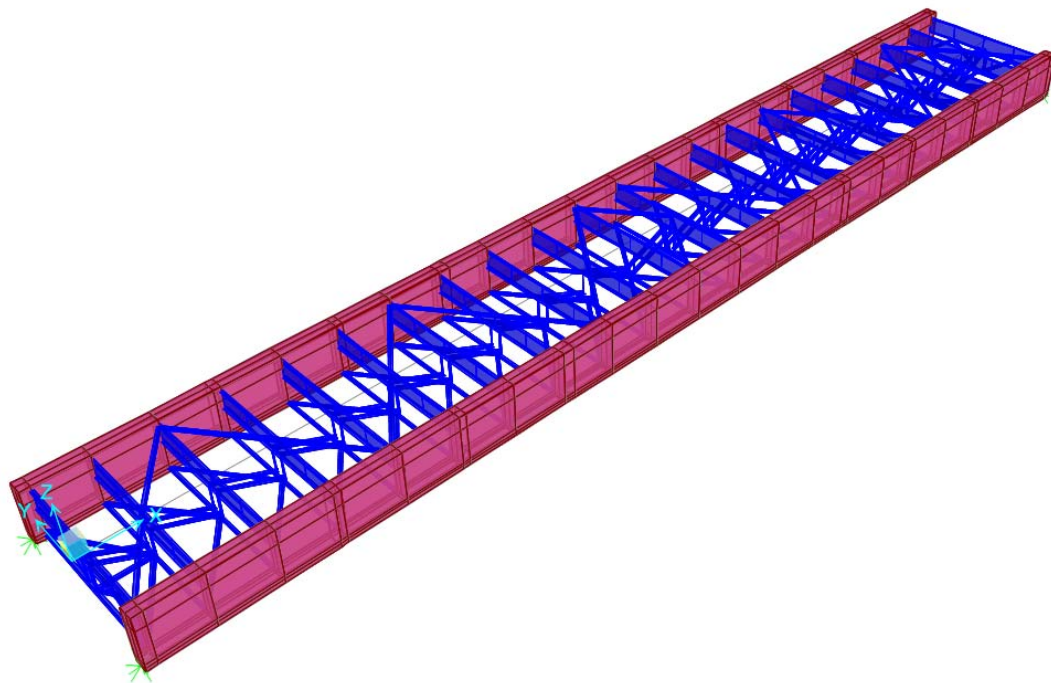
- Increased dead load from deck replacement
- Modified deck stiffness
- Cyclic loading from live load
- Cyclic loading from wind load
- Cyclic loading from temperature

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## Global CSi Bridge Model



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## Increased Dead Load

- 5 ¼" grid deck to 7" solid deck = 1,000 k
- Increases the negative moment at LB connection
- Considered a half-cycle with 0.7 ksi change in stress

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## Modified Deck Stiffness

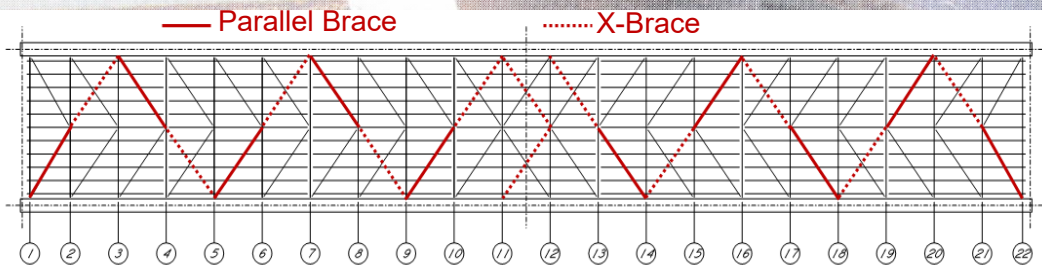
- With braces
  - No noticeable difference in brace forces
- Without braces
  - Slight increase in movement occurs before engaging deck due to stringer slots
  - Rely on stringer to floorbeam connections to transfer force

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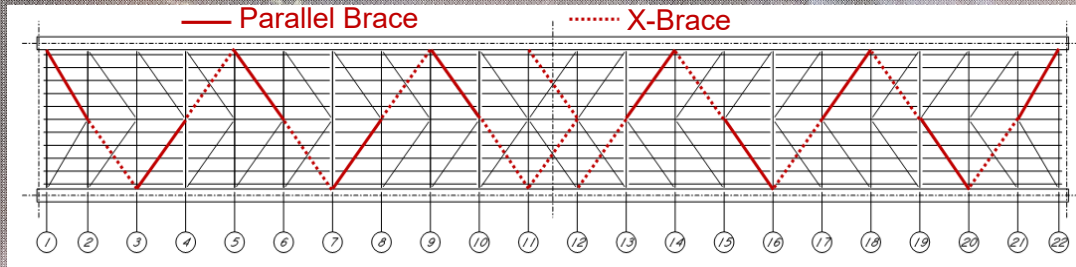
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# Global Behavior of Bracing

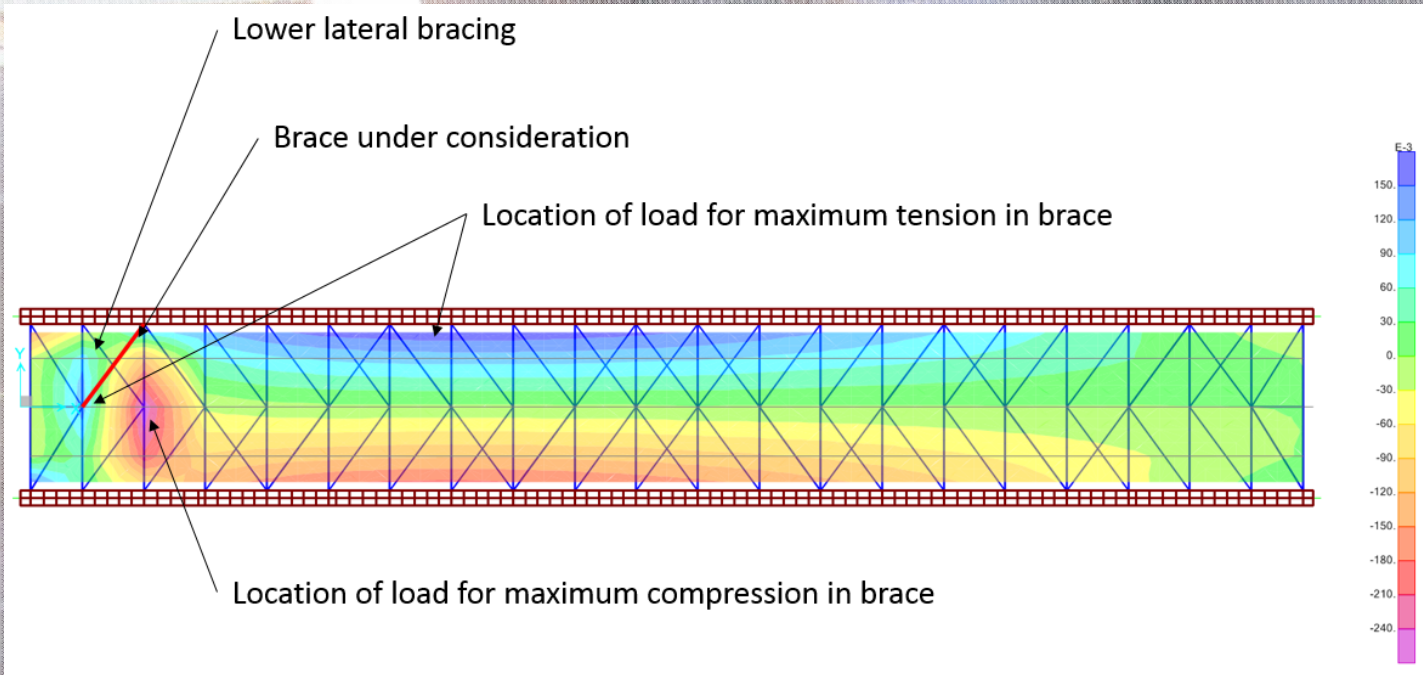


## Westbound Lateral Bracing Plan



## Eastbound Lateral Bracing Plan **HNTB**

# Global Behavior of Bracing

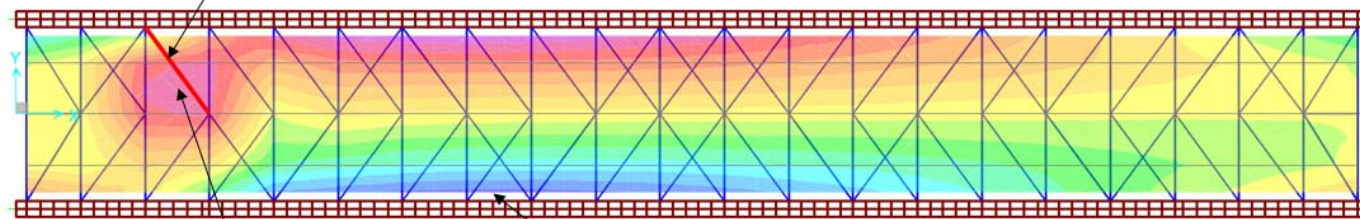


Influence Surface of X-Braces



# Global Behavior of Bracing

Brace under consideration  
Lower lateral bracing behind



Location of load for maximum tension in brace

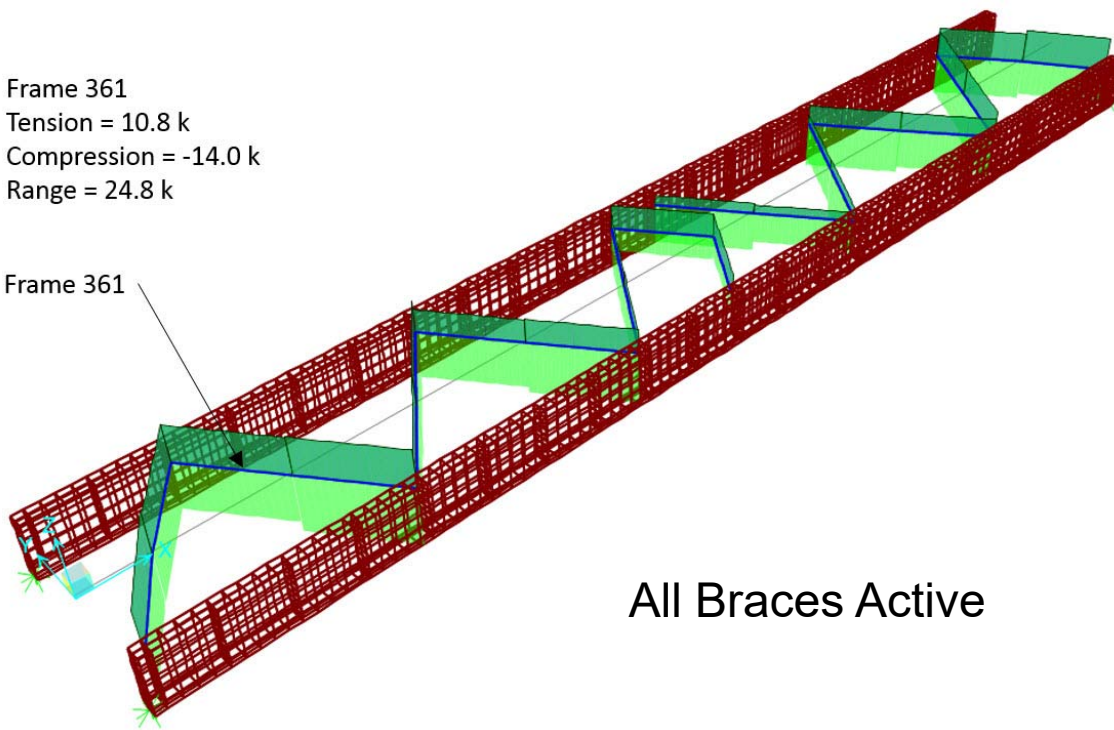
Location of load for maximum compression in brace

Influence Surface of Parallel Braces

# Global Behavior of Bracing

Frame 361  
Tension = 10.8 k  
Compression = -14.0 k  
Range = 24.8 k

Frame 361



All Braces Active

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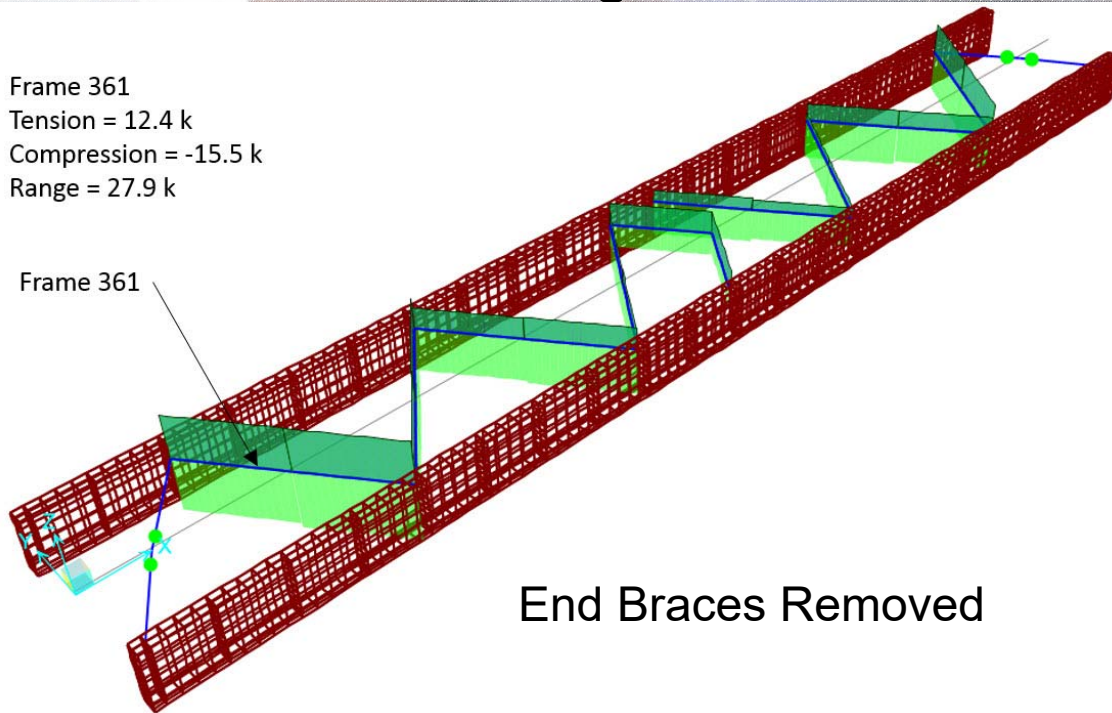
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# Global Behavior of Bracing

Frame 361  
Tension = 12.4 k  
Compression = -15.5 k  
Range = 27.9 k

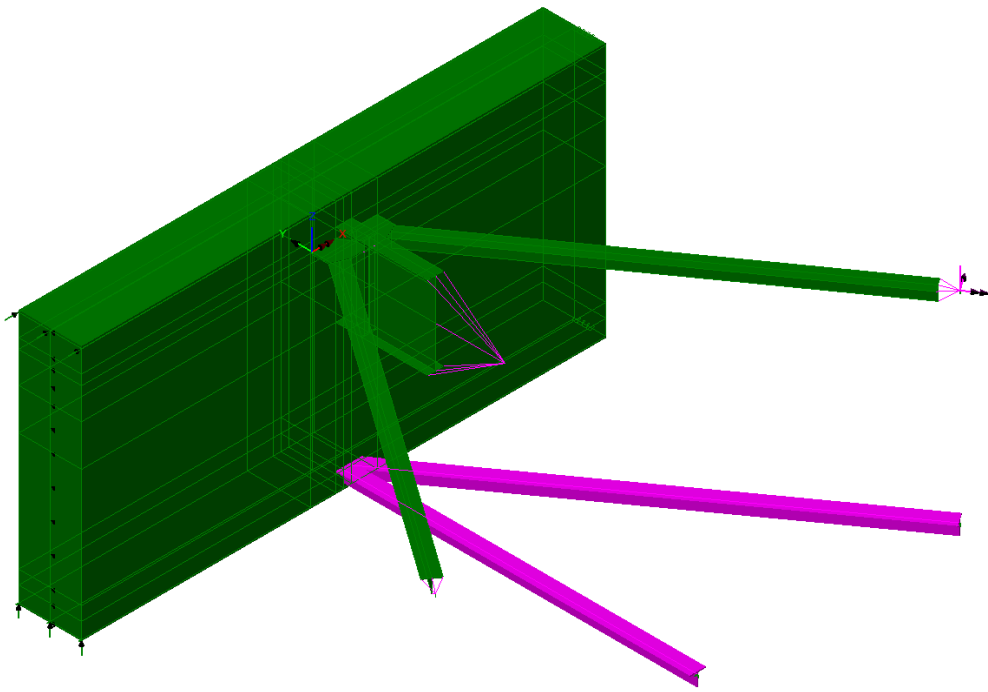
Frame 361



End Braces Removed

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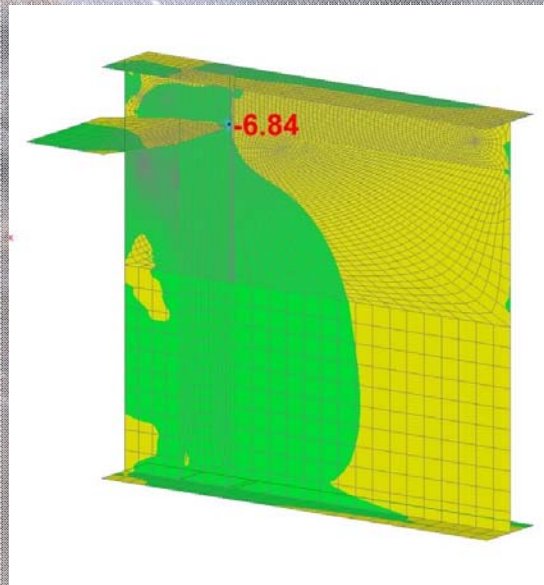
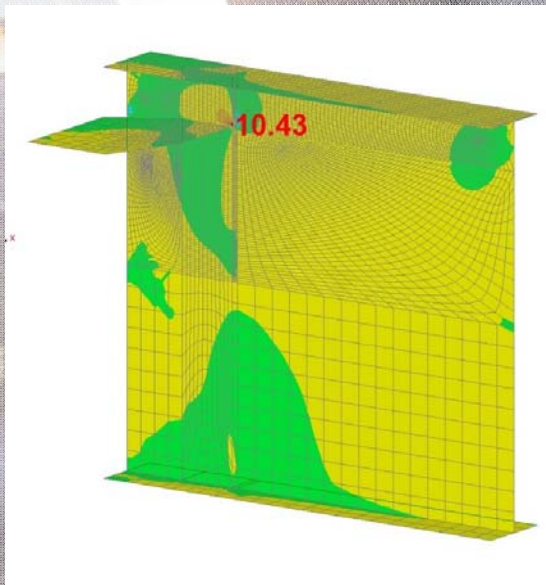
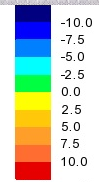
# Local Lusas Model



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# Cyclic Live Load As-Built



Tension Stress

Compression Stress

Total Range = 17.3 ksi

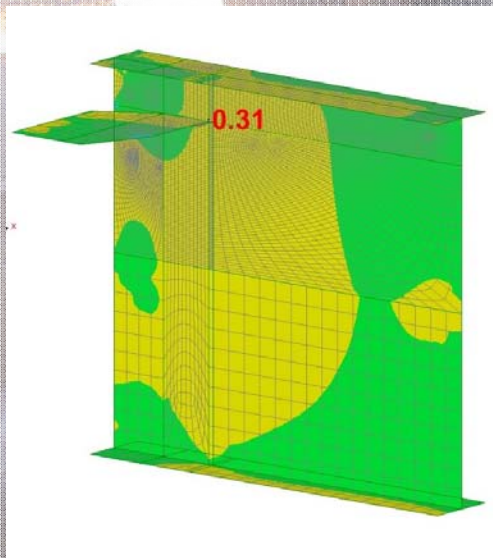
Infinite Fatigue Life = 4.5 ksi

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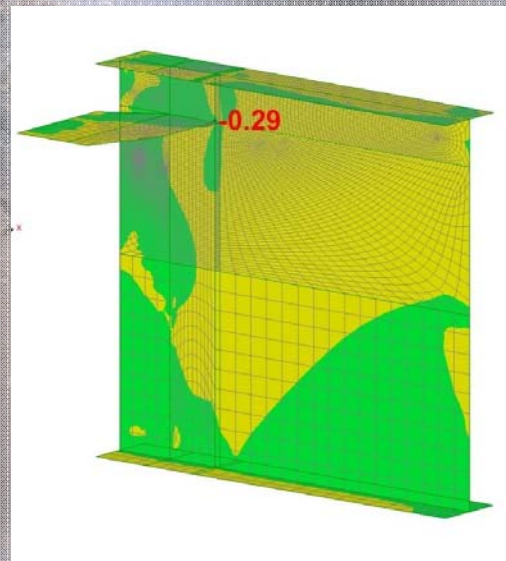




# Cyclic Live Load As-Designed



Tension Stress



Compression Stress

Total Range = 0.6 ksi  
Infinite Fatigue Life = 4.5 ksi

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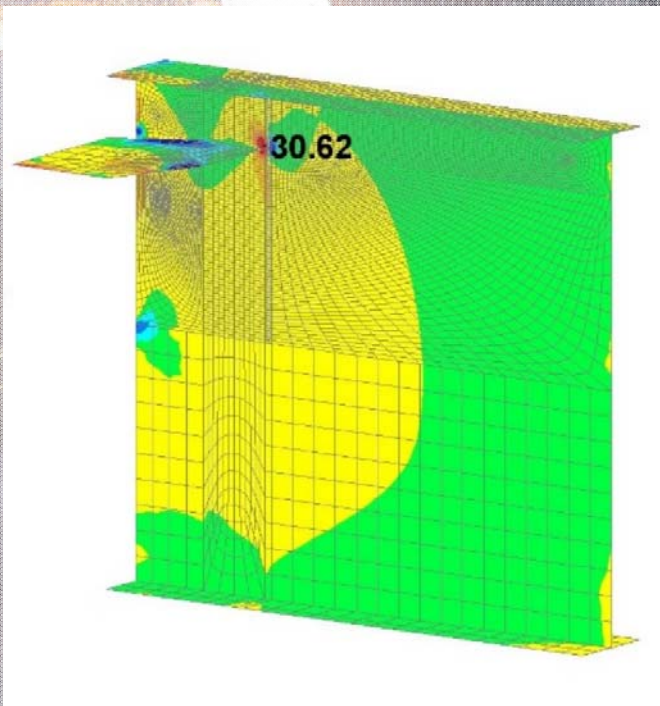
## Cyclic Wind Load

- AASHTO 17<sup>th</sup> Edition 2002
- 100,000 wind cycles
- 22 ksi for category E detail





## Cyclic Wind Load As-Built



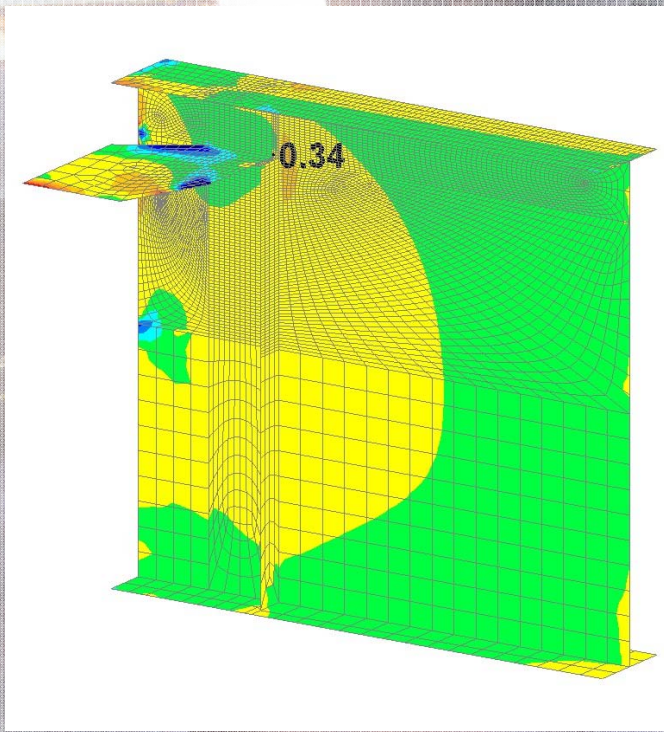
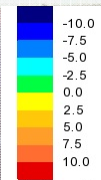
- Max Tension = 30.62 ksi
- Max range = 61.24 ksi
- Allowable range = 22 ksi

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## Cyclic Wind Load As-Designed



- Max Tension = 0.34 ksi
- Max range = 0.68 ksi
- Allowable range = 22 ksi

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## Temperature

- Uniform Temperature
- Temperature Gradient
  - South Box exposed to sun
- Negligible effect

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## Results

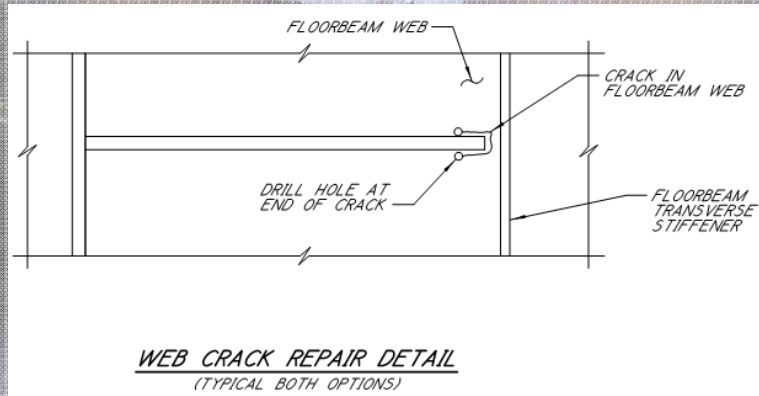
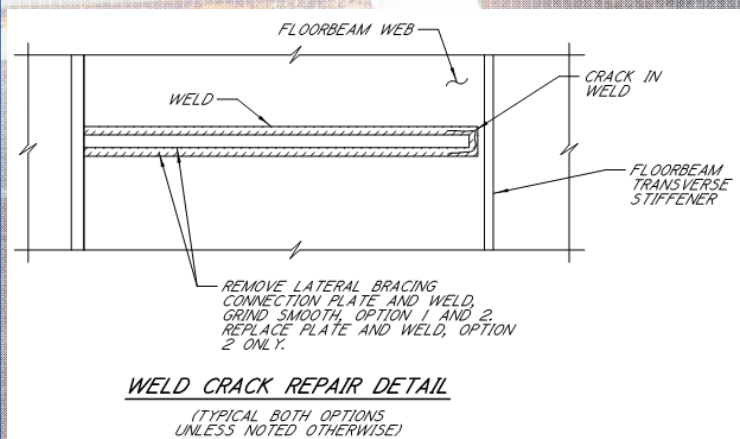
- Fatigue cracks from shortened tab plate and missing weld
- Category E detail
- Additional weight of deck decreased allowable fatigue range
- Primary cause is LL fatigue cracking

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# Crack Repair – All Options





## Proposed Solutions – Option 1

- Remove Upper Lateral Bracing
  - Prevents crack growth
  - Reduces negative moment in floorbeam
  - Rely on concrete deck for lateral load transfer at the top of the box
  - Temporary LB during deck replacement
  - Changes forces in bridge framing

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## Proposed Solutions – Option 2

- **Bolted Connection Retrofit**

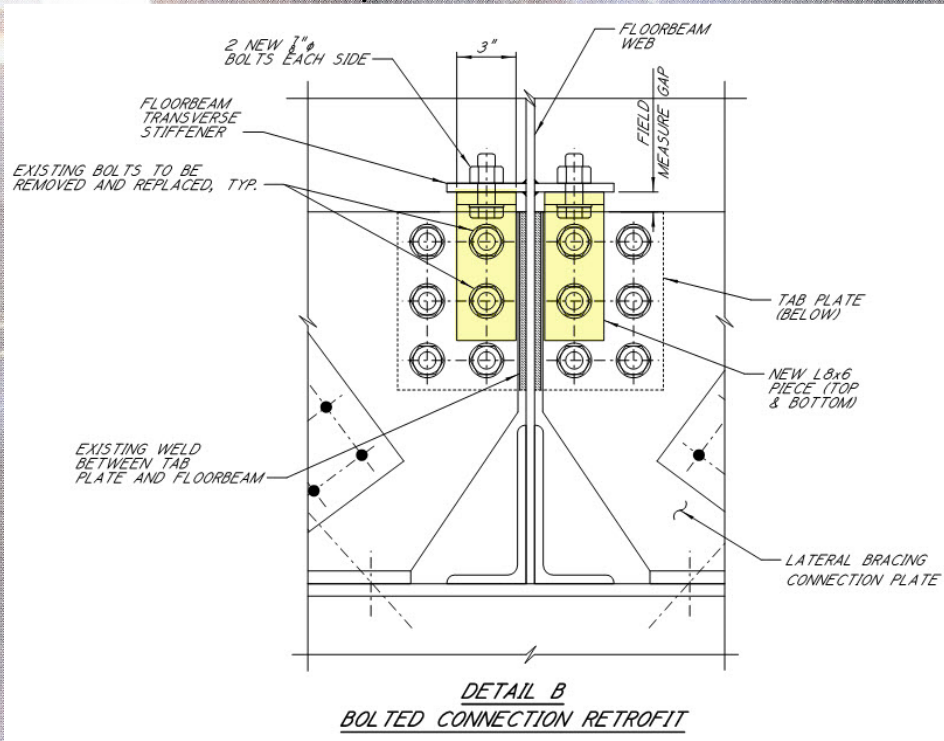
- Reinstatement of the original design intent
- Global behavior is not modified
- Field work includes field measurements
- The load in the brace will still be present

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# Proposed Solution – Option 2



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## Recommendations

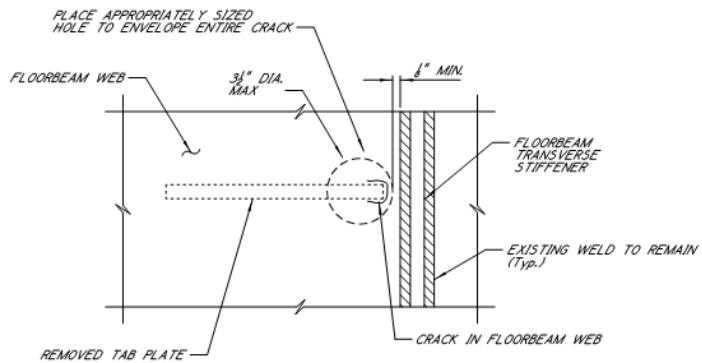
- Remove Lateral Bracing
- Drill holes to arrest web cracks
- Remove tab plate and weld to arrest weld cracks
- Remove gusset plates at all locations (unbolting)

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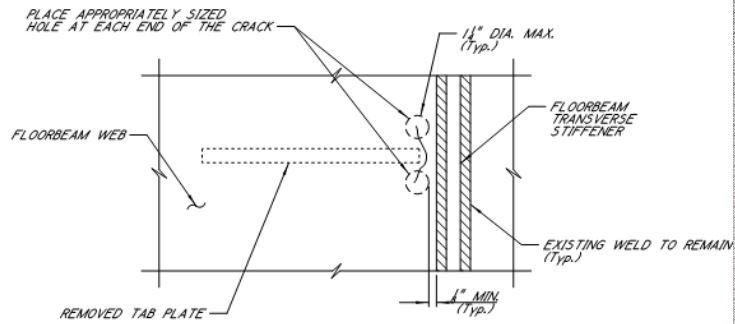
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# Crack Arrest Hole Repair



OPTION 1  
(WHEN WELD ENDS ARE  
IN CLOSE PROXIMITY)  
(NTS)



OPTION 2  
(WHEN WELD ENDS ARE  
NOT IN CLOSE PROXIMITY)  
(NTS)

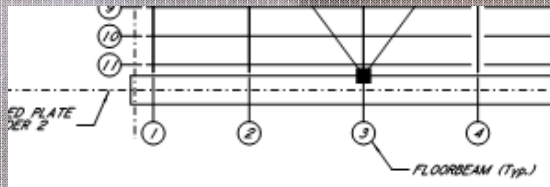
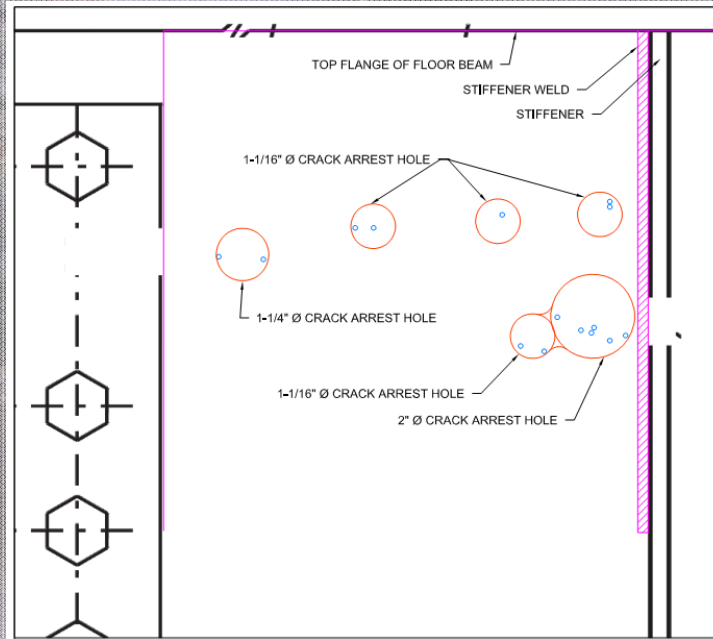
WELD CRACK REPAIR DETAILS

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# Actual Crack Mapping and Arrest Holes



Eastbound Bridge – Floorbeam 3



# Questions



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