Repair and Retrofit of Large Out-of-Plane Cracking on Utah's 0C 709 Bridge

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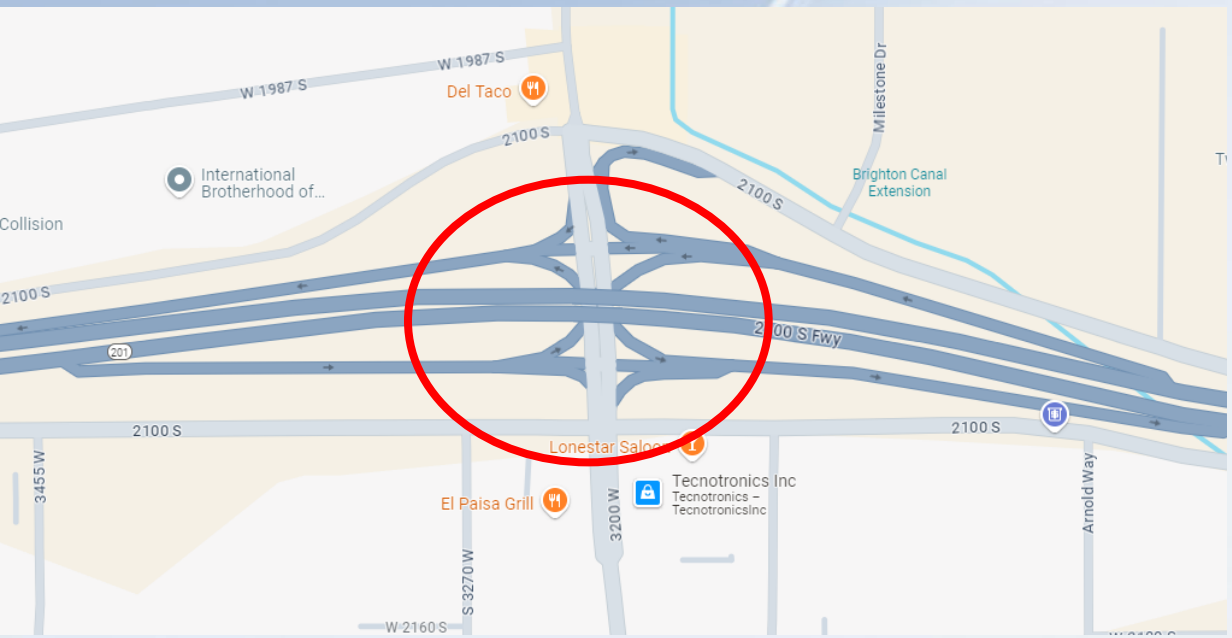
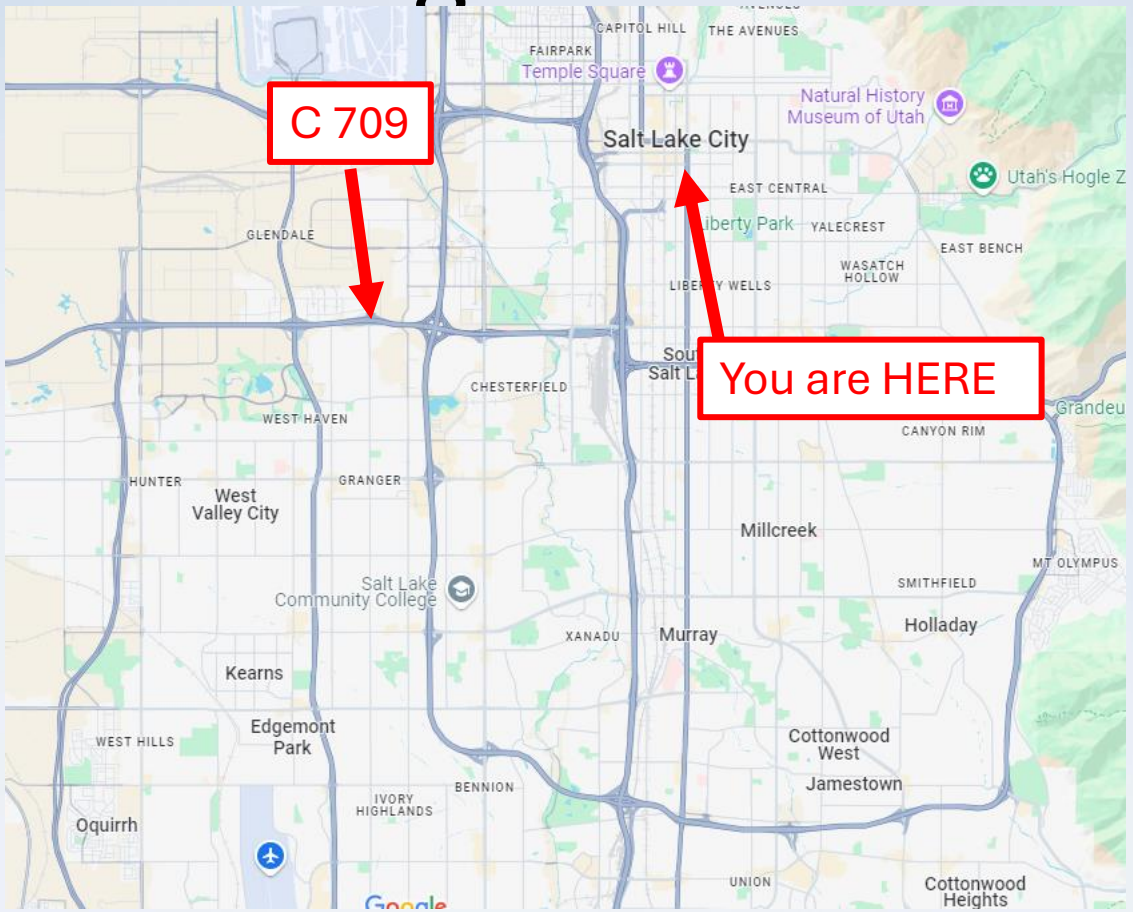
- SR-201 over 3200 West





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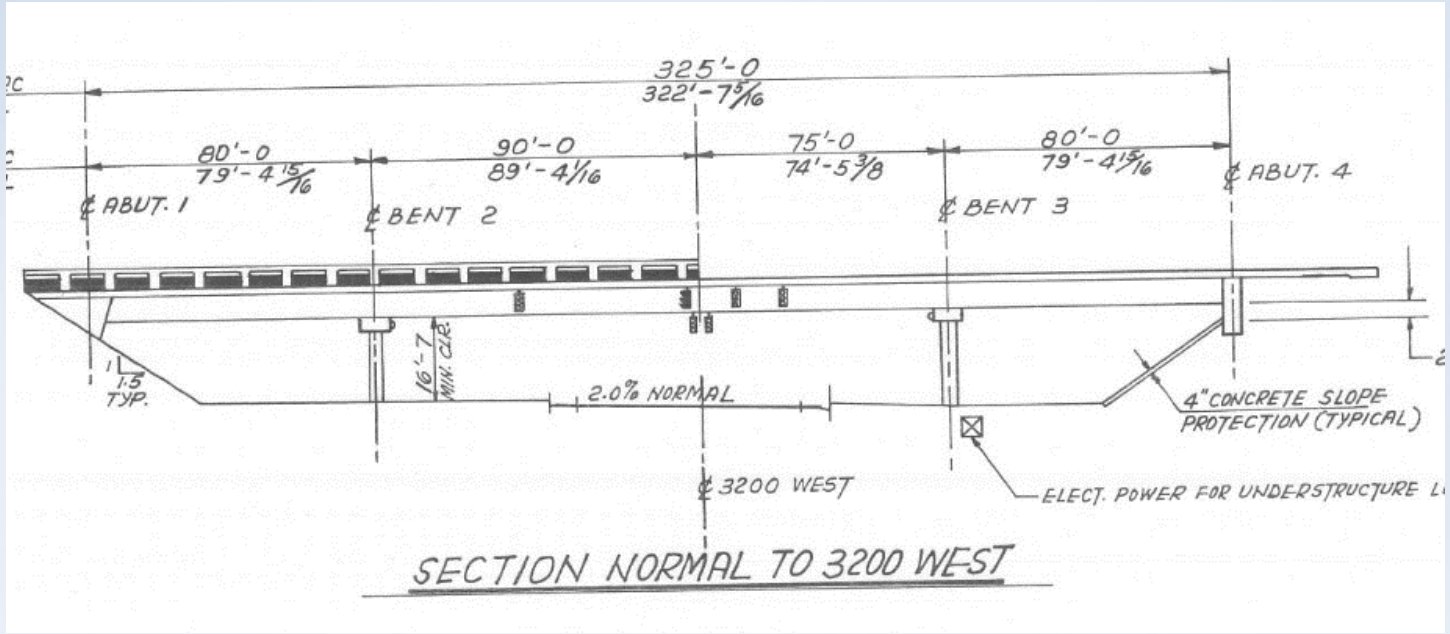
- Built in 1980
- 3 span continuous bridge
- Spans 1 and 3 are 80'-0"
- Span 2 is 165'-0"
- Top flange width
  - 14" most of span 2
  - 20" everywhere else
- 3/8" x 4" stiffeners



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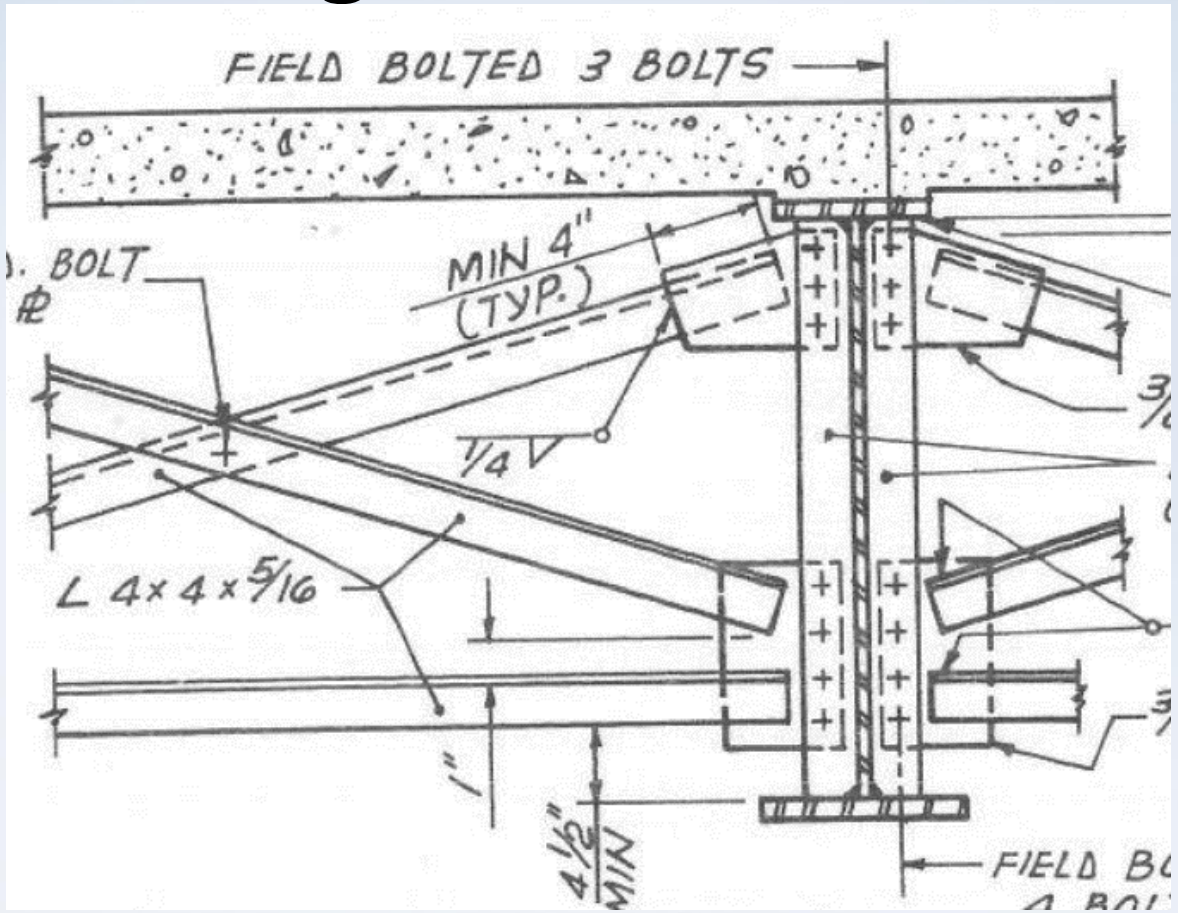
- Deck NBI 4
- Super NBI 4
- Sub NBI 5
- Routine inspection revealed cracking in web of girders
- UDOT inspectors perform mag-particle and dye-penetrant testing
  - 12/2022
  - 8/2023



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- About 40% of cross frame top connections

Evaluation and Retrofit

Analysis of the Causes of Cracking

Field observation and instrumentation

- This section focuses on capturing both the overall and local behavior of the bridge that contributes to fatigue cracking.

Finite element modeling

- Once calibrated, this tool can be utilized to visualize the observed behavior, provide a clearer explanation for the cause of cracking, and illustrate the details related to fatigue.

Retrofit Technique

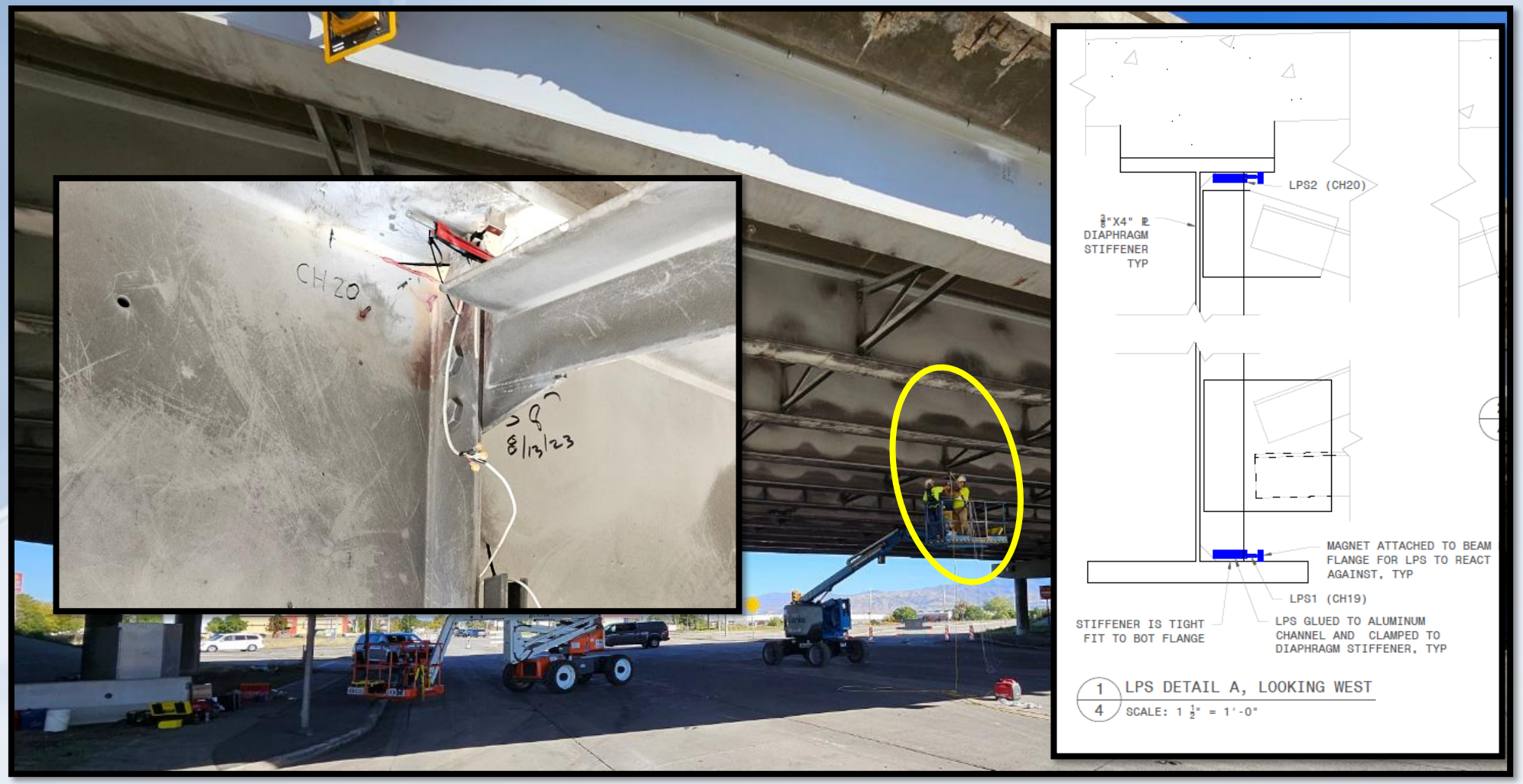
Selecting Retrofit Technique

- Refer to the document "*Maintenance Actions to Address Fatigue Cracking in Steel Bridge Structures (2021)*" to determine the effective retrofit technique.
- *Softening* or *Stiffening* the connection.

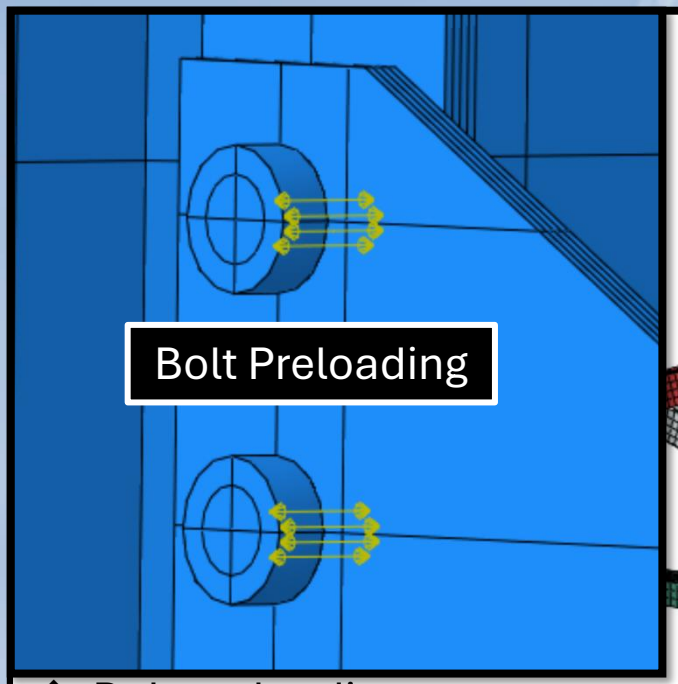
Finite element modeling

- Evaluate the effectiveness of the retrofit technique.
- Check the fatigue life of the retrofit to ensure no further cracking occurs.
- Evaluate how the retrofit affects the performance of other components within the bridge.

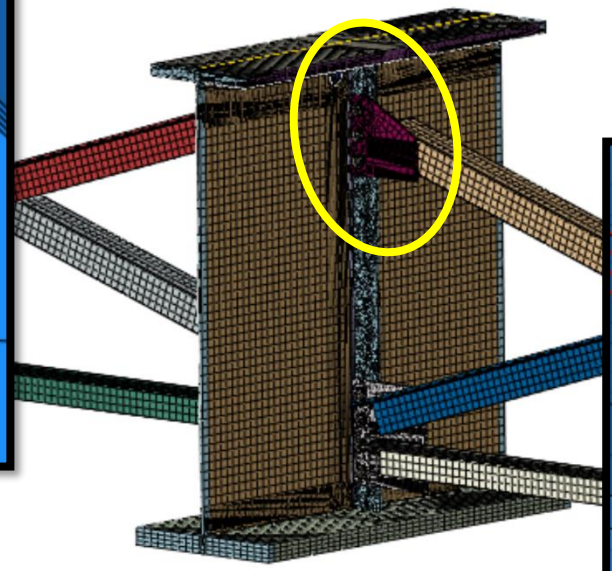
Field Observation and Instrumentation



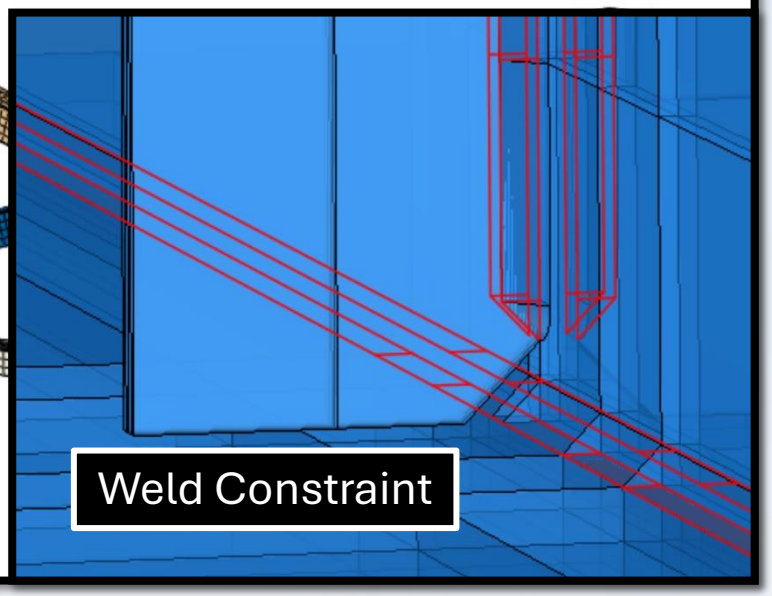
Finite Element Model (As-built w/ SF cracks)



- Bolt preloading
- Contact modelling between bolt, gusset plate and stiffener with friction



- Fillet welds modeled with no penetration
- Girder continuity was approximated by the symmetry boundaries



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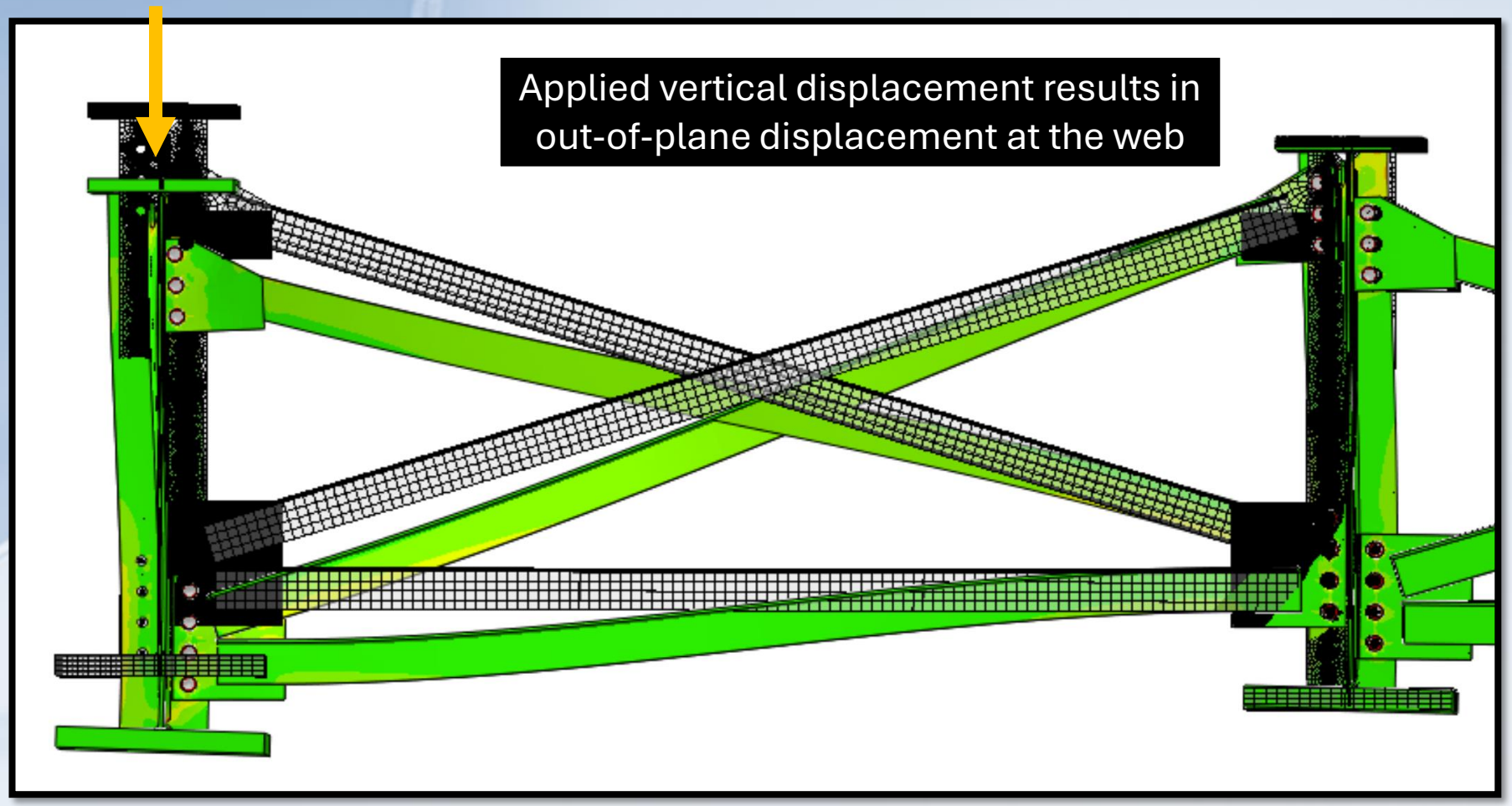
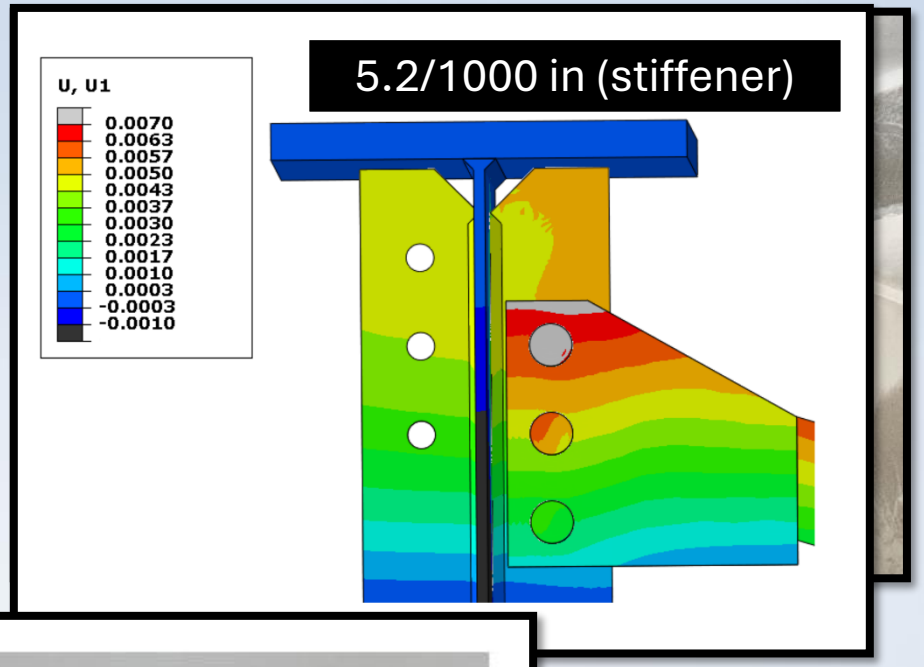
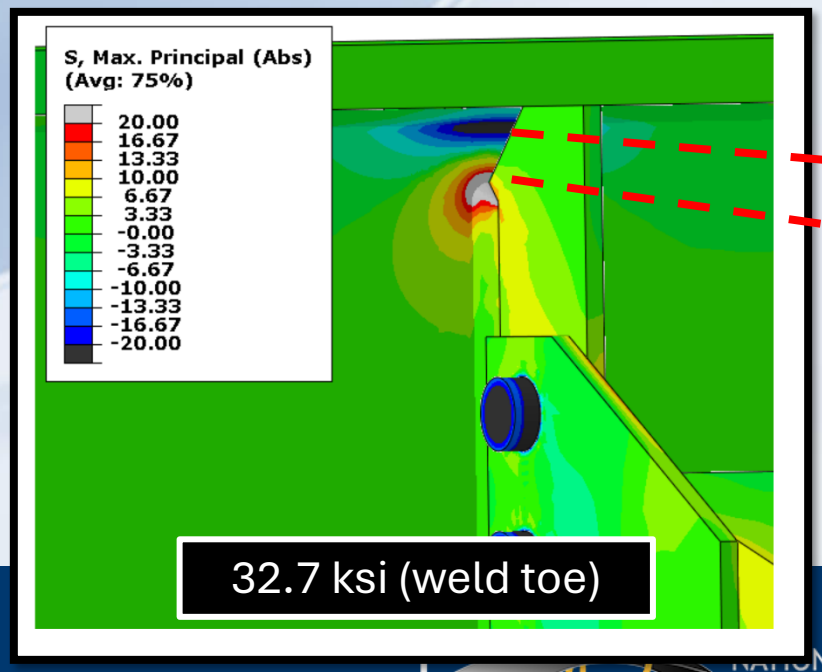
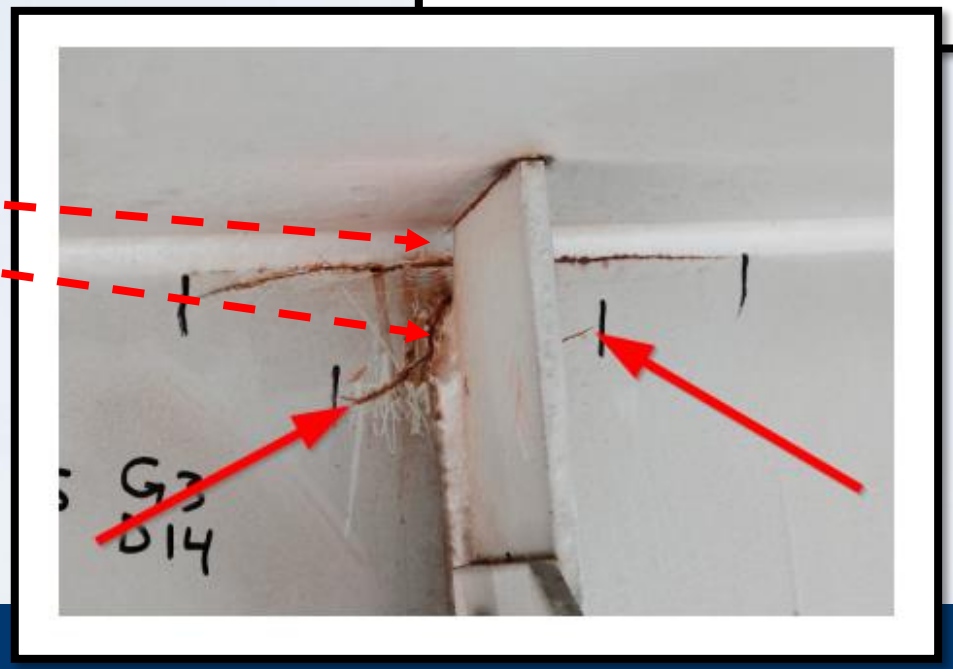


As-built w/ SF cracks

- Displacement
  - Field Measurement Max: 5/1000 in
  - FEA: 5.2/1000 in
- Hot Spot Stress (no holes)
  - 32.7 ksi
  - Locations consistent with observed cracking

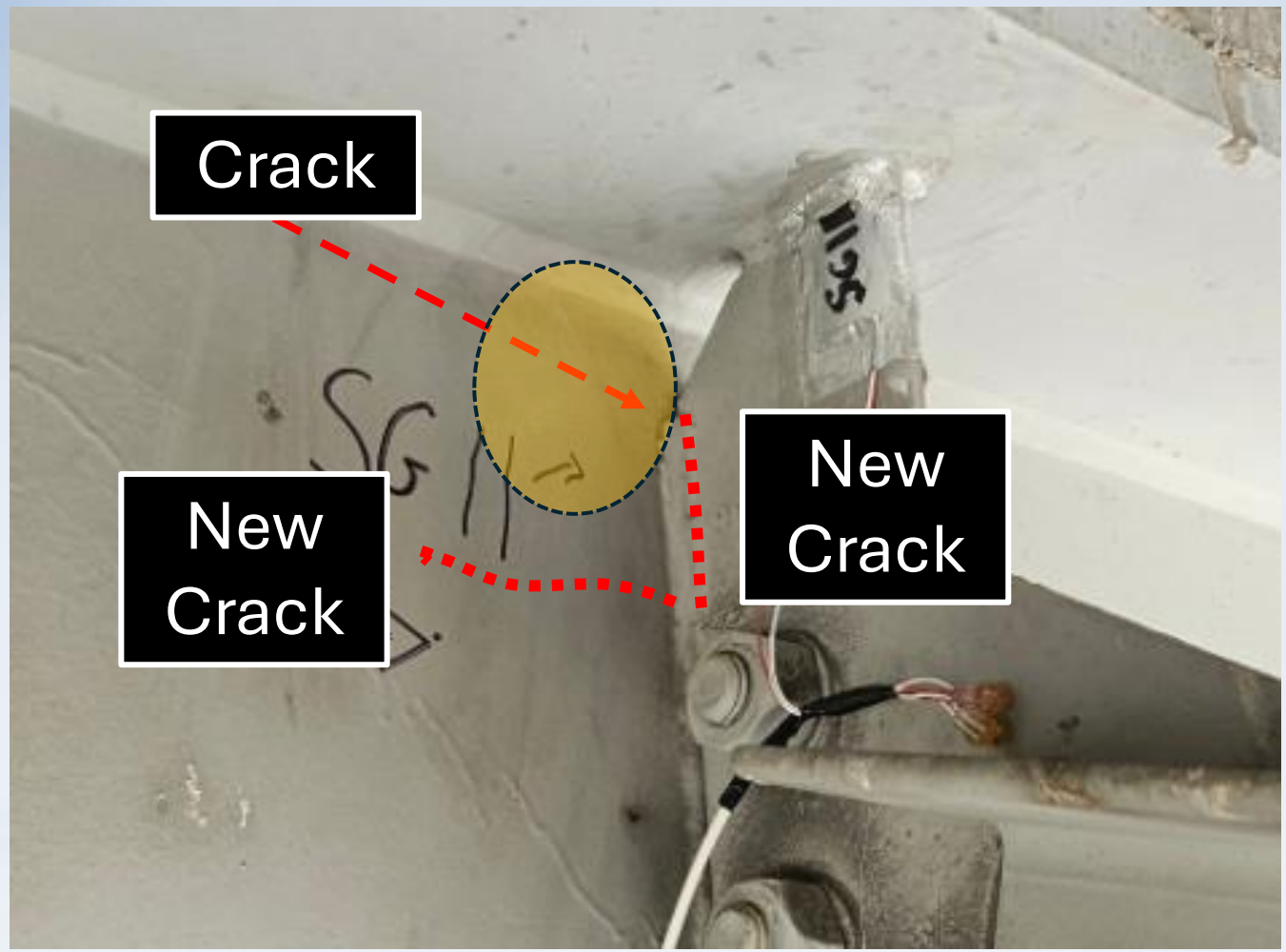






Drilling Holes – Crack Mitigation & Softening

Photograph courtesy of Iowa DOT



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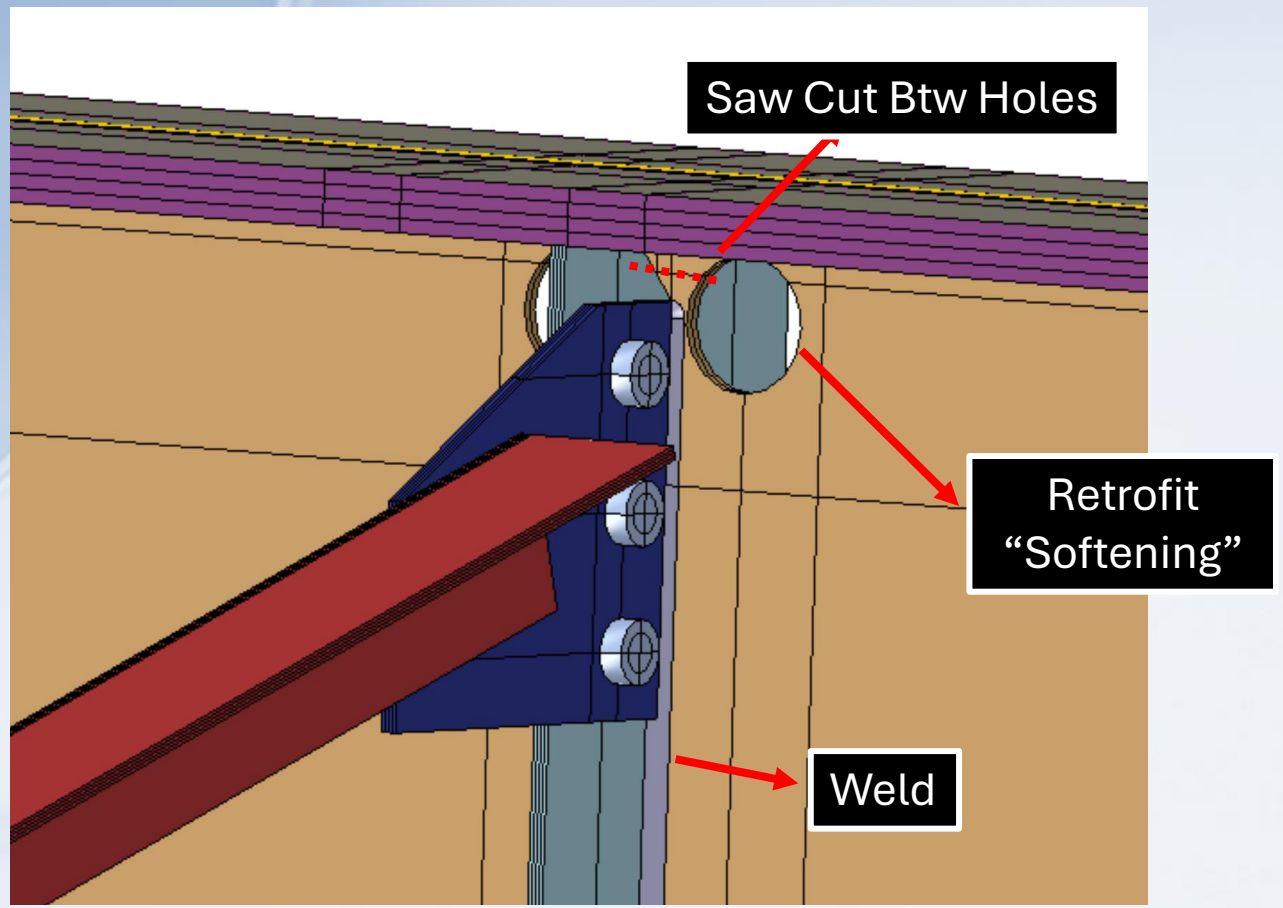
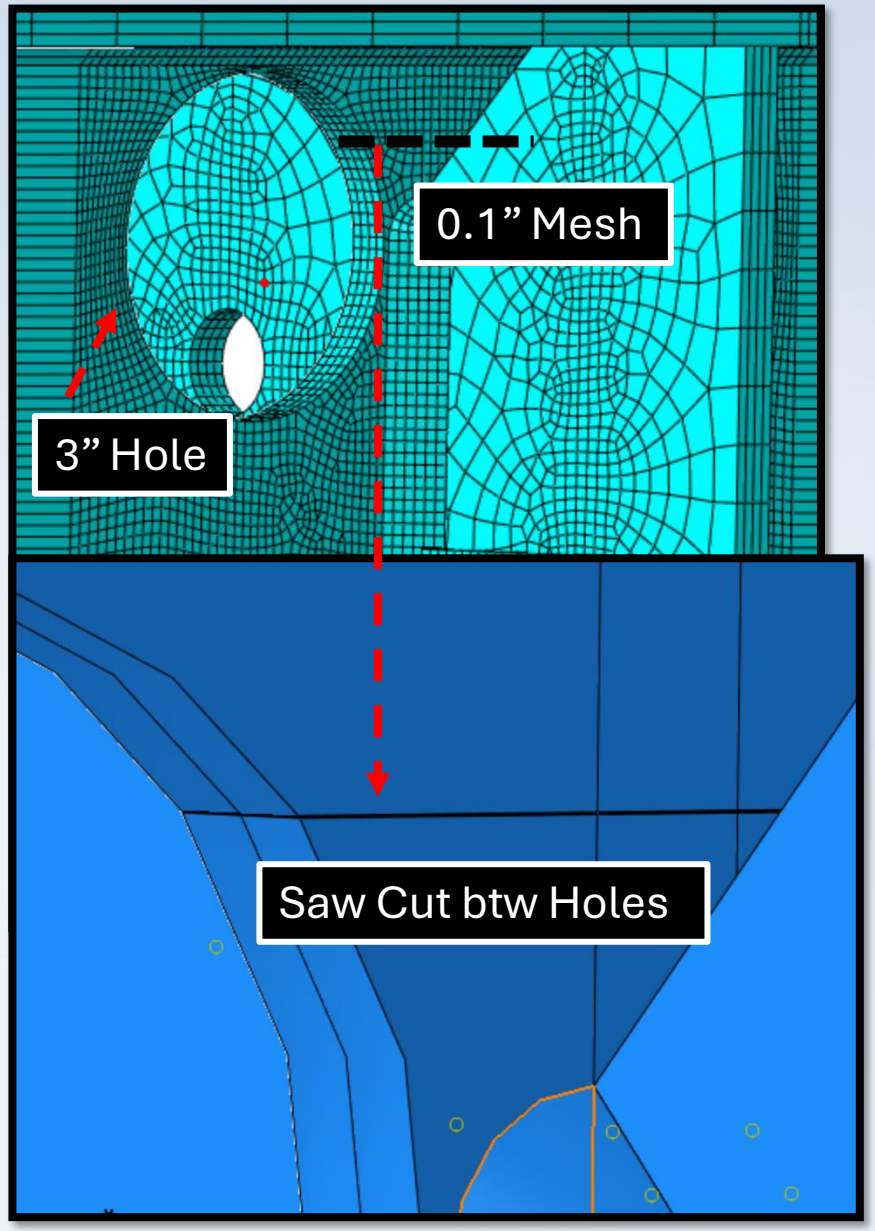


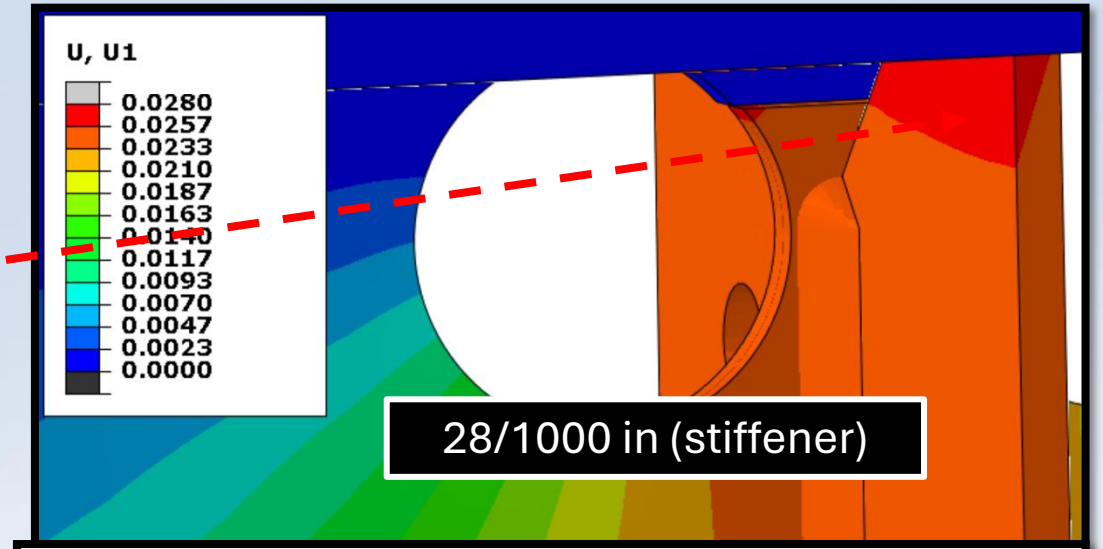
Retrofit Model with Holes

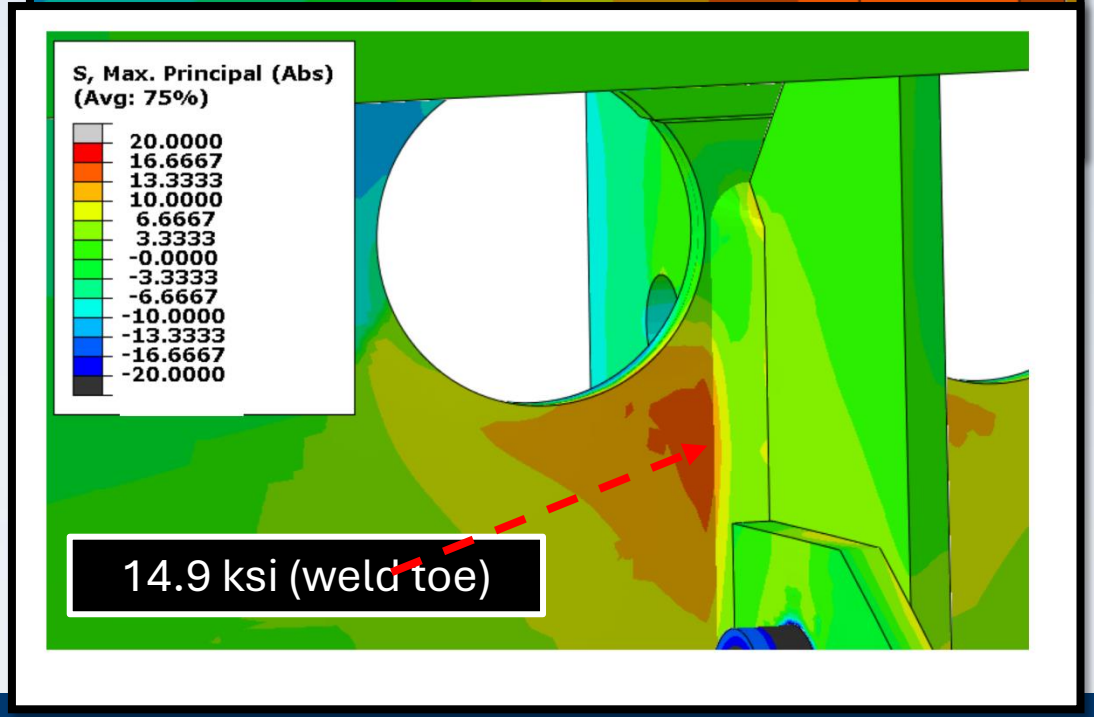
- Mesh density: 0.1 in for detail locations (holes, welds, etc)
- Coarse mesh density: 1.0 in for areas outside of stress concentrations
- C3D8R: An 8-node linear bricks w/ reduced integration & hourglass control
- Sawcut simulation - Between the holes, the nodes were duplicated and separated in the element
  - This simulates the effects of cutting (or cracking) between holes



Retrofit Model

- Displacement
  - FEA Retrofit: 28/1000 in
- Hot Spot Stress
  - 14.9 ksi
- Cross Frame Force
  - Before: 7.9 kips
  - After: 5.4 kips (70%)





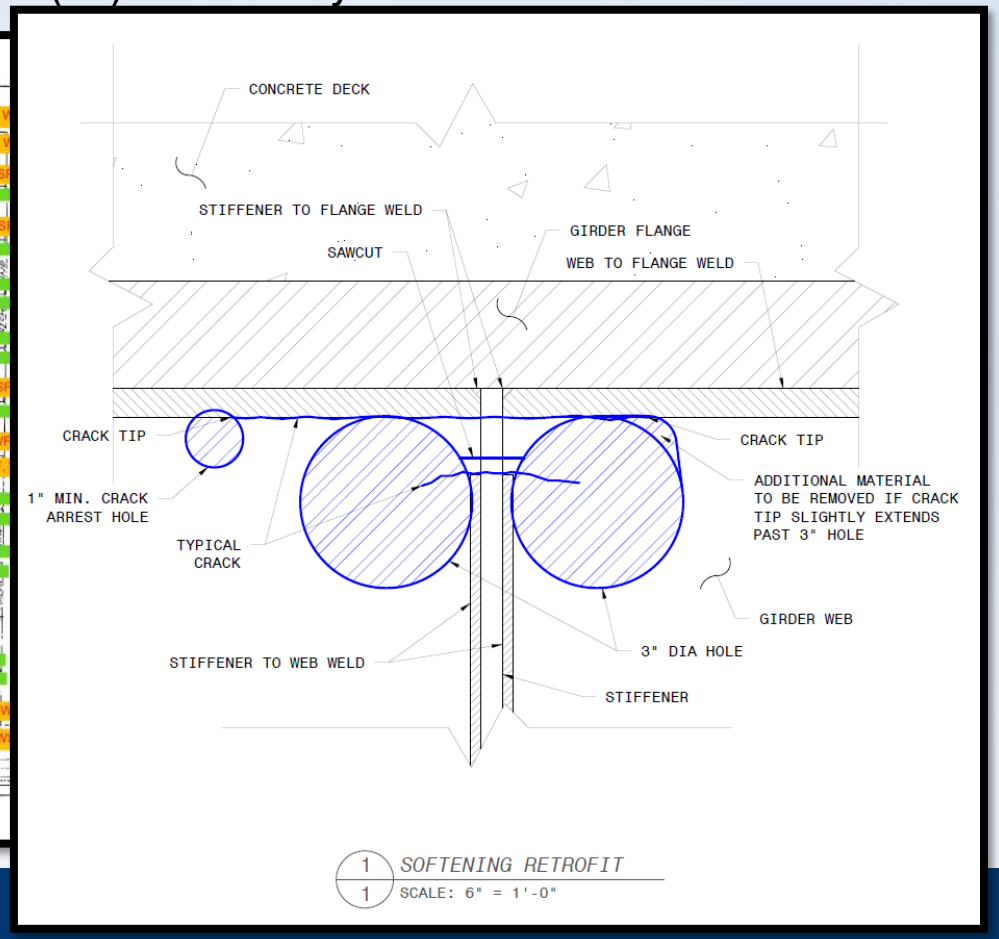
Estimated Life Comparison

At Weld Toe				
Type	**Mesh Size (in)**	**Stress Concentration Hot-spot (ksi)**	**Ratio (/BF)**	**Life Ratio**
Before Retrofit	0.1	32.7	**1.0**	**1.0**
After Retrofit	0.1	14.9	**2.2**	**10.57**

- Life Ratio = SC^3 (Before Retrofit) / SC^3 (After Retrofit)
- $N = A / S^3$ (SN curve)
- Approximately 10 times more life

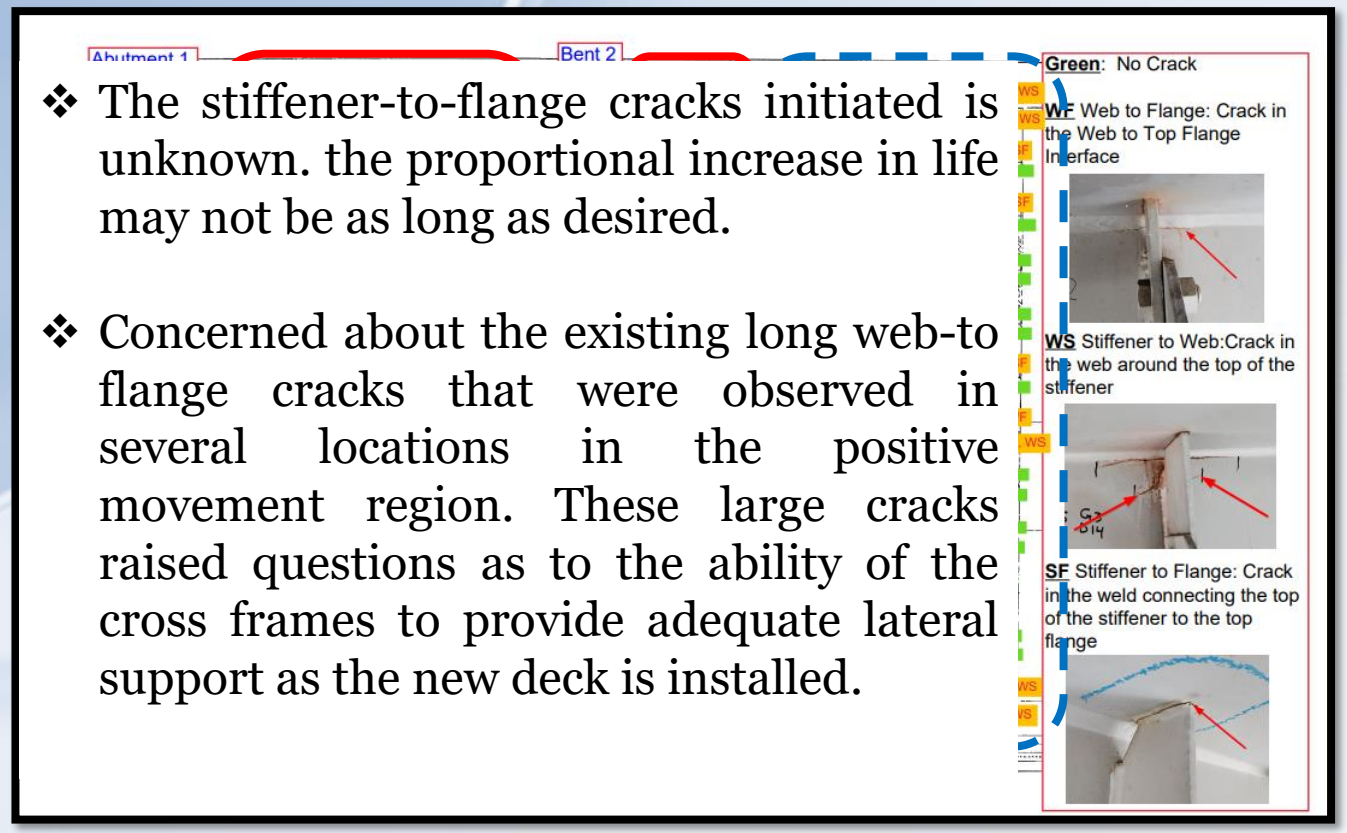
Web Plate Isolation Holes Drilling Locations

- Locations where there was no stiffener to flange weld in original design
  - First and third spans, as well as the second span's first cross frame location after the piers (8/13 locations)
  - Existing crack tips must be located inside the hole. Else smaller (1”) secondary hole must be drilled

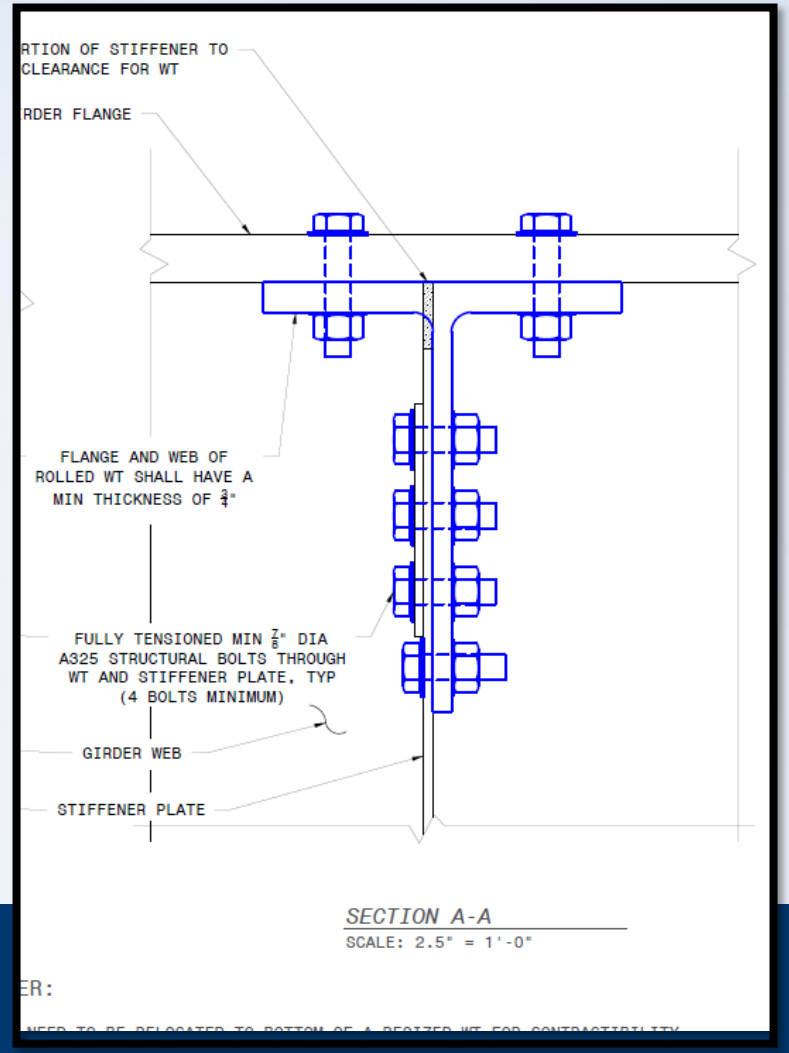


Stiffening Locations

- Locations where there was stiffener to flange weld in original design
- In the positive moment regions, while "Web Plate Isolation Holes" effectively mitigate fatigue cracking from out-of-plane displacements, their use is not recommended.

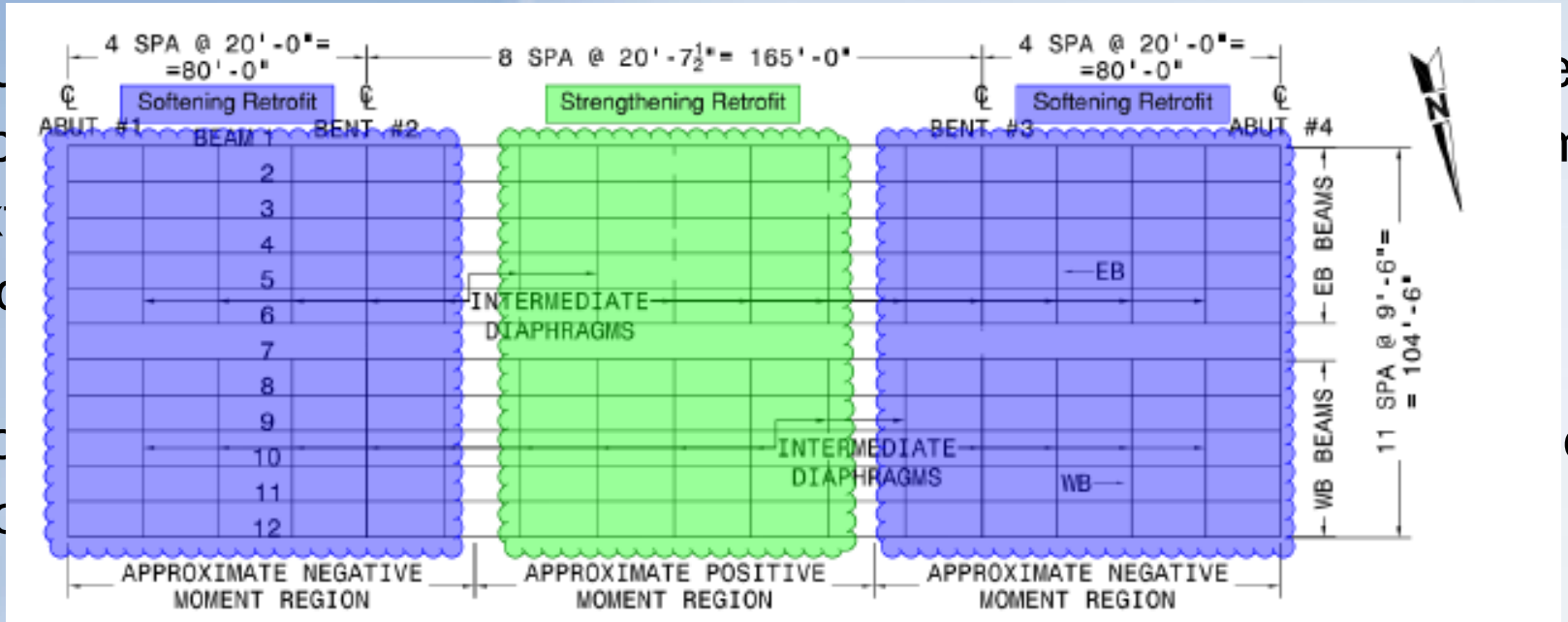


- The stiffener-to-flange cracks initiated is unknown. the proportional increase in life may not be as long as desired.
- Concerned about the existing long web-to flange cracks that were observed in several locations in the positive movement region. These large cracks raised questions as to the ability of the cross frames to provide adequate lateral support as the new deck is installed.



Conclusion

- The stu… …egorized as web… …mentation and ex… displac…
- Additio… …olation holes …



- Softening Technique: Implement "Web Plate Isolation Holes" specifically for negative moment regions to enhance fatigue life.

- Strengthening Technique: Use bolted WT sections to reinforce positive moment regions, ensuring structural integrity.

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Thank You!