



U.S. Department of Transportation
Federal Highway Administration
Office of Infrastructure

Non-Destructive Evaluation of Fracture Critical Members Fabricated from AASHTO M244 Grade 100 (ASTM A514/A517) Steel

FHWA Office of Bridges and Structures

January 2022



Disclaimer

- Except for any statutes or regulations cited, the contents of this presentation do not have the force and effect of law and are not meant to bind the public in any way. This presentation is intended only to provide information to the public regarding existing requirements under the law or agency policies.



Agenda

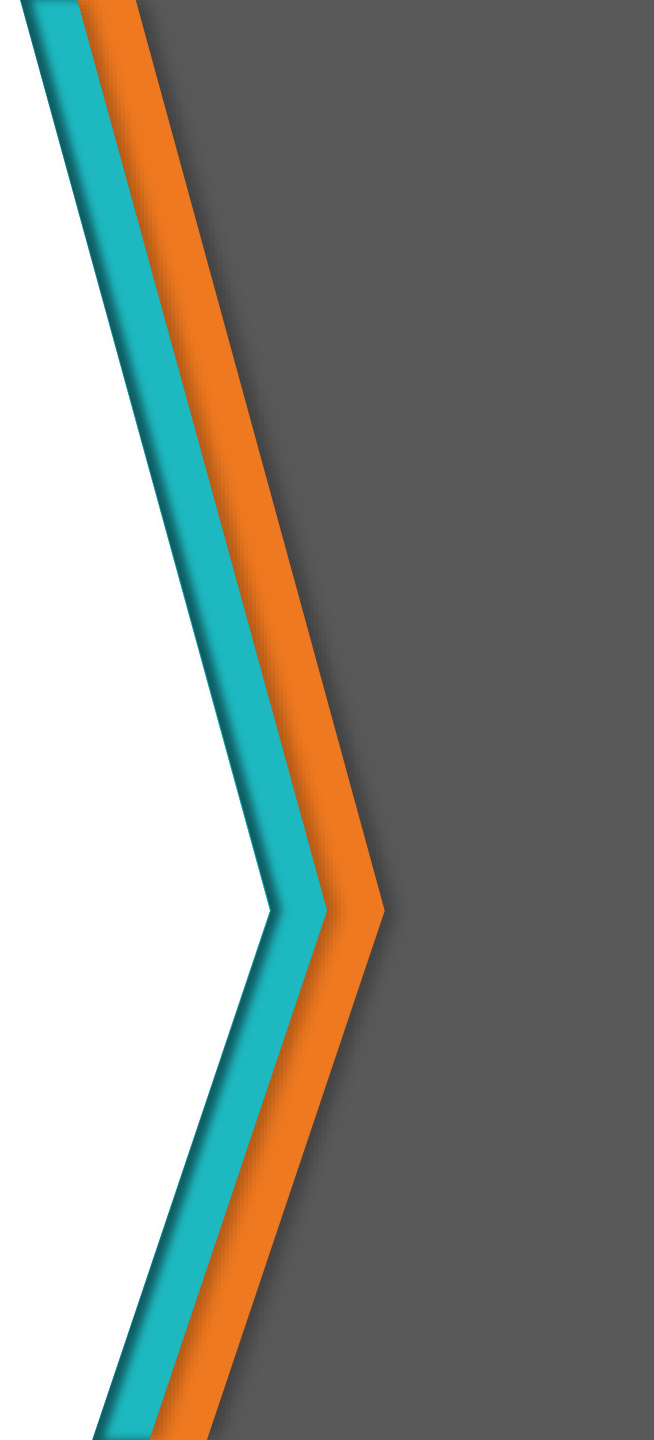
- Background
 - Sherman-Minton Bridge
 - Technical Advisory 5140.32
 - Hernando de Soto Bridge
 - December 13, 2021 Memo “Non-Destructive Testing of Fracture Critical Members Fabricated from AASHTO M244 Grade 100 (ASTM A514/A517) Steel”
- Technical Discussion
- Memo Implementation Discussion
- Open Discussion





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Background

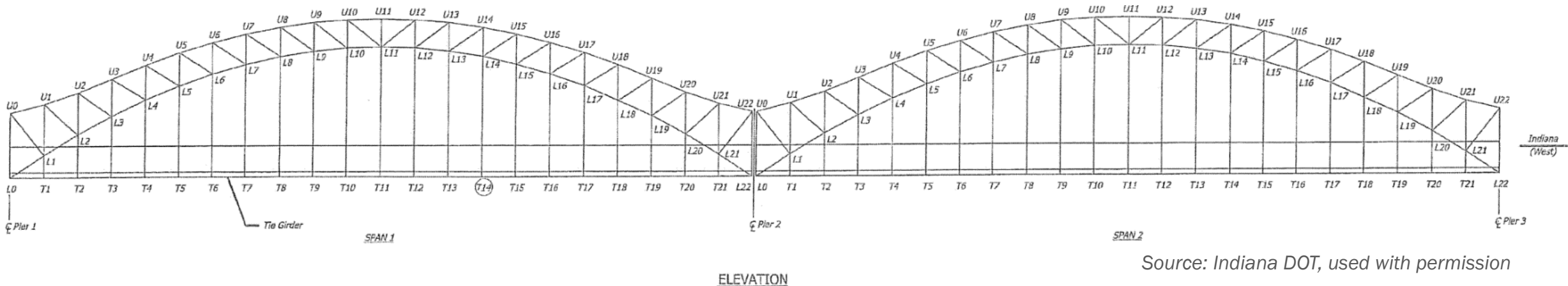


Background: Sherman-Minton Bridge

- Double-decked steel tied arch built in 1961.
- Carries Interstate 64 over the Ohio River
- Dual 800 ft. spans.
- Tie fabricated from “T-1” steel.



Source: Indiana DOT, used with permission



Source: Indiana DOT, used with permission



Sherman-Minton Bridge – Welding Investigations

- Cracking first documented in 1981
- Focused investigations performed in 1992, 1993, 1994, 1995, 1999, 2004, 2006, 2007
- Comprehensive investigation began in summer 2011
 - Documenting cracks
 - Conducting material testing
 - Installing bolted retrofits

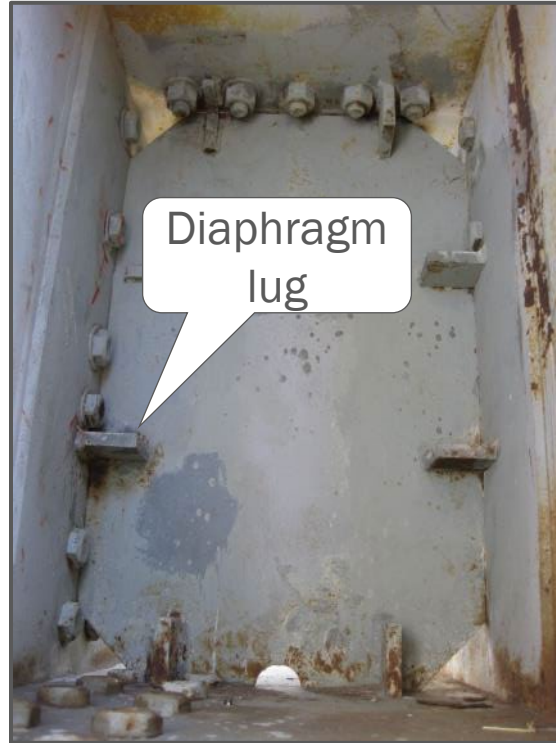


Sherman-Minton Bridge – Welding Investigations



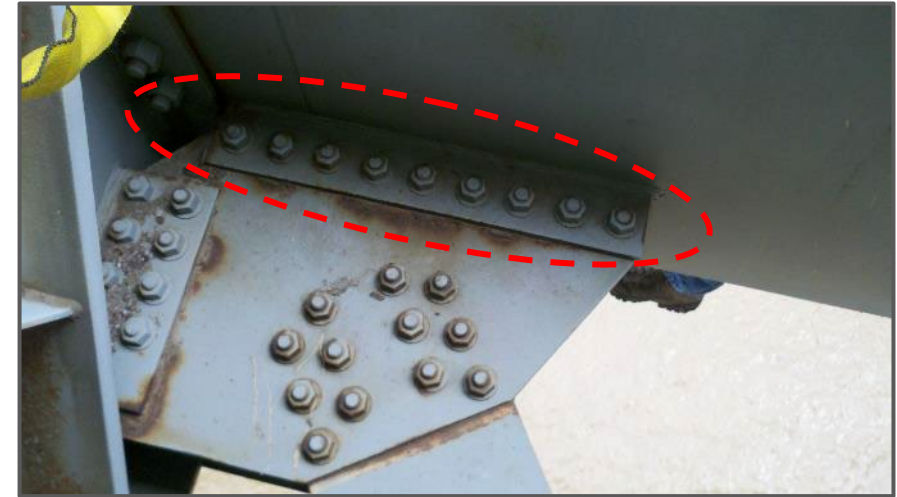
Source: Indiana DOT, used with permission

- 704 tie girder CJP butt welds.
- NDT identified discontinuities in over 80% of the web plate butt welds



Source: Indiana DOT, used with permission

- Diaphragm lugs fillet welded to tie girder.
- 2,112 weld legs.



Source: Indiana DOT, used with permission

- Lateral bracing gussets CJP tee welds to tie girder.
- 88 welds.



Sherman-Minton Bridge - Closure

- Removal of 3rd lateral gusset plate found a discontinuity of concern. Bridge closed Friday, Sept. 9, 2011.
- Bridge remained closed for 5 months to complete repairs



Fracture mechanics predicted crack was a critical size for brittle fracture if ambient temperature dipped below 30 °F.




Source: Indiana DOT, used with permission



Technical Advisory 5140.32

- Released September 12, 2011, shortly after Sherman-Minton closure
- *Recommends* that bridge owners:
 - Review inspection records to ensure components fabricated from T-1 steel have been regularly and appropriately inspected,
 - Follow up on deficiencies, prioritizing components primarily in tension (arch ties, hangers, truss members), and
 - Verify the soundness of all butt welds in tension in members fabricated prior to FCP adoption



Technical Advisory

Inspection of Fracture Critical Bridges Fabricated from AASHTO M270 Grade 100 (ASTM A514/A517) Steel
[Questions and Answers](#)
September 12, 2011
Technical Advisory 5140.32

PURPOSE

The purpose of this Technical Advisory is to provide recommendations regarding the in-service inspection of, and the treatment of critical findings identified on, fracture critical bridges fabricated from AASHTO M270 Grade 100 (ASTM A514/A517) steel, more commonly known as "T-1" steel.

BACKGROUND

1. The I-64 Sherman Minton Bridge is a fracture critical bridge which consists of two 800-foot tied arch truss main spans that carry six lanes across the Ohio River between Louisville, Kentucky and New Albany, Indiana that was constructed between 1960-1961, before the material and fabrication requirements of the AASHTO/AWS Fracture Control Plan for this type of bridge were adopted.
2. As the result of in-service inspection, several cracks were found in the butt welds or their associated heat-affected zones of the tension ties of both spans. It was subsequently determined that the cracking was very likely caused by hydrogen that was introduced into the weld as the result of improper fabrication procedures. T-1 steel is known to be very susceptible to this type of cracking.
3. Earlier this year, retrofit and repair work to address those cracks and additional inspection work to verify the soundness of the remaining butt welds in the tie began.
4. On September 8, 2011, inspectors discovered an additional critical crack in the tension tie that previously could not be seen through visual inspection because of the removal of a connection plate detail as part of the ongoing retrofit process.
5. After study and analysis of this newly found crack, it was determined that an unacceptable level of risk to the traveling public was associated with the continued operation of the bridge. As a result, on September 9, 2011 the bridge was closed.

RECOMMENDATIONS

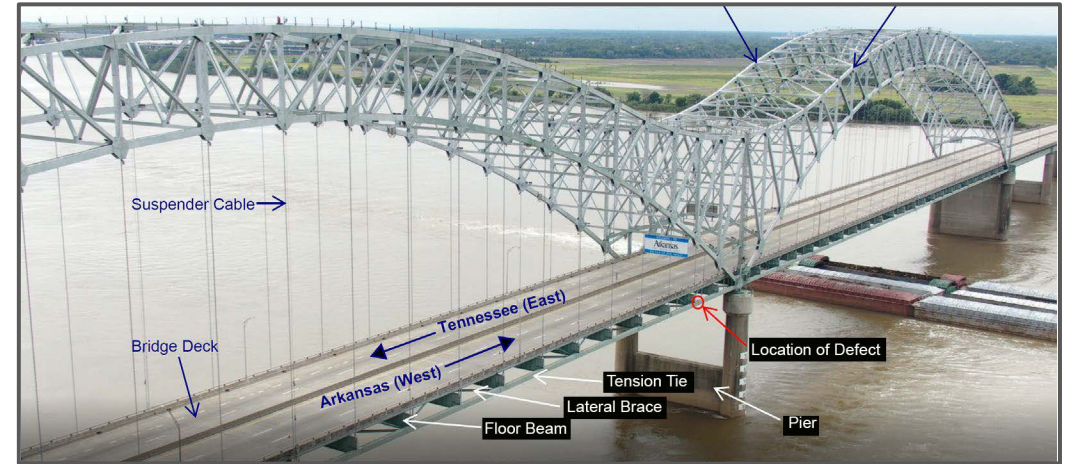
1. This Technical Advisory strongly recommends that State Departments of Transportation and other bridge owners review the inspection records of their inventory of fracture critical bridges to ensure any components fabricated with T-1 steel have been regularly and appropriately inspected and that any critical

Source: FHWA

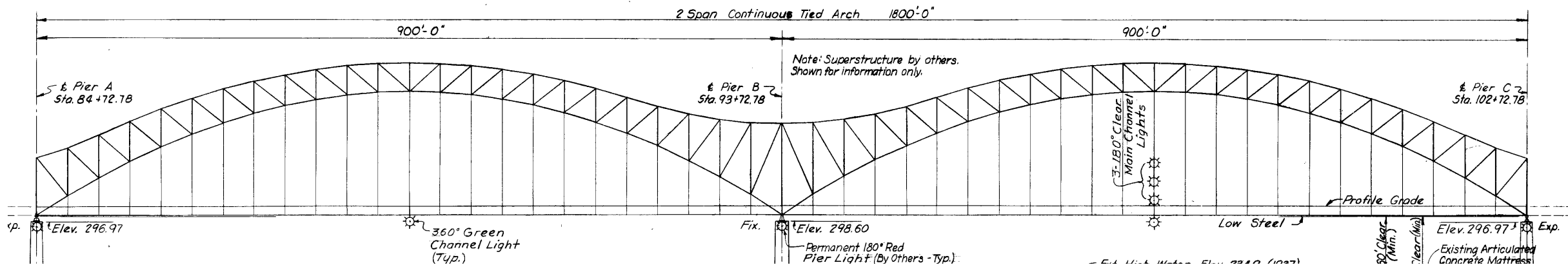


Background: Hernando de Soto Bridge

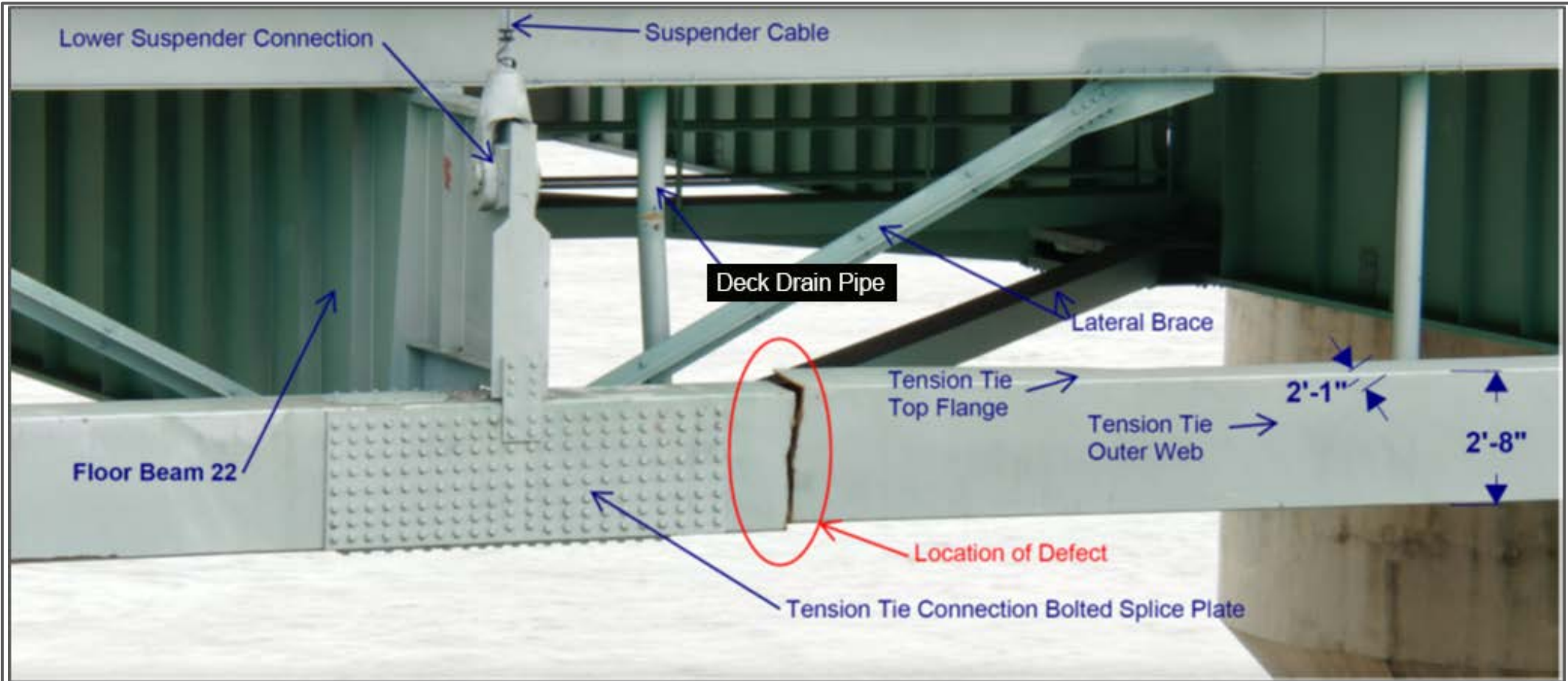
- Steel tied arch built in 1973.
- Carries Interstate 40 over the Mississippi River
- Dual 900 ft. spans.
- Tie fabricated from ASTM A514.



Source: Michael Baker International



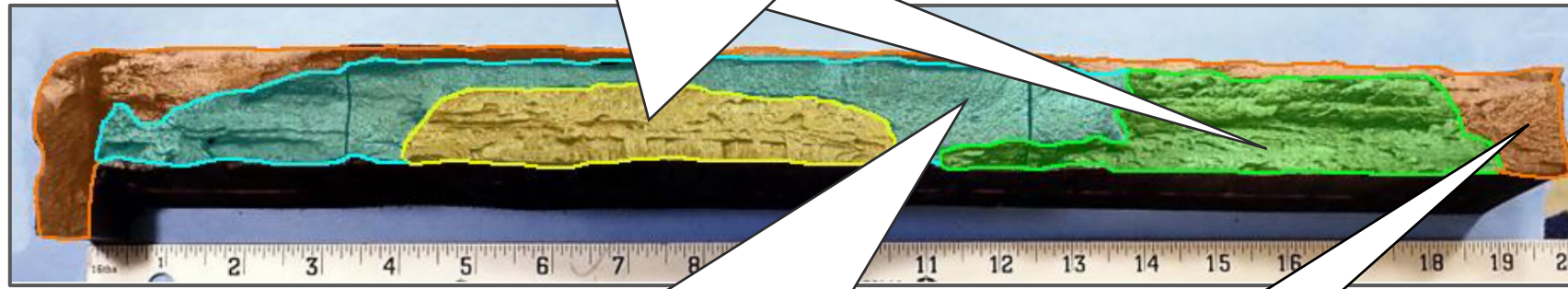
Hernando de Soto Bridge – Tie Girder Fracture



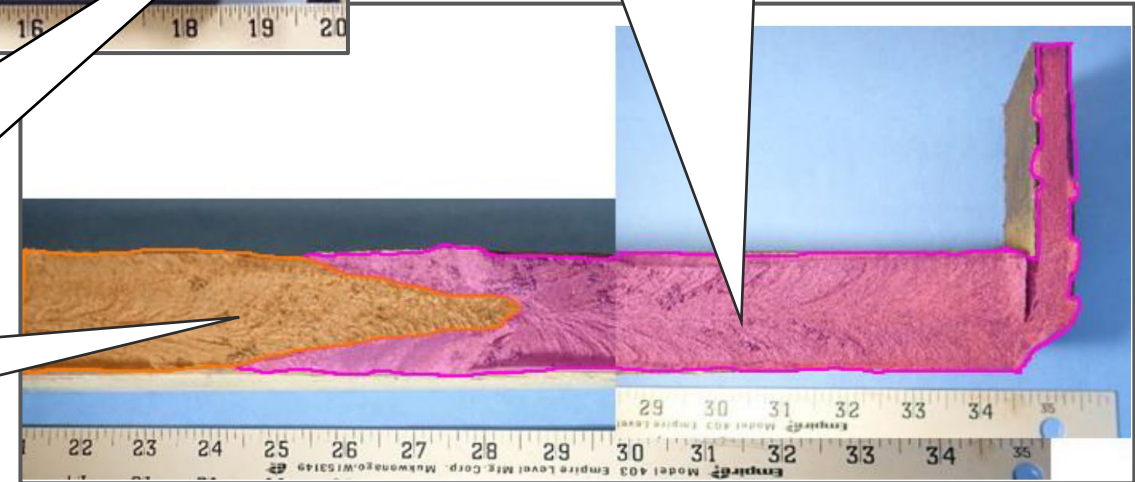
Source: Michael Baker International

Hernando de Soto Bridge – Fracture Surface

Yellow and green regions were surface breaking hydrogen cracks from fabrication. About 6.5" x 1" and 5" x 1.2".



Pink region was 3rd brittle extension. Happened after 2019.



Blue region was 1st brittle extension sometime after fabrication. Broke surface on inside of box, not outside.

Orange region (both images) was 2nd brittle extension. Broke through outer box surface sometime before 2016.

Source: Arkansas DOT



December 13, 2021 Memo

- *Requires* that State DOTs:
 - Identify bridges with fracture critical members fabricated from T-1 steel without requirements to meet the provisions of the AASHTO/AWS FCP and document them in the FCM inspection procedures¹
 - Supplement hands-on inspection of T-1 FCMs with Non-Destructive Evaluation verifying the soundness of butt welds in tension²
 - Unless previous verification has been documented
 - Previous verification needs have been performed a minimum of 48 hours after original welding (≤ 2 " thick, 72 hours for > 2 " thick)
 - Classify rejectable indications (using AASHTO/AWS criteria) as critical findings³
 - Report an inventory of bridges with T-1 FCMs and actions taken to perform verification and follow up on findings⁴

¹ 23 CFR 1.36, 23 CFR 650.313

² 23 CFR 1.36, 23 CFR 650.313

³ 23 CFR 1.36, 23 CFR 650.313

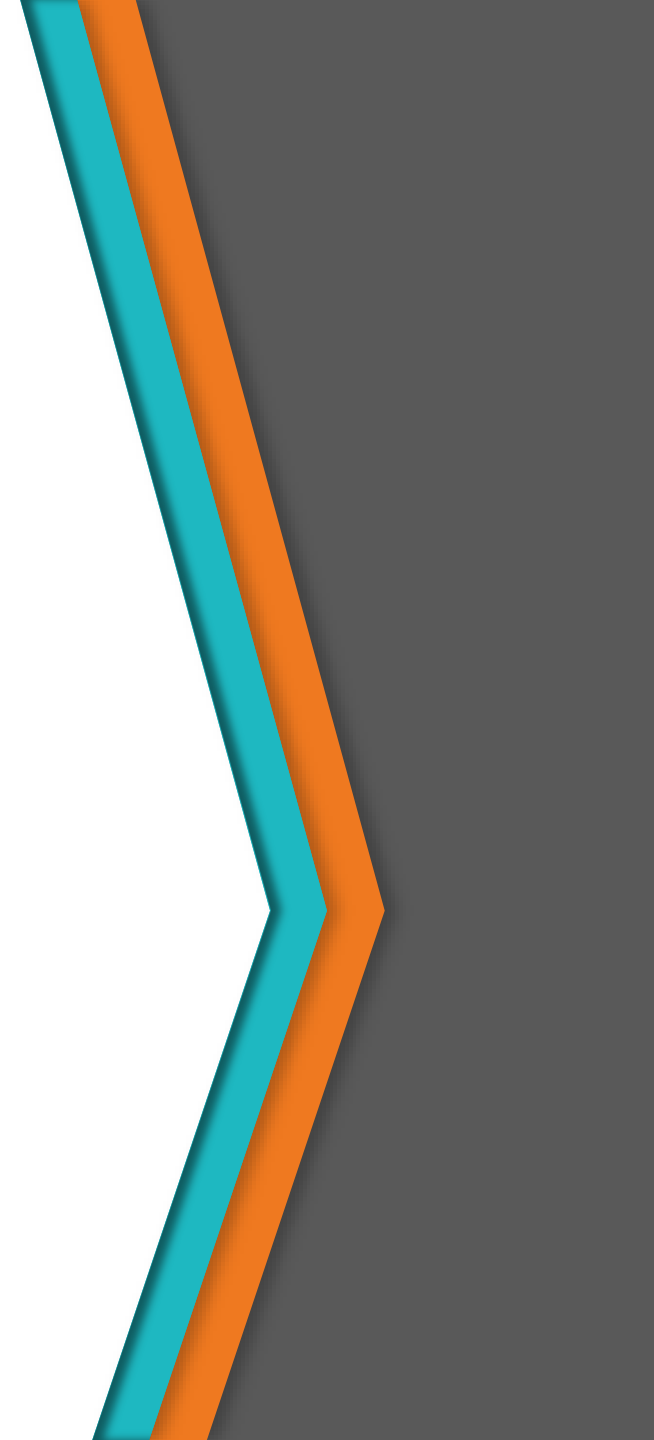
⁴ 23 CFR 1.36, 23 CFR 650.315



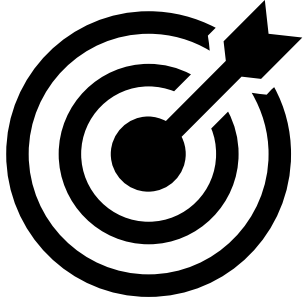


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Technical Discussion



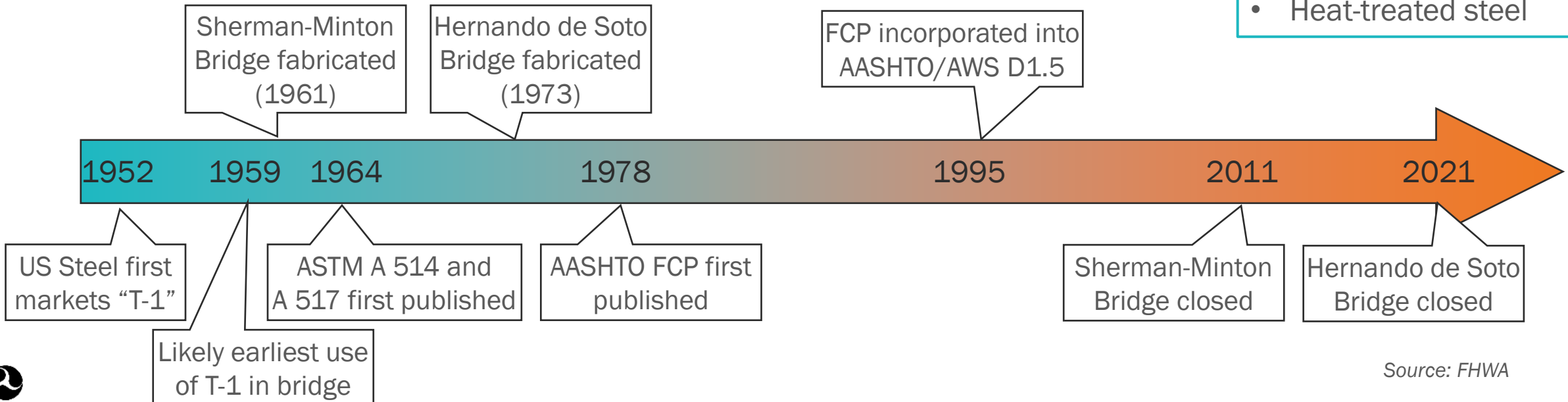
What is “T-1” Steel?



Steel with a yield strength greater than 100 ksi ($F_y \geq 100$ ksi)

Aliases:

- ASTM A514
- ASTM A517
- Grade 100
- Quench and Tempered (Q&T)
- Heat-treated steel



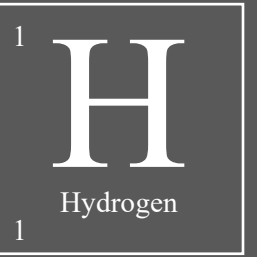
Source: FHWA



What is the AASHTO/AWS Fracture Control Plan?

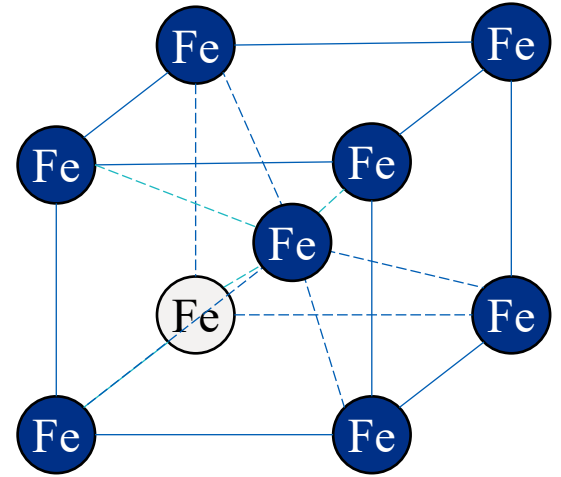
- Implemented first in 1978 as the AASHTO “*Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members*”
- Since 1995, included as Clause 12 of AASHTO/AWS D1.5 “*Bridge Welding Code*” as “AASHTO/AWS Fracture Control Plan (FCP) for Nonredundant Members”
- Provides supplemental requirements for materials, processes, procedures, inspection, and repair for welds in the fabrication of fracture critical members





What is Hydrogen Cracking?

- Hydrogen likes to be a molecule (H_2).
- Energy from welding dissociates H_2 into two atomic H's.
- Atom hydrogen (H) can easily move through a metallic crystal.
- Reconstituting H_2 in the crystal causes internal stress and cracking.



Source: FHWA

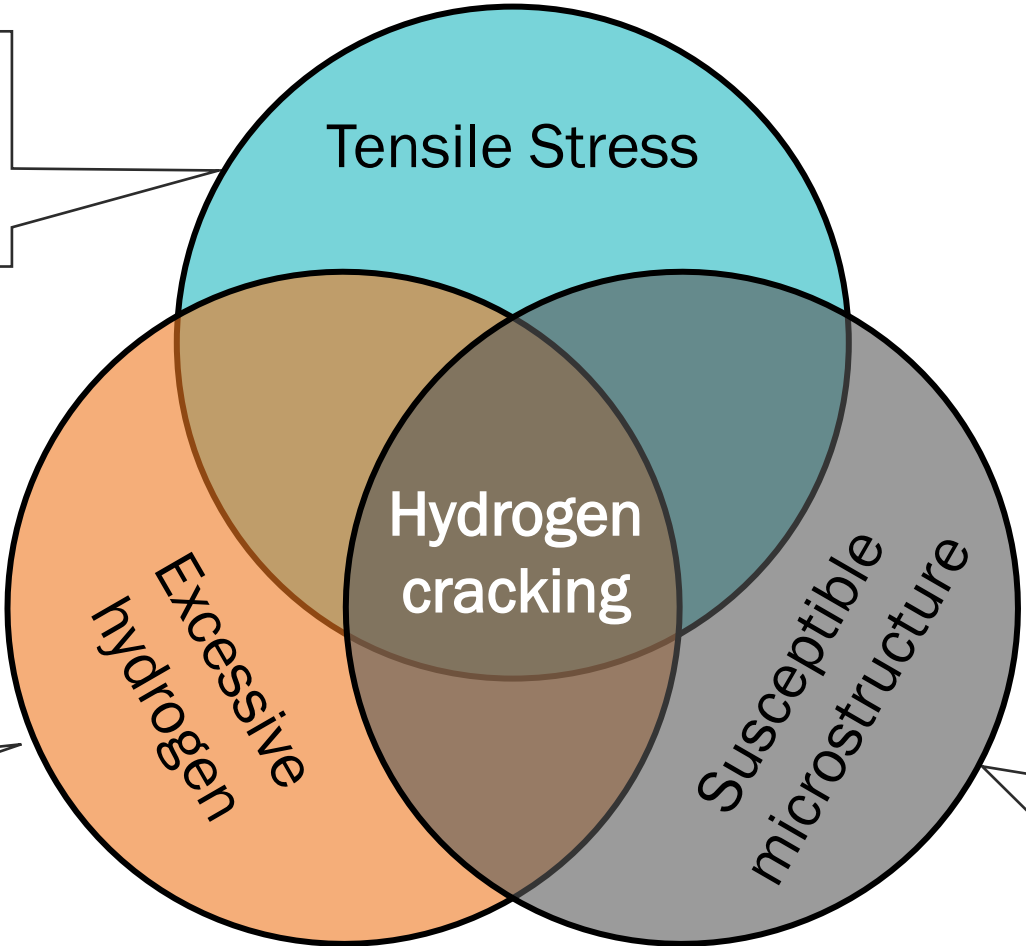


Migrates toward tensile stress....



What is Hydrogen Cracking?

It's a weld, there will always be tensile residual stress. Restraint also influential.



This can be controlled in fabrication.

Aliases:

- Delayed cracking.
- Cold cracking.
- Hydrogen assisted cracking.
- Hydrogen induced cracking.
- Hydrogen embrittlement

Q&T steels are tempered martensite, martensite is susceptible. Weld procedure also influential.

Source: FHWA



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Memo Implementation



How Can State DOTs Identify Bridges Subject to the Memo?

- Ultimately, will require review of bridge records
 - Materials used: contract plans, as-builts, shop drawings, mill certs
 - Location of butt welds: shop drawings
- File review can be narrowed by filtering NBI data:
 - Item 92A (Fracture Critical Details) = “Y”
 - Item 27 (Year Built): 1959 (likely earliest use) to 1995 (unless State adopted 1978 AASHTO guide specification)



How Should States Report the Inventory?

- Submit data to the Division Office
 - Method agreed to between State DOT and Division Office
 - Inventory to include *all* bridges with FCM fabricated from T-1
- Four data items:
 - a. Bridge Number → verification that T-1 FCM identified in procedures (Metric 16)
 - b. Month and year of soundness verification
 - c. Whether verification identified rejectable indications (Yes/No)
 - d. If (c.) is Yes, Month and year critical finding was resolved → (Metric 21)
- Items b, c, and d would be NA if bridge has T-1 FCMs, but no butt welds in tension



What Type and Coverage of NDE is Required?

- Refer to clause 6 of AASHTO/AWS D1.5:2015 (now Clause 8 in D1.5:2020), which covers welding inspection
 - Requires 100% RT and UT of butt welds in tension for fabrication
 - Radiographic testing will be physically difficult in-situ → UT will satisfy the requirements of the memo
- Part C of Clause 6/8 sets forth procedures and standards for ultrasonic testing of groove welds
 - Equipment qualification and calibration
 - Evaluation procedures
 - *Challenge – D1.5 does not provide minimum performance qualifications for NDE personnel*



What is a “Rejectable Indication”?

- Refer to Clause 6 of AASHTO/AWS D1.5:2015 (now Clause 8 in D1.5:2020)
 - Part D – Weld Acceptance Criteria
 - Table 6.3 (2015)/8.3 (2020) – “UT Acceptance-Rejection Criteria – Tensile Stress”





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Open Discussion

