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TRANSPORTATION RESEARCH BOARD

Casting Connections – Improving Performance and Durability of Steel Bridges

June 17, 2021

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 1.5 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact Reggie Gillum at RGillum@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

Learning Objective

Identify the benefits of castings in bridges structures

#TRBwebinar

Casting Connections – Improving Performance and Durability of Steel Bridges

Ronnie Medlock | High Steel Structures
Jennifer Anna Pazdon | CAST CONNEX
Matthew Conso | Massachusetts DOT

TRB Webinar
June 17, 2021

Jennifer Anna Pazdon, MSE, PE

Vice President

CAST CONNEX

Chair

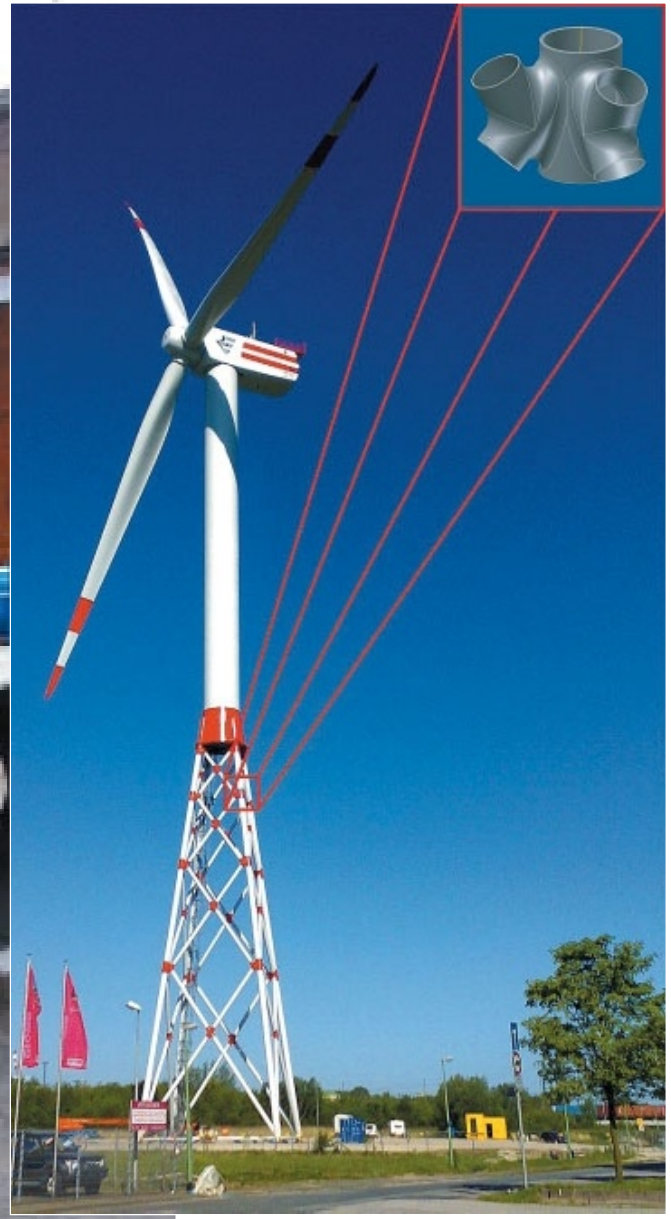
AASHTO/NSBA TG 17: Steel Castings

j.pazdon@castconnex.com

Leveraging Cast Steel Connections for Enhanced Performance, Economy and Aesthetics in Steel Bridge Structures

June 17, 2021 TRB Webinar

Jennifer Anna Pazdon, PE
Vice President, CAST CONNEX
Chair, AASHTO/NSBA TG 17: Steel Castings

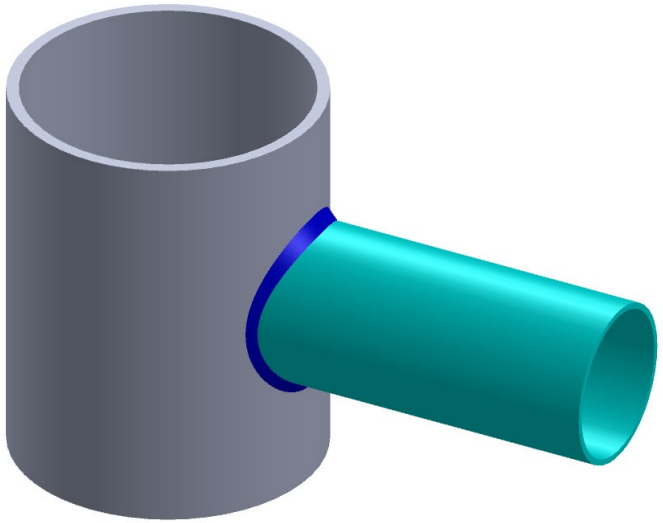


Performance Benefits of Castings

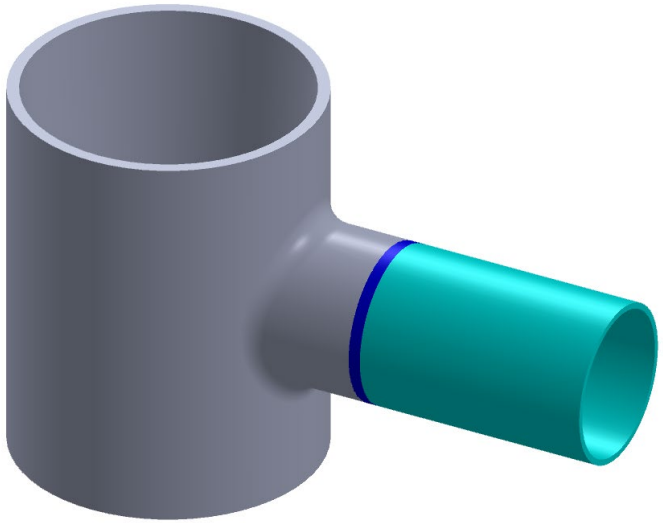
Performance Benefits of Steel Castings in Bridge Structures

- Improvement of fatigue life; extension of service life
- Tonnage savings in steel members framing into cast connections
- Reduced deflections and improved predictability of structural response
- Improved coating system performance/longevity
- Improved quality through simplification of fabrication
- Enhanced constructability, reduced risk

Fatigue Life Improvement Afforded By Cast Steel Nodes

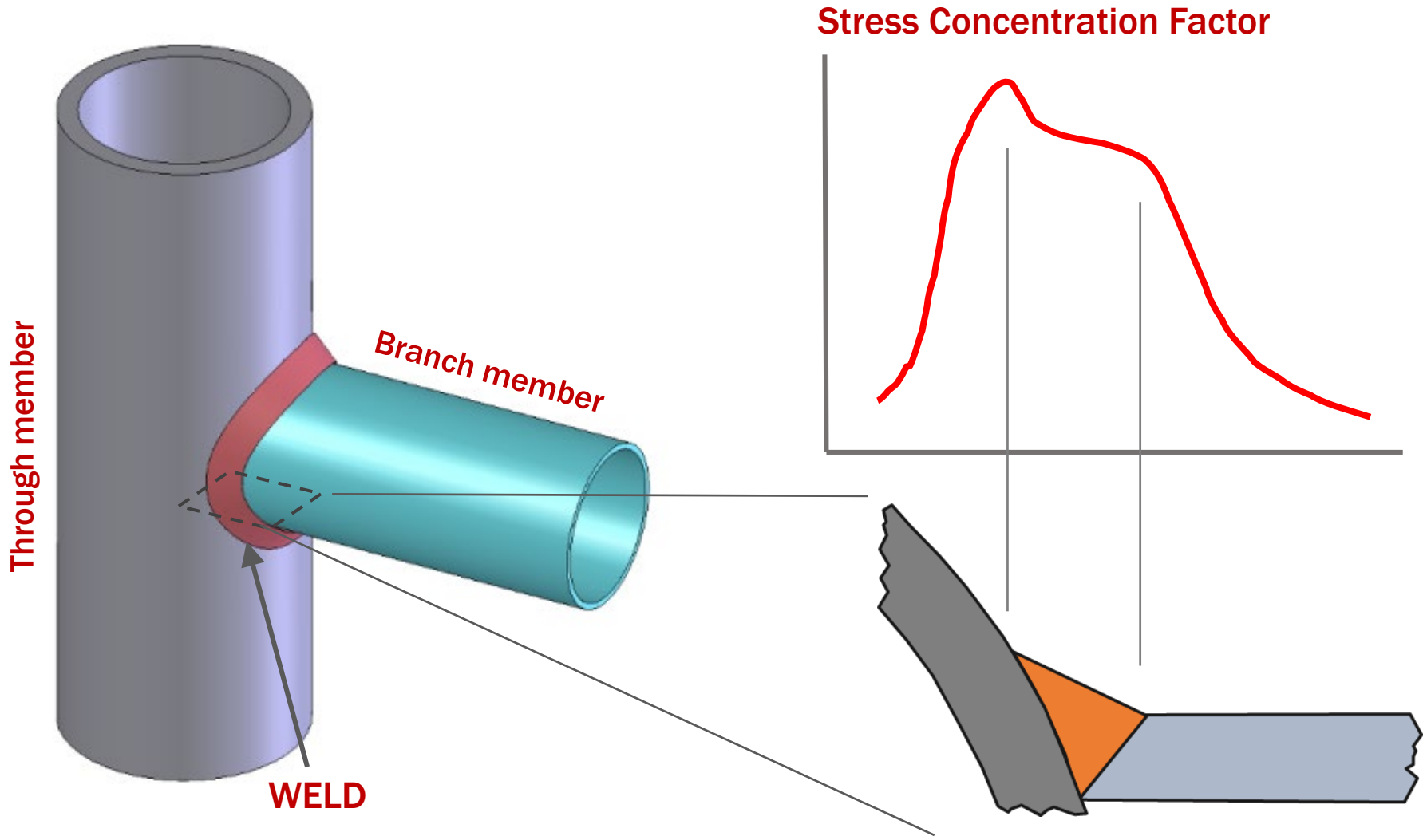


Conventionally Fabricated Junction
Welded HSS-to-HSS Joint (TYK)

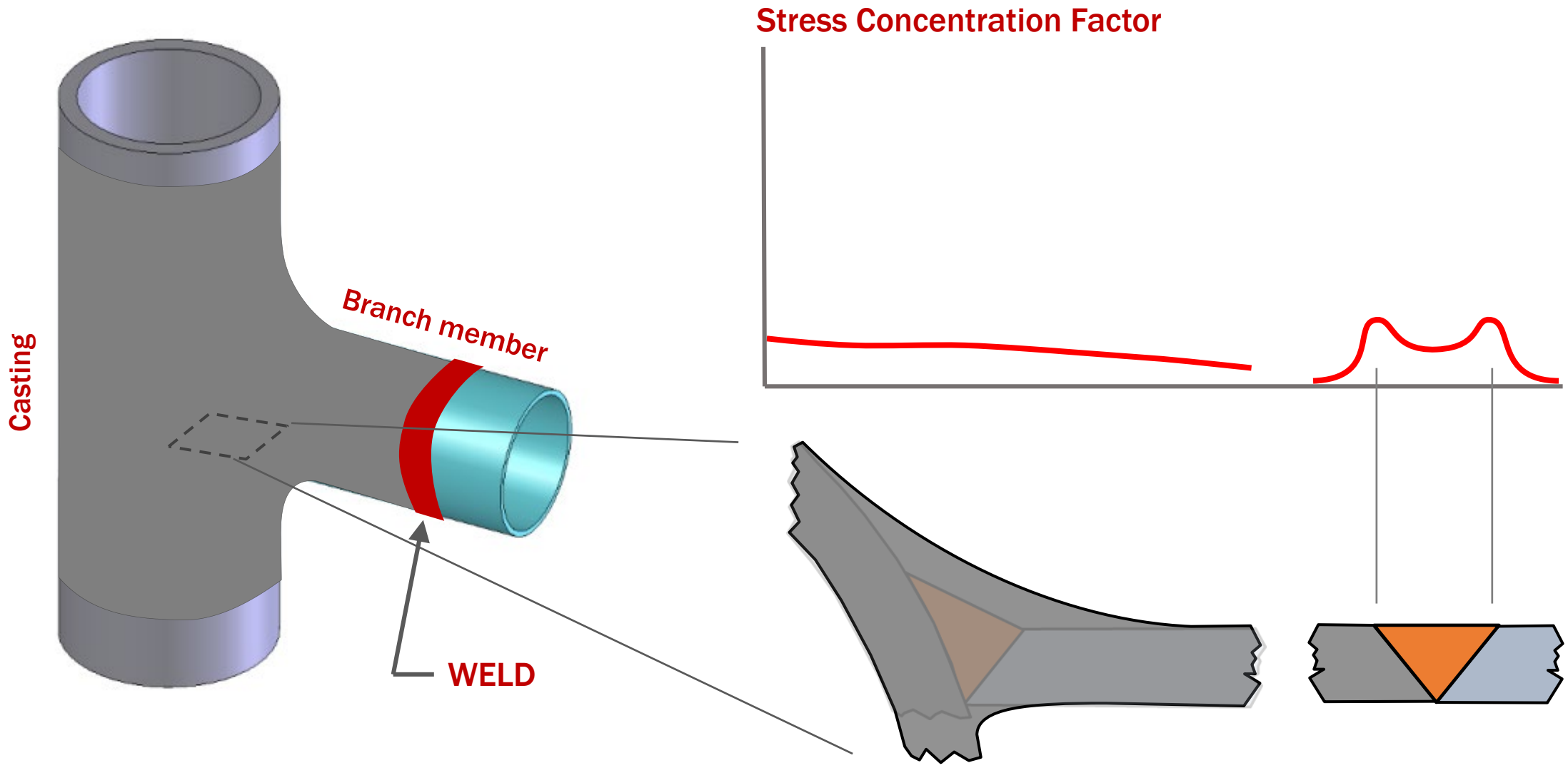


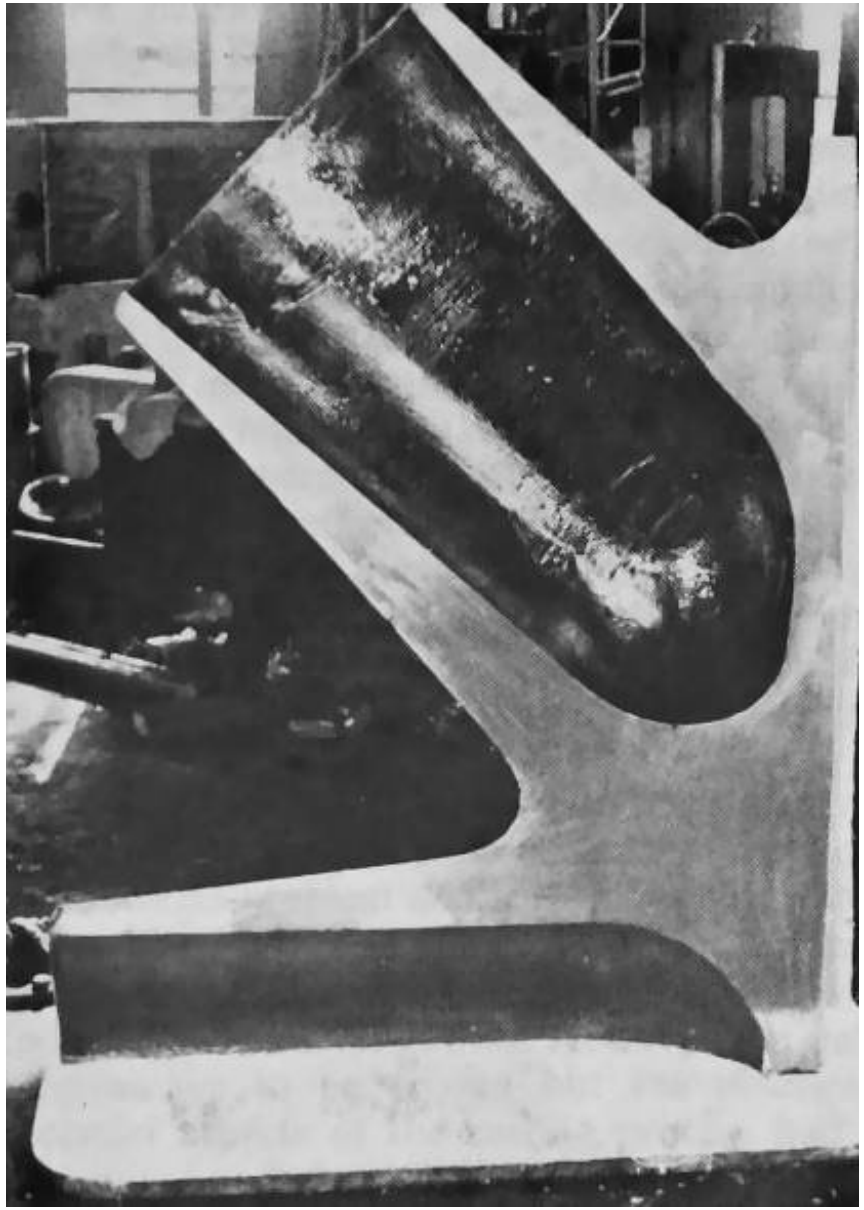
Cast Steel Junction
Welding HSS-to-Casting Joint (Butt)

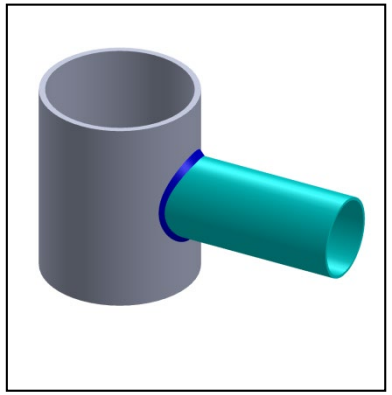
Conventionally Fabricated HSS-to-HSS Connection

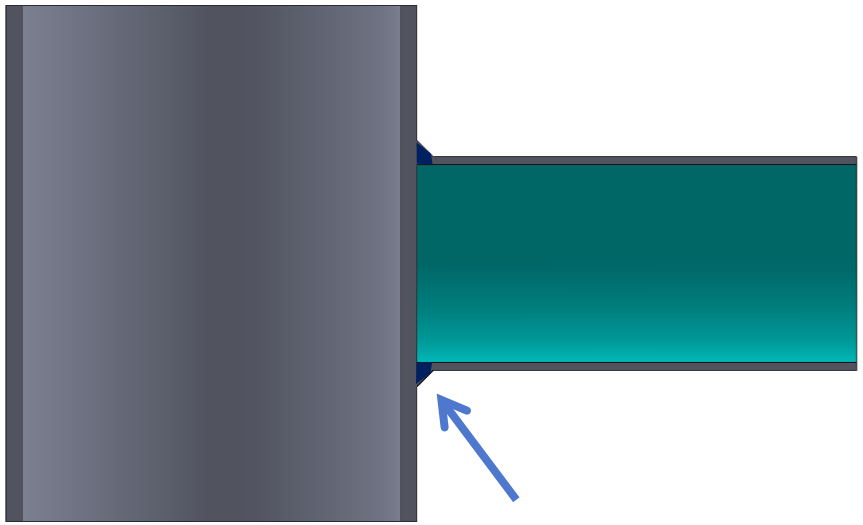


Connection with Cast Steel Node

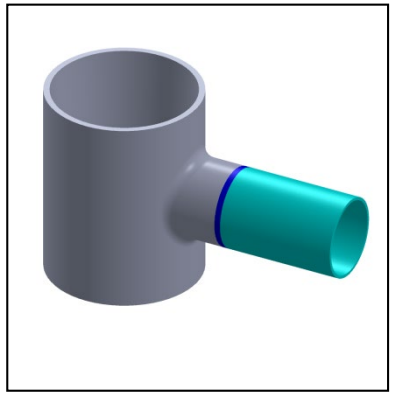


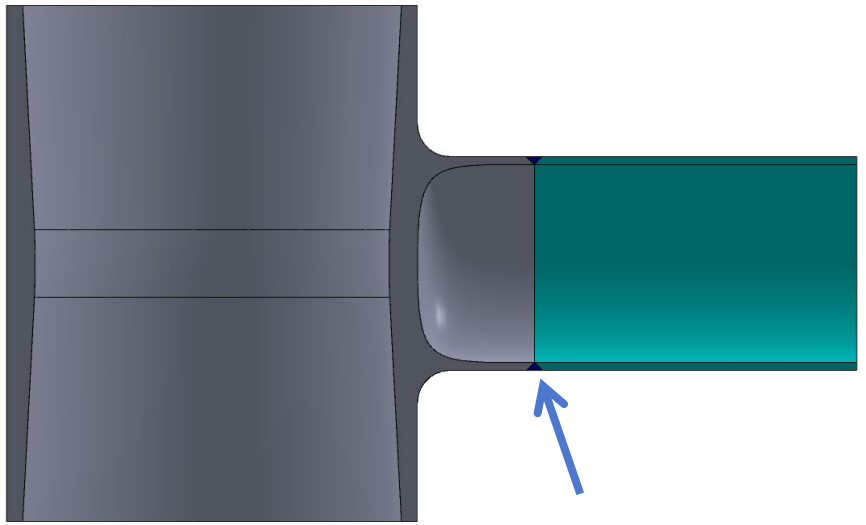




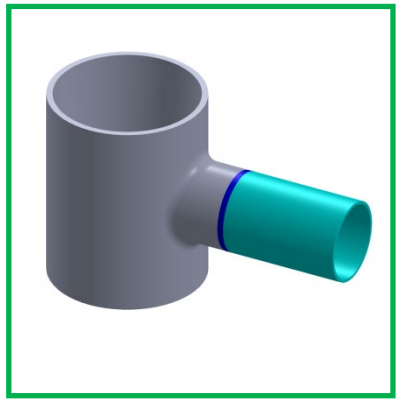


- Weld at region of high stress
- Welded joint is more geometrically complex; fit up is typically uneven
  → stress risers are more severe

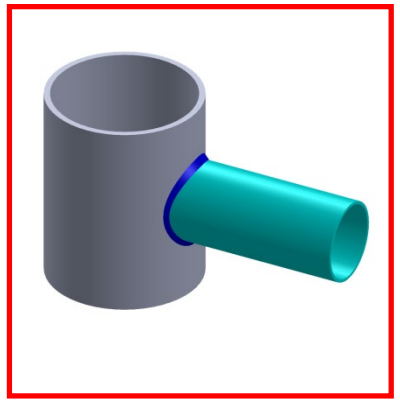




- Weld at region of lower stress
- Welded joint is simple; fit up is more uniform
  → stress risers are less severe



Butt splices, CJP groove welds
Stress Category C_1



T, Y, or K with CJP groove welds
Stress Category DT

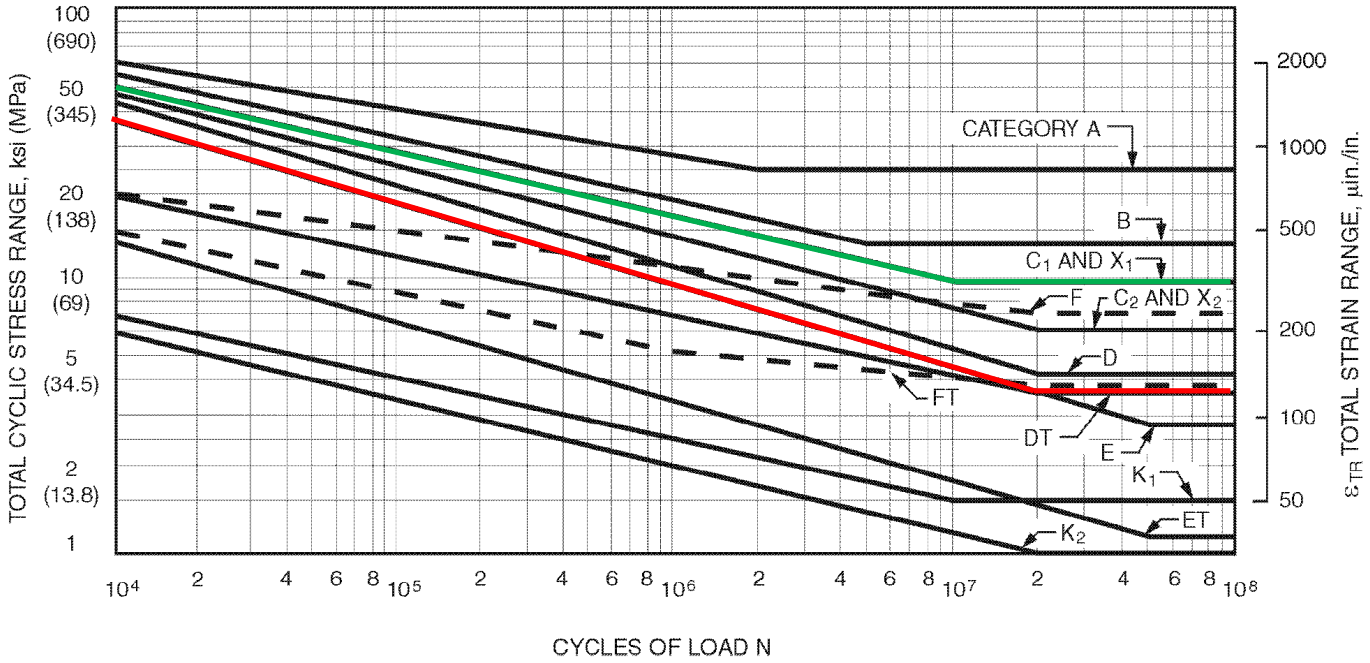
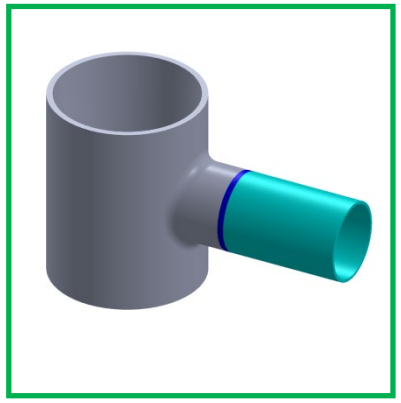
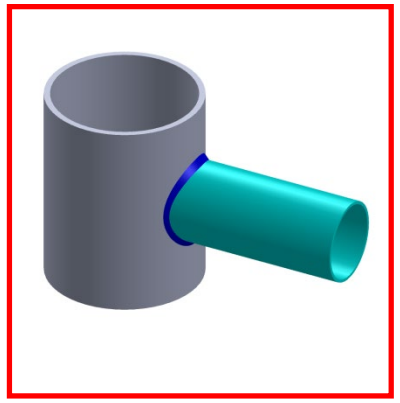


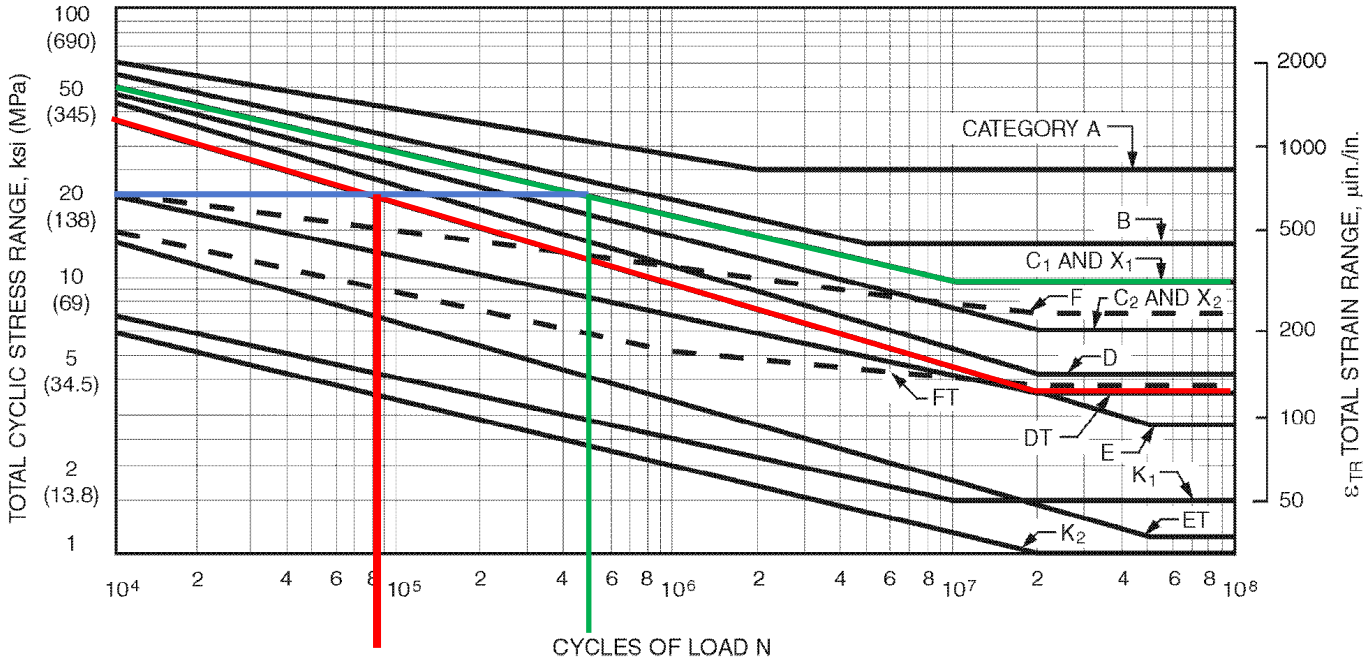
Figure 2.13—Allowable Fatigue Stress and Strain Ranges for Stress Categories (see Table 2.6), Redundant Tubular Structures for Atmospheric Service (see 2.36.6.3)



Butt splices, CJP groove welds
Stress Category C_1



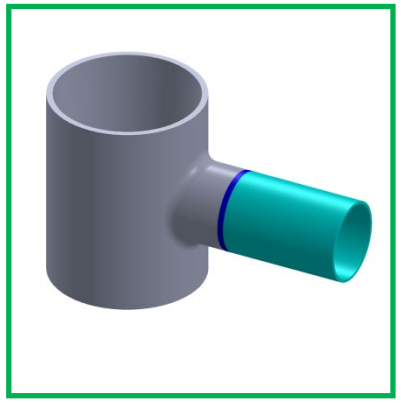
T, Y, or K with CJP groove welds
Stress Category DT



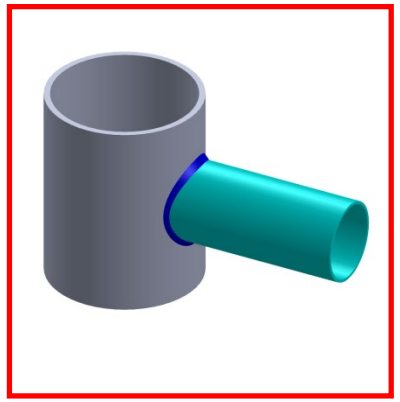
80,000 500,000

Figure 2.13—Allowable Fatigue Stress and Strain Ranges for Stress Categories (see Table 2.6), Redundant Tubular Structures for Atmospheric Service (see 2.36.6.3)

6.25 times improvement



Butt splices, CJP groove welds
Stress Category C_1



T, Y, or K with CJP groove welds
Stress Category DT

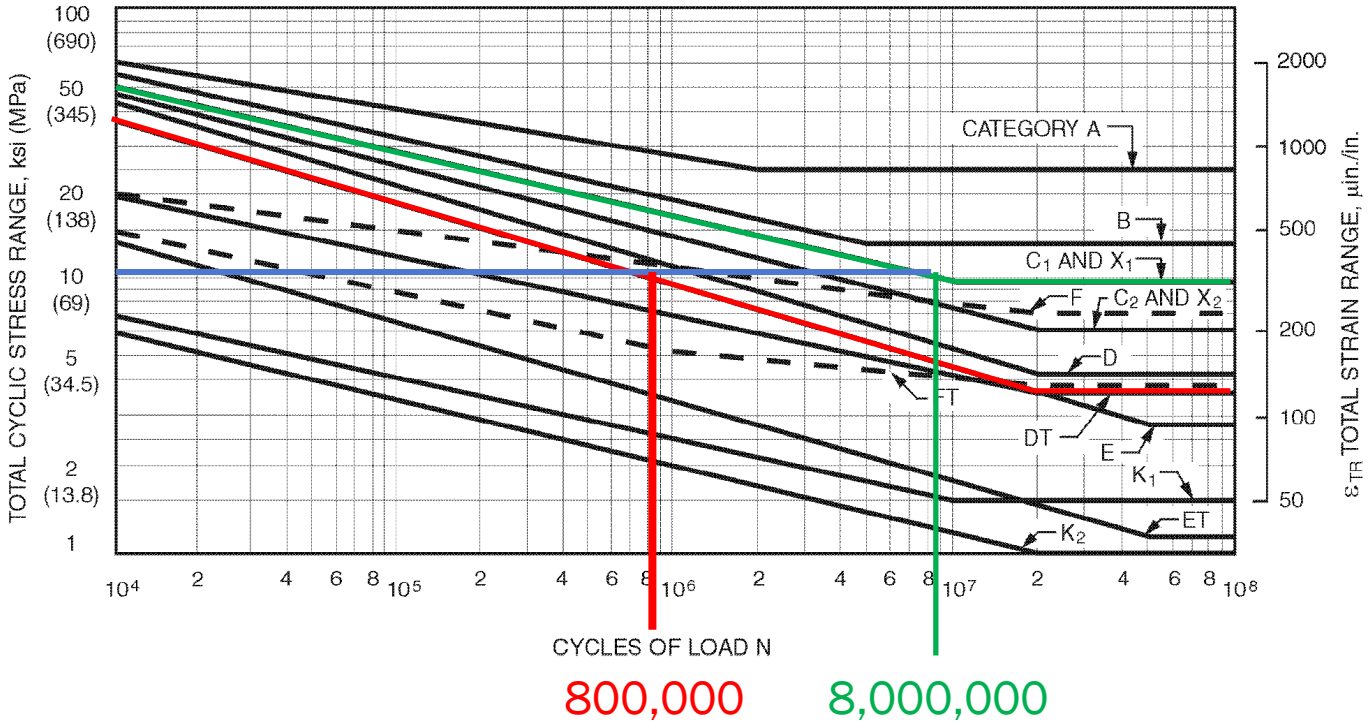
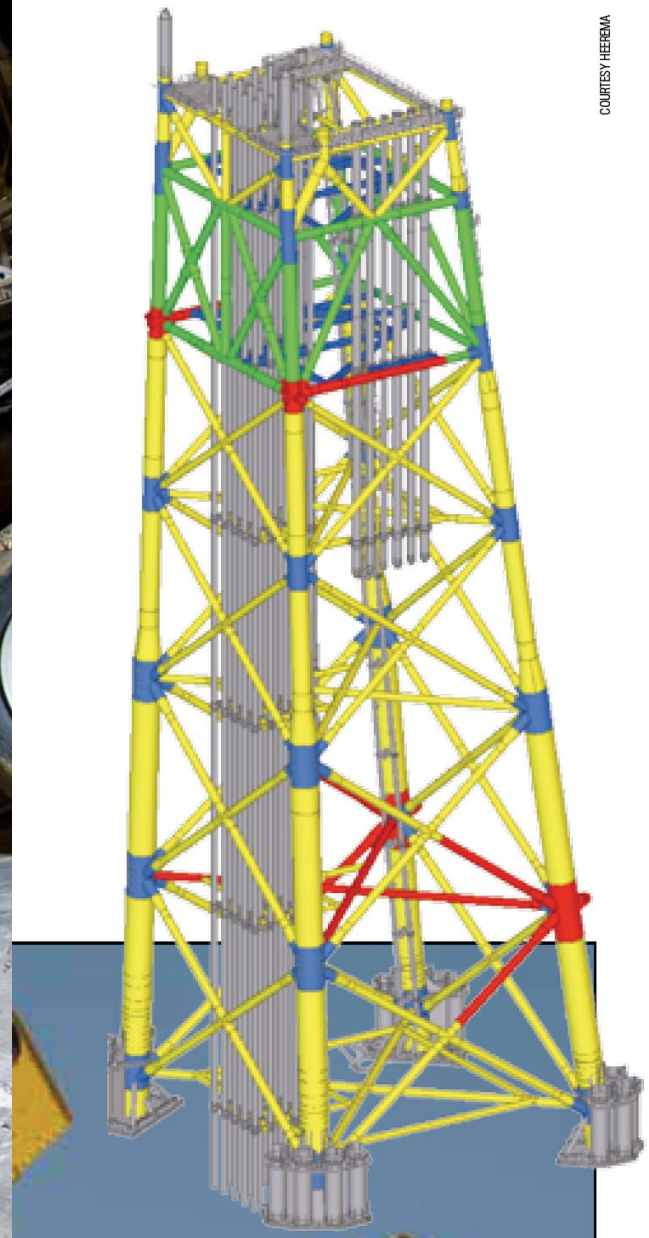


Figure 2.13—Allowable Fatigue Stress and Strain Ranges for Stress Categories (see Table 2.6), Redundant Tubular Structures for Atmospheric Service (see 2.36.6.3)

10 times improvement

The dominant design factors for HFG at various points of the jacket are shown below.

In place – Strength
In place – Fatigue
Accidental – Boat impact
Temporary – Lift and transport



COURTESY HEEREMA

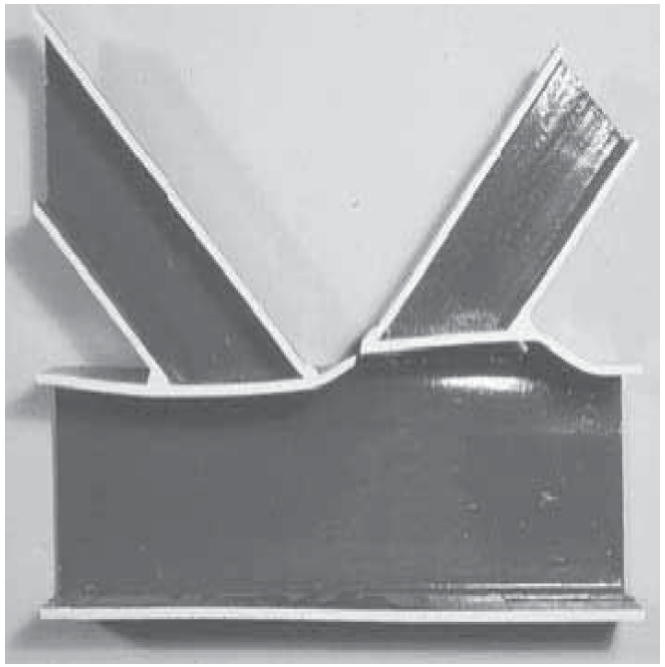
Tonnage Savings

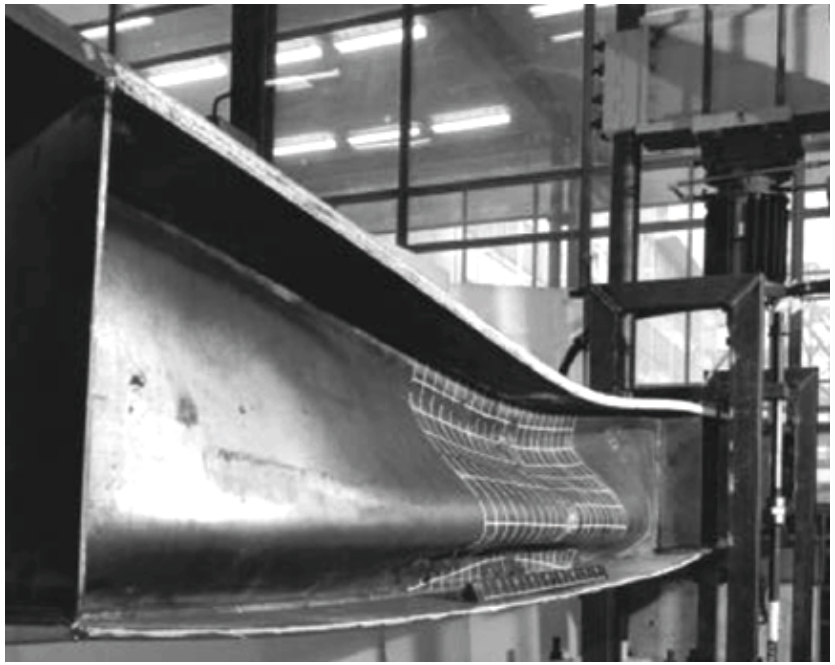
Use of cast steel nodes can offer **overall steel tonnage savings** based on Strength Requirements in structural frames (trusses, grillages, grid shells, diagrids, etc) in two ways:

1. **Preclude Local Connection Limit States**, which can otherwise drive member selection

2. **Reduce the Governing Member Forces in Connected Members**, thus resulting in lighter steel framing

Local Connection Limit States

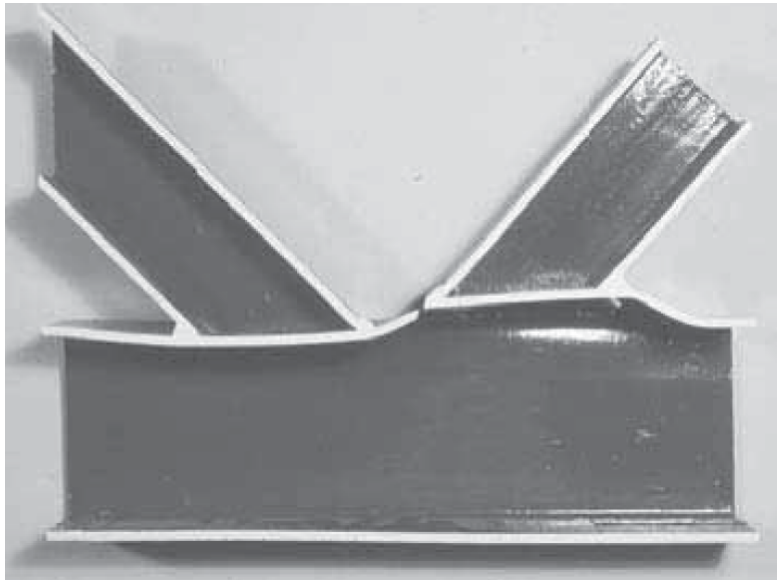




HSS:
Shear Yielding (Punching)
Chord Plastification
Shear of Chord Side Walls
Local Yielding of Branches
Chord Distortion Failure

W-Shapes:
Flange Local Bending
Web Local Yielding, Crippling, Buckling
Web Panel-Zone Shear

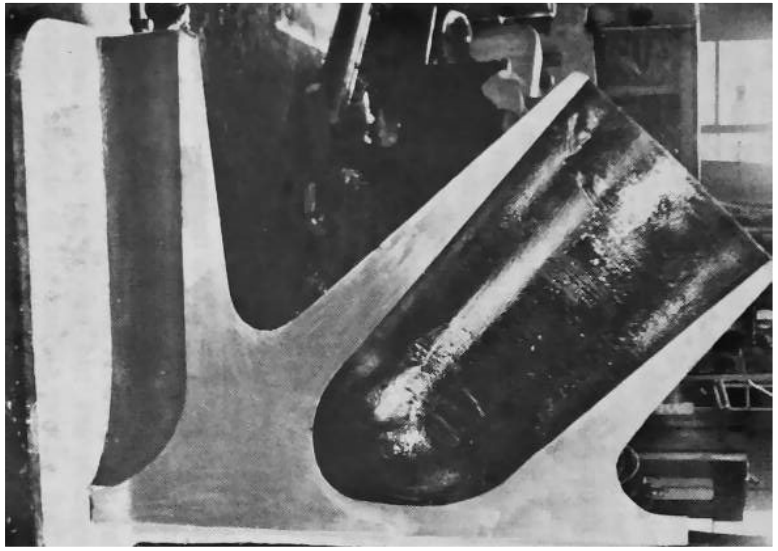
Preclusion of Local Connection Limit States with Castings



When they govern, addressing local connection limit states requires either:

1. Local connection reinforcement/stiffening
2. Upsizing the member

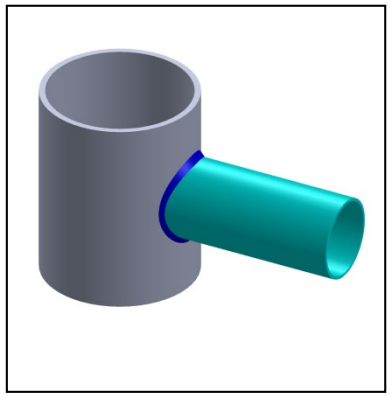
Both are costly.

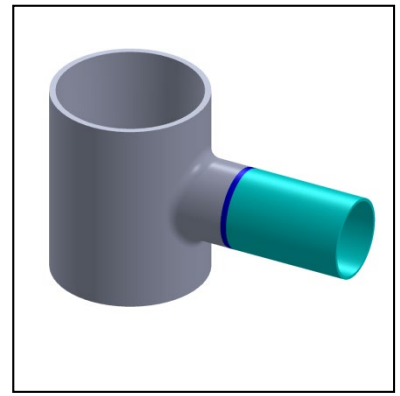


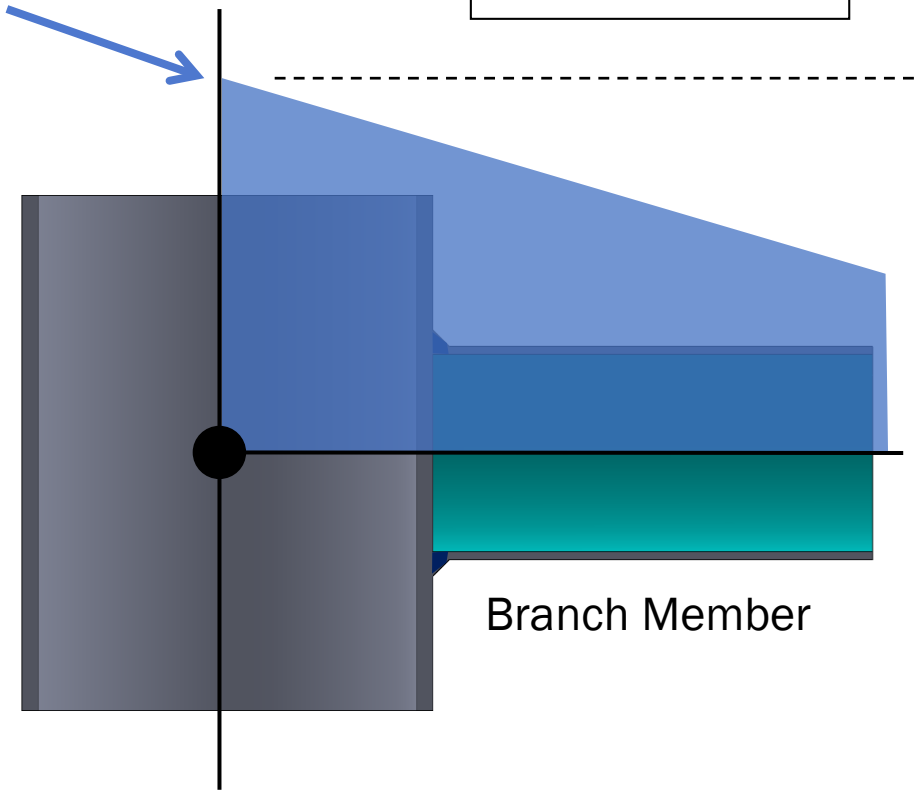
Castings can be designed to preclude local connection limit states such that the members can be selected exclusively based upon member forces

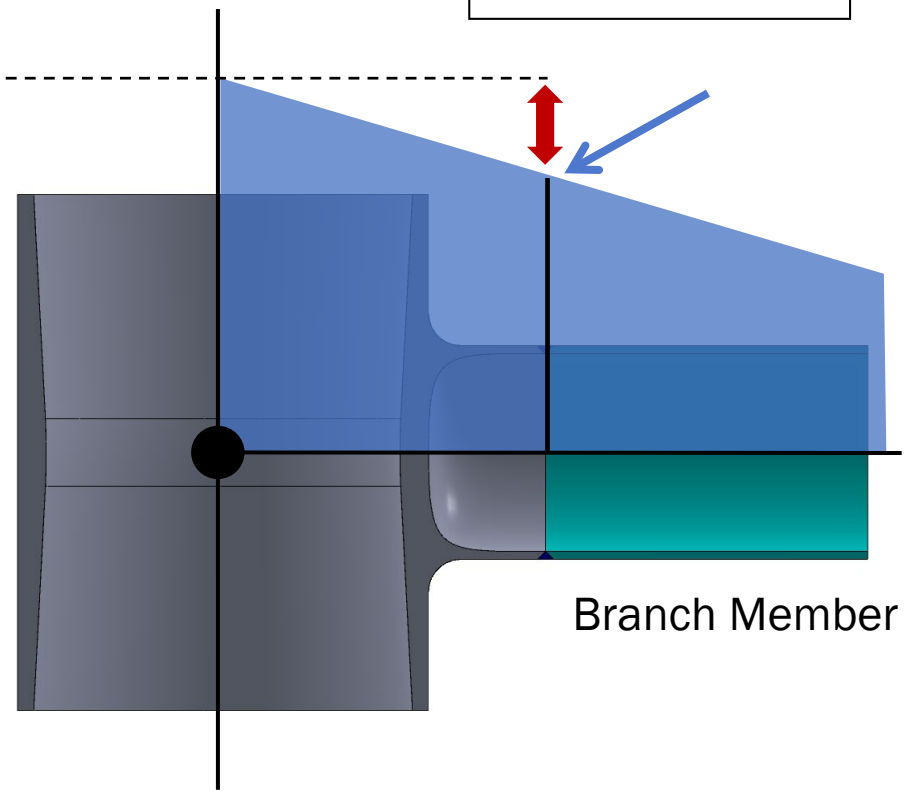
Moreover …

Reduction in Member Design Forces

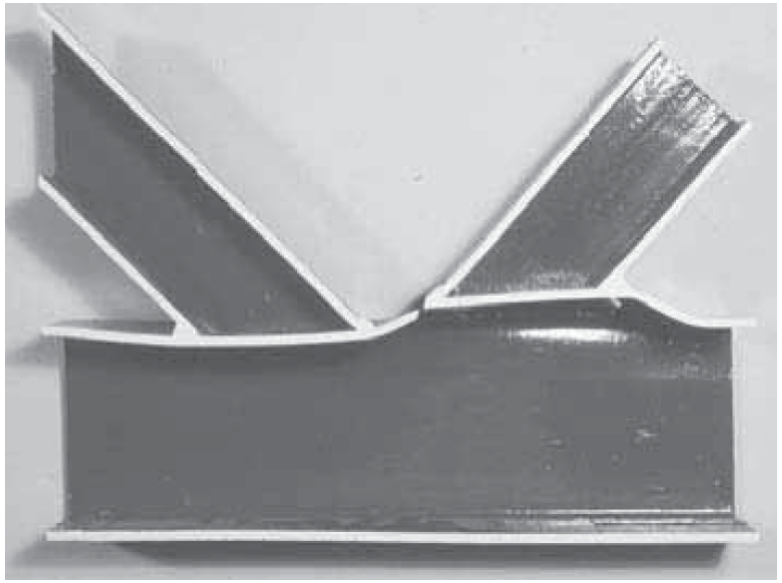


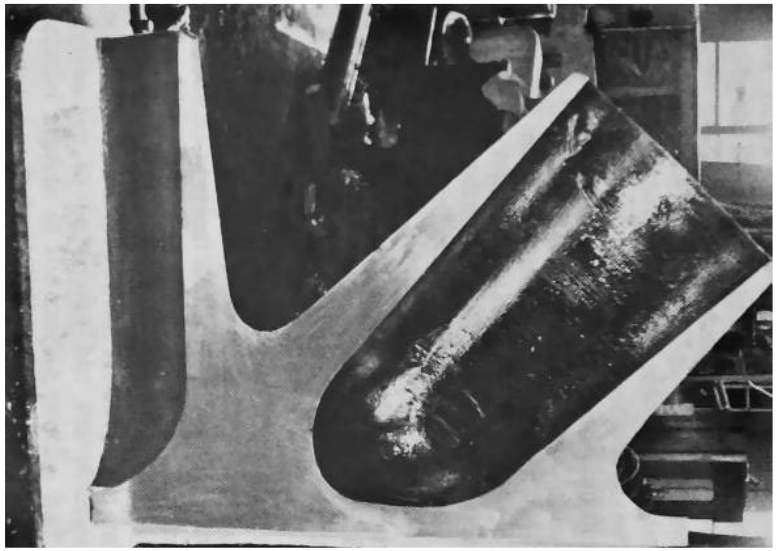






Tonnage Savings via Casting Use – Strength Requirements



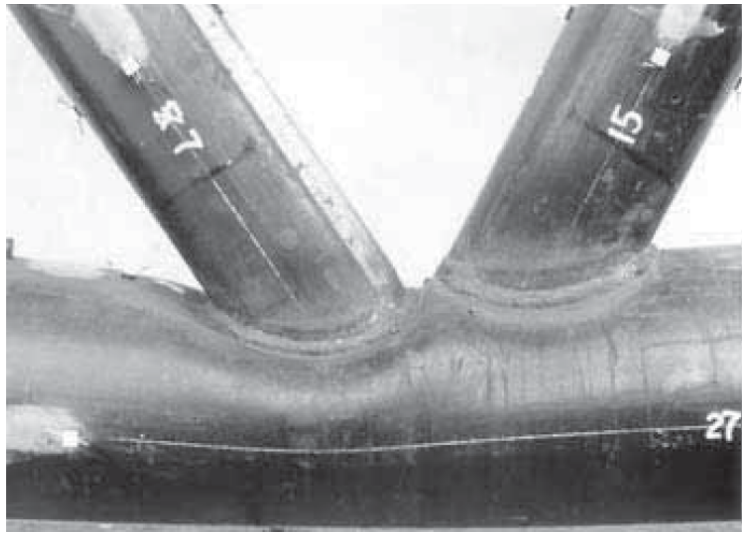


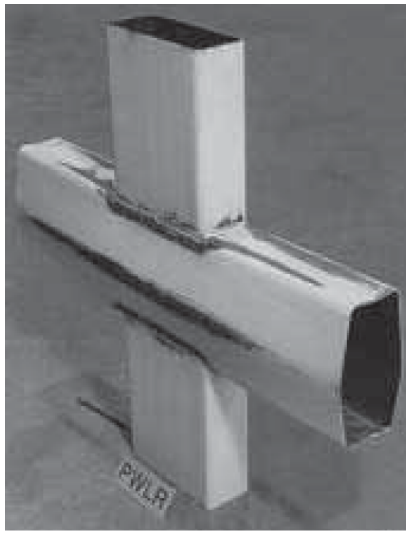
With cast nodes:

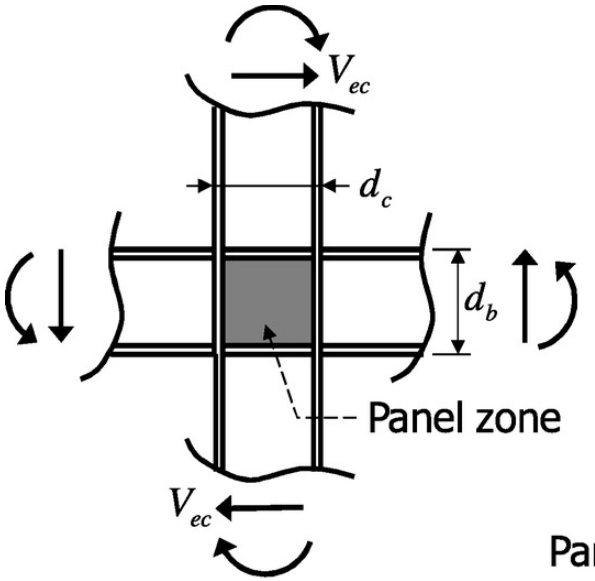
- Member selection is not dependent on local connection strength
- Member forces are reduced based on member end offset to casting/member interface point

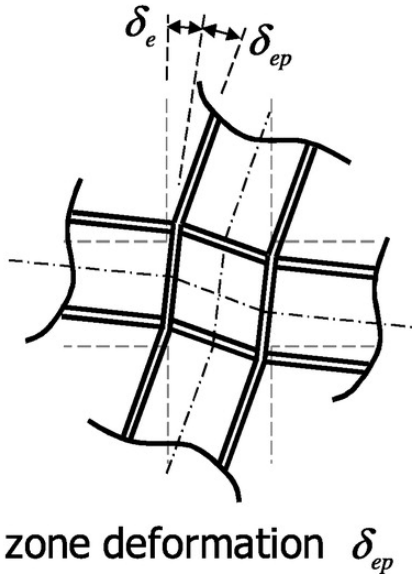
→ results in **economies in overall tonnage**

Reduced Deflections & Improved Predictability of Response





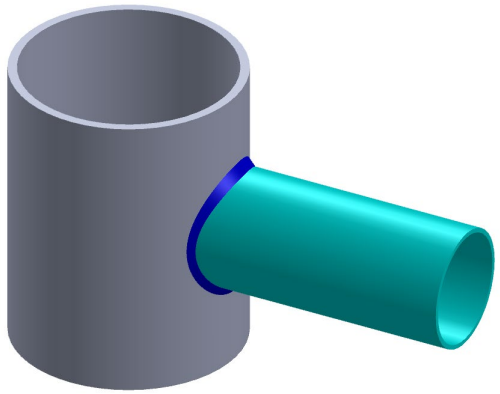




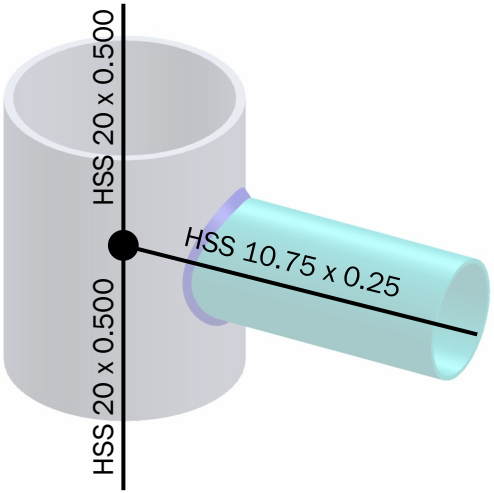
Connections can be flexible!

- Deformations can be underestimated by as much as 20% in bridges constructed with HSS if connection flexibility is neglected (Frater and Packer, 1992)
- Estimates of the fundamental period may also be underestimated by a similar proportion

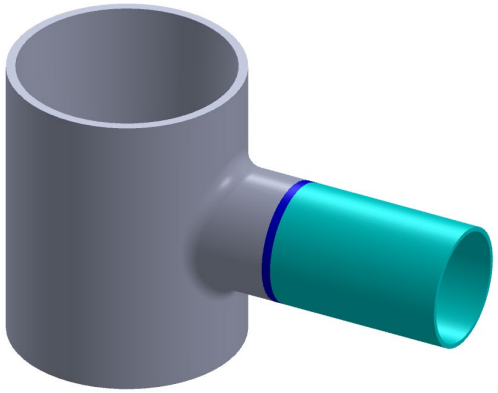
Improved Predictability of Structural Response with Castings



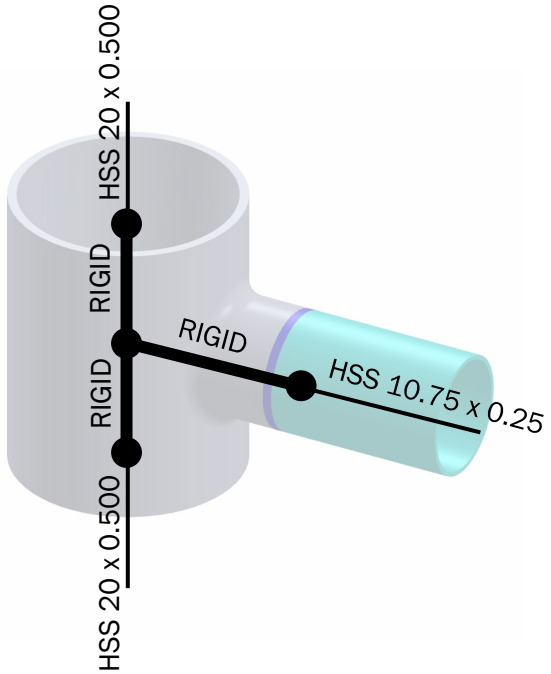
Actual
HSS-to-HSS
Connection



Typical Frame Analysis Model
(without consideration for
connection flexibility)



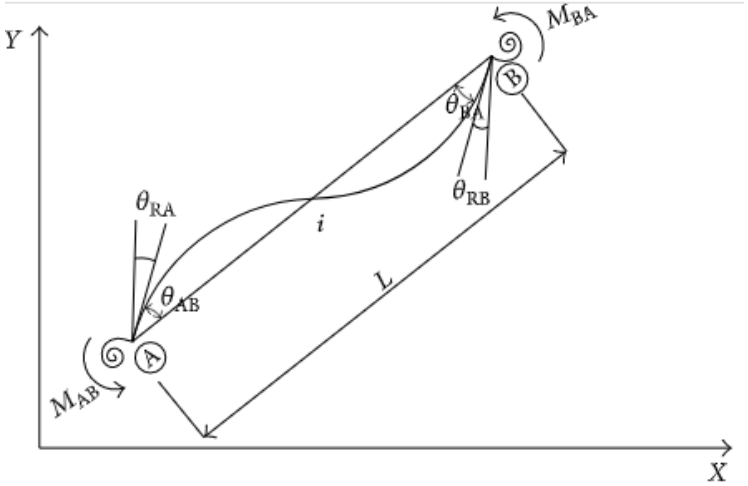
Actual
Cast Node-to-HSS
Connection



Frame Analysis Model
with Rigid Links within
Cast Node Region

Increasing Stiffness

Tonnage Savings due to Increased Connection Stiffness



Frame member with semi-rigid connections

Because cast nodes are stiffer than conventionally fabricated connections:

- Structures with cast nodes are generally stiffer than structures without
- When deflections or natural period considerations govern member selection, use of cast nodes will result in economies in overall tonnage

Coating System Performance

Sharp edges, outside corners, crevices and welds are often sites where coating failures and corrosion begin due to reduced coating barrier protection

Coating System Performance

Cast connections replace corners and crevices with generous radii and smooth transitional geometry, improving coating system performance.

Cast nodes also move welds away from one another, accommodating simple girth welds that are far easier to weld, inspect, and coat.

Cast nodes often have less surface area than alternative fabricated connections

Fabrication and Erection Benefits

Geometric freedom afforded through casting manufacturing can be leveraged to create connections that improve constructability (e.g. eliminate field welding, improve weld access, etc)

Castings can simplify or eliminate complex fabrication

- Improved quality of construction
- Potential cost savings

Machined casting tolerances and geometric consistency is unmatched

- Improved fit-up tolerances
- Reduced risk in the field

"Every Dollar saved in the field is worth Two or Three in the shop"

- Bill Lindley, Senior Vice President, Engineering, W&W STEEL

Summary: Performance Benefits of Steel Castings in Bridge Structures

- Improvement of fatigue life; extension of service life
- Tonnage savings in steel members framing into cast connections
- Reduced deflections and improved predictability of structural response
- Improved coating system performance/longevity
- Improved quality through simplification of fabrication
- Enhanced constructability, reduced risk

Steel Castings in Bridges Worldwide

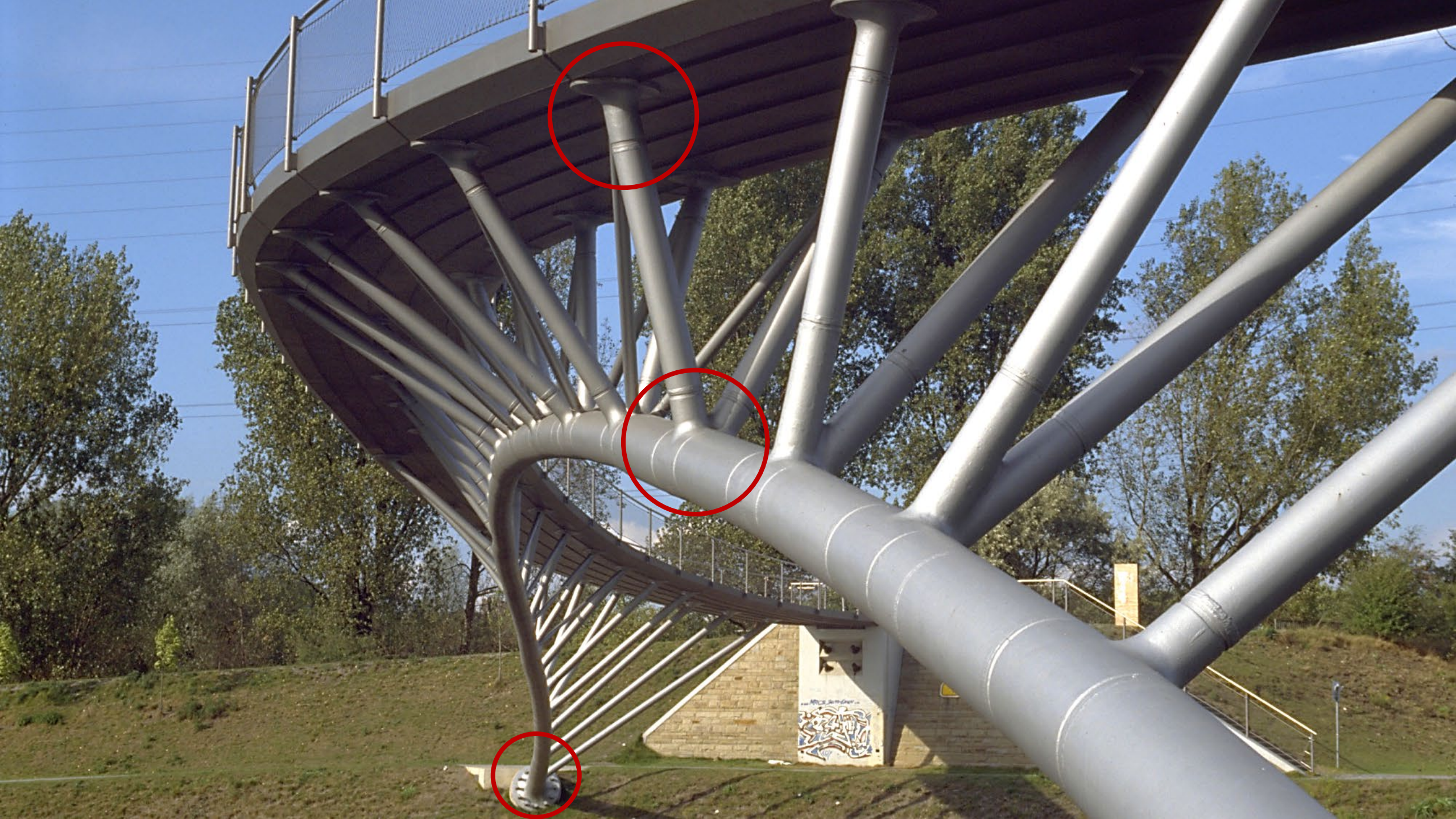
THREE COUNTRIES BRIDGE
HUNINGUE (FRANCE), WEIL AM RHEIN (GERMANY), BASEL (SWITZERLAND)

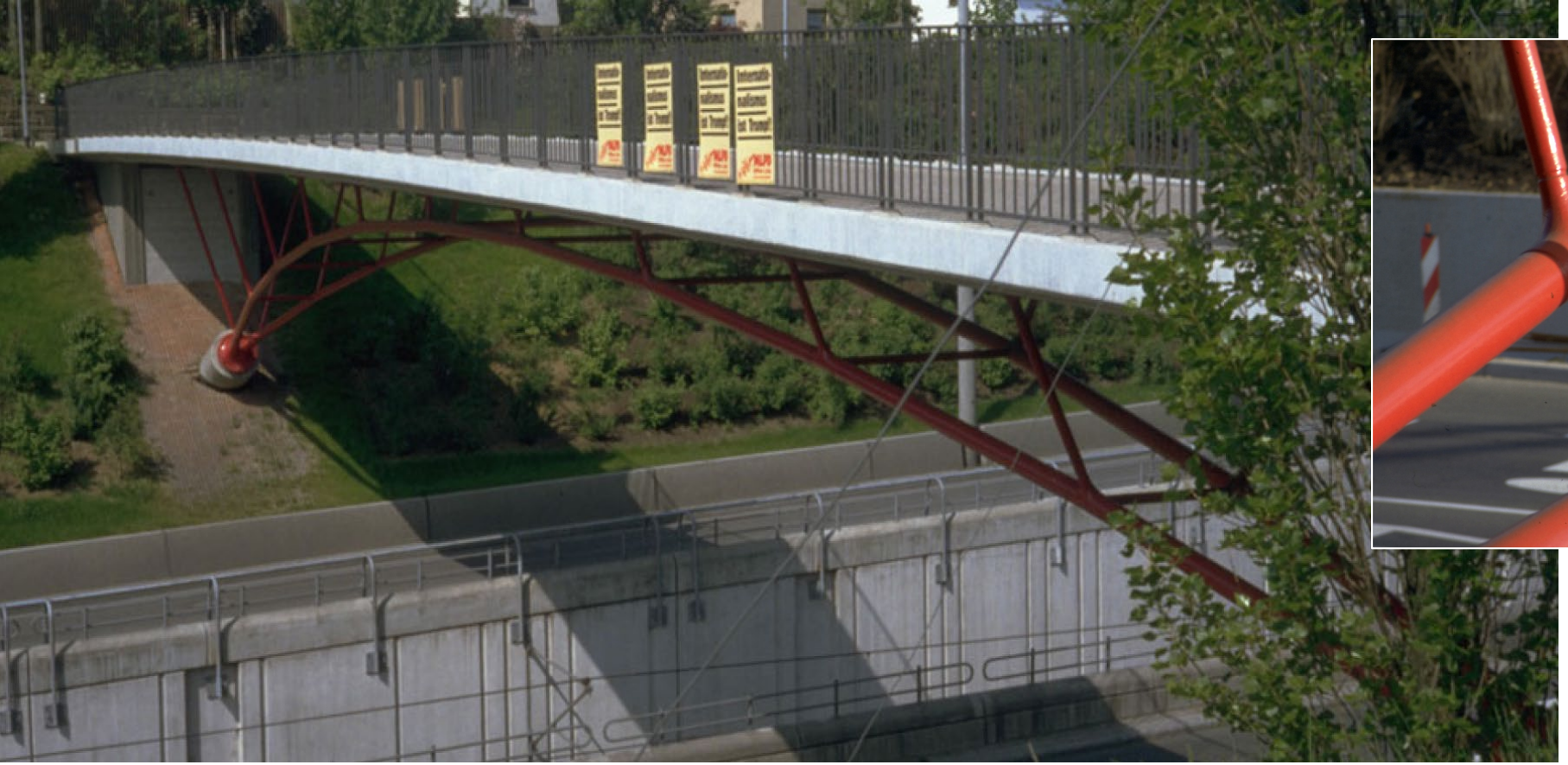
Completed 2007
Owner: City of Weil-am-Rhein and Commune des Trois Frontières
Engineer: Leonhardt, Andrä und Partner
Architect: Dietmar Feichtinger

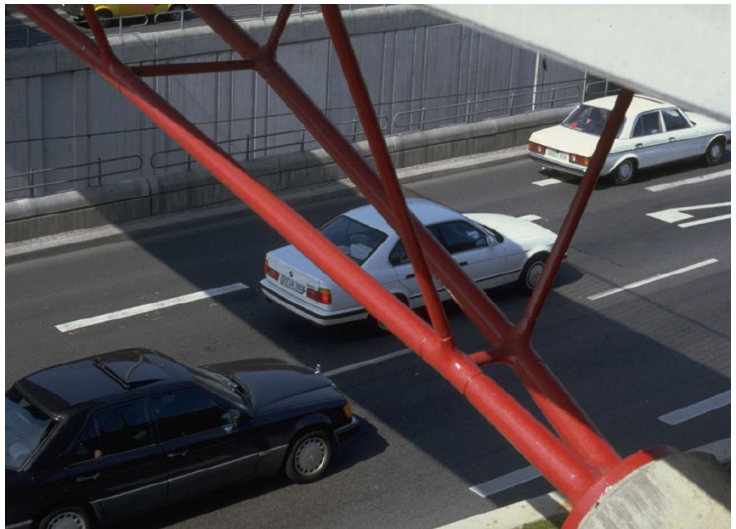

2

Completed 1997
Owner: Kommunalverband Ruhrgebiet KVR
Engineer: SBP
Architect: Diekmann und Lohaus

RIPSHORST BRIDGE
OBERHAUSEN, GERMANY

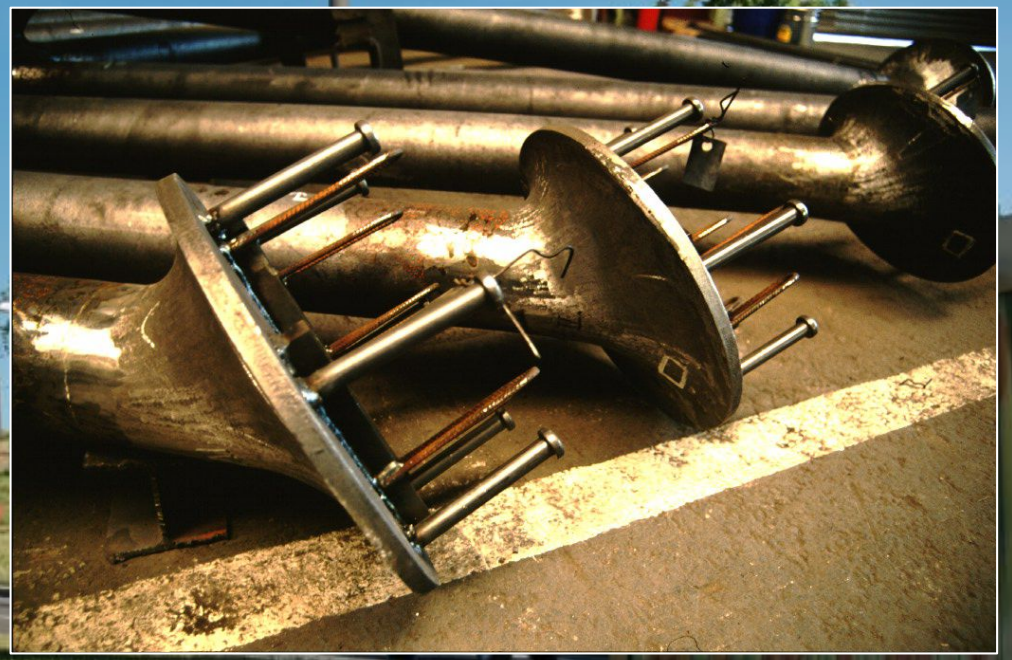






SAMARASTEG (I)
STUTTGART, GERMANY

Completed 1992
Owner: City of Stuttgart
Engineer: SBP
Architect: Ulrich Otto



SAMARASTEG (II)
STUTTGART, GERMANY

Completed 1992
Owner: City of Stuttgart
Engineer: SBP
Architect: Ulrich Otto

BRIDGES LEÓN
LEÓN, SPAIN

Completed 2006
Owner: City of León
Engineer: SBP
Architect: Juan Herreros

MÜNCHINGEN VIADUCT
KORNTAL-MÜNCHINGEN, GERMANY

Completed 2005
Owner: City of Stuttgart
Engineer: Leonhardt, Andrä und Partner

Completed 2006
Owner: German Federal Ministry of Transport
Engineer: Weyer Beratende Ingenieure im Bauwesen GmbH

SANKT KILIAN VIADUCT
SANKT KILIAN, GERMANY

HUMBOLDTHAFEN BRIDGE
BERLIN, GERMANY

Completed 2002
Owner: Deutsche Bahn AG Railway Company
Engineer: SBP and Leonhardt, Andrä und Partner
Architect: Gerkan, Marg and Partners

EMORY UNIVERSITY HOSPITAL PEDESTRIAN BRIDGE

ATLANTA, GA

Owner: **Emory Healthcare**
Engineer: **Walter P Moore**
Architect: **Smithgroup**
Fabricator: **Steel LLC, Stein Steel**
Casting Supplier: **CAST CONNEX**

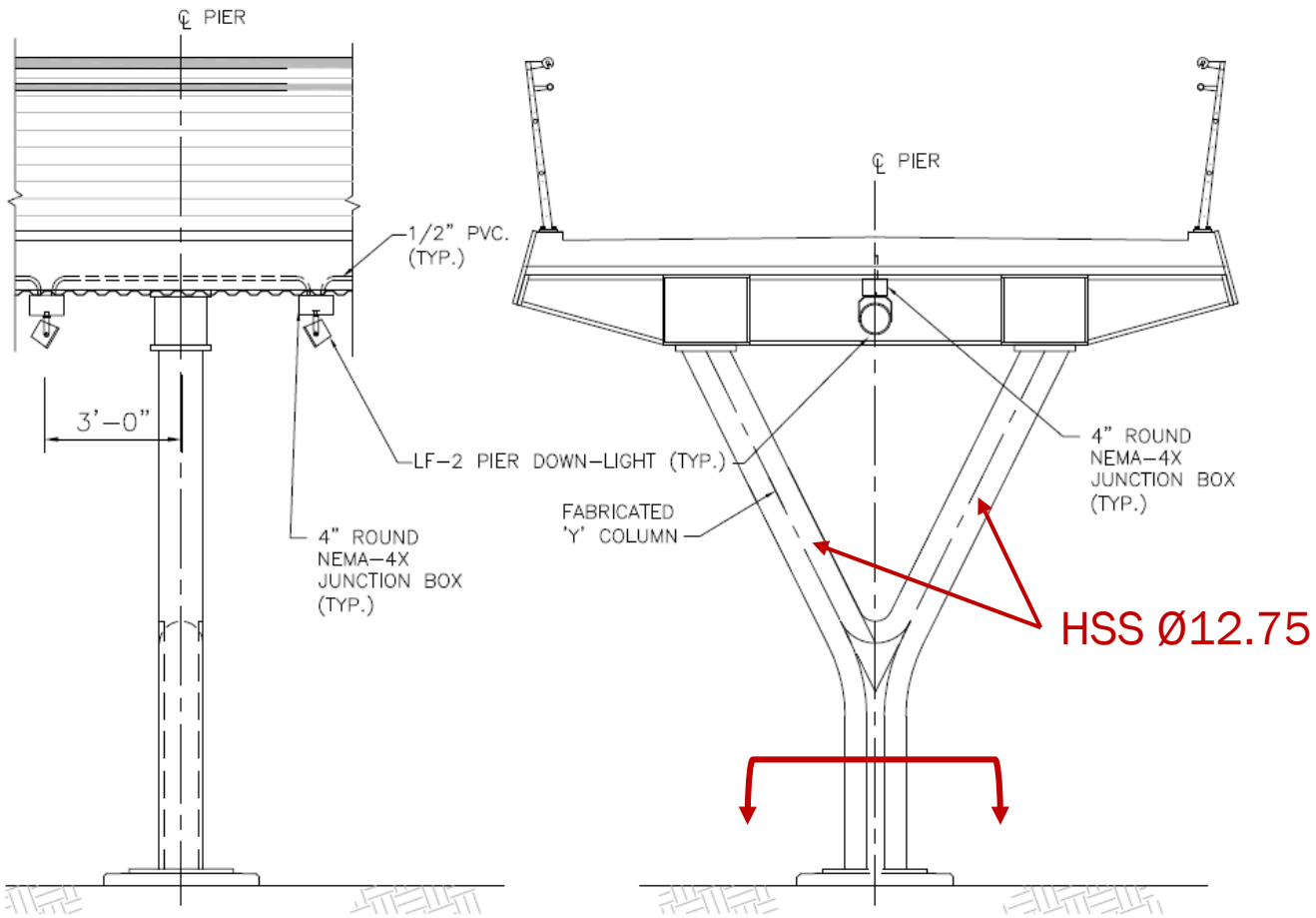
FRANCES APPLETON PEDESTRIAN BRIDGE

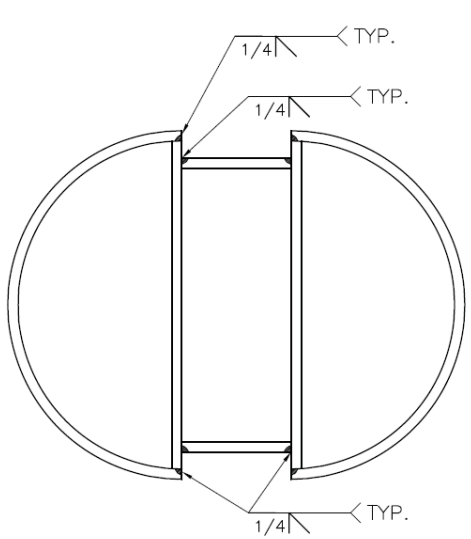
BOSTON, MA

Owner: **MassDOT/DCR**
Engineer: **STV Incorporated**
Architect: **Rosales + Partners**
Fabricator: **Newport Industrial Fabricators**
Casting Supplier: **CAST CONNEX**

2020 PRIZE BRIDGE AWARDS
NATIONAL AWARD - SPECIAL PURPOSE

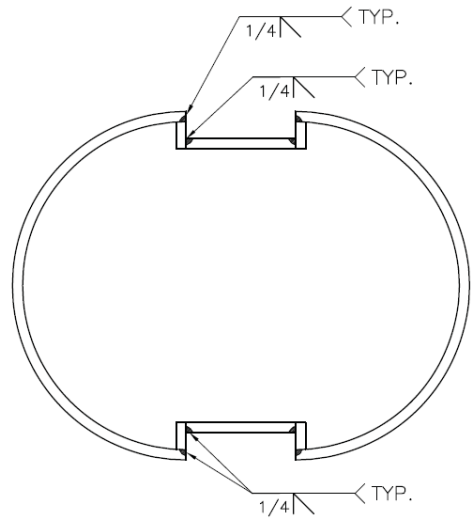
2019 ARTHUR G. HAYDEN MEDAL





TYPICAL STIFFENED SECTION

SCALE: 3" = 1'–0"



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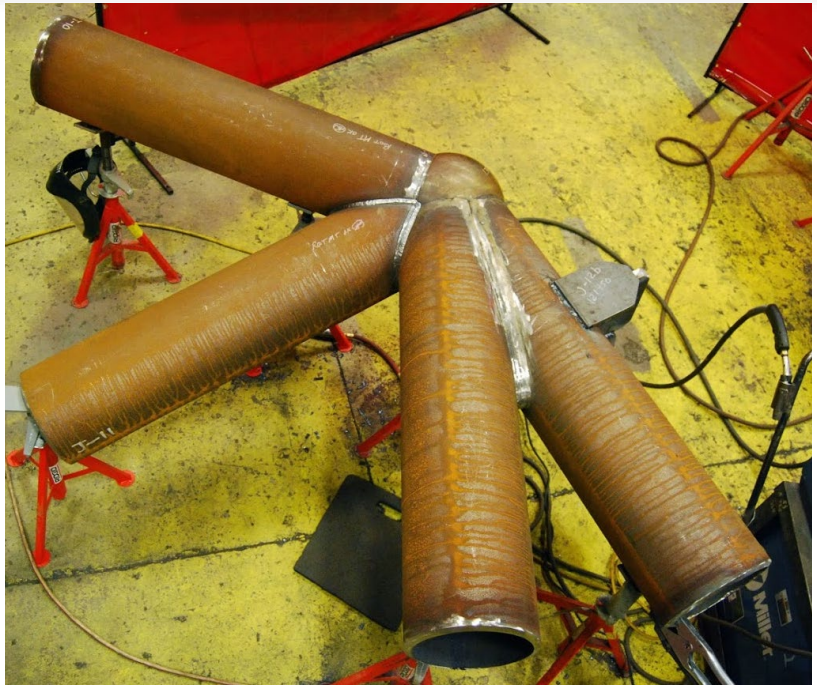
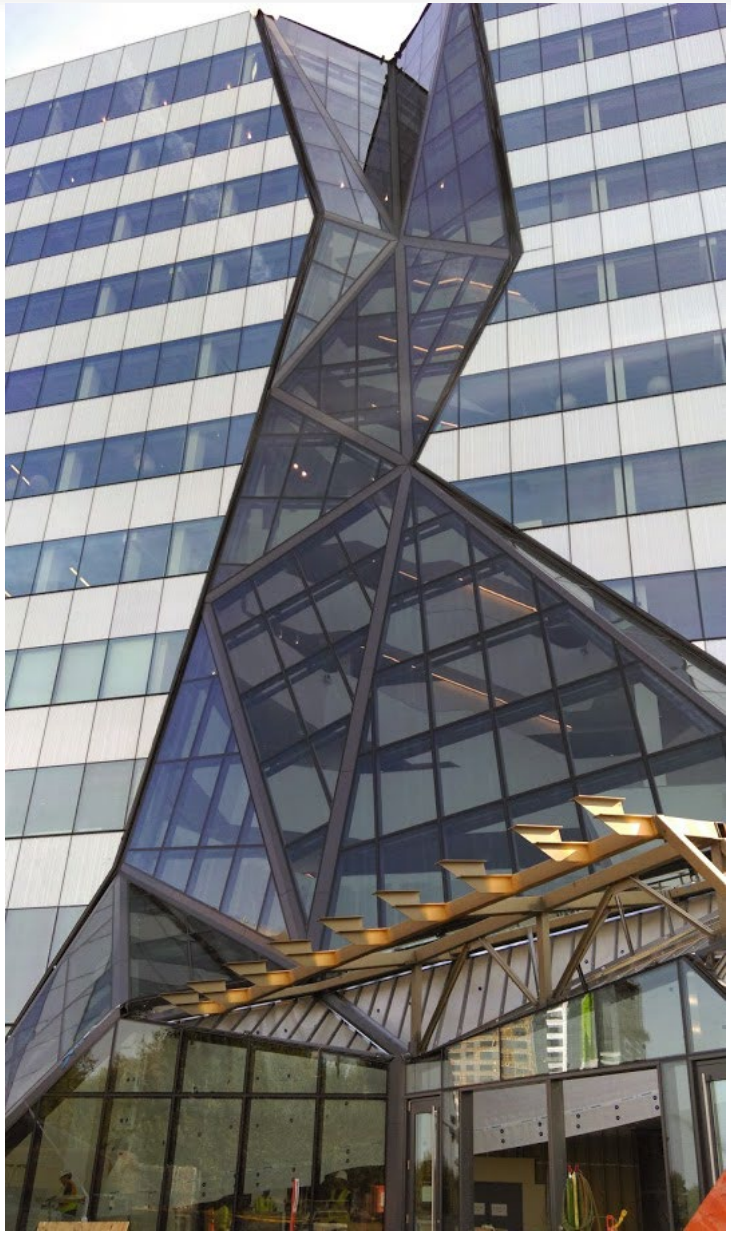
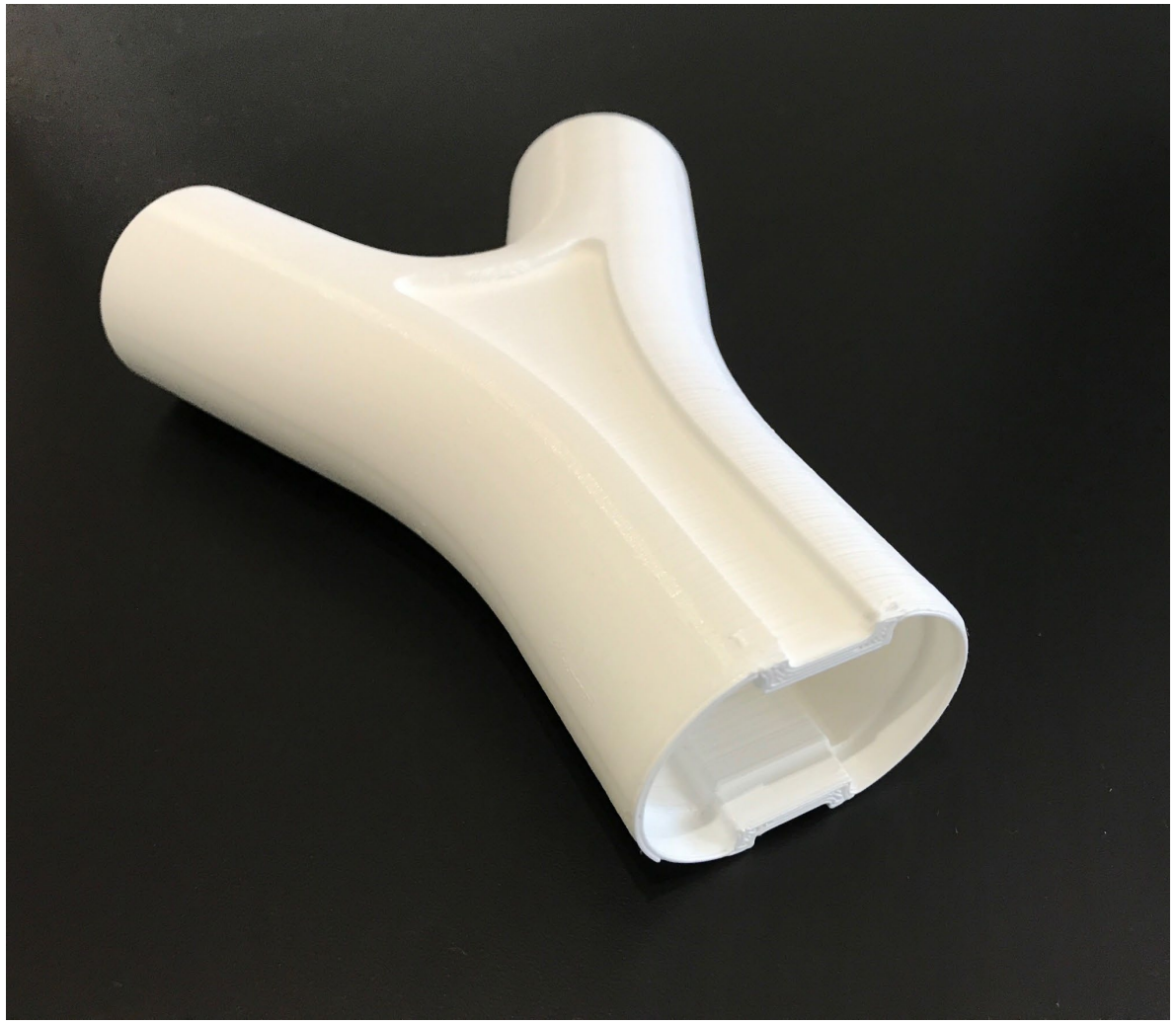
SCALE: 3" = 1'–0"

Complex Fabrication: Newport Industrial Fabricators

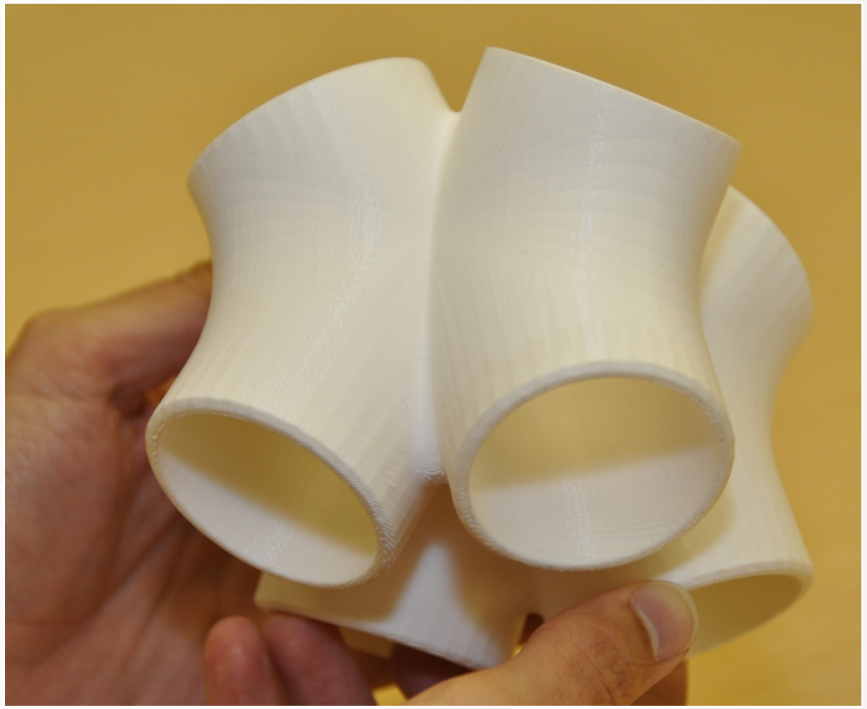


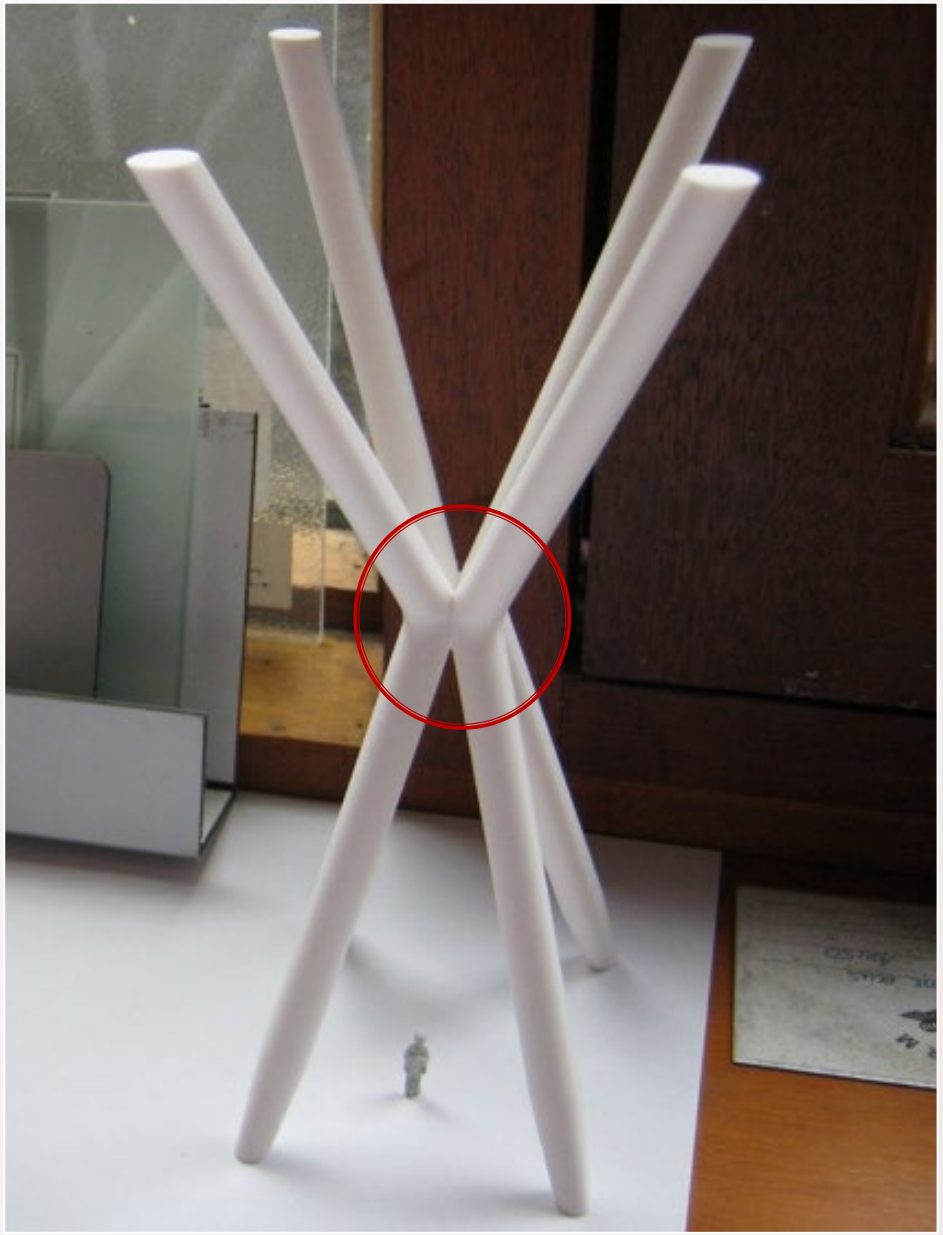


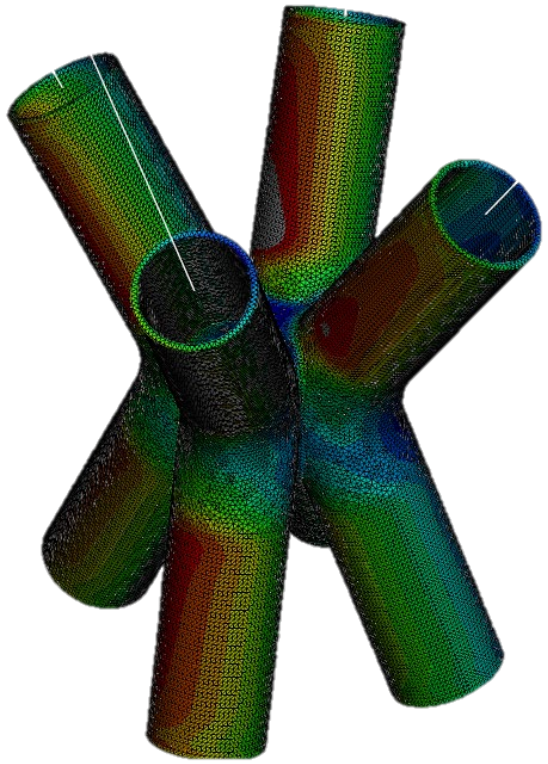
Cast Steel Node: Concept Through Manufacturing

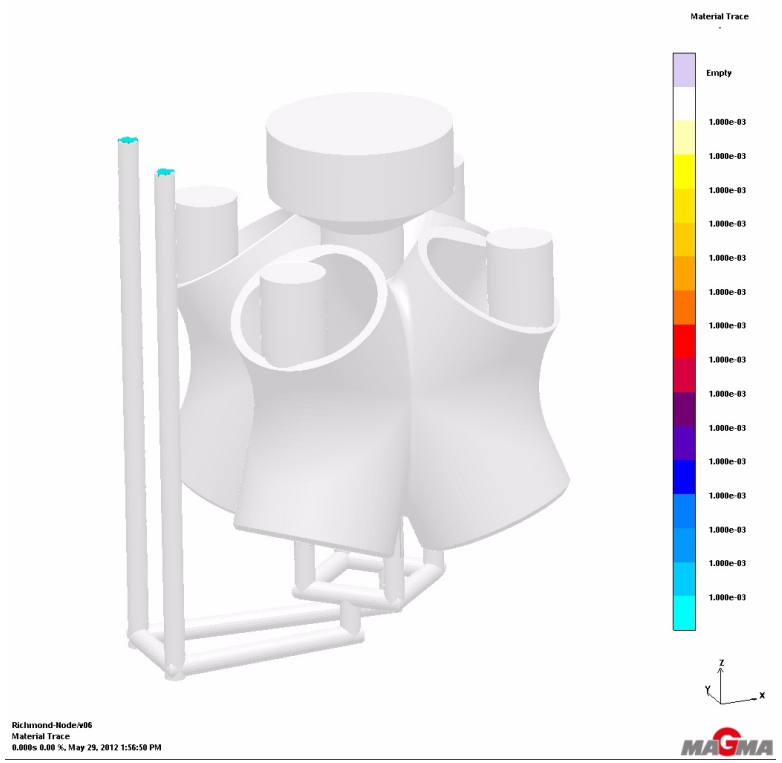


Steel Casting Engineering and Manufacturing





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Material Trace
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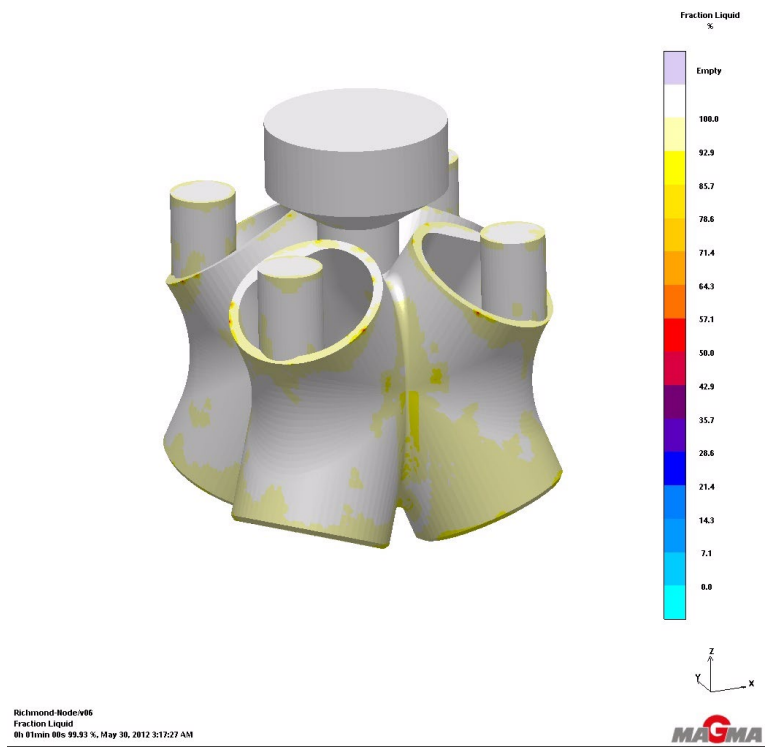
MAGMA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Richmond-Node/v06
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MAGMA


MultiCan

Non-Destructive Examination

- Radiographic Testing
- Ultrasonic Testing
- Magnetic Particle Inspection
- Visual Examination

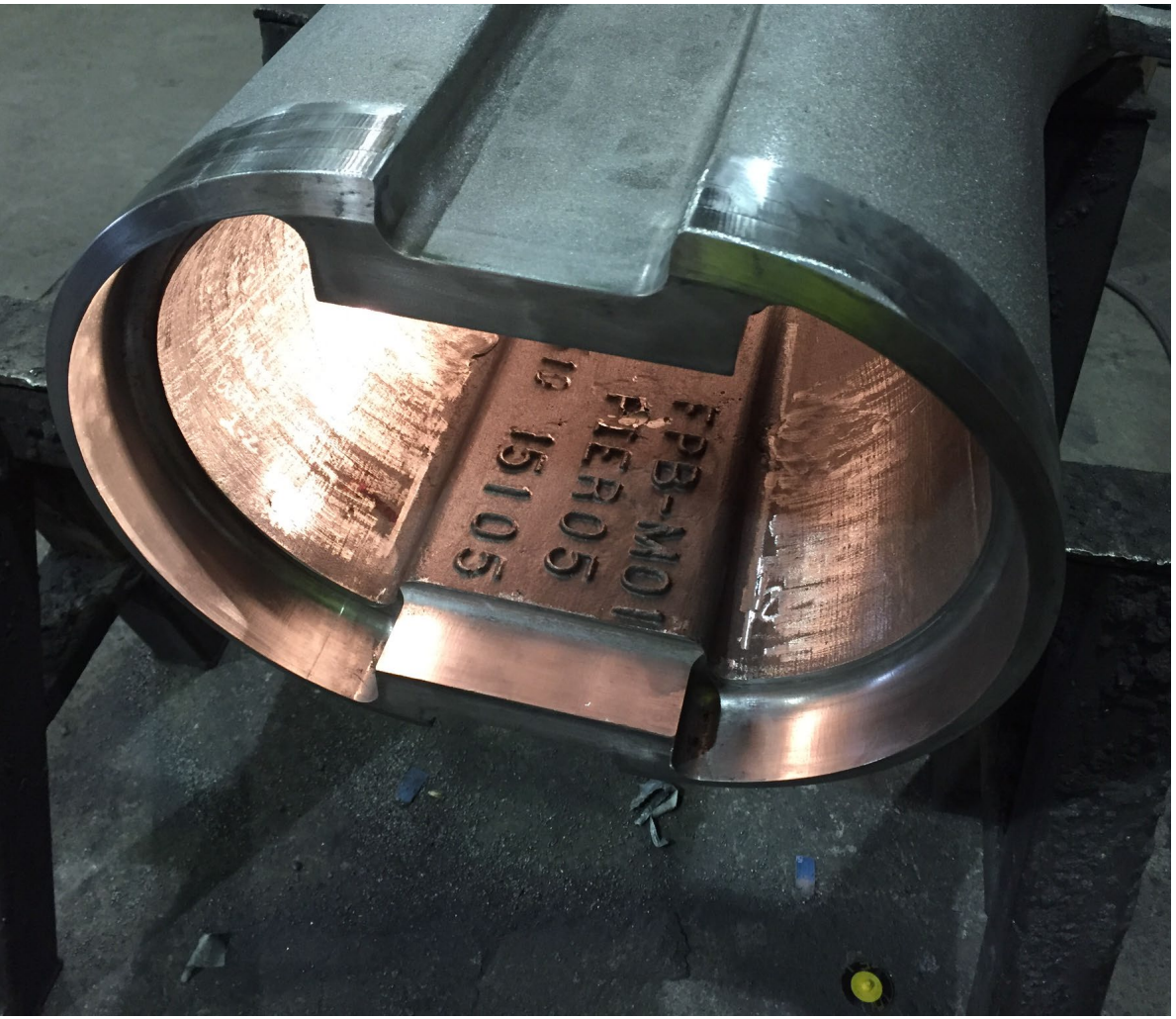
- **Acceptance criteria** are based on predefined “levels”, each of which correlates to allowable indication size and distribution, which in turn correlates to the structural efficacy of the casting

- **Areas of castings which have indications that exceed acceptance criteria are weld repaired (production welding)** and re-examined to confirm conformance to specification, prior to final heat treat


123

Cast Steel Node: Concept Realization

Welded Joint Detailing – Fatigue Performance Considerations



Photos Courtesy of NIF

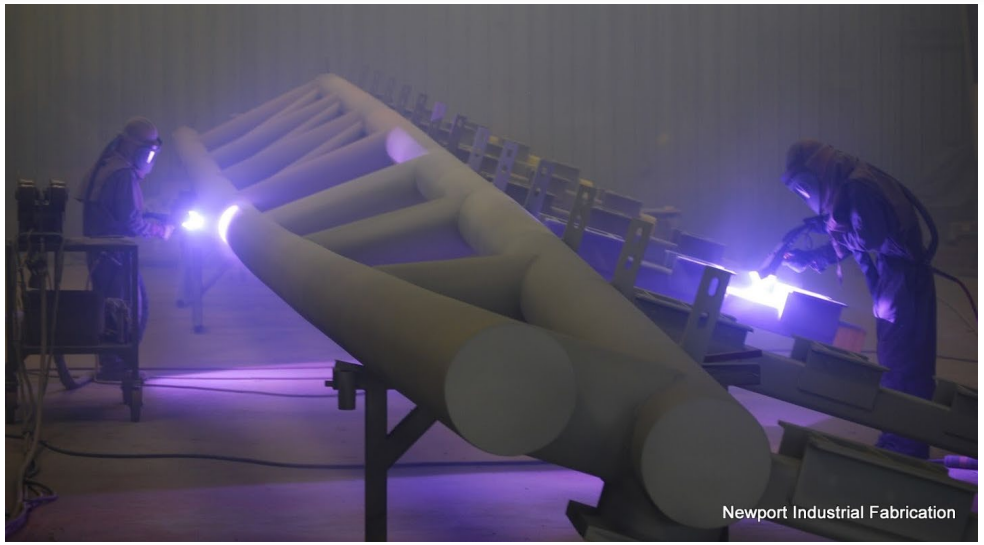
Fabrication: Newport Industrial Fabricators

Photos Courtesy of NIF

Photos Courtesy of NIF

Photos Courtesy of NIF

Coating: Newport Industrial Fabricators



Photos Courtesy of NIF, UNO


Nicolas Janberg & Structurea

Casting Connections – Improving Performance and Durability of Steel Bridges

Ronnie Medlock | High Steel Structures
Jennifer Anna Pazdon | CAST CONNEX
Matthew Conso | Massachusetts DOT

TRB Webinar
June 17, 2021

AASHTO/NSBA TG 17 – Steel Castings **NEW**

Chair: Jennifer Anna Pazdon, PE | Vice President, CAST CONNEX

Vice Chair: Jason Stith, PE, SE | Michael Baker

Mission

The mission of AASHTO/NSBA TG 17 is to develop and disseminate resources specific to the US steel bridge community to support the increased and effective use of castings in steel bridges.

Deliverables

To facilitate use of steel castings in bridges in the United States the steel bridge community need understand how to design with them, which will be a guide (G document), and how to specify them, which will be a specification (S document).

Fanny Appleton Pedestrian Bridge- Use of Cast Nodes

- Mathew Conso
- Metals Control Engineer
- Massachusetts Department of Transportation

Matthew Conso
MassDOT Metals Control Engineer

- Civil Engineer Degree – UNH ’06
- MBA – UMass Boston ’11
- CWI – Since 2018
- With MassDOT since 2006
  - Bridge Inspection
  - Bridge Design
  - Bridge Maintenance
  - Metals Control since 2011

Longfellow Bridge Project

- Rehab of 1900 Bridge
- Design Build Project
- $307.6 Million
- Staged Construction
- Carries Vehicular, Pedestrian, MBTA Subway
- 11 Spans
- Riveted Steel Rib Arch
- 1,800 feet long

Fanny Appleton Bridge

- Pedestrian Bridge
- 9 Spans
- Tubular Steel Arch
- 610’ Long
- Spans Storrow Drive
- Connects Boston to Esplanade

Fanny Appleton Bridge Proximity to Longfellow Bridge

Part of a Larger Initiative

- Vital Link to the Walking Ring around the Charles River Basin
- Includes replacement of:
  - Arthur Fiedler Bridge
  - Proposed 5 sided box beam bridge
  - North Bank Bridge

Architectural Design

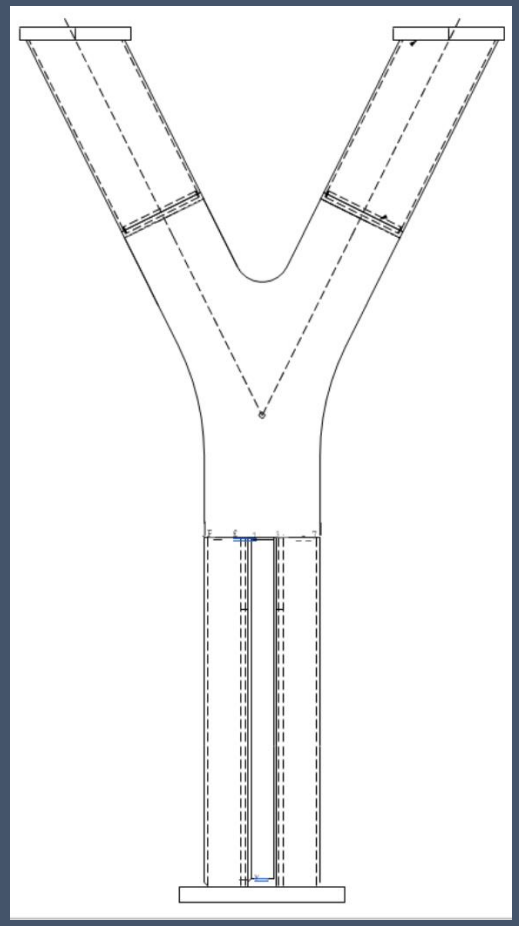
- Signature Bridge
- Compliment Longfellow Bridge as well as blend into green spaces
  - Offer views of the river
  - Replace existing bridge and upgrade to ADA
  - Allow emergency 4x4 access
- Main Span is 2 Tubular chords
- Chords flare out to full bridge width at center span
- 2 parallel box girders support cast-in-place concrete deck

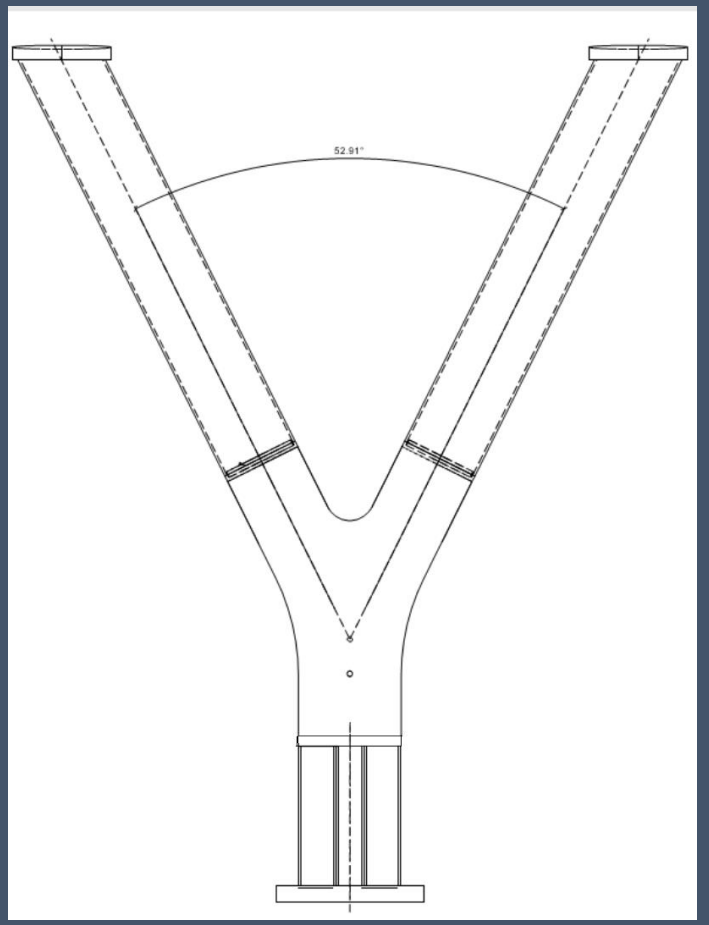
Pier Design

- Resemble Tree trunks and branches
- Flow with Main arch chord flare
- Originally intended to be Concrete

Pier Design

- 10 unique piers
- All use identical castings
- Divided into 3 parts for fabrication



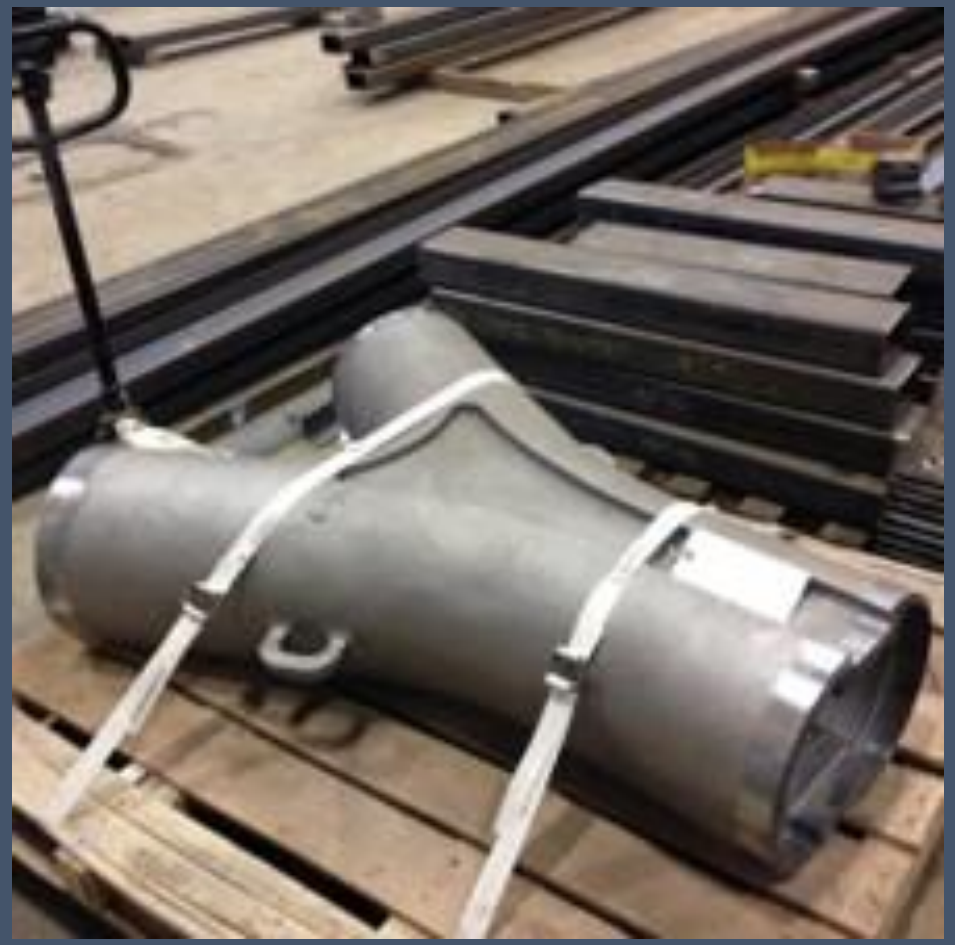


Pier Design

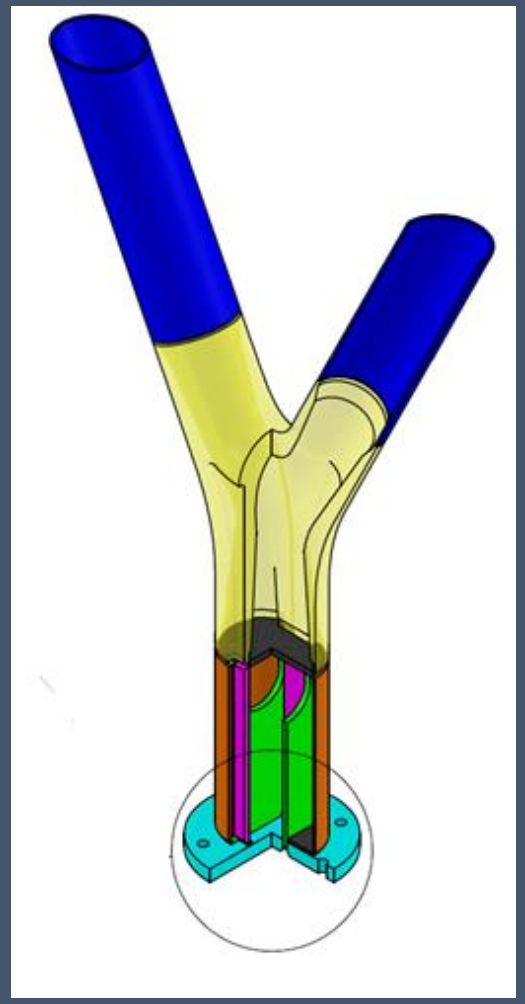
- Bottom built up section
  - Required internal stiffening
  - Unique design required multiple piece of steel to create architect's detail

Fabrication - Procurement

- Top & Bottom
  - Standard A500 Pipe and A709 Plate
  - Nothing different
- Middle Casting
  - Arrived palatized
  - Dimension checked
  - Material Conformance verified by QC and QA



Fabrication – Pier Segments



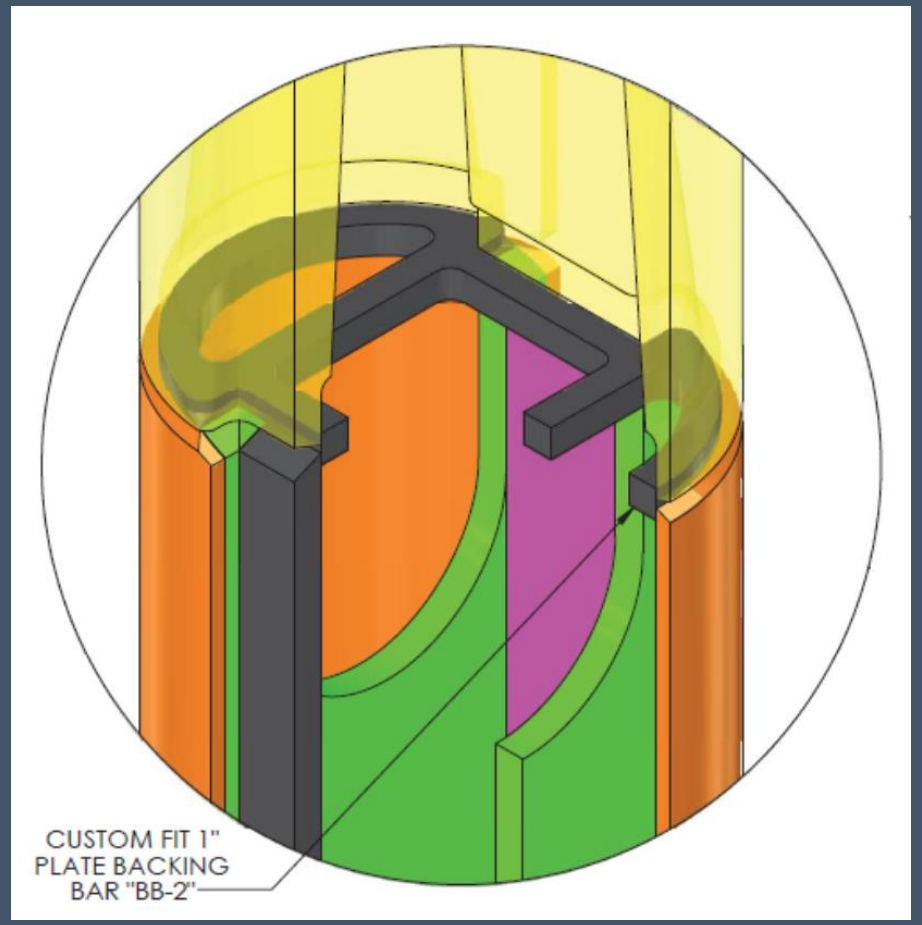
- 3 Segments of Fabrication
  - Top - A500 Pipe
  - Middle – Casting
  - Bottom – Built up member
    - A500
    - A709

Fabrication - Welding

- Combination of AWS D1.1 and D1.5 Welding Codes
- PQR verification tests
  - A500 to Casting
  - A709 to Casting
  - A500 to A709
  - A709 to A709
- All done using FCAW
- WPS Weld procedures
  - Multiple full penetration welds using backing bars
  - Multiple fillet
  - Preheats increased above standard code values out of caution

Fabrication

- A500 to Casting
  - Straight forward
    - Minor adjustments for fit up
    - Use of off the shelf backing ring
    - Single V groove joint
- Casting to built-up base
  - Fairly Straight Forward
    - Single V groove joint
    - Customized backing ring required



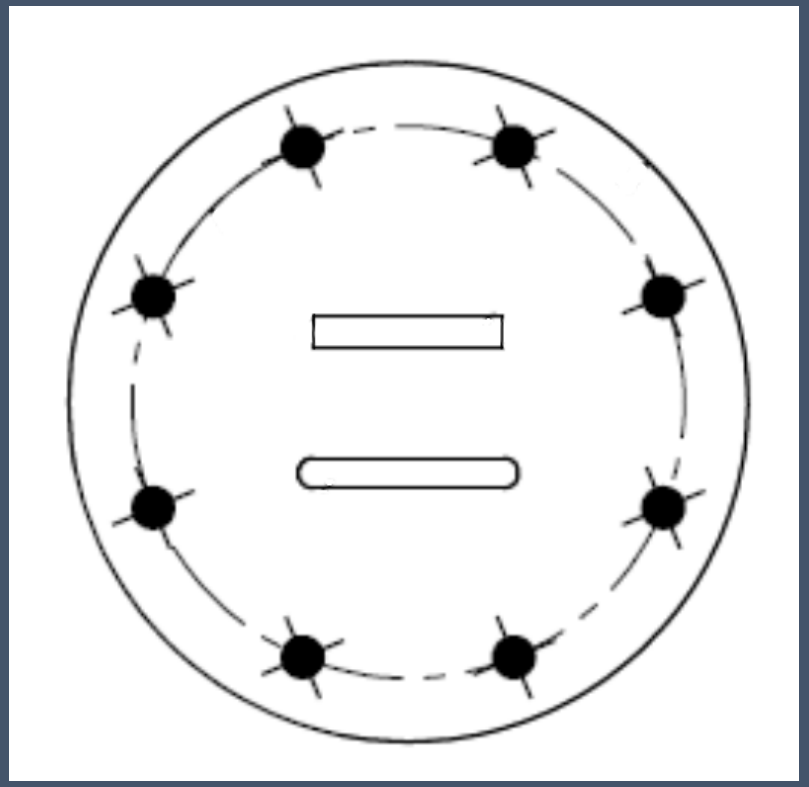
Fabrication

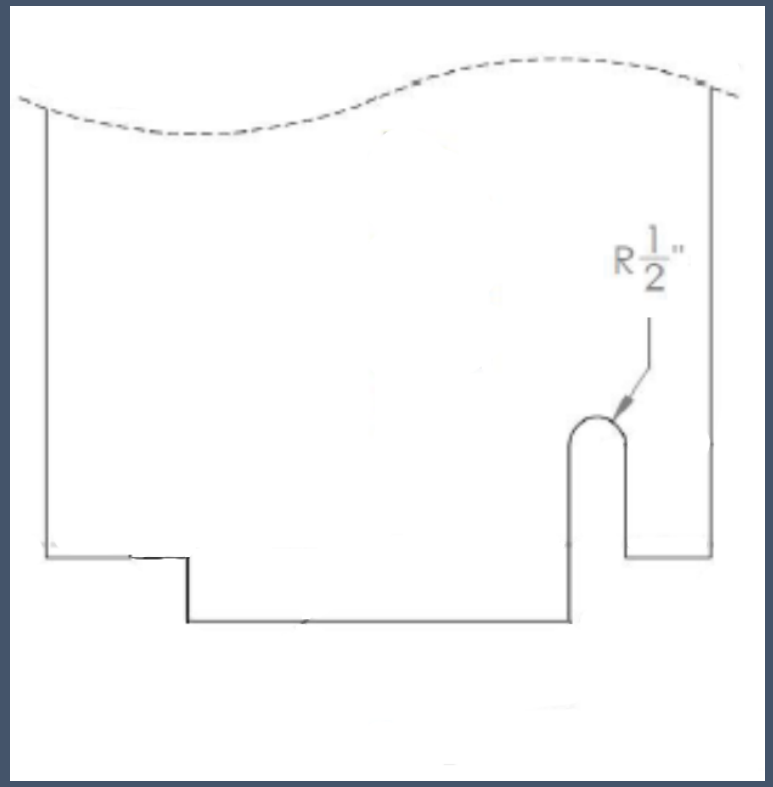
- Built up bottom
  - Multiple pieces required to match casting geometry
- Ran into issues between design and welding codes
  - Reentrant corners
  - Plug welding
  - Backing bars

Fabrication- Reentrant Corners

Original design

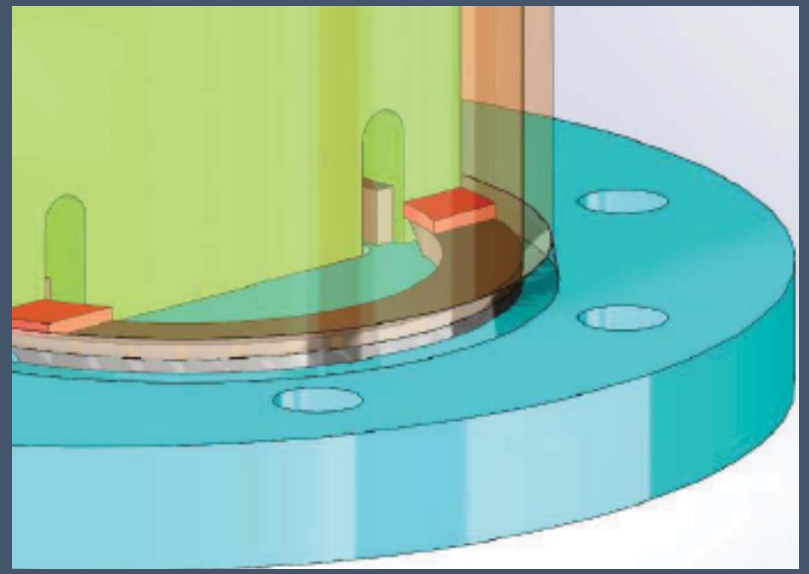
- **Baseplate had square slots**
- **Interior stiffener legs had 90° cutouts**





Solution

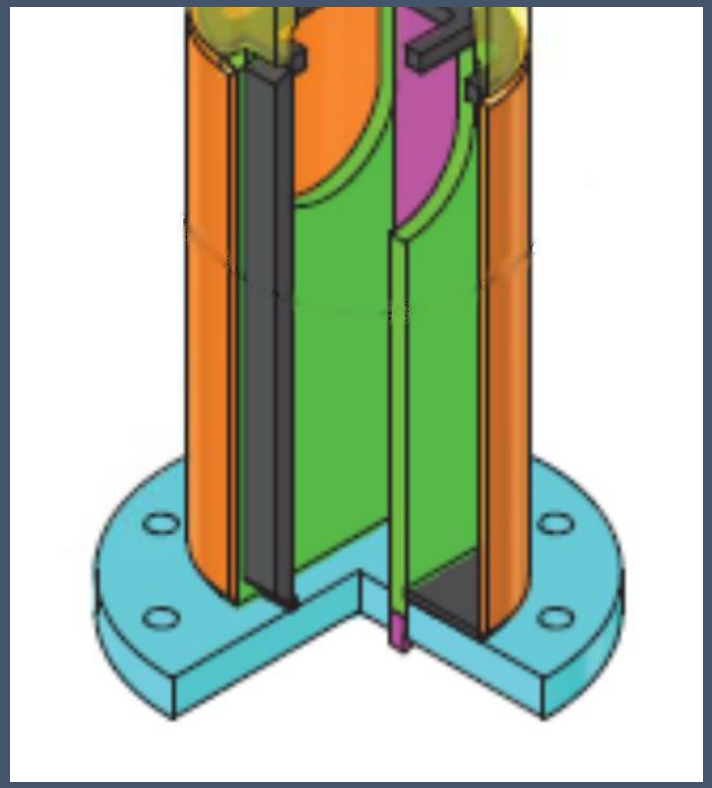
- **Add half circle cutouts at end of slots**
- **90° cutouts to incorporate a half circle cutout**



Fabrication – Eliminating Plug Welds

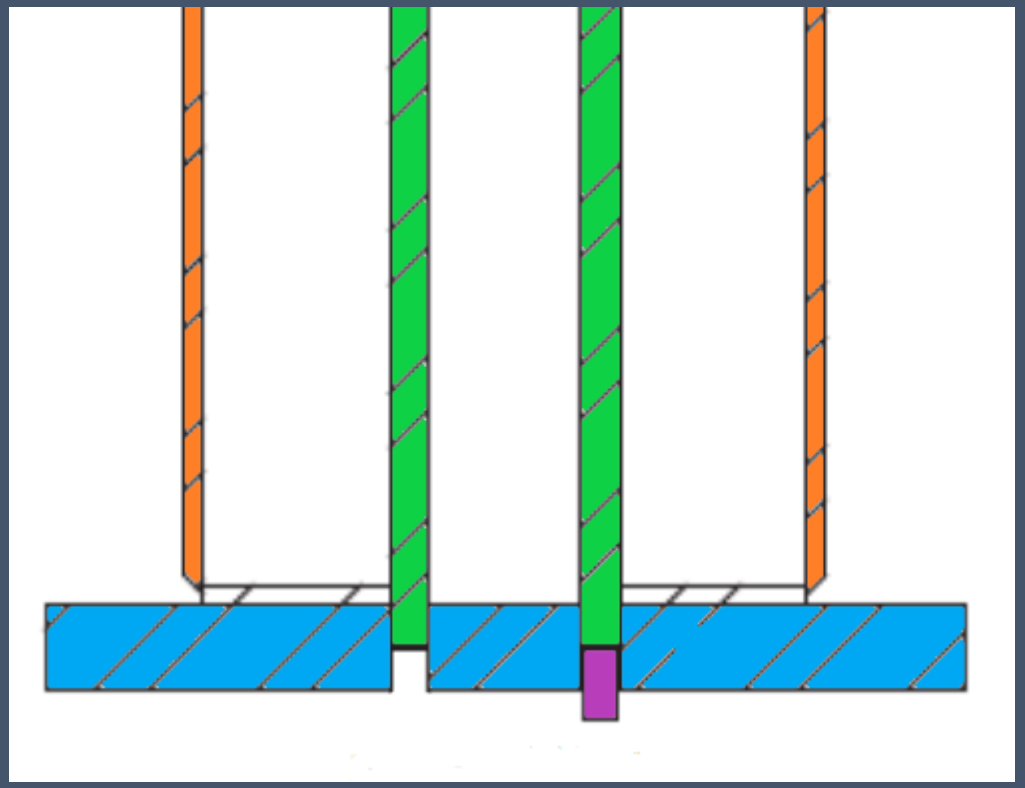
Original design

- **Fillet weld stiffener to baseplate**
- **Fill void with filler metal**



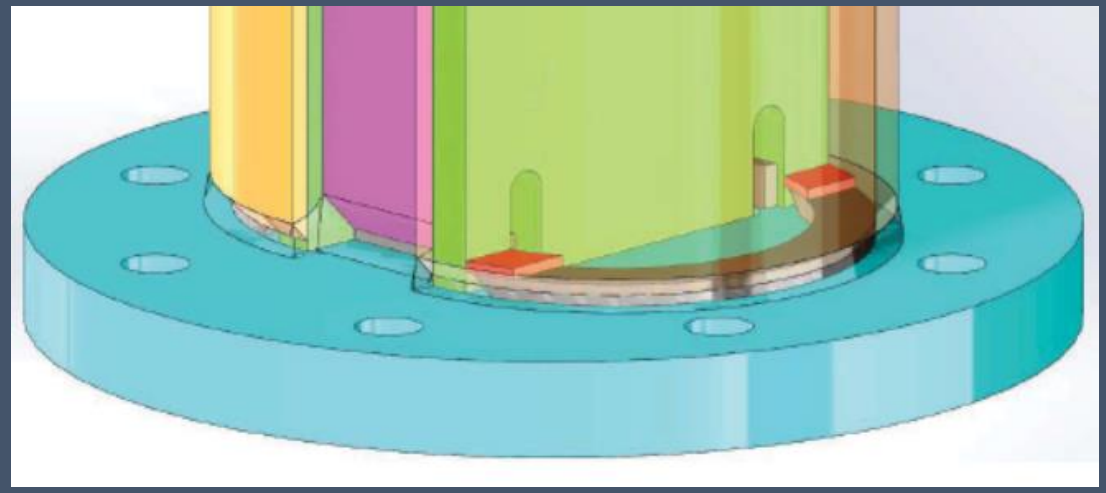
Solution

- **CJP additional plate to extend stiffener past baseplate**
- **Fillet weld extension plate to baseplate**



Fabrication – Backing Bar Usage

- Original Design
  - Semicircular backing for A500 would abut internal stiffeners
  - CJP weld would continue across stiffener and backing interface utilizing stiffener as backing



- Solution
  - Use a second backing plate to fully fuse original backing to internal stiffener
  - Weld CJP as originally planned

Erection

Erection

Erection

Finished Result

Finished Result

Take Away

- Castings – Solution to difficult designs in steel
- When using castings as a component involve all parties in the conversation from the beginning
- Still new to fabricators and designers
- Paper designs ≠ work in reality
- Samples of casting will need to be specially requested for weld qualification test

Bridge Name?

Fanny Appleton

Henry Wadsworth Longfellow

Today's Panelists

#TRBWebinar

Moderated by:
Ronnie Medlock,
High Steel Structures

Jennifer Pazdon,
Cast Connex

Matthew Conso,
Massachusetts DOT

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