Casting the Future

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In Civil Engineering, a **gerberette** is a mobile system cast steel for the overall stability of a structure by establishing a connection between a post and beam . . Each piece is 8 m long and weighs 10 tons.

http://fr.wikipedia.org/wiki/Gerberette

http://www.greatbuildings.com/buildings/Javits_Convention_Center.html

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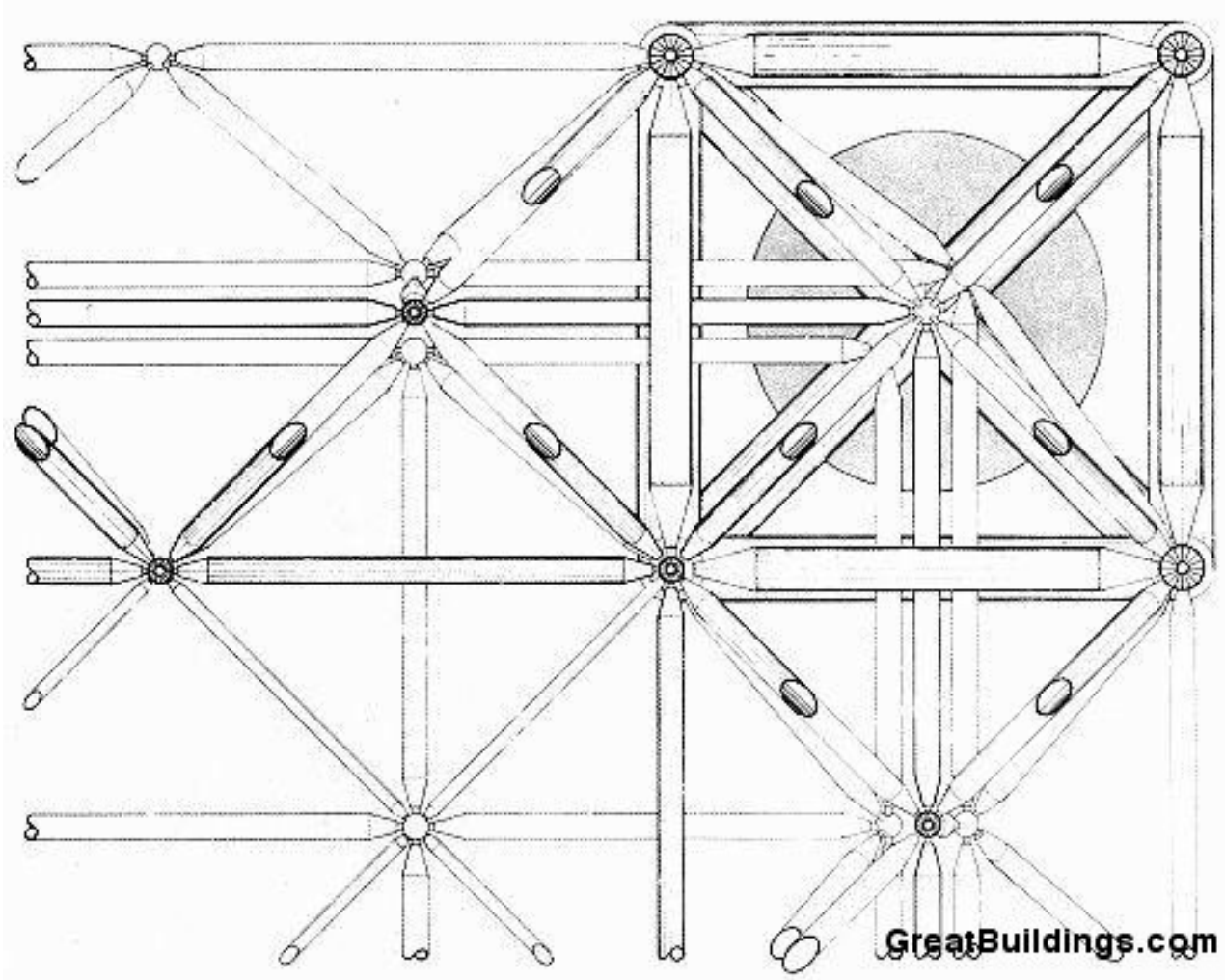


However, Freed's futuristic space frame is surprisingly well preserved, said Tian-Fang Jing, a principal of Weidlinger Associates (structural engineers on both the original job and the renovation). Fast-track scheduling left the original supplier of the casting nodes unable to maintain quality control, but cracked ones were later replaced by Japanese forged-steel nodes, which remain sound

http://archpaper.com/news/articles.asp?id=5990#.VRAdJY1FDX4

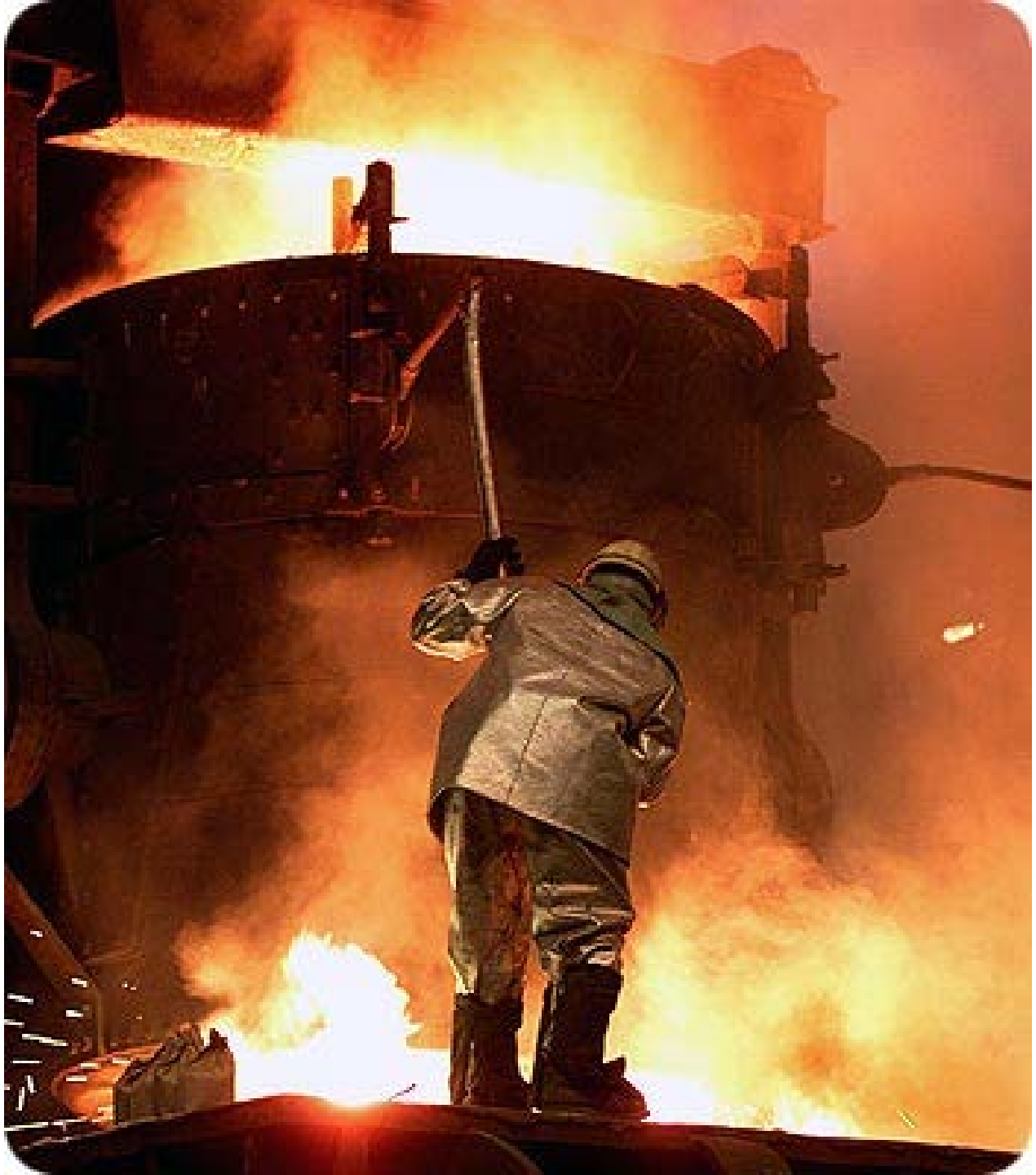
http://www.enclos.com/service-and-technology/technology/structural-glass-facades/other-considerations/cables-rods-castings

The casting of structural components demand a high level expertise in both the design and fabrication process. Cast nodes for the space frame structure on the Jacob K. Javits Convention Center in New York, for example, were famously discovered during construction to contain cracks, requiring the disassembly of nearly half of its structure and a project delay of almost two years. An intimate knowledge of the materials and processes of casting is critical to the development and implementation of a custom cast structural component. Among components appropriate for casting are spiders and glass-fixing devices, spacer struts and anchor assemblies. Various options for material and finish must be considered depending upon component design application.

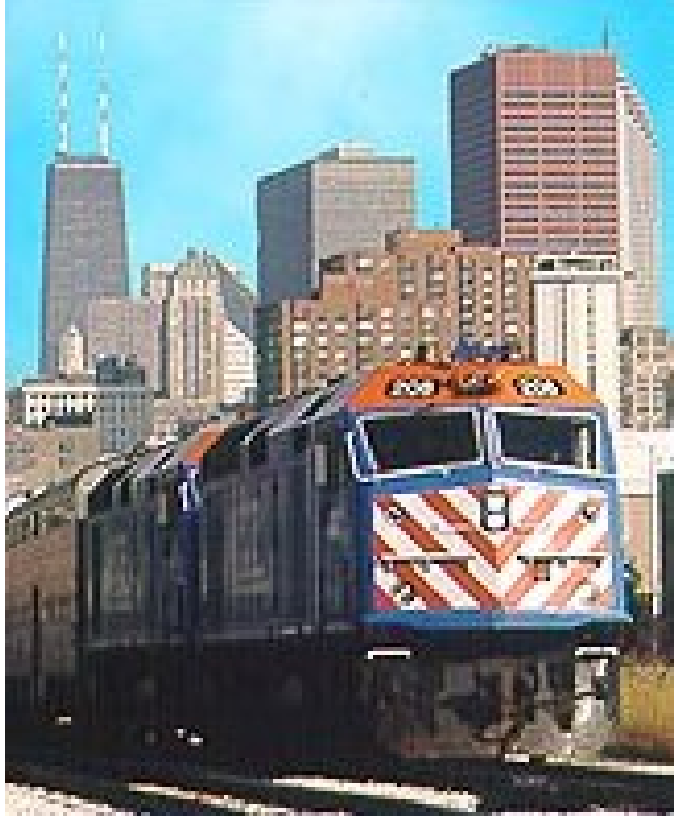

West Tower Saddle Castings
West Splay Castings
Cable Shoe Castings
East Tower Saddle Castings
Cable Band Castings
Cast Zinc “Jewels”
East Splay Castings
Cable Shoe Castings

All steel is cast!

Most steel is
made from scrap
melted in an
Electric Arc Furnace.



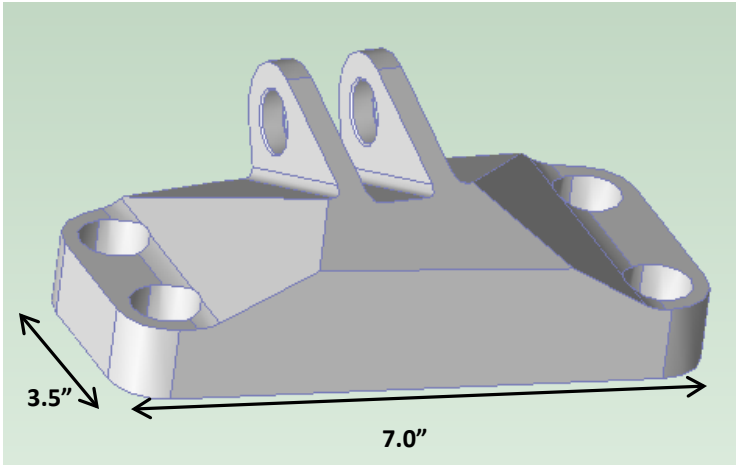
Steel castings are capable of high performance in tough conditions.

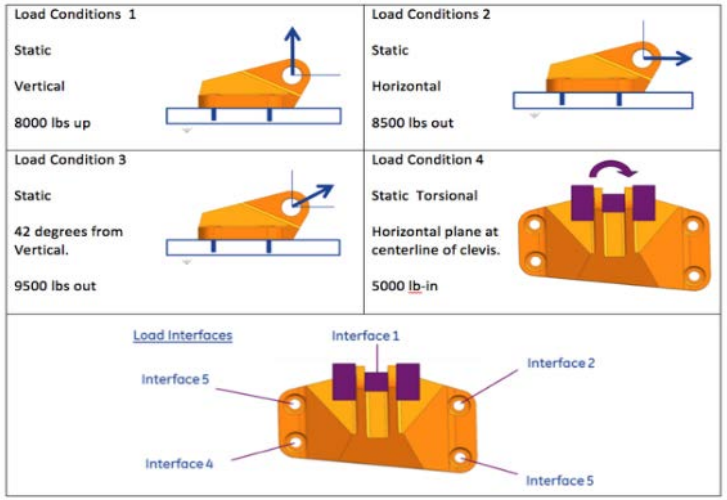


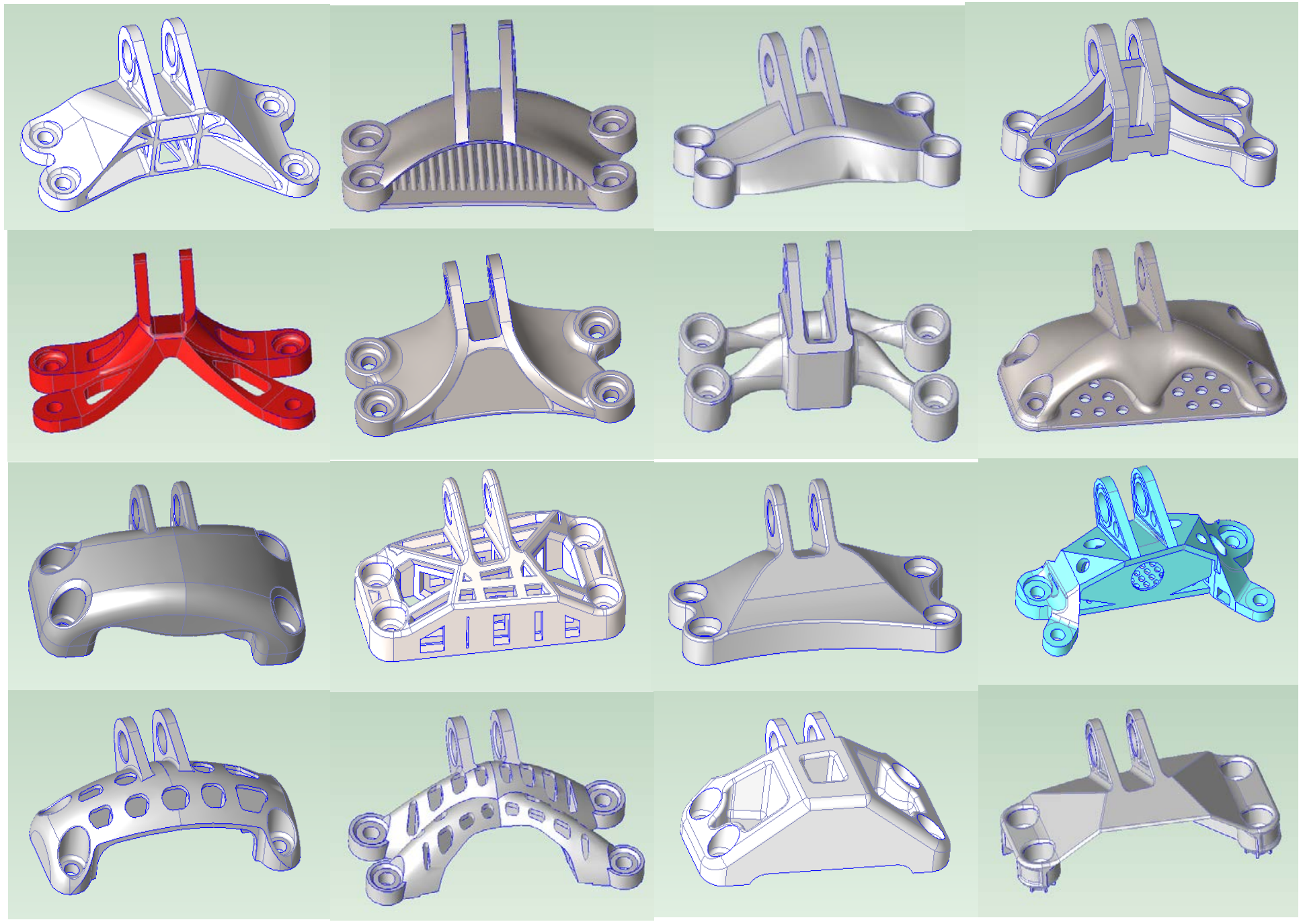
Steel Castings in Red

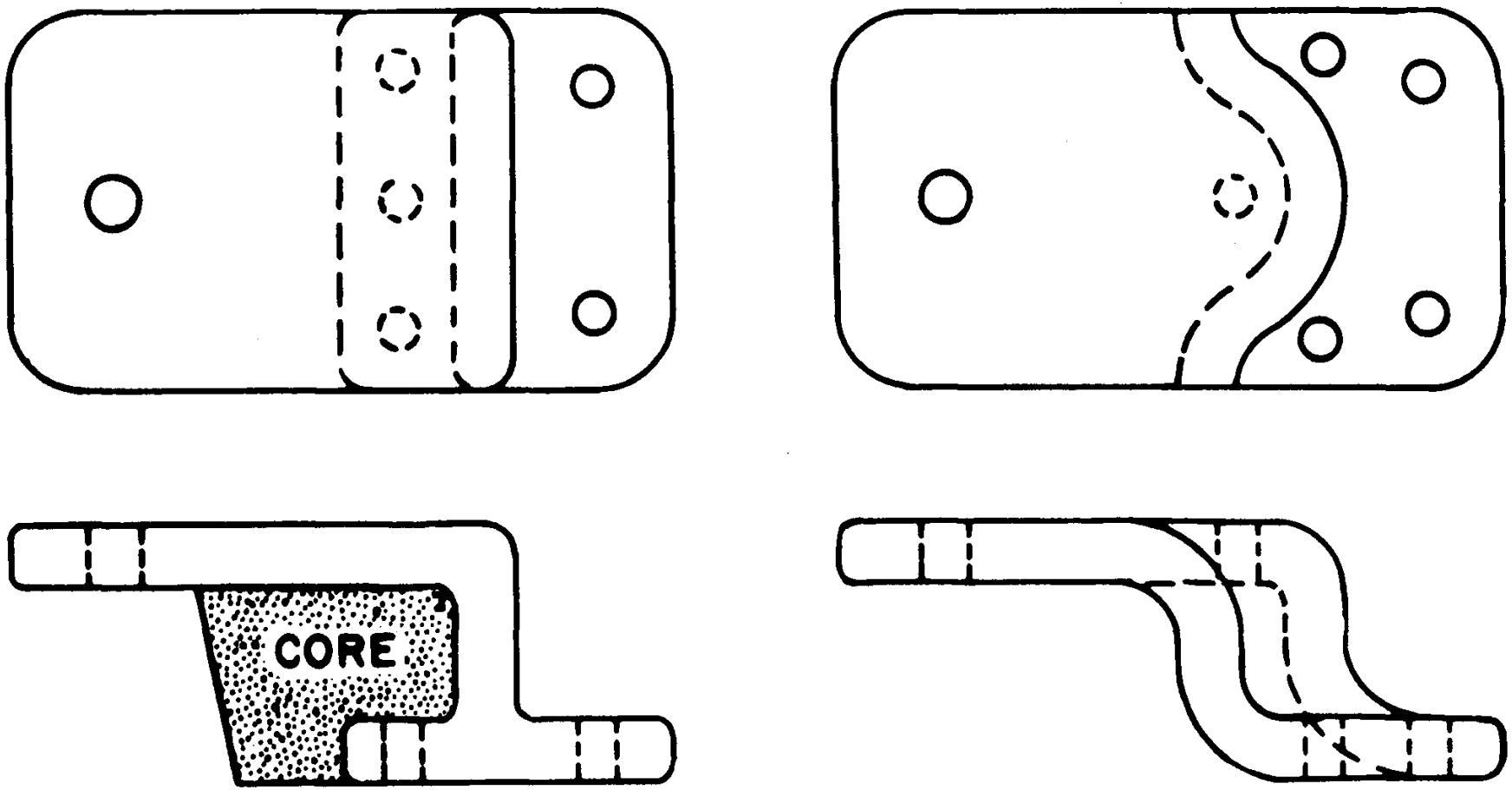
Example for New Casting Model

- GE Bracket Design Contest
- Contest was for designs to be built by additive manufacturing
- Template design provided, designers must satisfy loading and dimensional constraints
- Provided a case study for the castability model

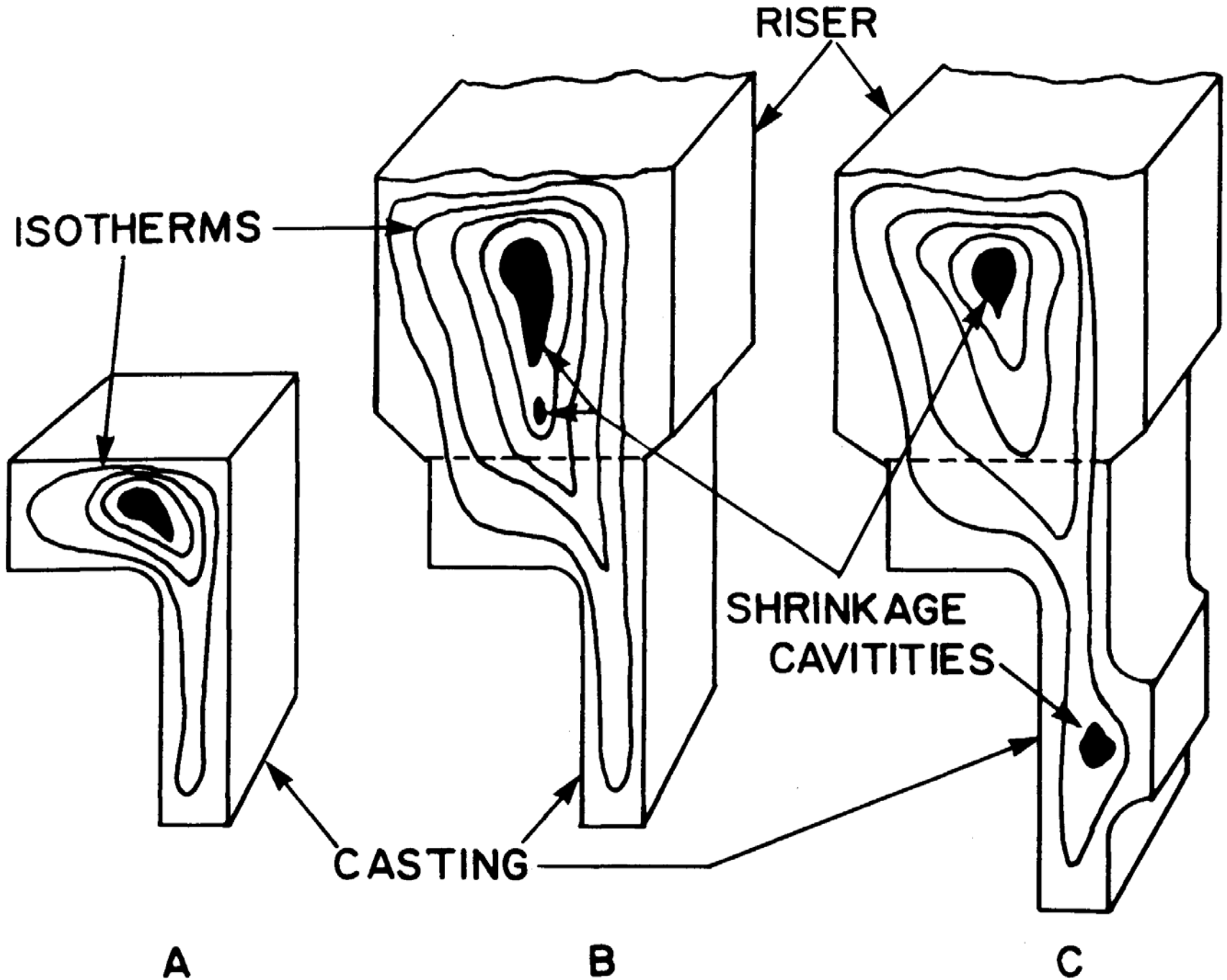




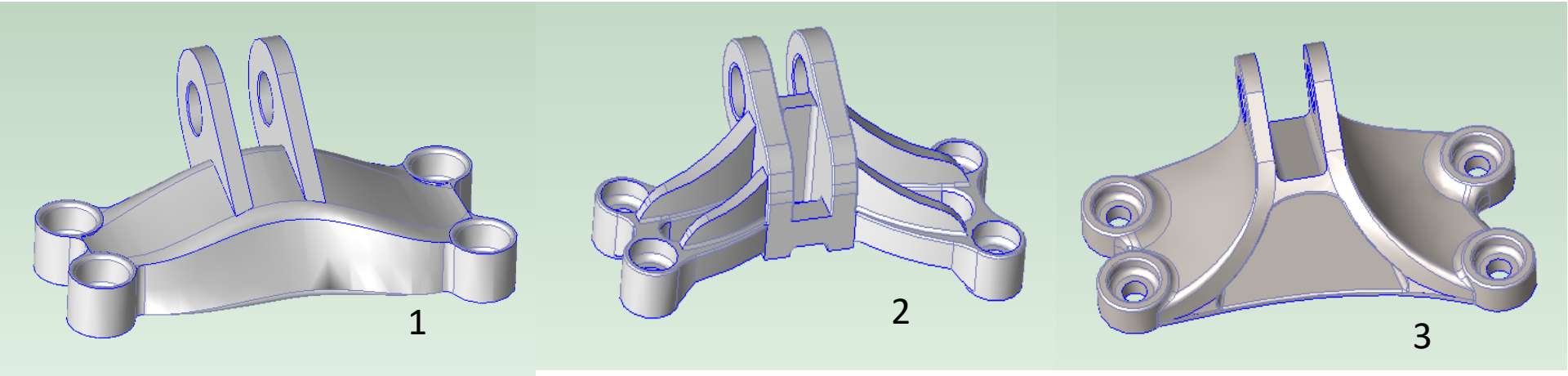




Using a nontraditional geometry like the “omega” improves casting and performance.


RISER
ISOTHERMS
SHRINKAGE
CAVITITIES
CASTING
A
B
C

Model Result Winners

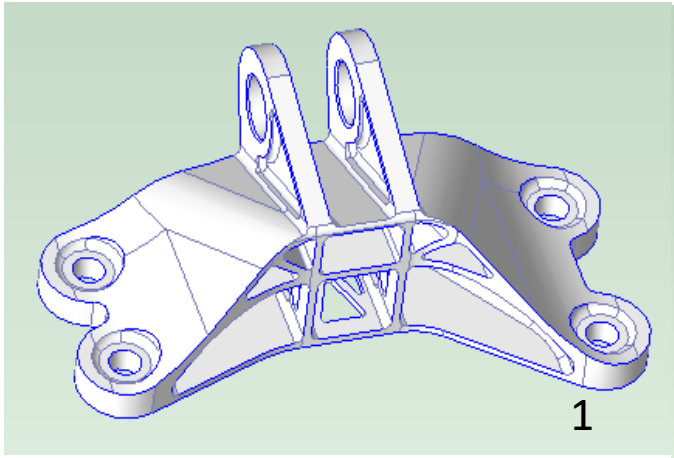


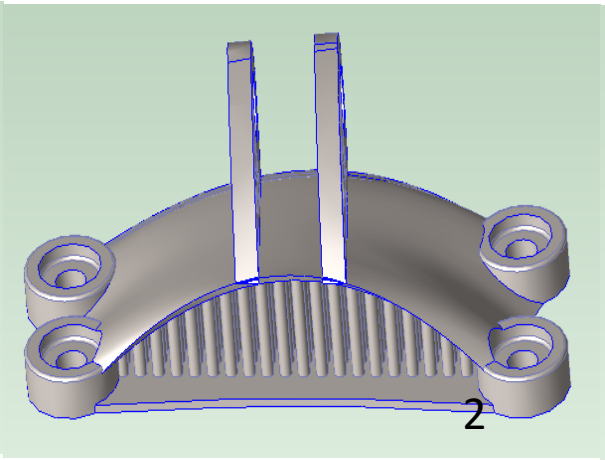
1) GE Engine Bracket
   - 2 risers, 2 cores
   - Total cost = $7.13

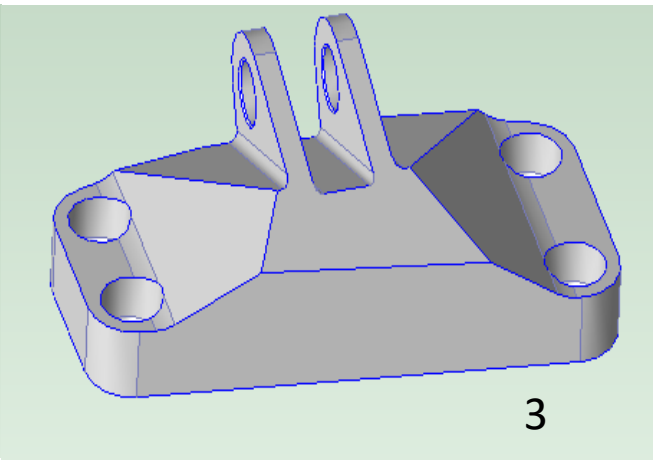
2) Ti-bracket
   - 3 risers, 2 cores
   - Total cost = $8.03

3) Madfrog
   - 2 risers, 3 cores
   - Total cost = $8.07

Model Result Losers







1) GE JEB V1

- 12 risers
- 13 cores
- Total Cost = $23.83

2) Part3

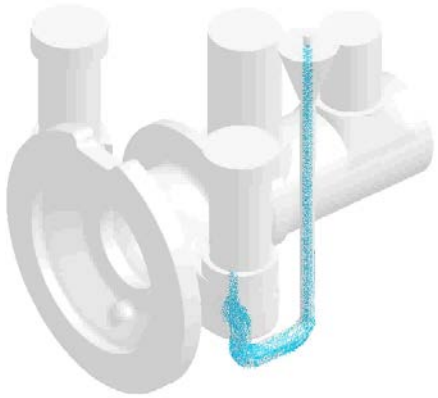
- 21 risers
- 2 cores
- Total Cost = $24.04

3) Engine Bracket

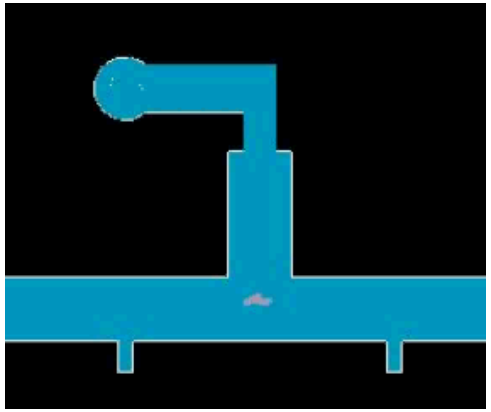
- 12 risers
- 16 cores
- Total Cost = $27.98

Modeling Solidification and Casting Manufacturability

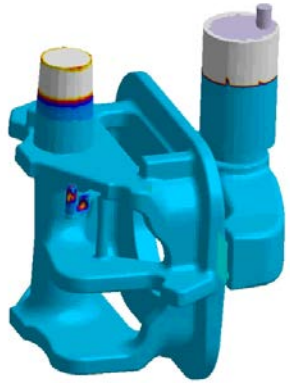
Inclusions



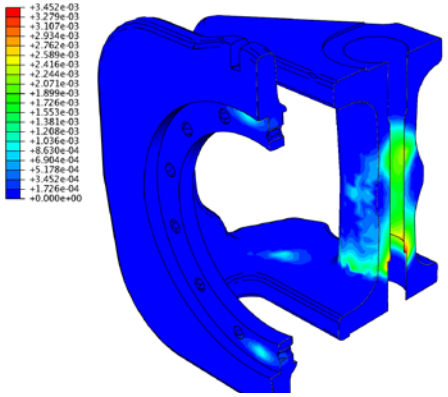
Cracks/Hot Tears



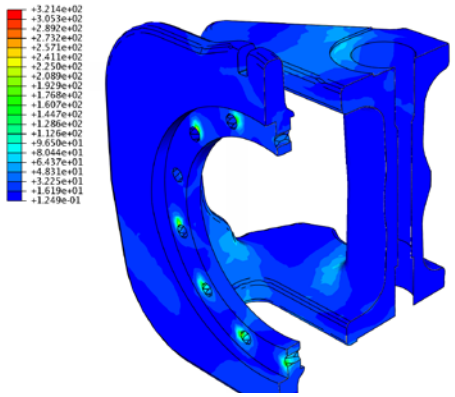
Porosity



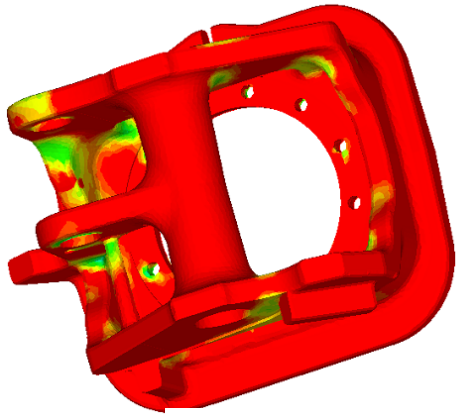
- Develop computer models to predict casting performance:
- Combine modeling of casting process and stress analysis.



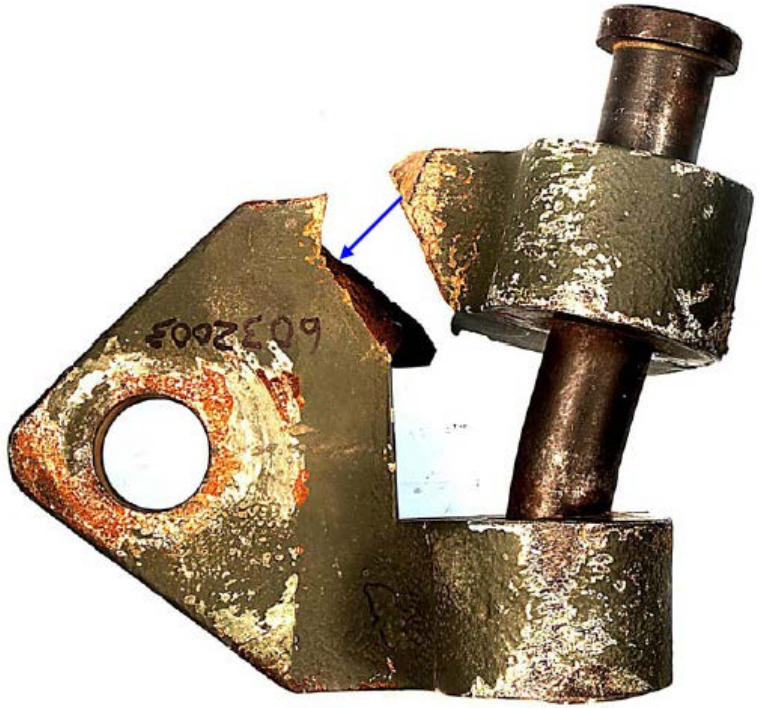
Porosity Fraction

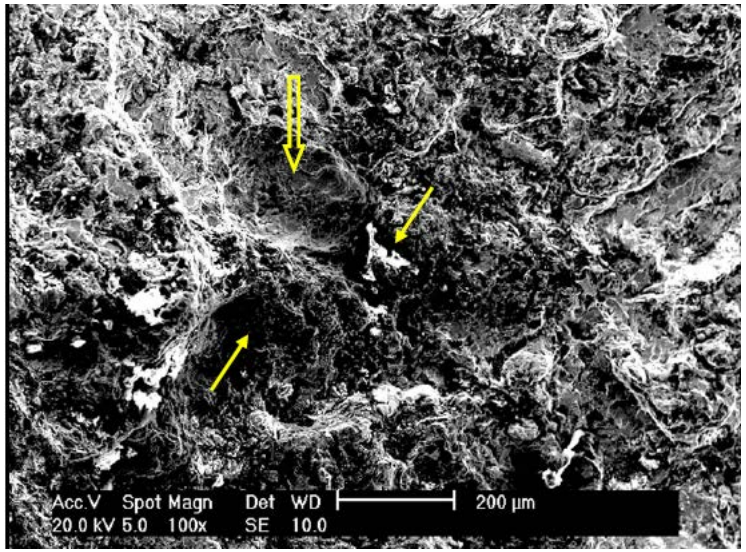


Von Mises Stress (MPa)



Fatigue Life





Performance Limitations

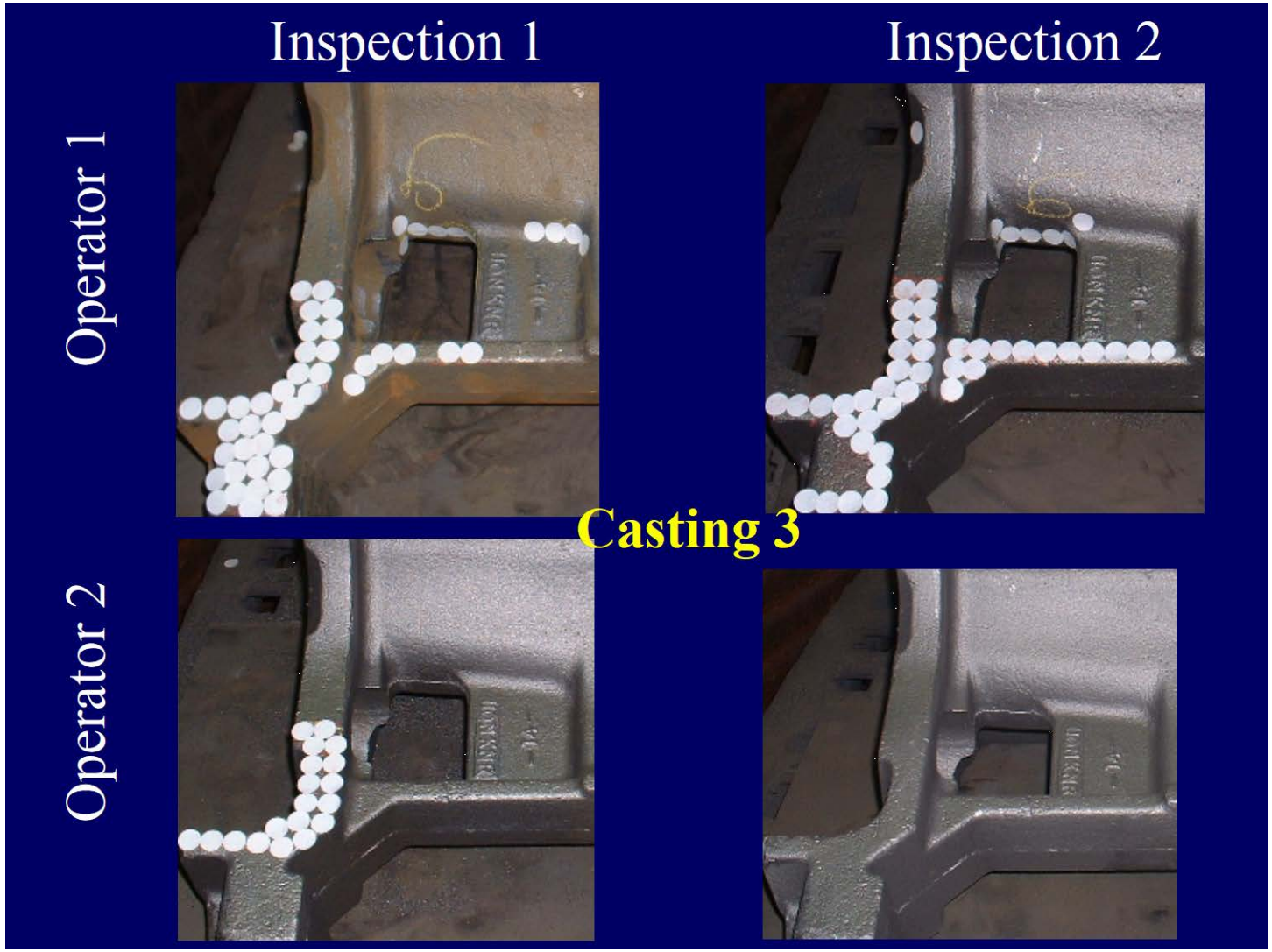
- All manufacturing processes have limits
- New design failures likely inadequate design
- Field failures likely misuse/poor manufacture
- Failure occurs at the most heavily loaded section at the largest performance-limiting feature, BUT failure is not due to defect
- Use manufacturing process to enhance performance

Visual Inspection and non-destructive testing (NDT)

These are all based on a personal evaluation and are subjective and variable.

Picture shows same casting evaluated twice by two inspectors. This shows the variation in visual inspection. The same variation is typical of NDT.

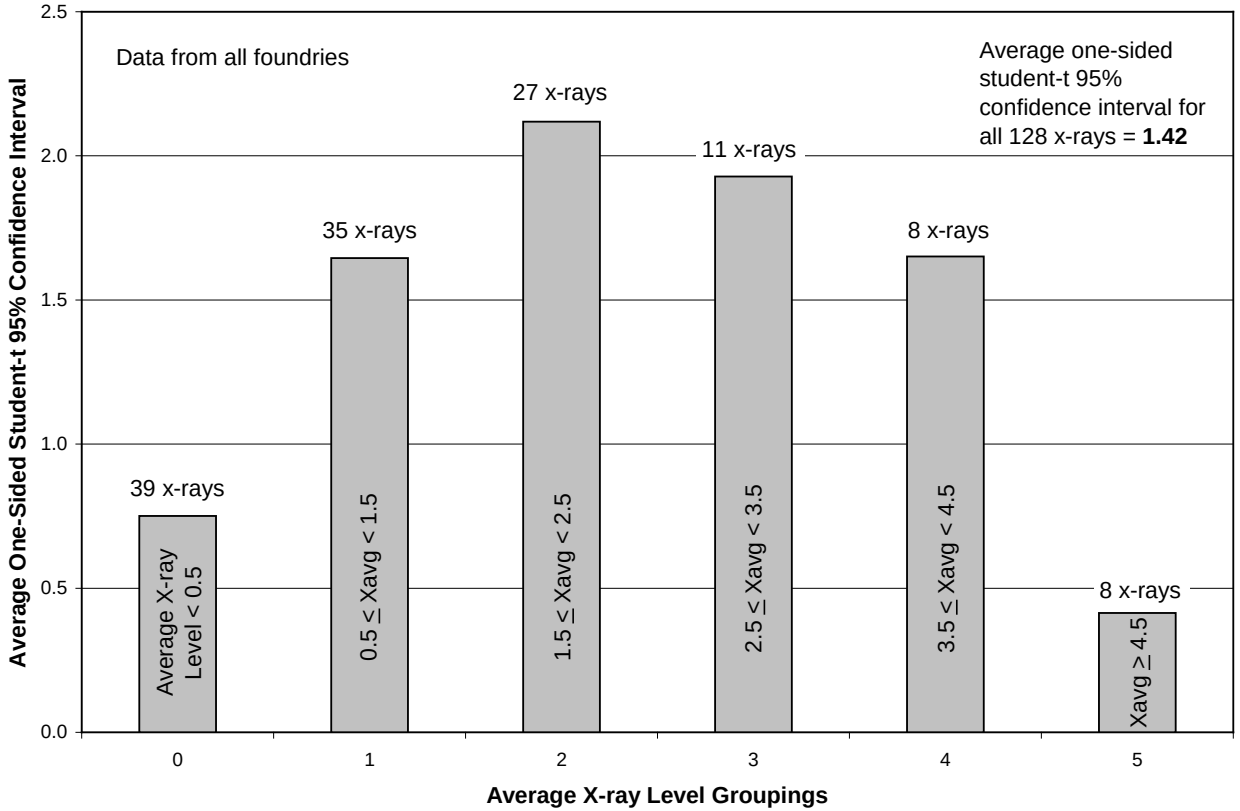
The standards are based on the expected quality of the steel casting. They are not related to performance.



A radiographic evaluation of 3 could just as well be evaluated as a 2 or 4.

Variation in the Ratings:

Confidence intervals of x-ray level ratings grouped by average x-ray level



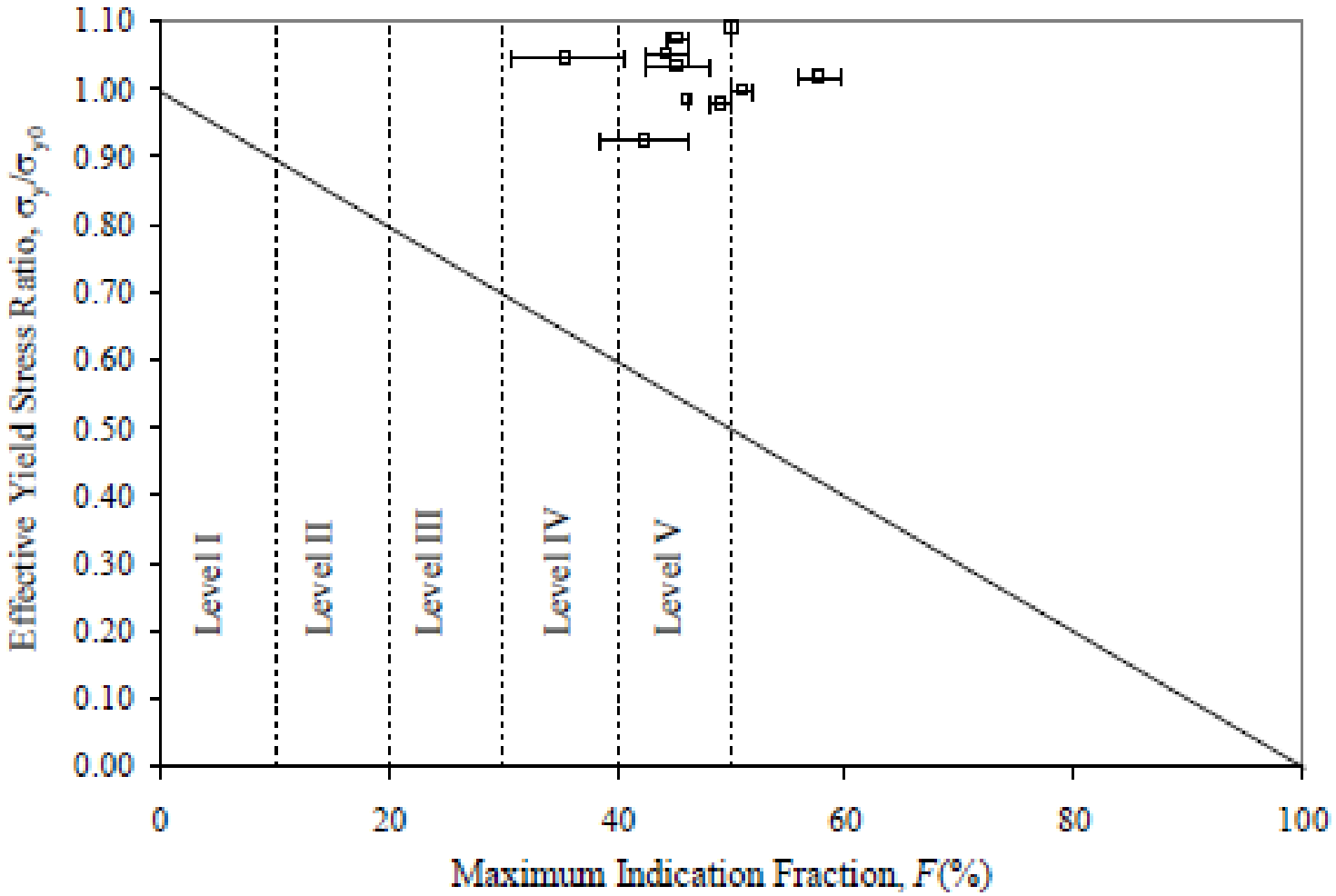


Figure 27. Effective yield stress ratio from tensile testing versus the maximum indication fraction data F compared with the proposed relationship between effective stiffness and the maximum indication fraction.

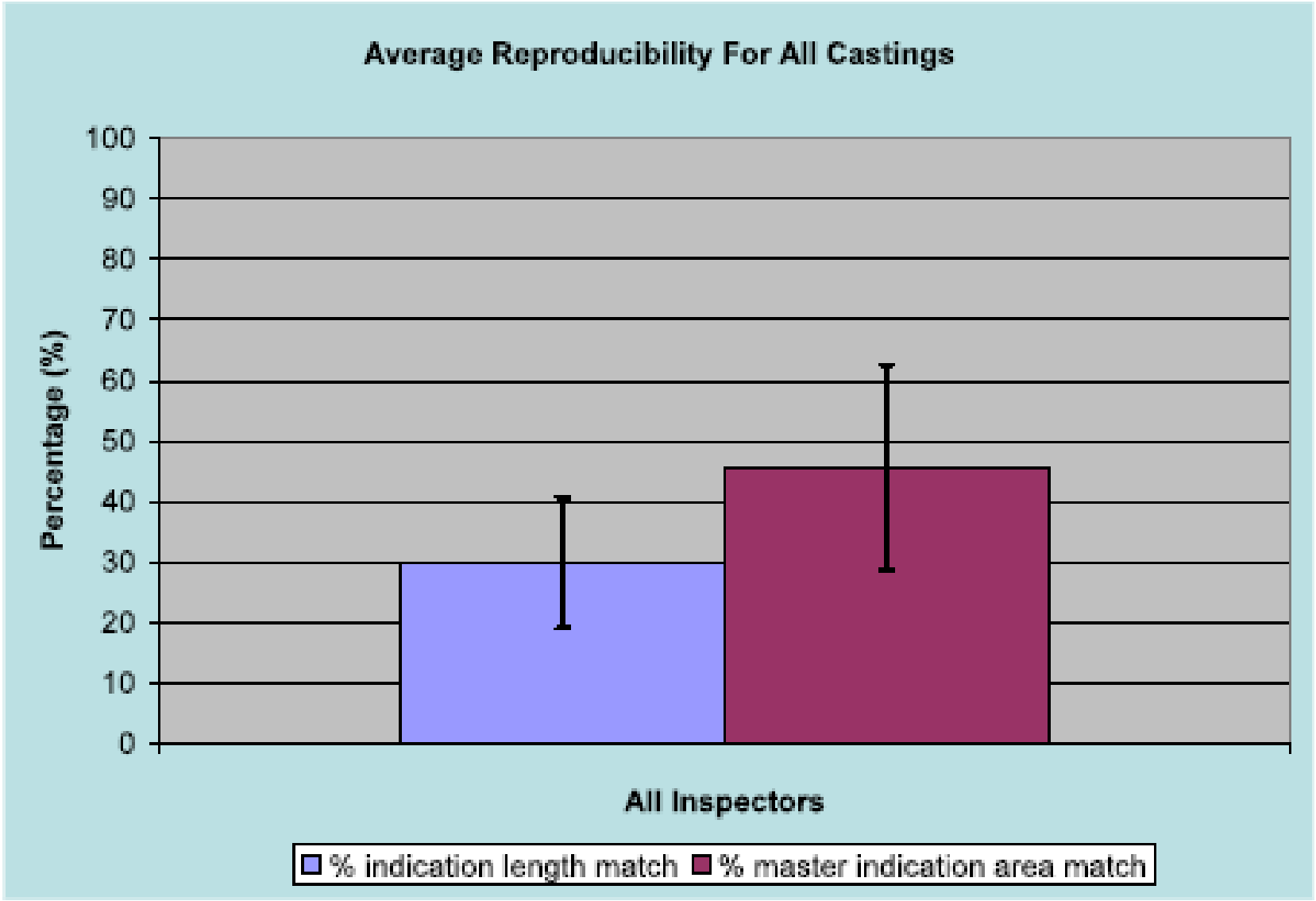
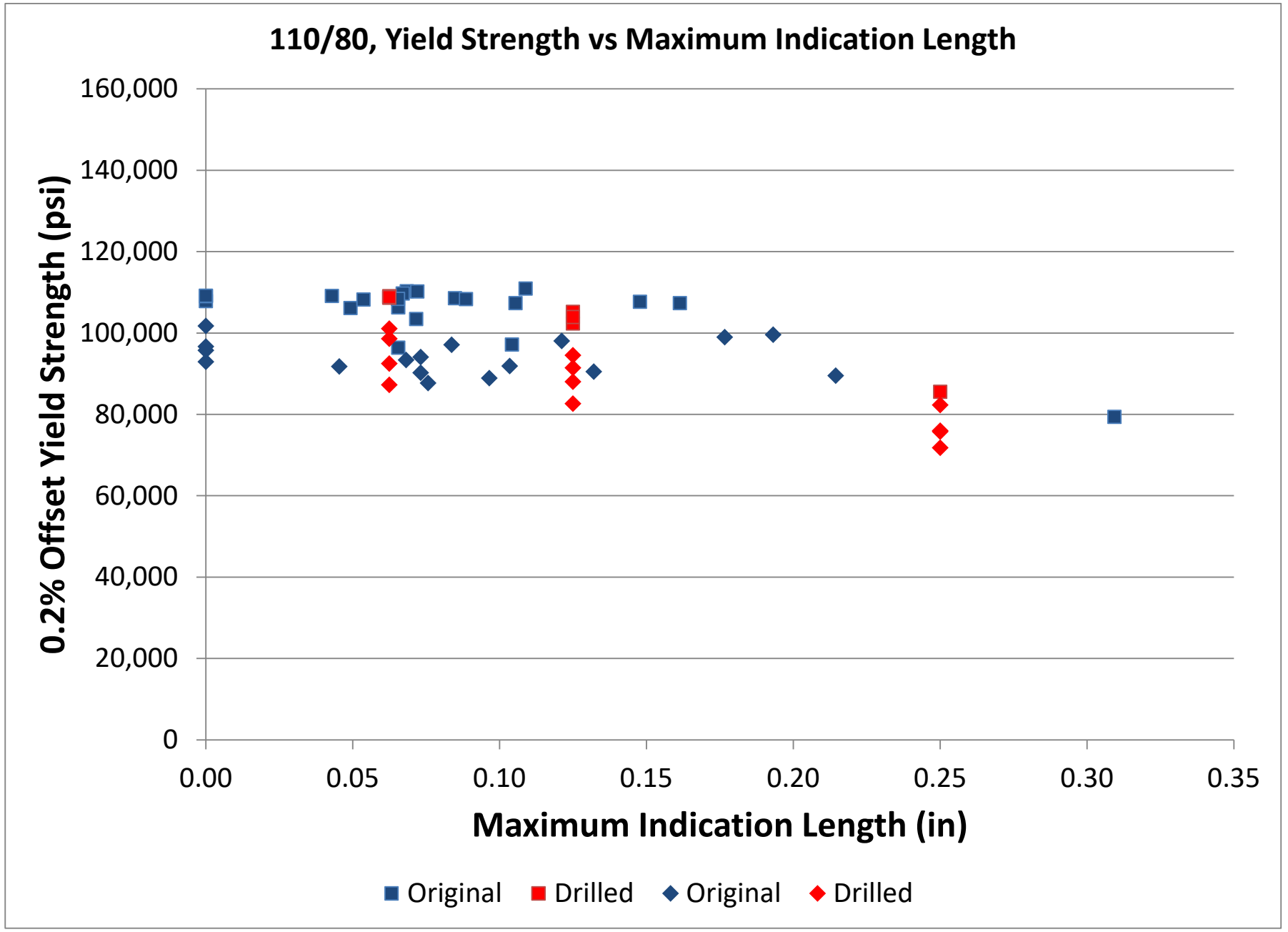


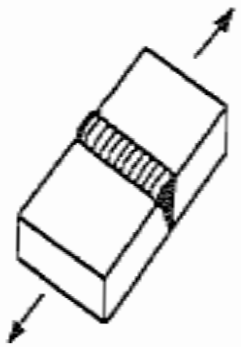
Figure 24. Average reproducibility for all castings and for all inspectors for MP R&R Foundry 2.


110/80, Yield Strength vs Maximum Indication Length
0.2% Offset Yield Strength (psi)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Maximum Indication Length (in)
Original
Drilled
Original
Drilled

Welding is part of the Casting Production Process

- Welding on ASTM grades is restricted and must conform to ASTM A488 according to ASTM A703 or A781
- Weld procedures must be developed for all grades including testing by either the ASTM A488 or ASME Section 9
- All welders must demonstrate their qualifications to the procedures developed.
- ASME Section 9 for pressure vessel applications does not make a distinction between cast, rolled or forged steels and the same composition.
- Need to add cast grades to the AWS pre-qualified WPSs

“Fatigue Design of Welded Joints and Components” - IIW

216		Transverse butt welds welded from one side without backing bar, full penetration	
		root controlled by NDT	71
		no NDT	45

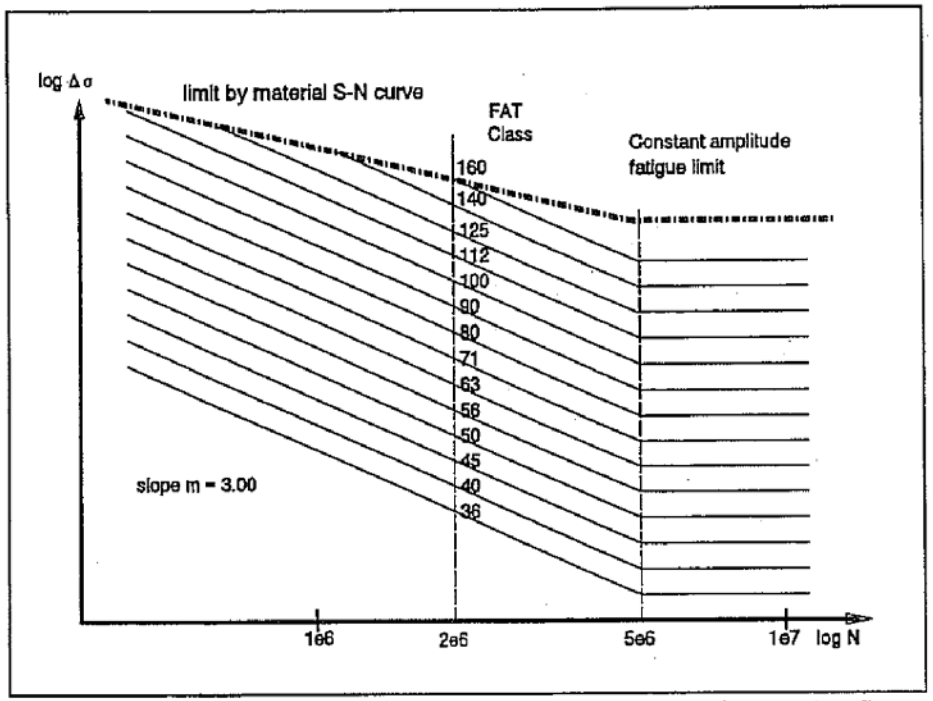
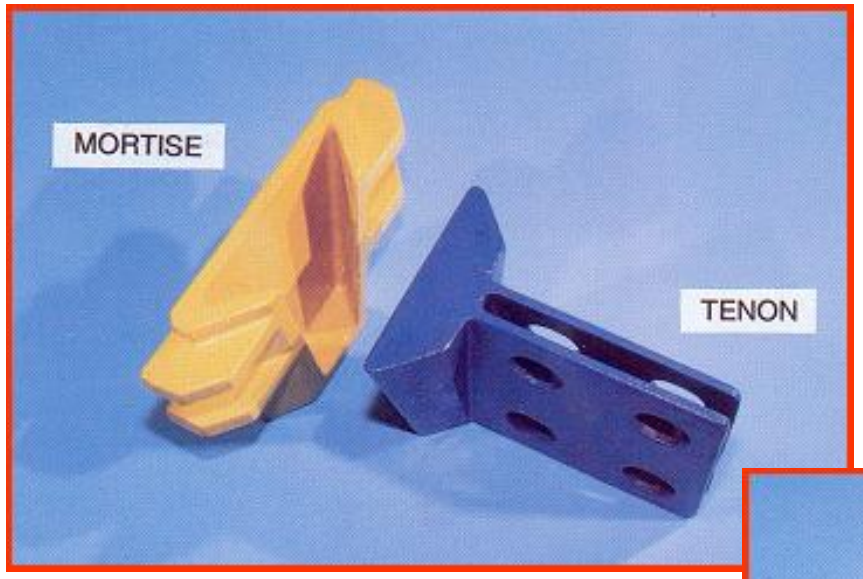
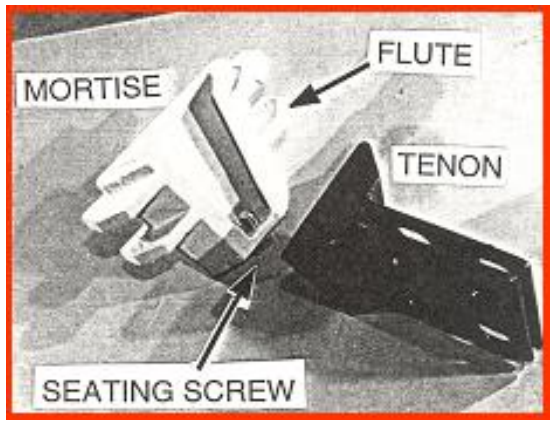
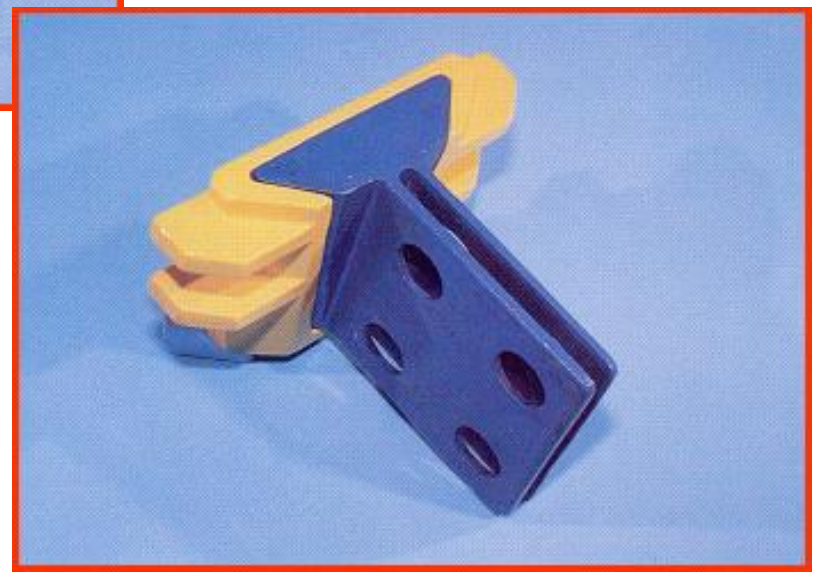


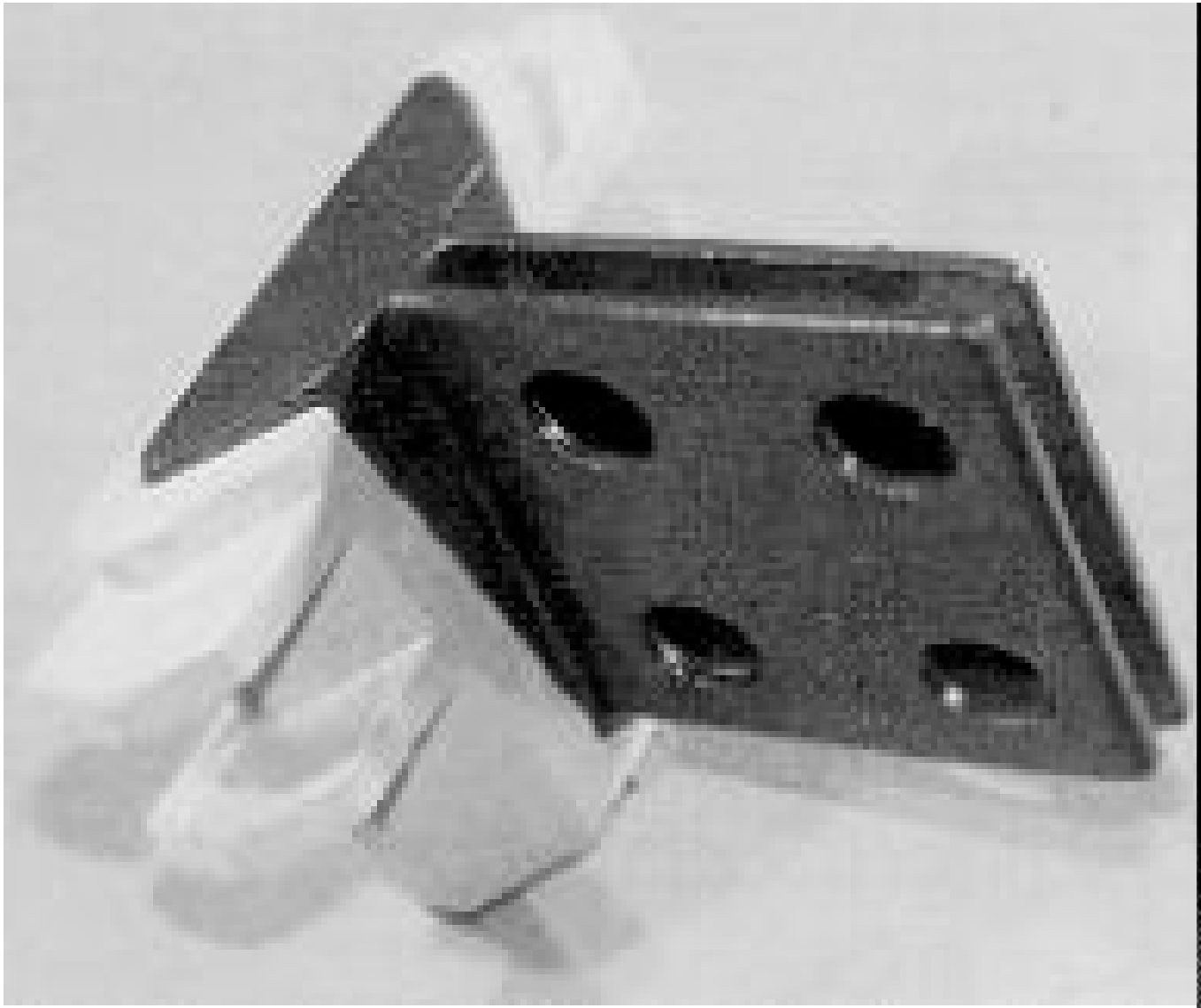
Fig. (3.2)-1: Fatigue resistance S-N curves for **m=3.00**, normal stress (steel)

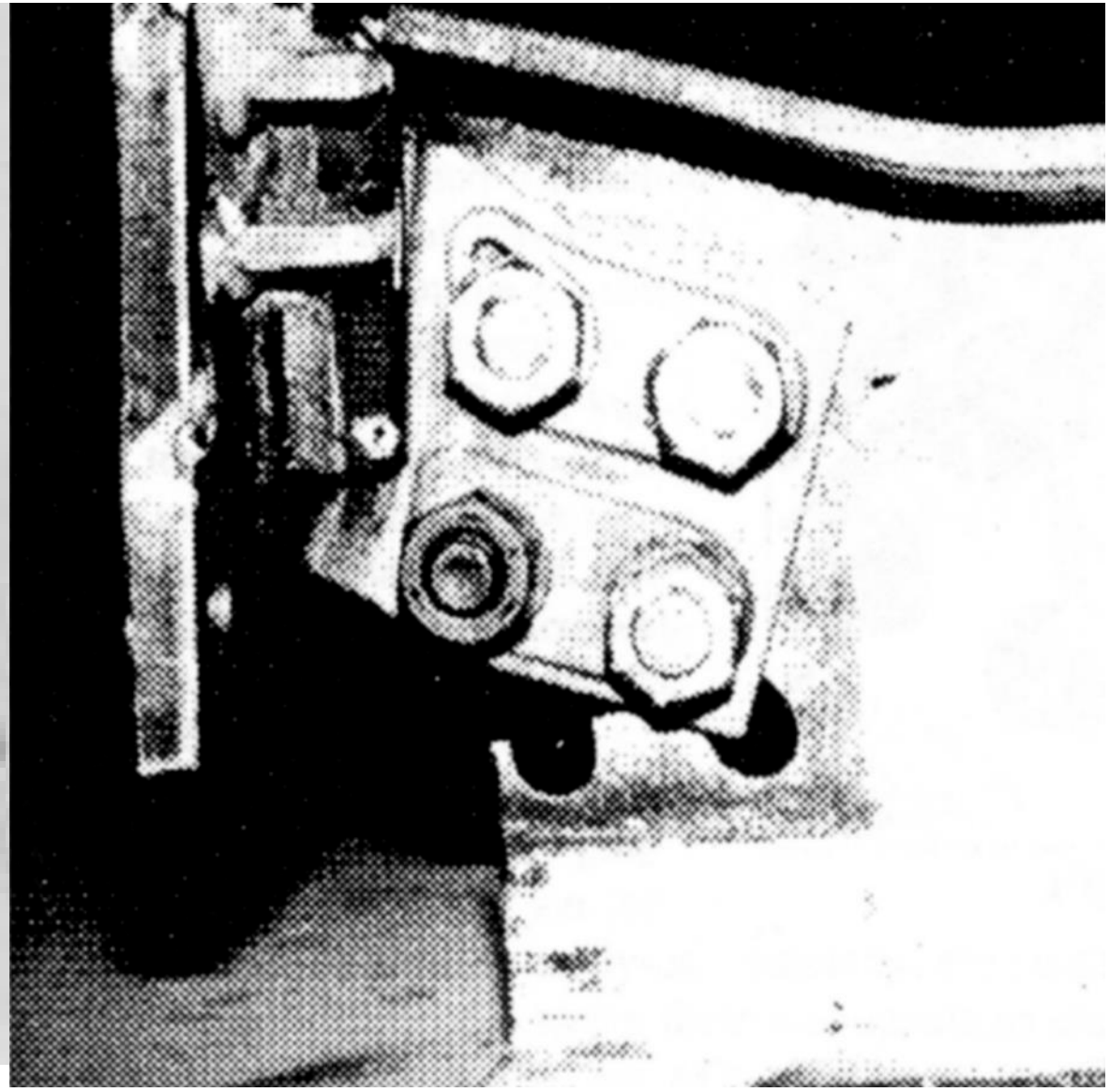
ATLSS CONNECTOR:



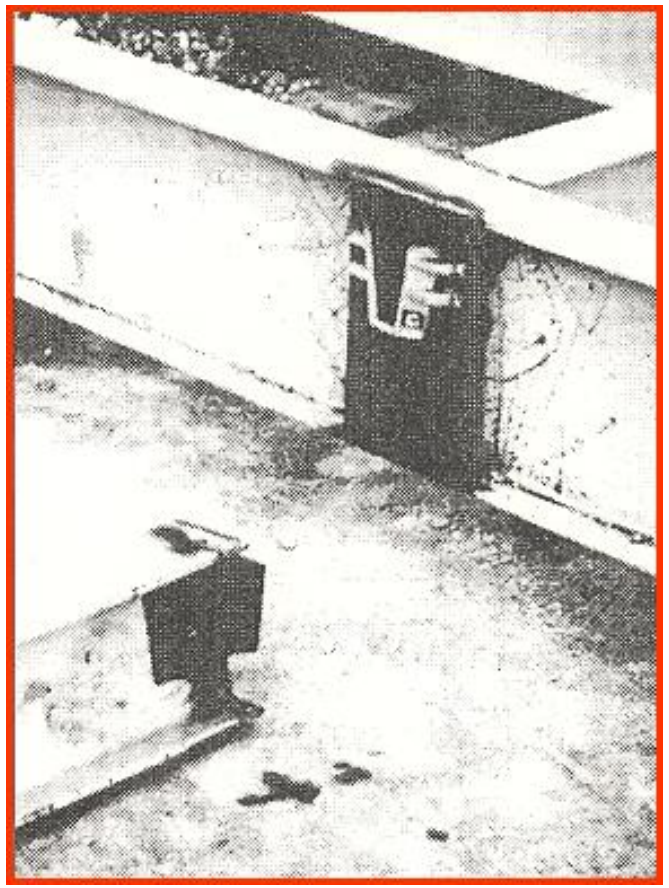




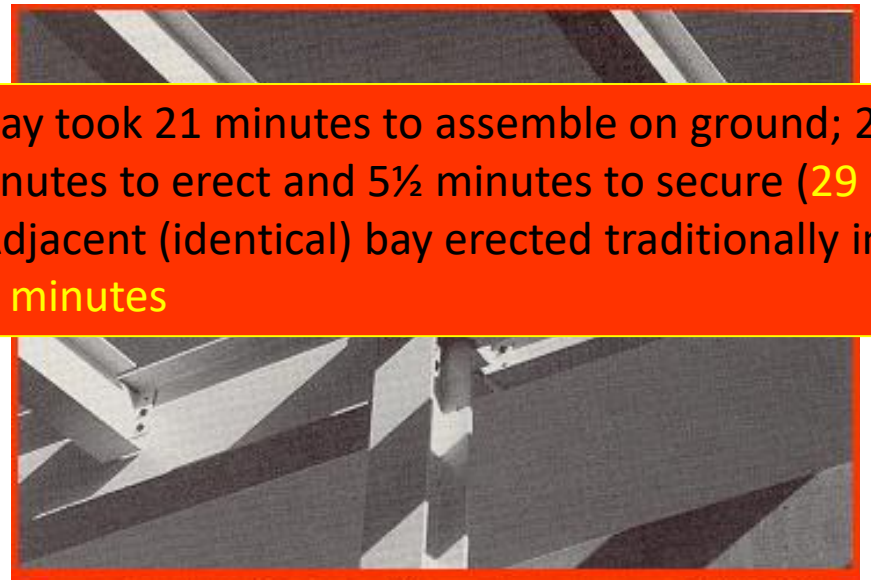




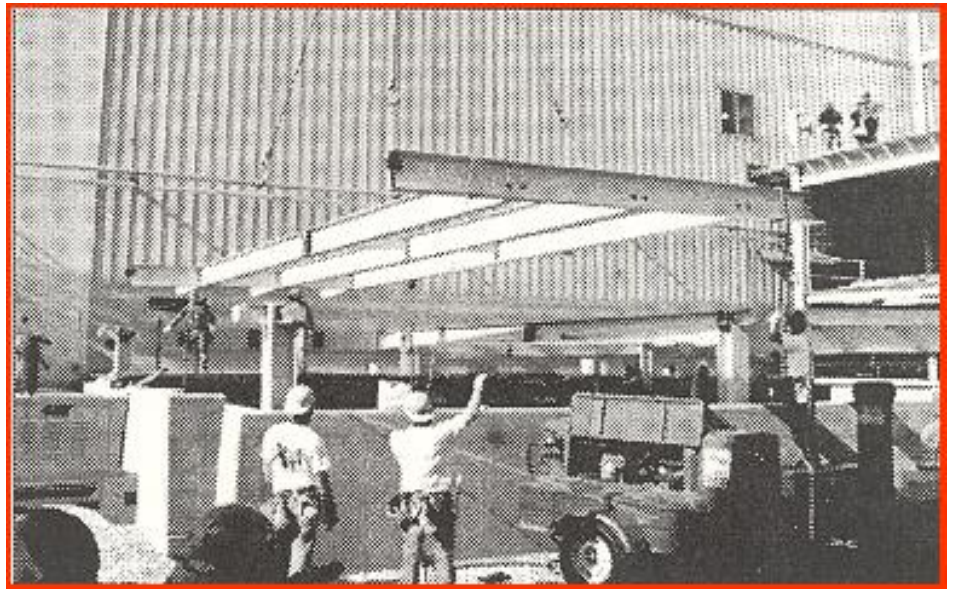
First Implementation: Iowa



- Gravity framing
- 20´x 36´ bay



- Bay took 21 minutes to assemble on ground; 2½ minutes to erect and 5½ minutes to secure (29 min)
- Adjacent (identical) bay erected traditionally in 1hr. 15 minutes



Northridge Earthquake, January 17, 1994

- More than 100 Special Moment Frames (SMFs) suffered extensive brittle fracture

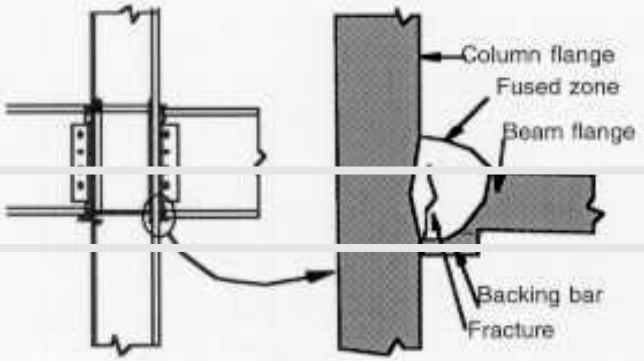


Figure 1: Typical Fracture Initiation

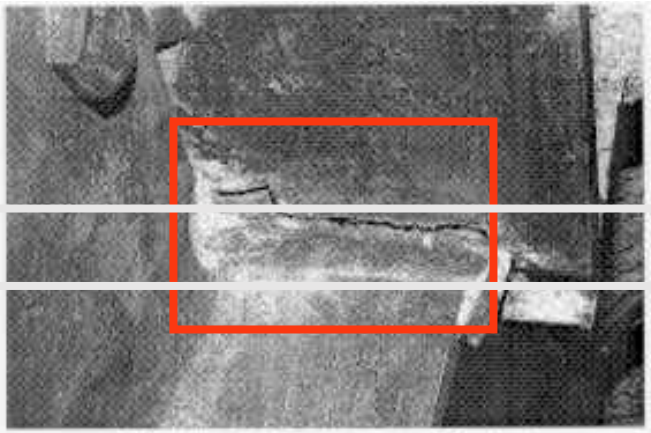
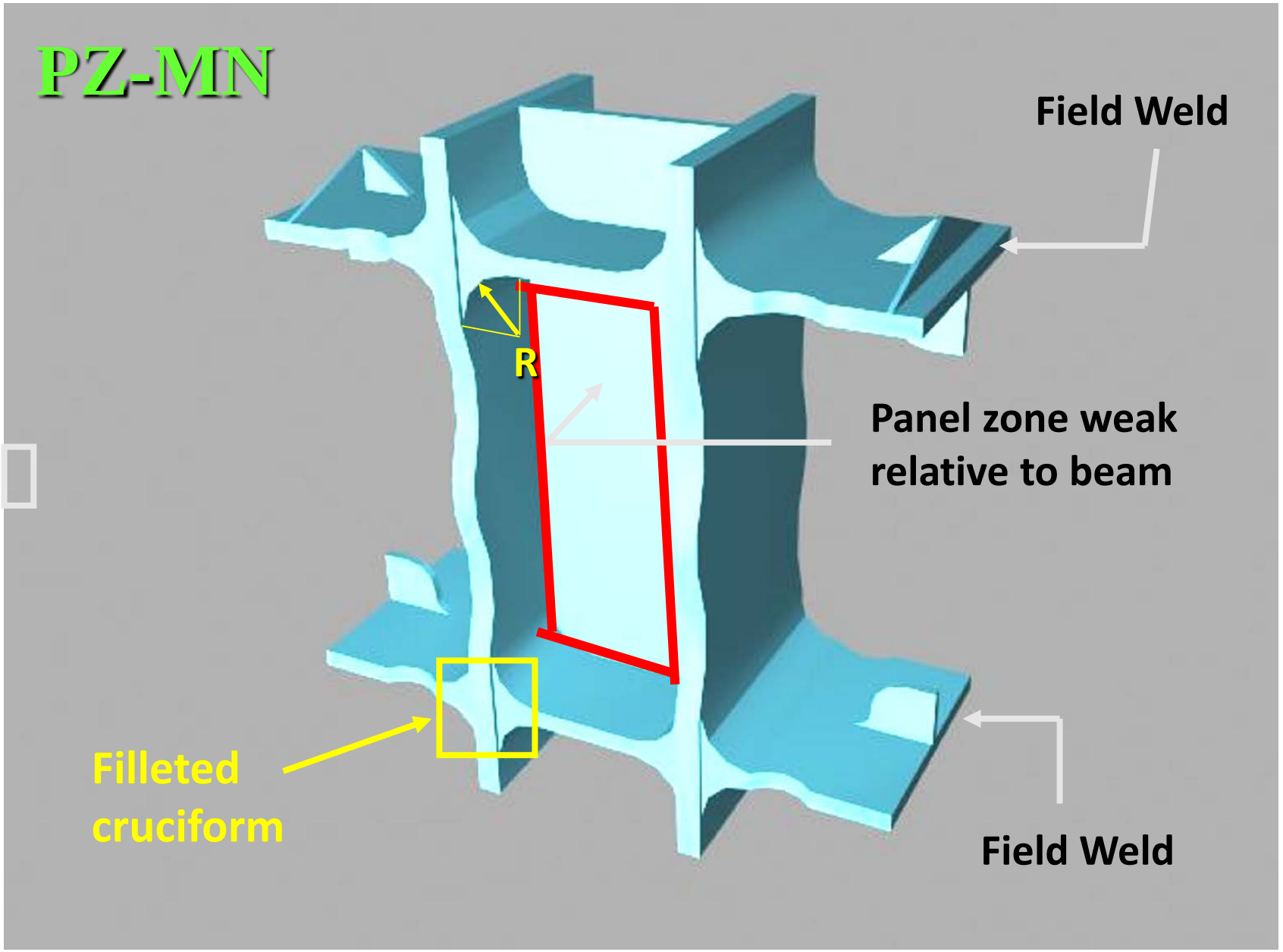


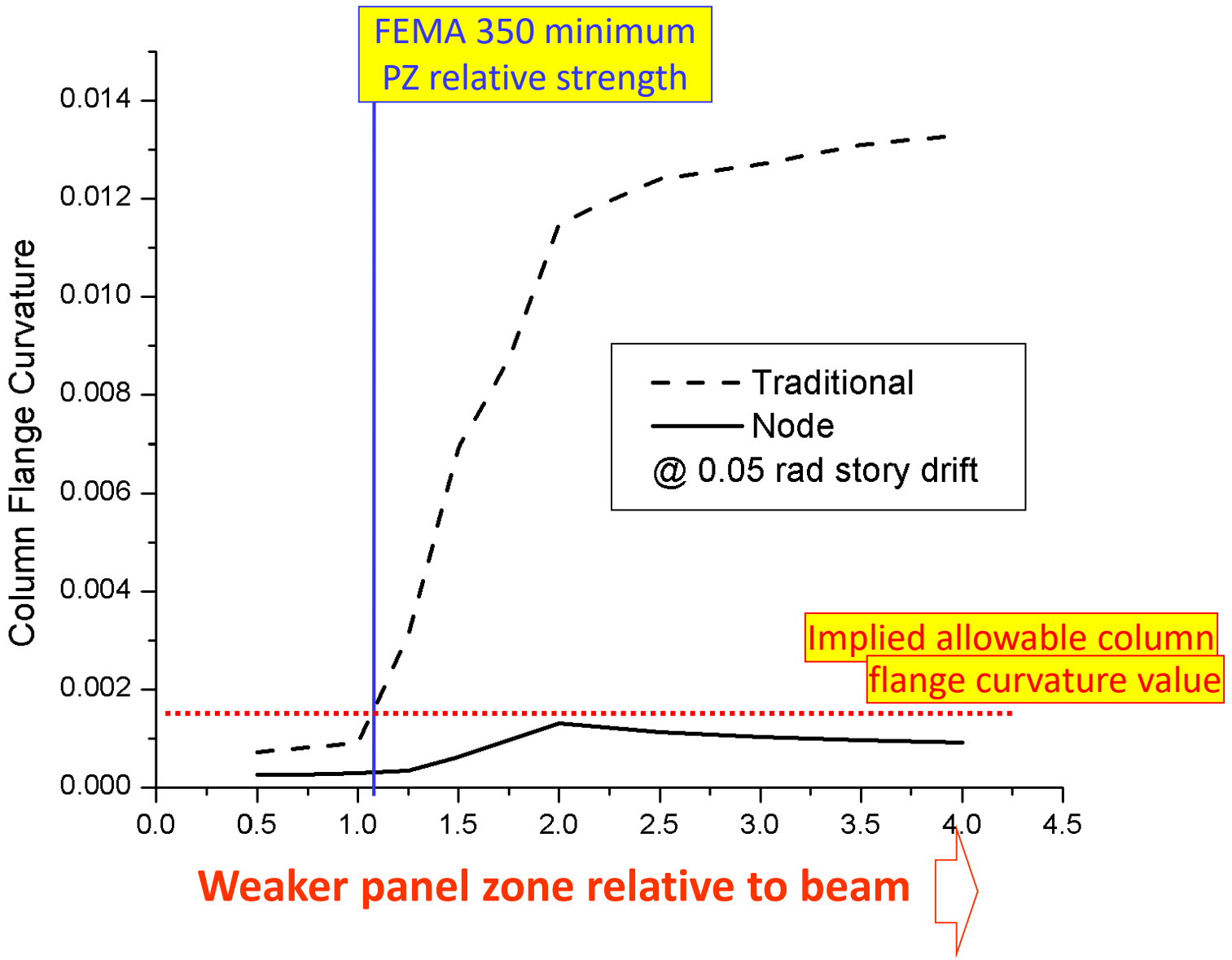
Figure 2: Fractured Joint

- Among many reasons cited as contributors to the failures, it was agreed that this connection's inherent configuration is not conducive to ductile behavior, and the situation is exacerbated by placing the weld region at this location.

Panel Zone Dissipator Modular Node



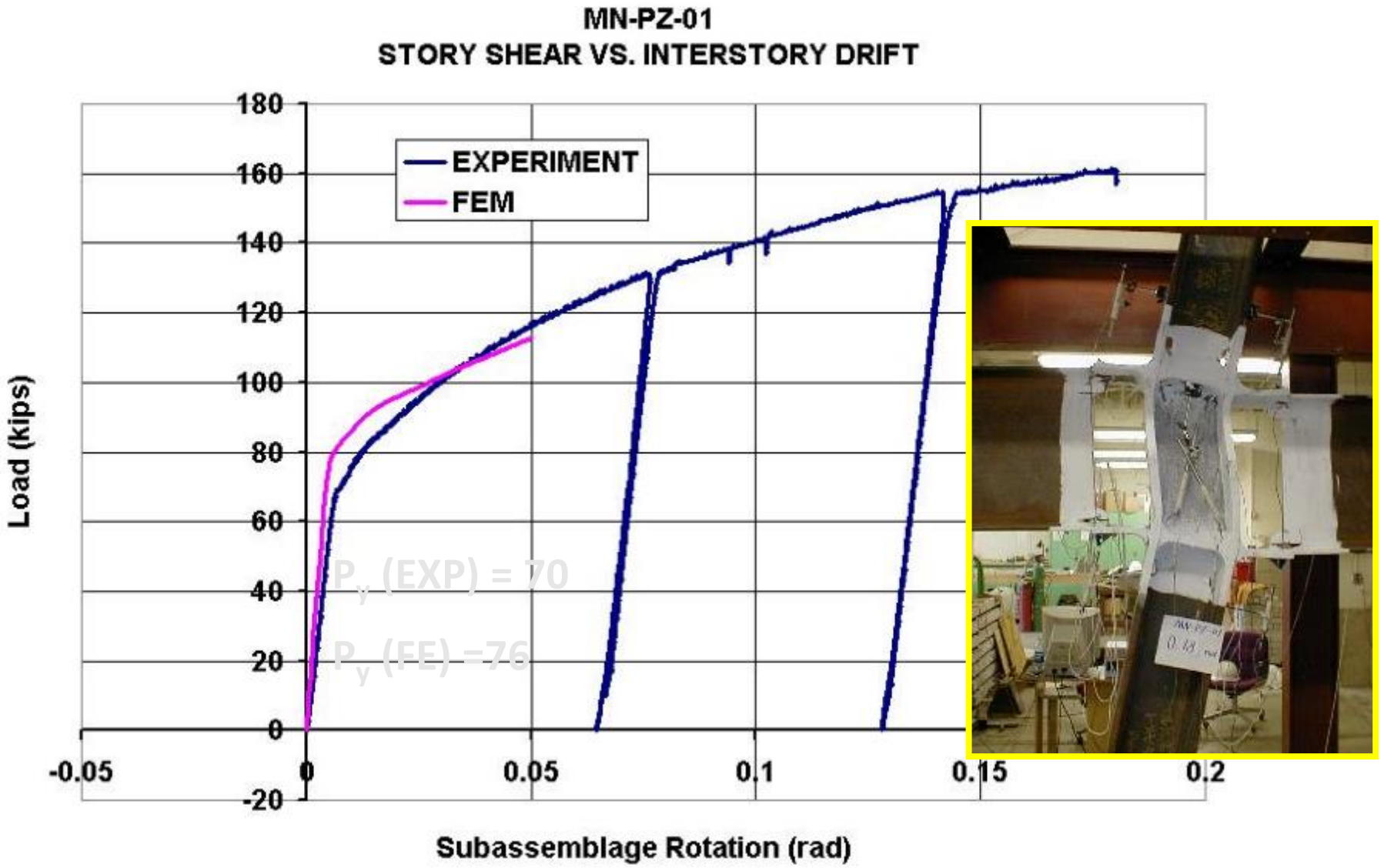
Column Flange Kinking in Connection



Experiment Subassemblage

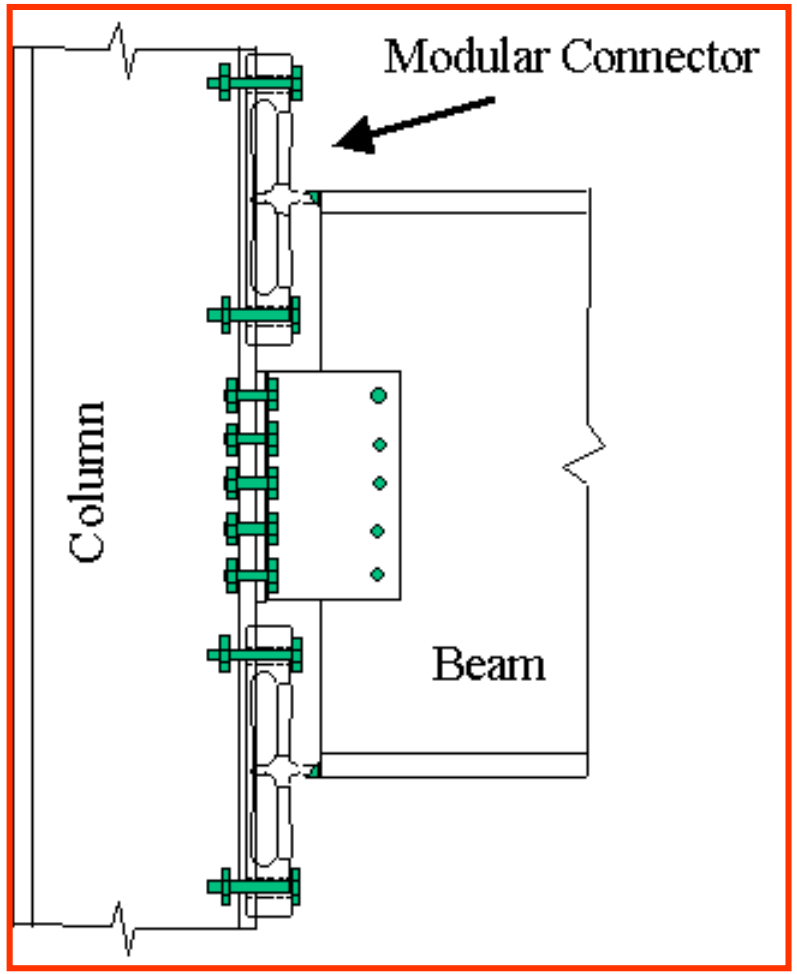
Industry Partner

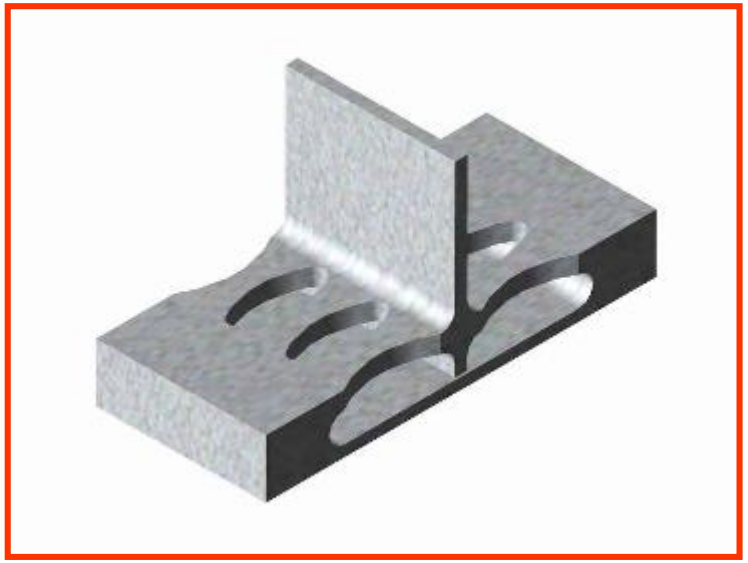
PZ-MN-01 Monotonic Test



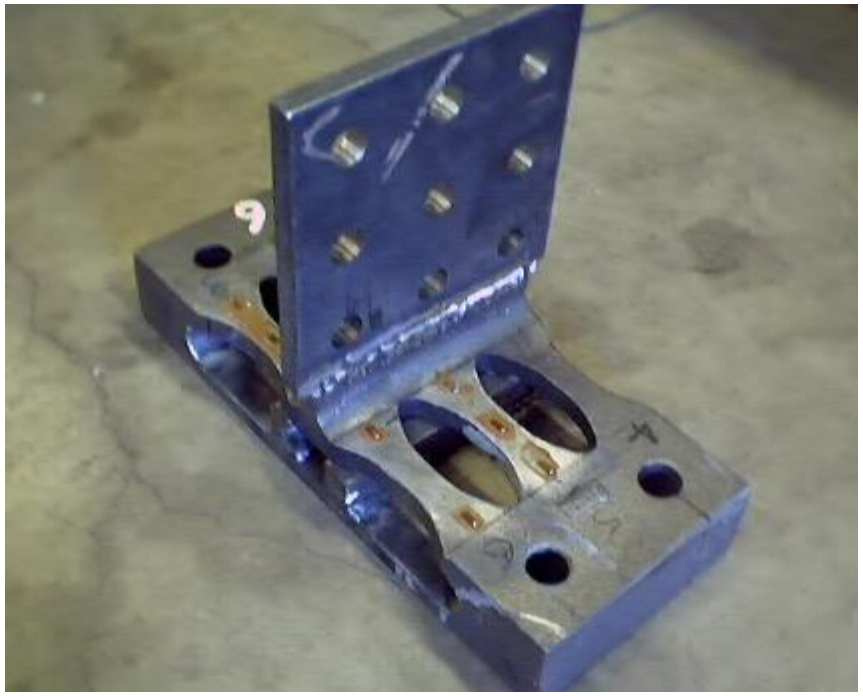
PZ-MN-02 FEMA Cyclic Test

Bolted Cast Modular Connector (MC)

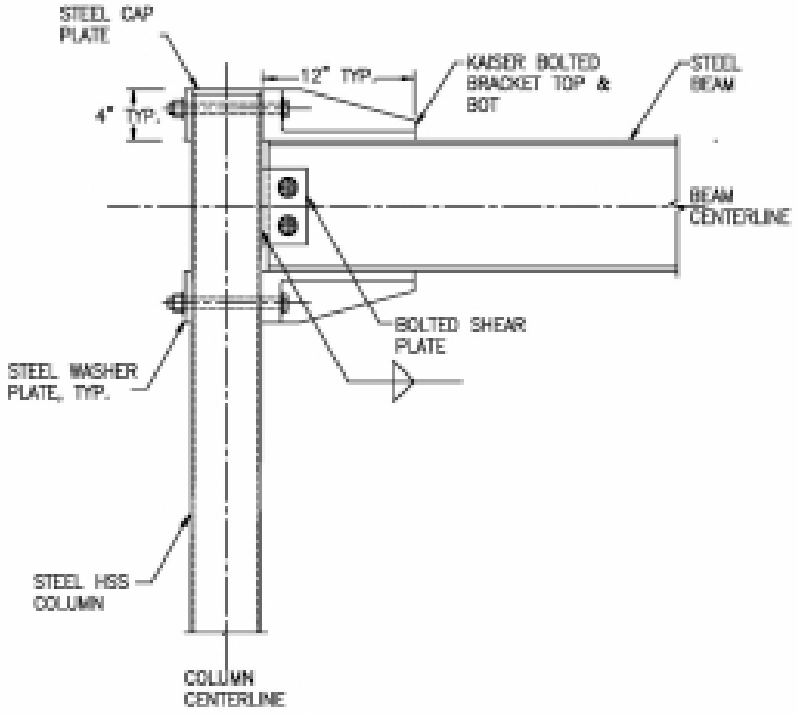


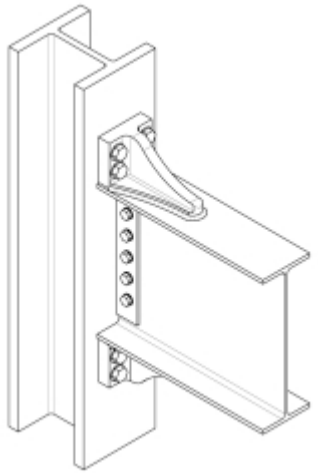


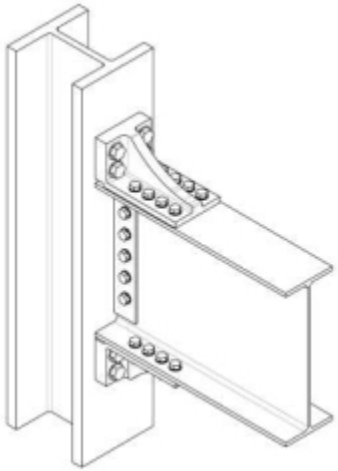
MC Half-scale Prototype Castings



Kaiser Bracket

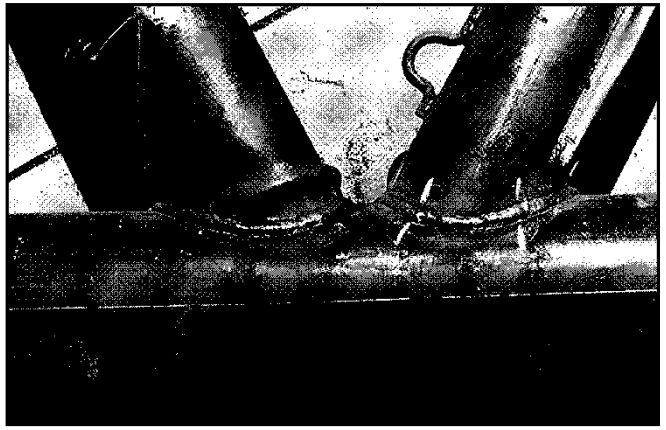






Modular Castings for HSS

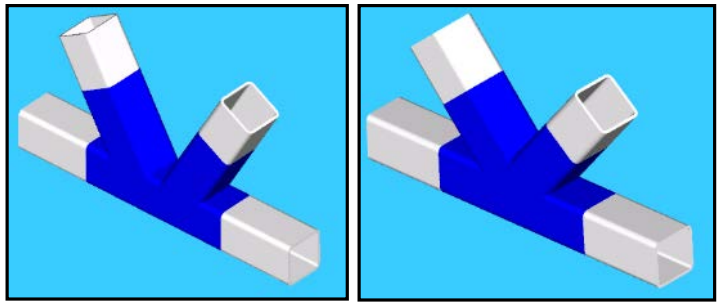
- Increase section thickness uniformly
- Non-uniform “fine-tuned” section
- Cast integral stiffeners, diaphragm
- Insert cast stiffeners, diaphragm
- Additional section using collar or saddle



Round Gap K Connection Failure (from Packer & Henderson)

- The cast modular node approach will also allow for the elimination of certain branch preparation including:
  - Fish mouth or bird mouth cuts
  - Mitered cut
  - Difficult fit-up for flare-bevel welds for equal width branch and chord members

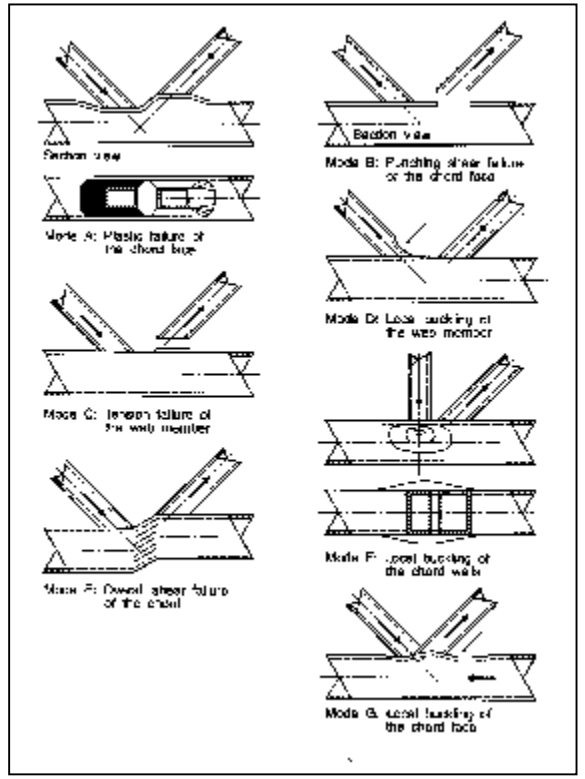
This is particularly helpful w/round HSS



Modular Castings for HSS

- Allow reduction in chord size by eliminating primary failure modes A, B & mode F for deep chords, and/or
- develop branch member to full capacity (yield/buckling strength)
- Increase buckling strength by decreasing effective length factor, K
- If branch member is fully developed, modes C & D must be carefully addressed, including evaluating:
  - the viability of fillet welds
  - the need for a more compact branch member
  - the impact on decreasing effective length

HSS Truss Connection Failure modes (after Packer)

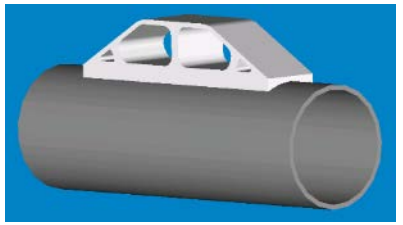


Failure modes A,B,C,D,E,F & G for K and N rectangular HSS truss connections (J.A. Packer and J.E. Henderson, 1997).

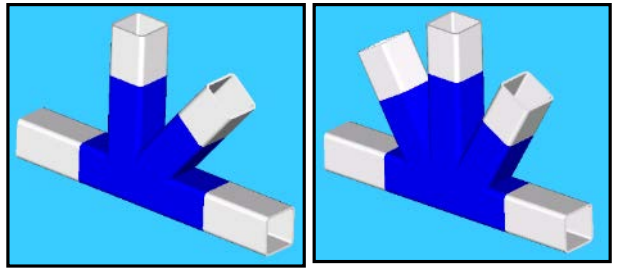
Round K connections: Promote the use of overlap connections without costly fabrication and the use of gap connections without the weak failures

Cast Component Types for HSS

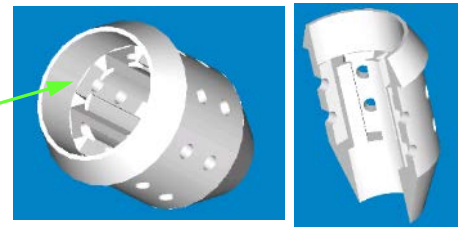
- A “Level 1” Solution: Cast Attachment
  - cast collar, attachment, or insert added to chord
  - minimizes main member pieces, cutting operations
  - traditional (welded/bolted) connections
  - supplements local strength to eliminate failure modes to develop (or nearly) member strength



- A “Level 2” Solution: Cast Node
  - full node placed between chord pieces
  - traditional (welded/bolted) connections
  - eliminate failure modes to develop member strength



- A “ Level 3” Solution: Enhanced Cast Connector
  - Possesses some feature to enhance the connecting:
    - Field splice
    - Facilitated erecting
    - Housing of secondary elements



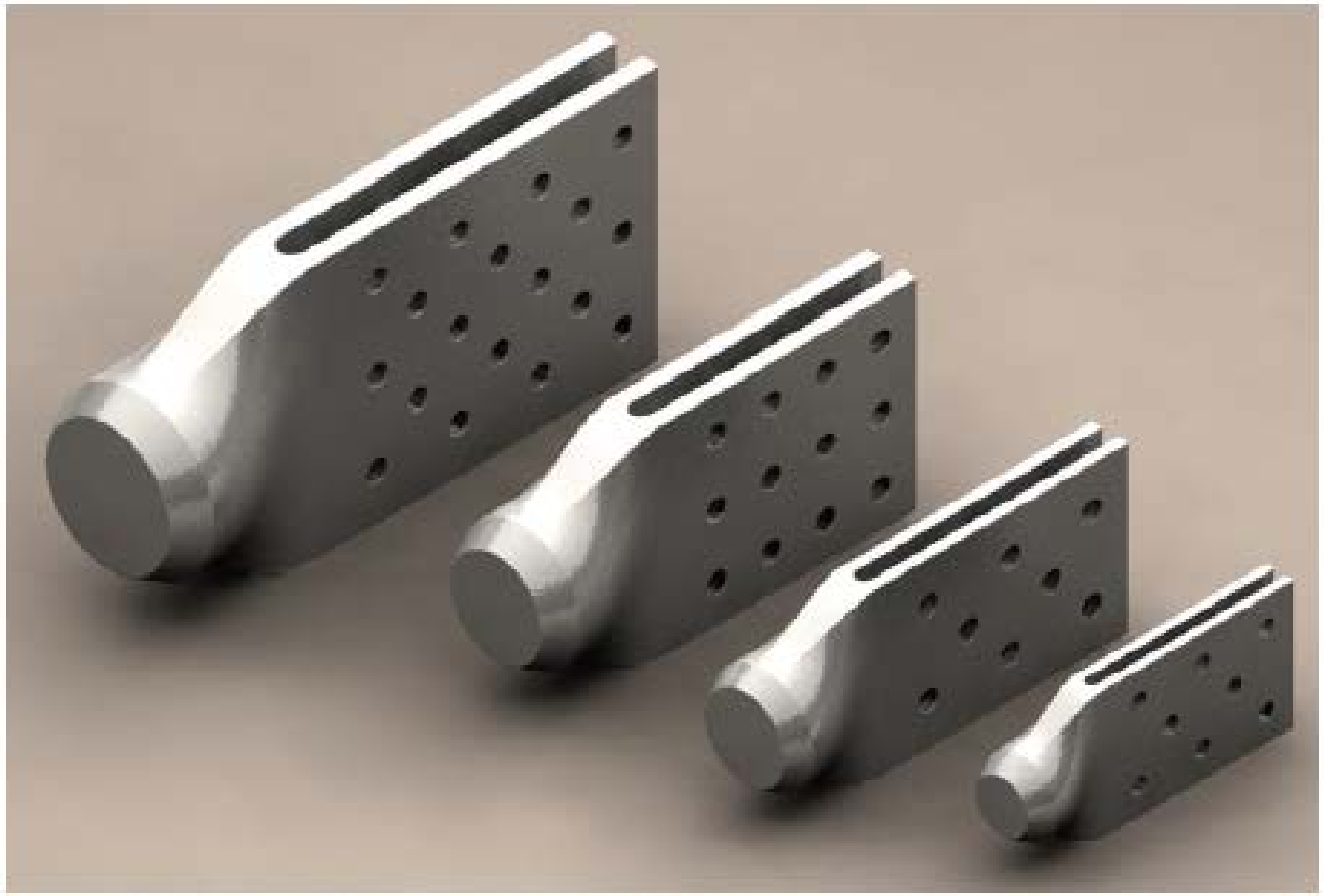
Impact on Shop Costs: Cast Components for HSS

- Economics of a “Level 1” Solution:
  - **The approach will add (per joint):**
    - 1 smaller casting
    - 1 shop weld – likely fillet
  - **The approach will eliminate:**
    - Difficult welds (Flare, fish-mouth or bird-mouth type welds)
    - Branch preparation (no special equipment required)
    - Modest reduction in weight
- Economics of a “Level 1” Solution:
  - **The approach will add (per joint):**
    - 1 larger casting
    - 2 shop welds – likely FPW
    - Cutting of chord pieces
    - Multiple Section sourcing
  - **The approach will eliminate:**
    - Difficult welds (Flare, fish-mouth or bird-mouth type welds)
    - Branch preparation (no special equipment required)
    - Significant reduction in weight due to chord optimization

CONVENIENT CONNECTIONS

Cast connections provide an efficient and attractive connection alternative for exposed hollow sections.

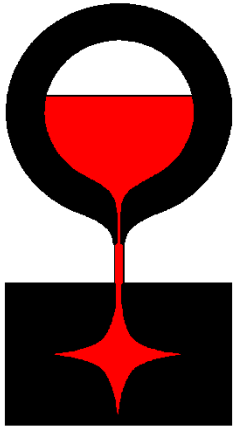
BY CARLOS DE OLIVEIRA AND TABITHA S. STINE, P.E., LEED AP



Cast ConneX high-strength connectors for seismically loaded HSS bracing connections (left). A connected brace in frame (right).

Carlos de Oliveira is CEO of Cast ConneX Corp. Tabitha S. Stine is AISC's director of technical marketing.

Cast ConneX Universal Pin Connectors.



Questions

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www.aisc.org/conferencepdh
95757

PROUD TO BELONG

2013 Now Available – 2015 THEY ARE HERE!

April 12, 2018

By Wayne Braun

AISC ASSOCIATE

BRADKEN

Credits for Contributions

CASTCONNEX

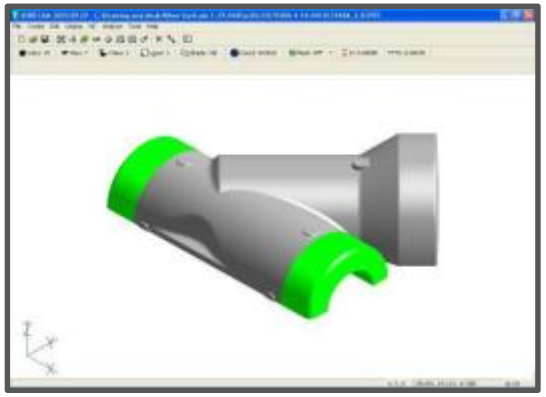
http://www.castconnex.com/ (Toronto, ON CAN)
Carlos de Oliveira, M.A.Sc., P.Eng.
President and CEO
Tel: (647) 725-1447
carlos@castconnex.com

Newport Industrial Fabrication (Newport, ME USA)
http://www.nif-inc.com/
President - Dan Gerry dan@nif-inc.com
Project Management – Ryan Gerry ryan@nif-inc.com
Tel 207-368-4344
Fax 207-368-5552

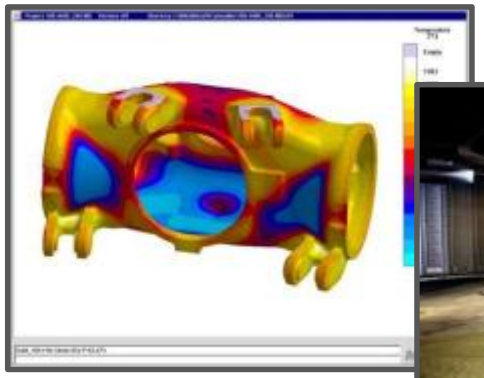
Structural – Have been here for many, many years!

Sector Gate: Flood Control
~ 70,000 lbs

Undercarriage: Locomotive
Casting: 9,400 lbs
Assembly: 13,000 lbs



Valves: Various designs including Wye valves, similar to Node Connections



Structural components for the mining and construction markets

Cast Connections Are Here……

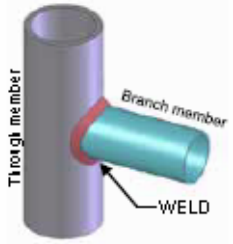
Traditional Construction Connection

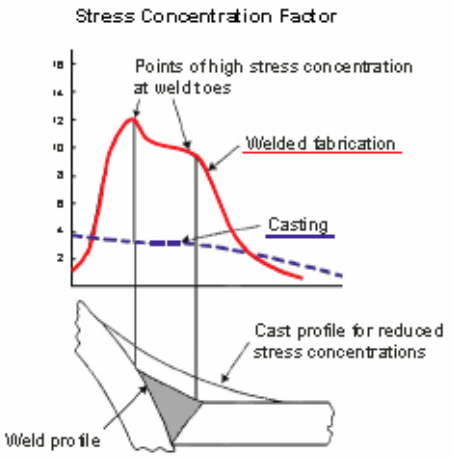
<u>The money is in the connections</u>

- Connectors in buildings are less than 5% of the weight but 60% of the cost
- Labor related costs are 60% of the construction cost

<u>Cast modular connectors offer many benefits</u>

- Reduce labor and erection costs
- Improve performance
- Easily transfer loads

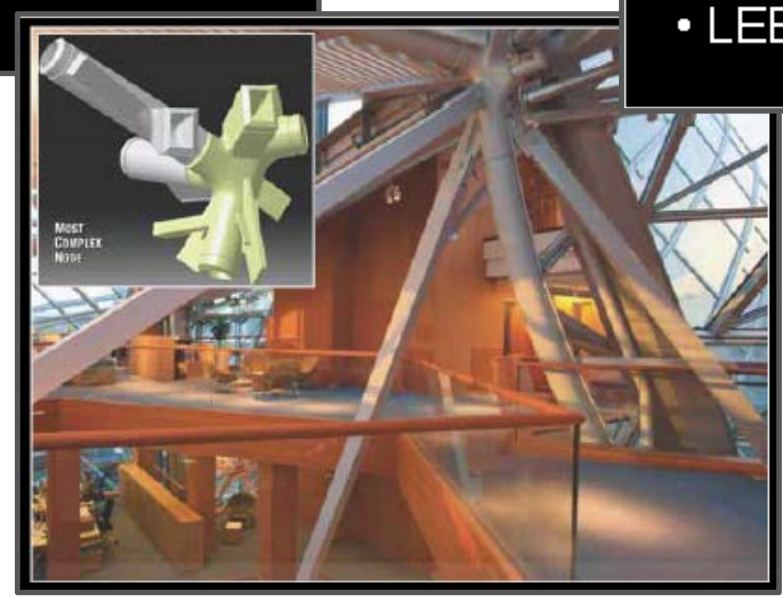




CASTCONNEX

When to consider steel castings

- Complex connections,
- Connections subject to very high loading,
- Architecturally exposed joints,
- Fatigue critical connections,
- Repetitive details.



Benefits:

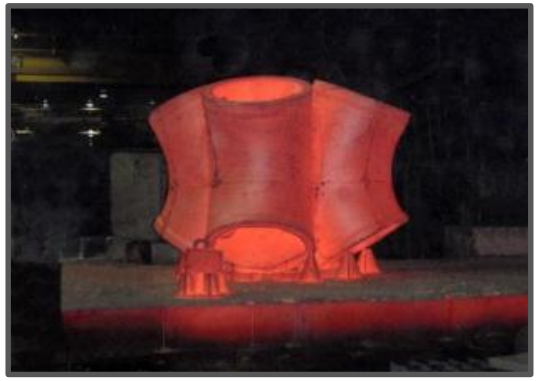
- Improved connection stiffness, strength, and fatigue resistance,
- Unparalleled aesthetics,
- Simplified fit up, fabrication, and erection,
- LEED credits

What is a casting?

Definition (Steel Founders Society of America- SFSA): A casting may be defined as a ***"metal object obtained by allowing molten metal to solidify in a mold",*** the shape of the object being determined by the shape of the mold cavity.

1. Complex Metal Shapes/Complex Connections
2. Formed from Liquid Metal - Irregular Internal Cavities
3. Critical components that transmit power, connect structures, and consolidate parts.
4. Architectural Esthetics, Cost
5. LEED Credits as they are made from recycled steel scrap

How a casting is made: QRCW



<u>Queen Richmond Center West (Toronto, ON CAN)</u>

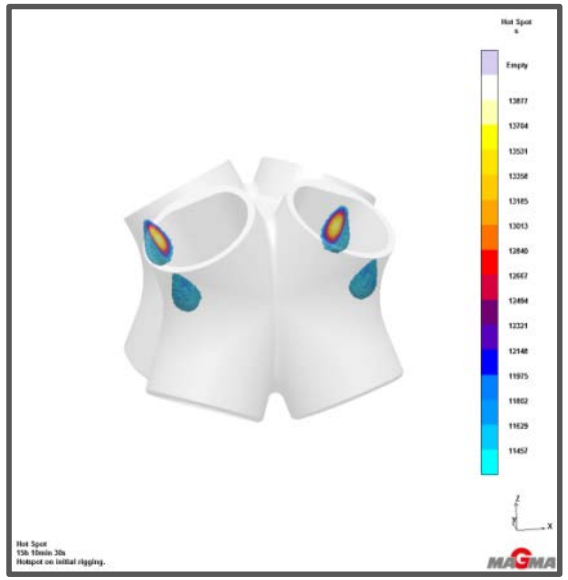
✓Market: Structural Exposed Steel
✓QRC West is a landmark development in Toronto's Downtown West
✓Pour Weight: 50,500 lbs.
✓Casting: ~ 30,600 lbs.
✓Material: A216, WCC
✓Scope: Pattern, Casting, Machining

Making A Casting

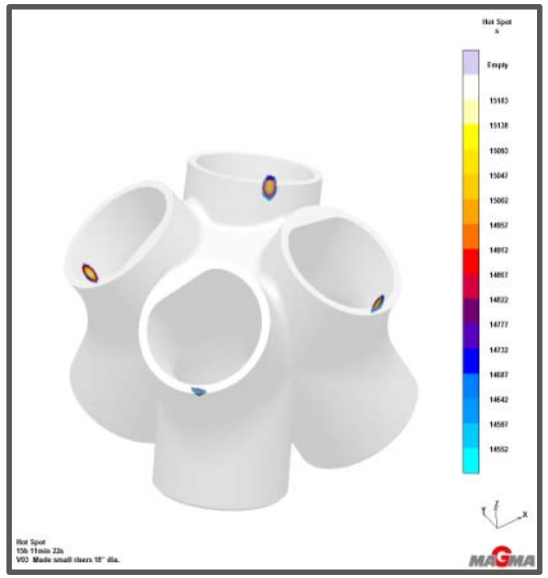
1. Design
2. Pattern Equipment
3. Mold
4. Molten Metal
5. Rough Casting
6. Finished Casting

Solidification Modeling (Queen Richmond West – Toronto, Canada)

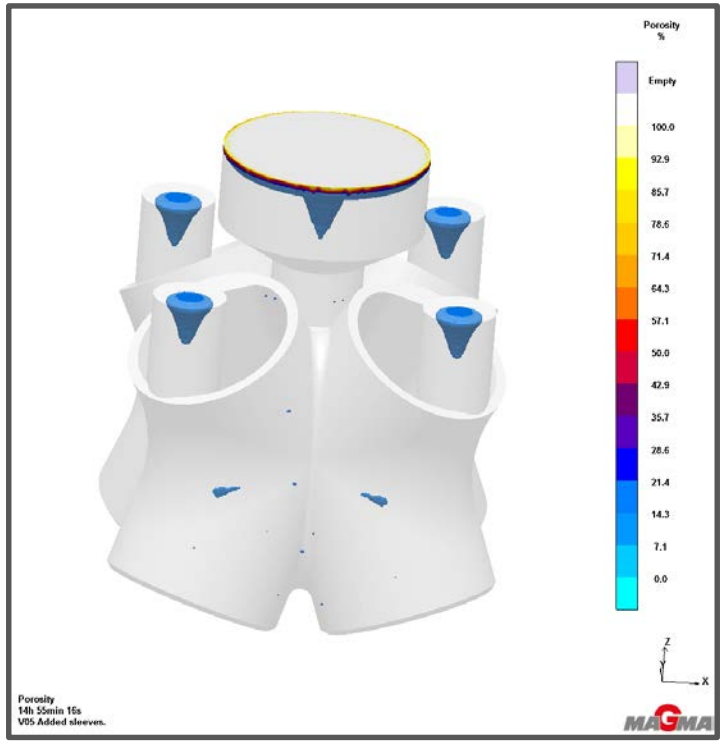
Initial Attempt



Second Attempt



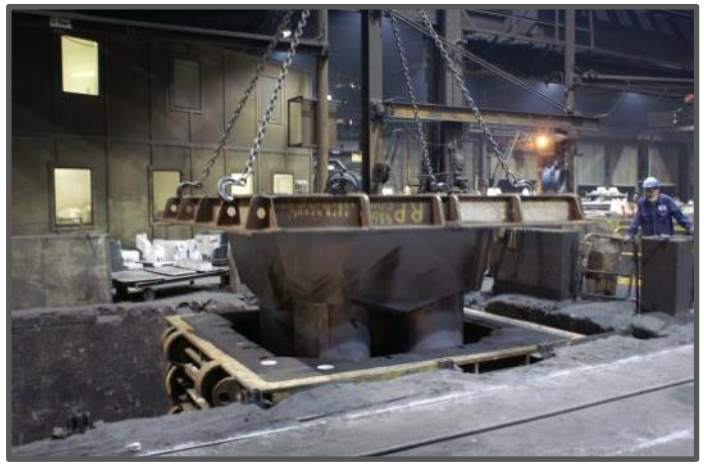
Final Rigging



Pattern Equipment – Cope (Top), Drag (Bottom)

Pattern Equipment – Core Boxes (Internal Passages)

Molding



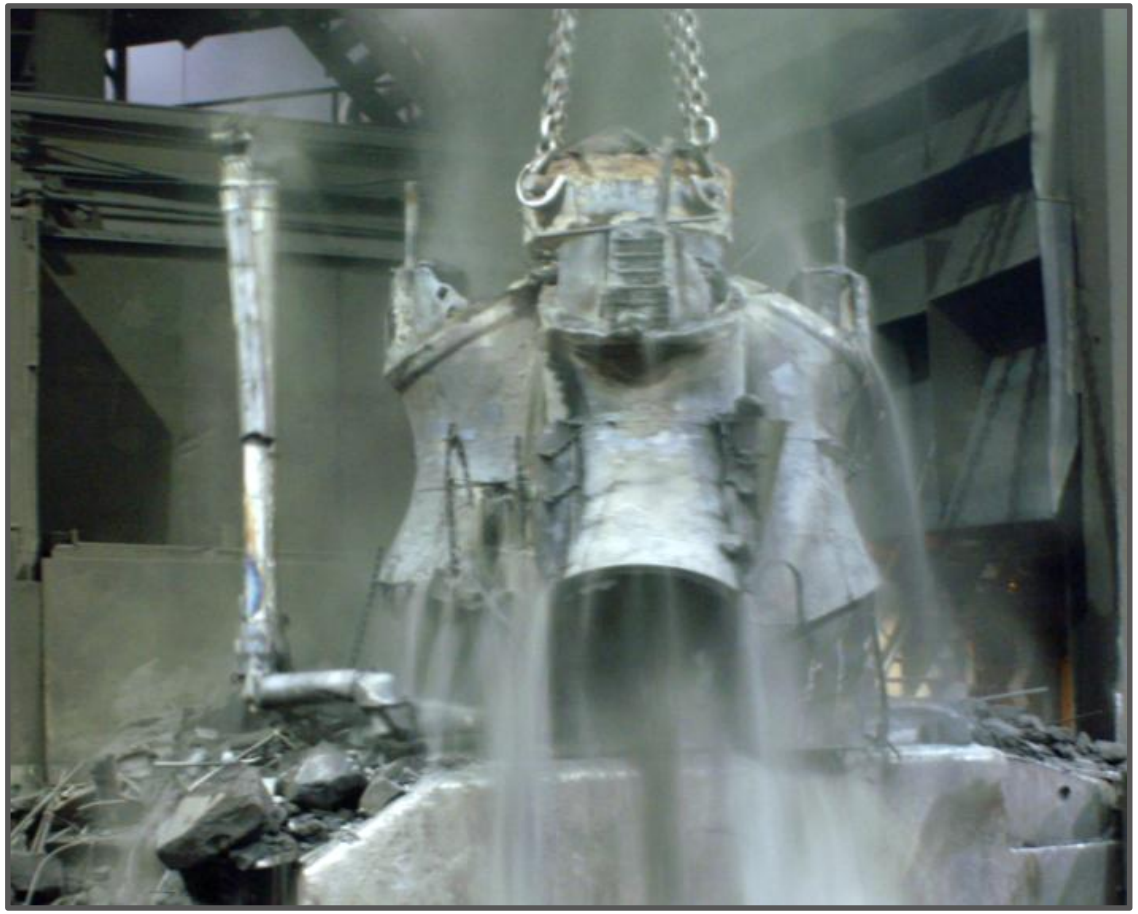
Preparing Cores for Setting in Mold

Gages to assure dimensioning

Mold Closing

Pouring

Shakeout



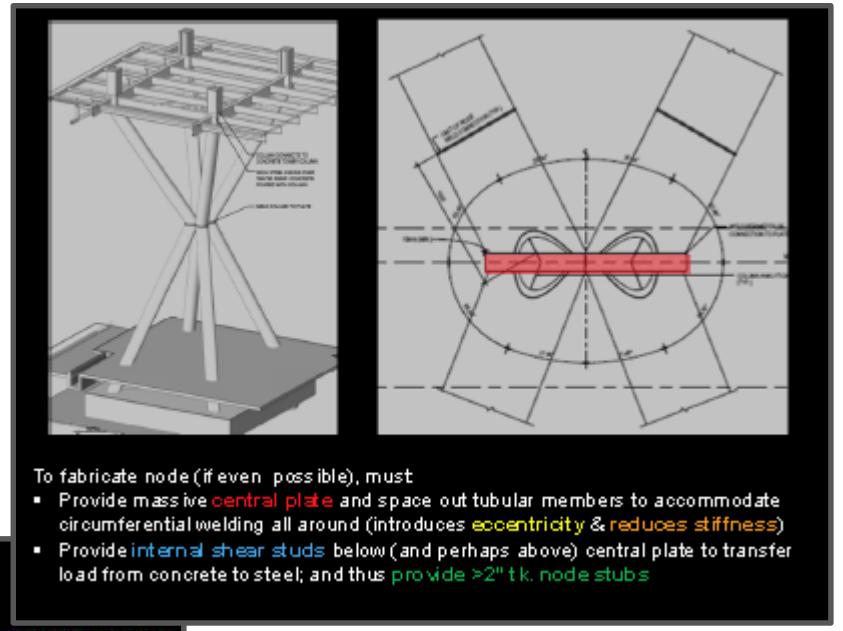
Cleaning and Finishing

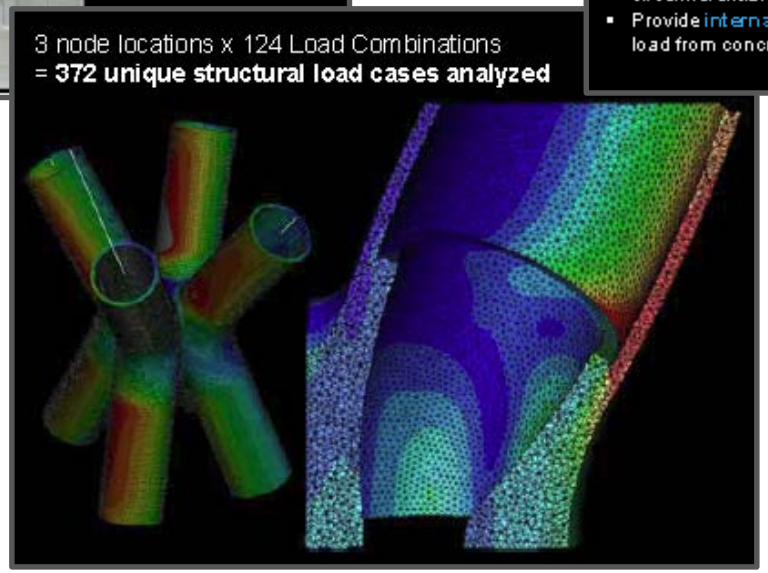
Templates can assure critical feature are maintained

Inspection & Value Add

Casting Formation

Queen Richmond Center West





Queen Richmond Center West

Transbay Transit Center

San Francisco, CA

Initial involvement April 2010:
Visits to Atchison, KS

1)Erick Del Angel, lead Architect: **Adamson & Associates**

2)Randolph Volenec, Senior Project Manager: **Pelli Clarke Pelli**

3)Chuan Do, VP, Bruce Gibbons, Senior Principal, Alber Chen, VP" **Thornton Tomasetti**

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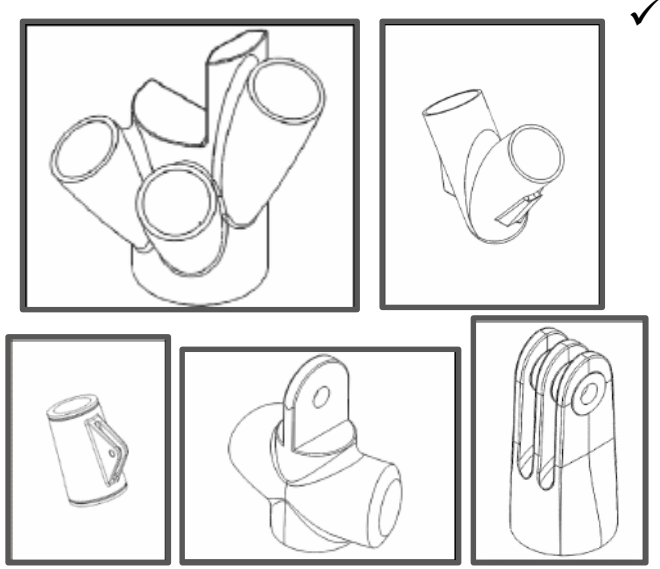
Structural Market

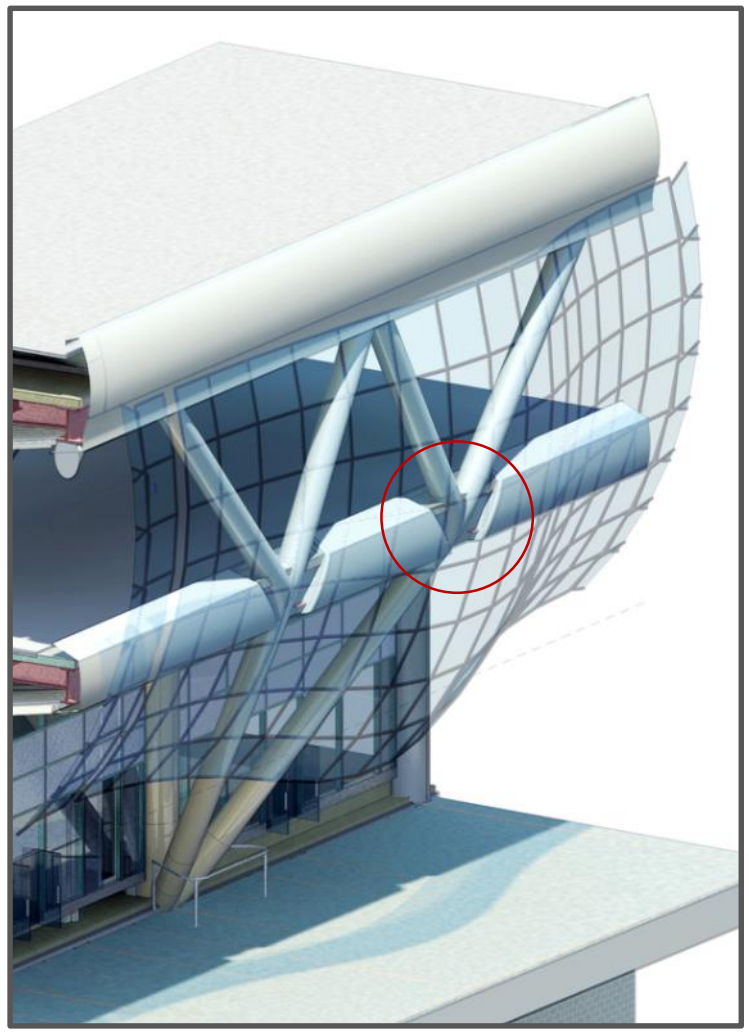


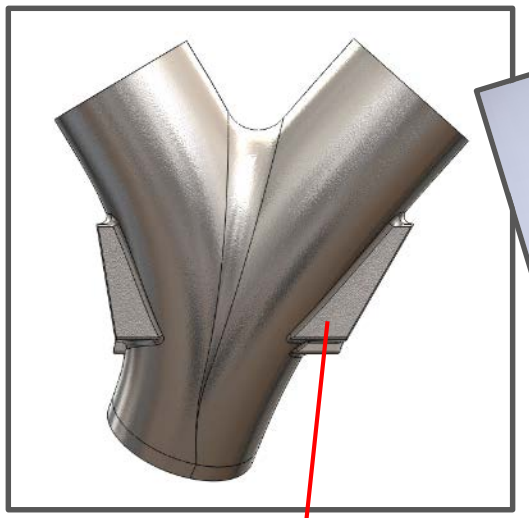
Transbay Transit Terminal (San Francisco, CA)

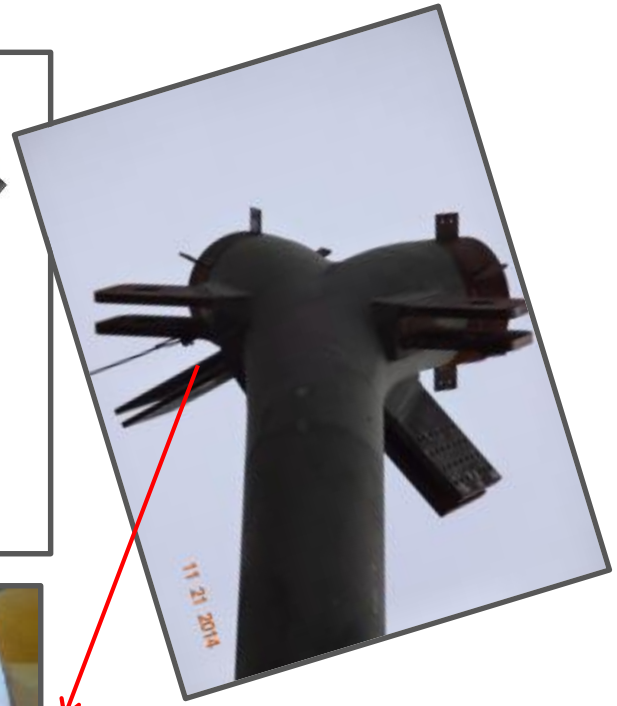
- **Many Lessons Learned**

✓Market: Structurally Exposed Steel
✓The project requires the production of 304 steel castings made up from 75 unique geometries,
✓totaling approximately 3.3 million pounds of cast steel.
✓The cast steel nodes range in size, geometry, and weight, with the smallest node weighing approximately 3,900 lbs. and the heaviest, 46,300 lbs.
✓Scope: Patterns, Casting & Machining

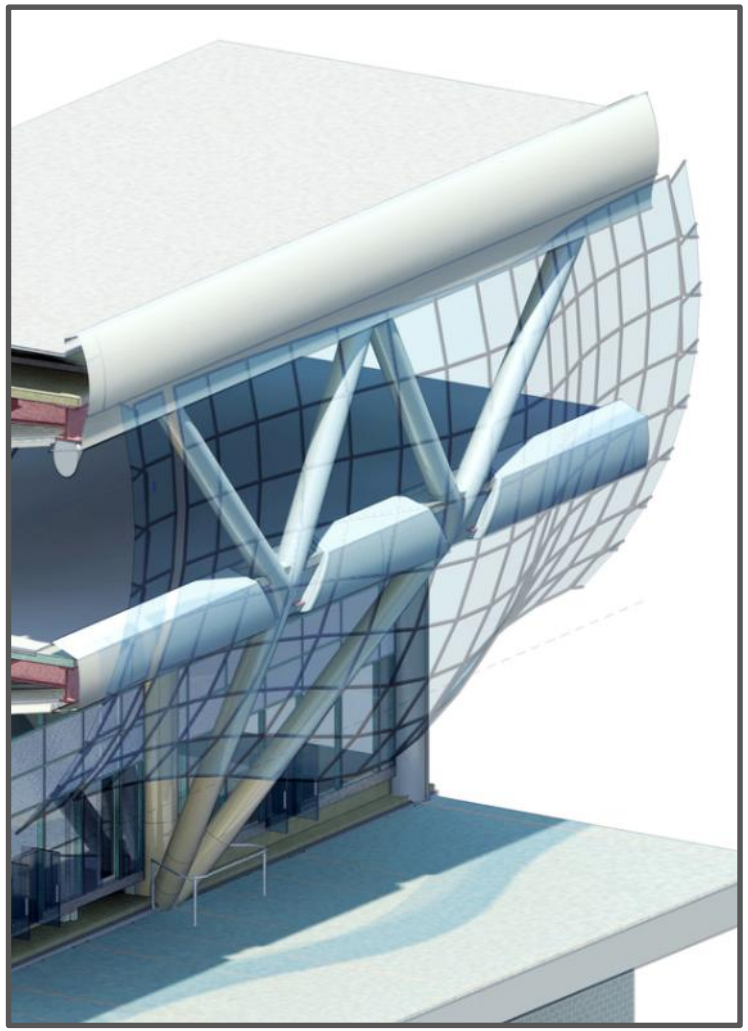
Mounting and Fabrication Surfaces

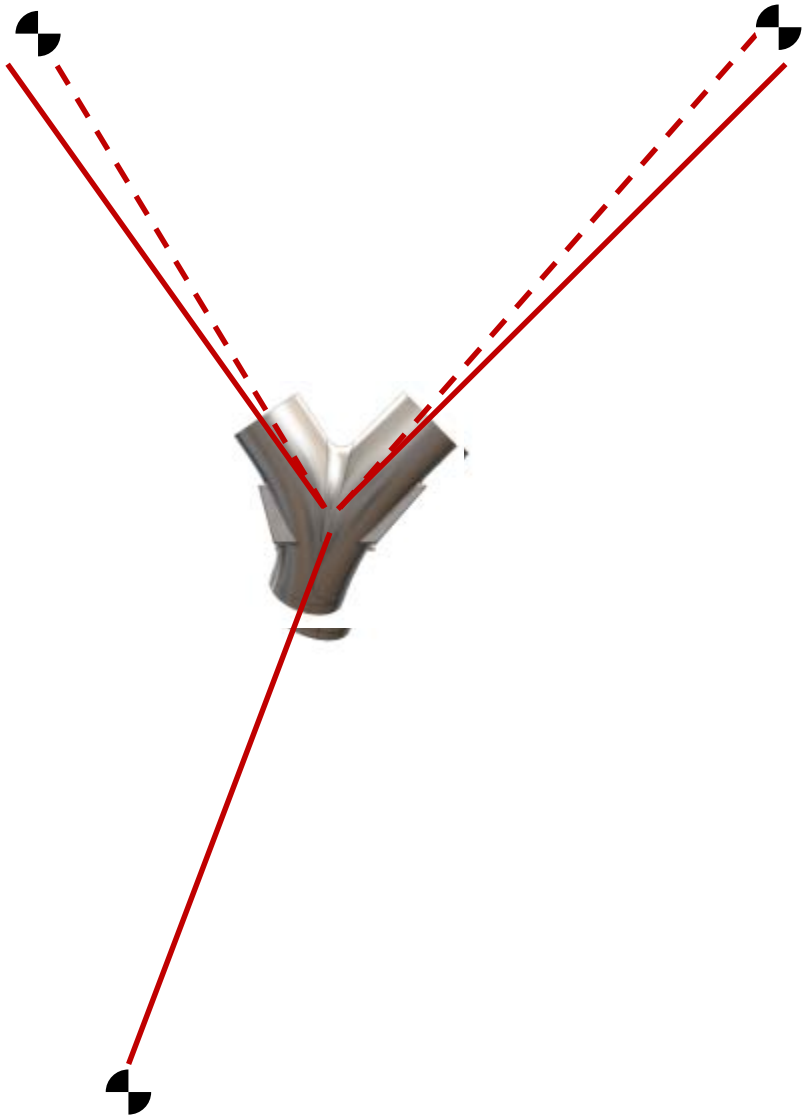






A Cast Node is **NOT** a Valve

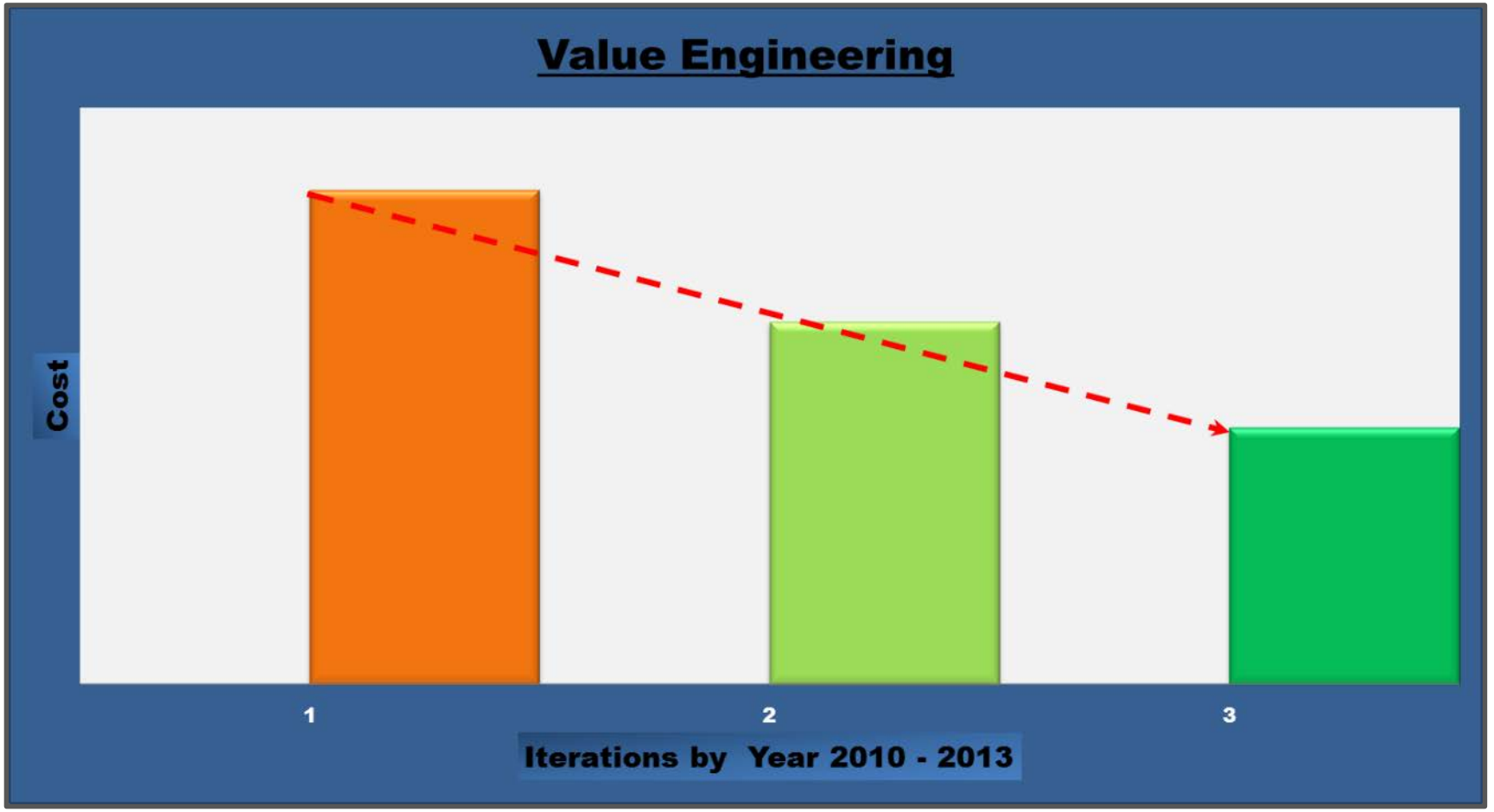




Field Erection

Field Erection

Cost Estimation History



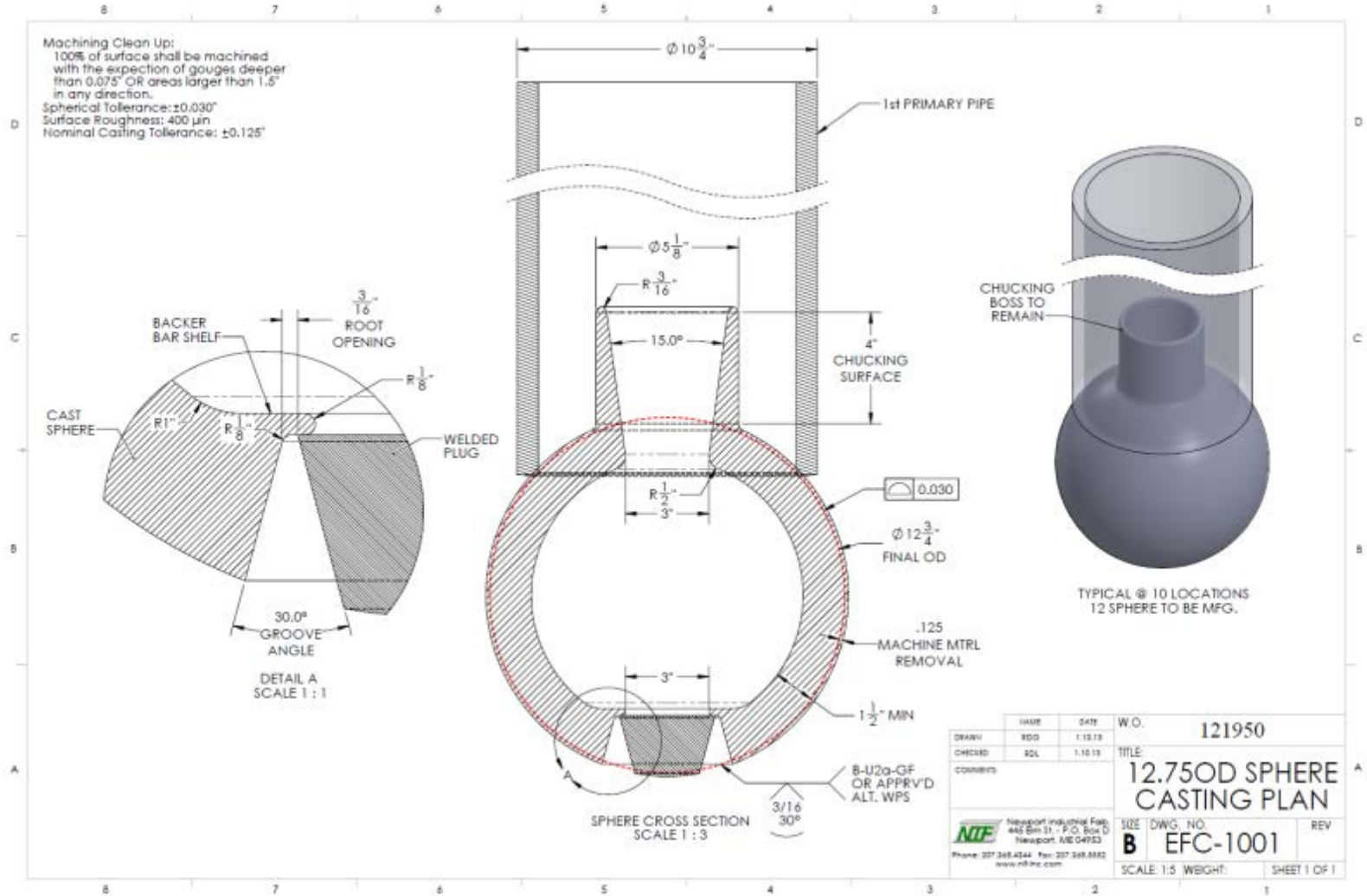
Newport Industrial Fabrication - EF Waterfall

EF Waterfall

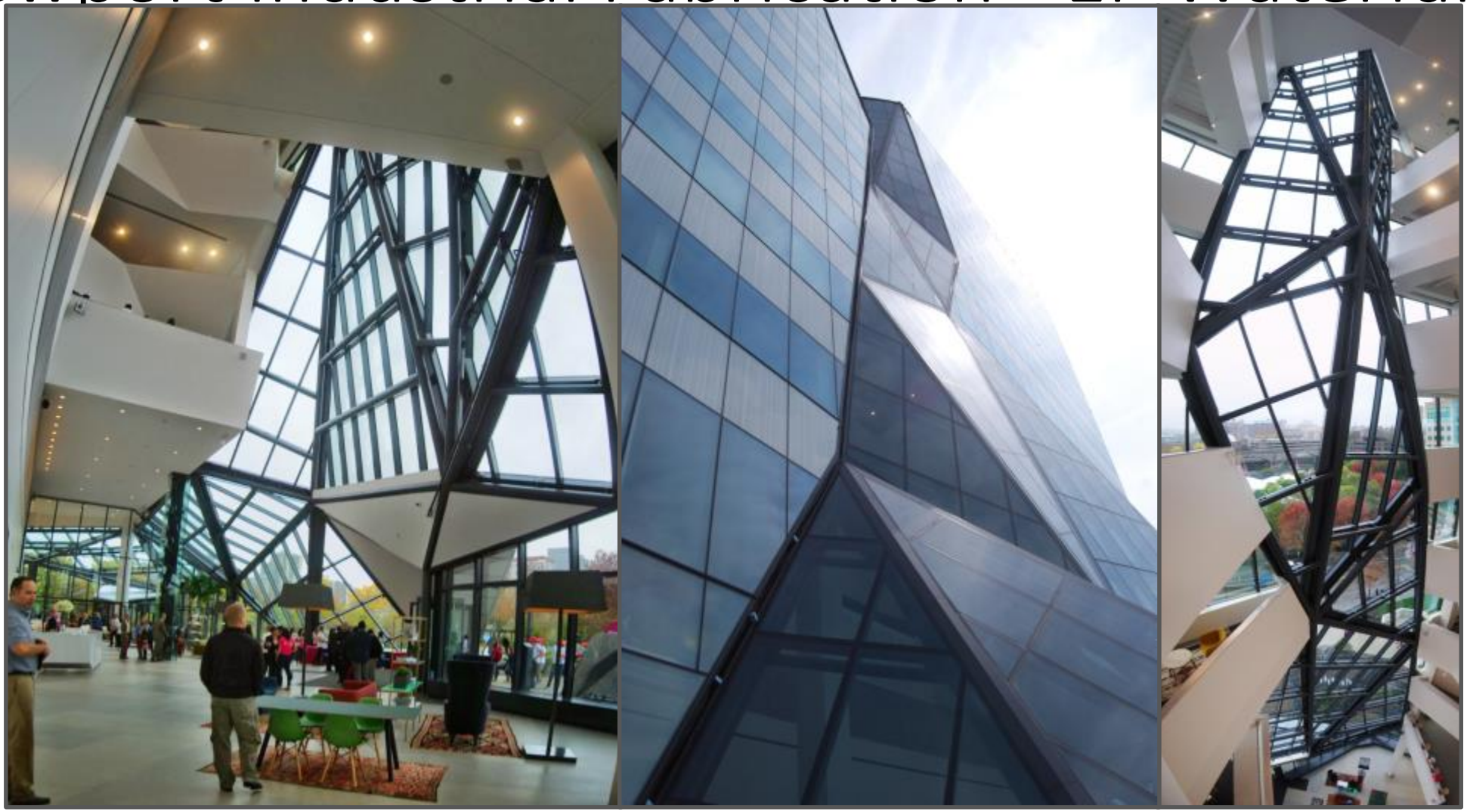
- **Flexible Fabrication/Assembly, Architectural Elegance**

- ✓ 1,600 lbs., 8 unique sphere-node designs
- ✓ Work Scope: *Machined to sphere (QC measure)*
- ✓ Designed/Fabricated: Collaborative
- ✓ End user: Skanska (contractor) / Education First (owner)
- ✓ *Lessons learned or realizations about the use of casting in this job or future projects…..*

Newport Industrial Fabrication - EF waterfall



Newport Industrial Fabrication - EF waterfall

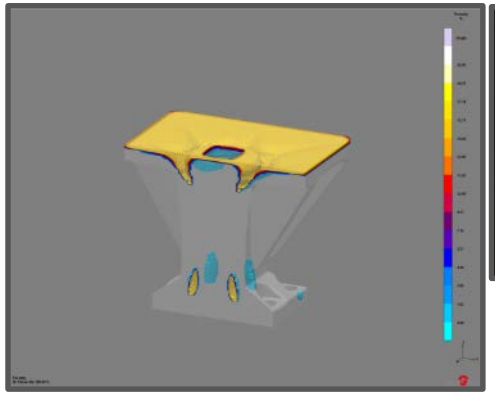


Greenville-Spartanburg International Airport

GSP Column Caps

❖ **A Case for familiarity with Market**

- ✓ 7,000 lbs.
- ✓ Machined Complete
- ✓ Cast and machined at Bradken: in Amite, LA
- ✓ Design Modification provided by Cast ConneX after Bradken advised casting needed be reviewed by a Structural Engineer
- ✓ End user: Skanska



Arthur Ashe Tennis Stadium (USTA)

Cast Brace Connector

❖ **A Case for Surface Finish**

- ✓ 7,900 lbs. (16 nodes)
- ✓ Machined Complete Cast and machined at Bradken: in Atchison, KS (Pattern, Casting & Machining)
- ✓ Designer Cast ConneX
- ✓ End user: U.S. Tennis Association (USTA)

Foundries and the Structural Market

Architect-Structural Engineer

Experienced Foundry

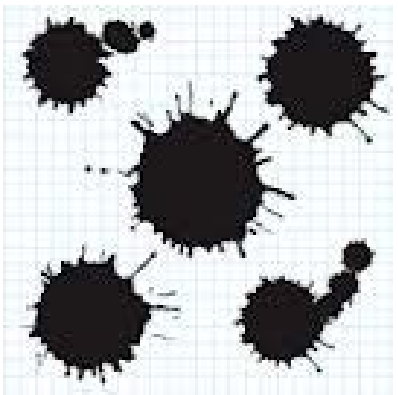
Foundry

- Shape
- Appearance
- Integrity
- Weight
- Finish
- Testing
- Connection

- Configuration
- Set-up
- NDT
- **Wall Thickness/Material properties**
- Surface Finish
- FAI/Production
- Machining?

Cast Connection Concepts….. Can you make these?

And…..How much does it cost??



Thank You.

CASTCONNEX

NTF

AISC ASSOCIATE

BRADKEN

Appendix

Additional Slides If Required

Choice of Materials

1. Plain carbon steels preferred
   - No need to quench for properties
   - Low CE for field welding
2. For slightly better properties
   - Micro alloy with molybdenum(Provides through hardness and acts as a strengthening agent with almost no effect on ductility)
   - Maintain lower CE for field welding
3. Higher strength alloy steels
   - Require quenching to meet property requirements
   - Higher CE will severely restrict welding (preheat, post weld HT)

Material Selection

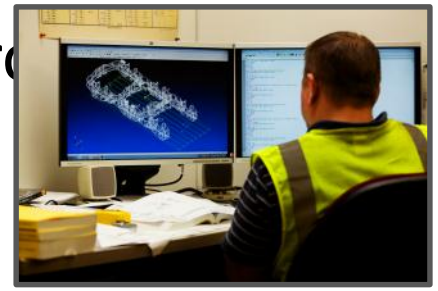
	Performance Requirement	A27 Grade 70-40	A148 Grade 80-50	A958 Grade 8620	A216 WCB	A216 WCC
Minimum Ultimate Tensile Strength	80 ksi	70 ksi min	80 ksi min	80 ksi min	70 - 95 ksi	70 - 95 ksi
Minimum Yield Strength	50 ksi	40 ksi min	50 ksi min	50 ksi min	36 ksi	40 ksi
Minimum Elongation	22%	22% min	22% min	22% min	22%	22%
Minimum Reduction of Area	35%	30% min	35% min	35% min	35%	35%
Chemistry Control	Very Tight	Max Values Specified	Max Values for S and P	Max/Min Valuesfor all	0.30 Max C - 0.5 CE Max	0.25 Max C - 0.55 CE Max
Heat Treatment Spec. and Control	Very Tight	Not Specified	Not Specified	Specified	Normalized	Normalized
					Very foundry Friendly and Easily Weldable	

Medium Carbon Steels: Carbon steel is one of the most widely used materials in the industry. This material is used not only in many of the water- and steam-pressure containing systems in power plants but also in the supports for these systems. Although many applications are on the pressure containing applications of carbon steels, it can also be a useful tool for structural carbon steel fabrication issues. Carbon steels have a good content of carbon, so it is easy to cast. especially A216 WCB.

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15}$$

How to have a positive casting experience

1. Consult with foundry during the design pr



2. Utilize commonly used alloys if possible (consider field weld ability)

3. Determine quantities required as accurately as possible

4. Choose appropriate NDT (soundness) specifications