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Course Description

The Case of the Disappearing Right Angle: Innovation in Architectural Steel

March 13, 2015

The use of Architecturally Exposed Structural Steel (AESS) over the past two decades has brought with it many new ways of using steel in structural systems. The application of AECC has developed to reflect appropriate responses to detailing that are differentiated by acknowledging the building function, distance to view and finish requirements.

It would seem that standard construction and design preferences have given way to non rectilinear styles that include the widespread use of curves, castings and tension structures. The presentation will explore various methods of achieving curves in steel as well as applications in several significant projects. Modern steel castings bear little resemblance to their brittle historic cousins. Finally tensile systems will be examined both in terms of their ability to exploit the lightness of steel as a major structural system as well as in conjunction with the use of cable systems for glazing support. The presentation will be rich with first person experience and images of all presented projects.



Learning Objectives

- Gain an understanding of how building use, form, distance to view and finish impact the design of AECC.
- Become familiar with methods for creating curved steel, and how these are applied to buildings.
- Become familiar with the modern use of steel castings by looking at several recent important projects.
- Develop an understanding the creation of tension systems in steel as they apply to support structures as well as glazing support systems.



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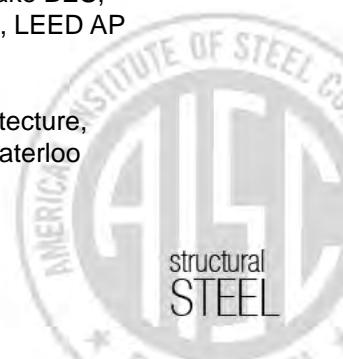


The Case of the Disappearing Right Angle: Innovation in Architectural Steel

There's always a solution in steel.



Terri Meyer Boake BES,
B.Arch, M.Arch, LEED AP
Full Professor
School of Architecture,
University of Waterloo



ARCHITECTURAL STEEL DESIGN



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THE CASE OF THE DISAPPEARING RIGHT ANGLE: INNOVATION IN ARCHITECTURAL STEEL

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Specifying AE^SS

- The identification of AE^SS by AISC in 2003
- Major factors to determine differentiation:
 - Distance to view
 - Use of the building
 - Budget
- Realization that the over-specification of welding and grinding were pricing projects out of possibility

The image shows the cover of the AISC publication "Architecturally Exposed Structural Steel". The title is at the top in white on a blue background. Below it is a photograph of a modern building's interior with a complex steel truss system and glass walls. The AISC logo is in the bottom right corner.

Beyond the orthographic



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And into a new world that is supported by innovative, advanced technologies and practices

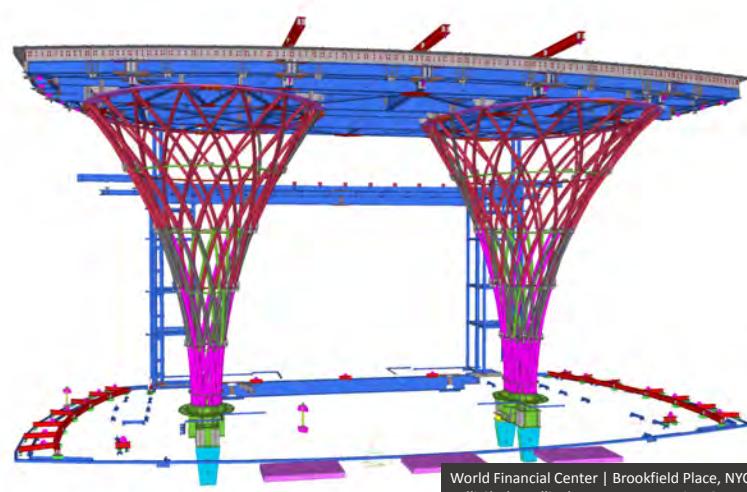


Image: Walters Inc.

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ARCHITECTURAL STEEL DESIGN

SCOPE OF THE PRESENTATION

- Creating curves
- Contemporary castings
- Tensile structures

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ARCHITECTURAL STEEL DESIGN

CREATING CURVES



Wells Fargo Building, Salt Lake City, Utah
HKS Architects

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3 Ways of Tackling “Curves”



Arganzuela Bridge, Madrid, Spain
Dominique Perrault, MC2 – Julio Martínez Calzón

- Bend the steel
 - Using a 3 point smooth bending machine
 - Using a plate rolling machine
 - Using a brake press
 - Heat applied bending
- Facet the building to give the appearance of curves while using straight members
- Cut curved forms out of plate material

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Bending Steel Issues



- Member type
- Orientation of member
- Length of member
- Shipping considerations
- Sourced out work
- Accuracy of curve
- Multiple curves

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Hard Way vs. Easy Way?

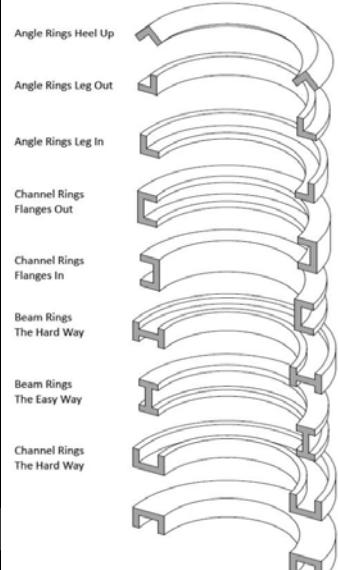


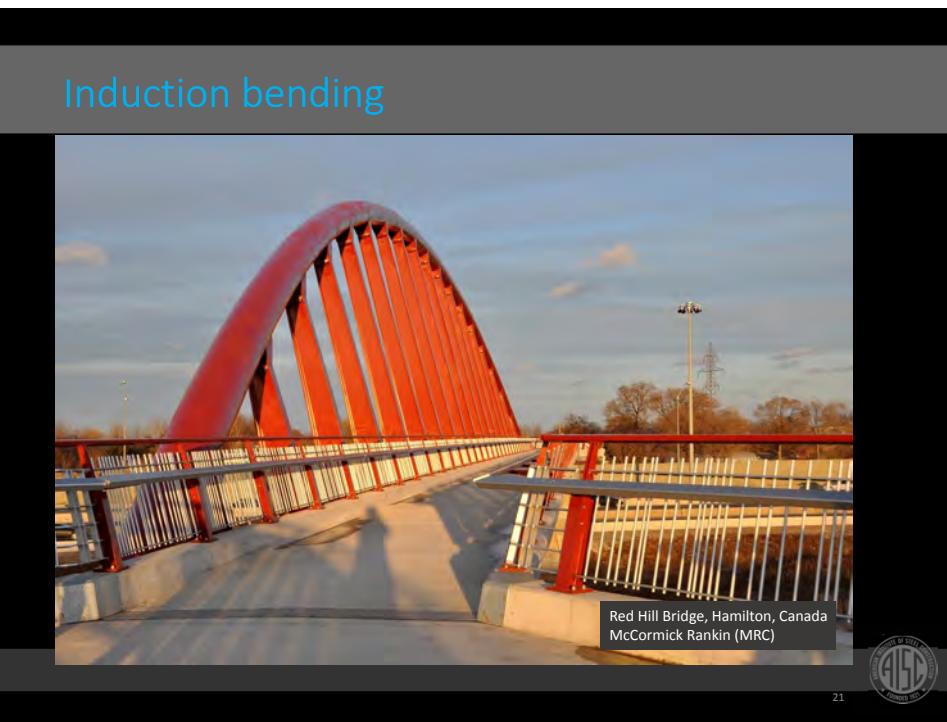
Image: Vincent Hui

- Angle Rings Heel Up
- Angle Rings Leg Out
- Angle Rings Leg In
- Channel Rings Flanges Out
- Channel Rings Flanges In
- Beam Rings The Hard Way
- Beam Rings The Easy Way
- Channel Rings The Hard Way

- Different shapes are more or less “easy” to bend
- Tendency for buckling on tighter curves
- Thin steel likely to buckle
- Heavier steel harder to bend

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Correctness of curve



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Transportation Issues



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Straight ends!



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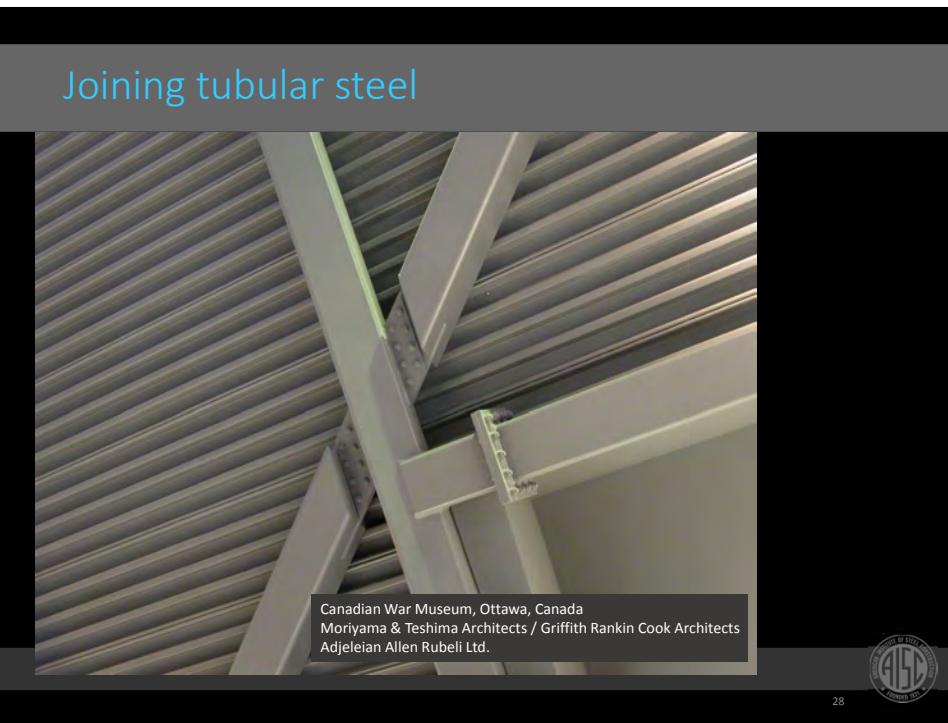
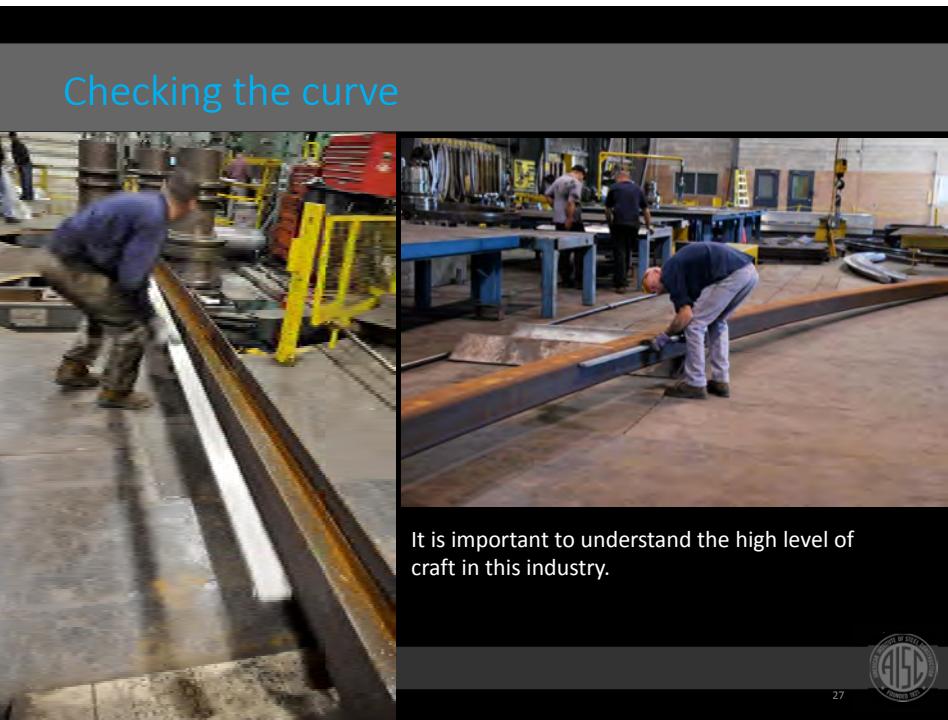


Rolling plate with a 3 point pressure system



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Splicing bent steel

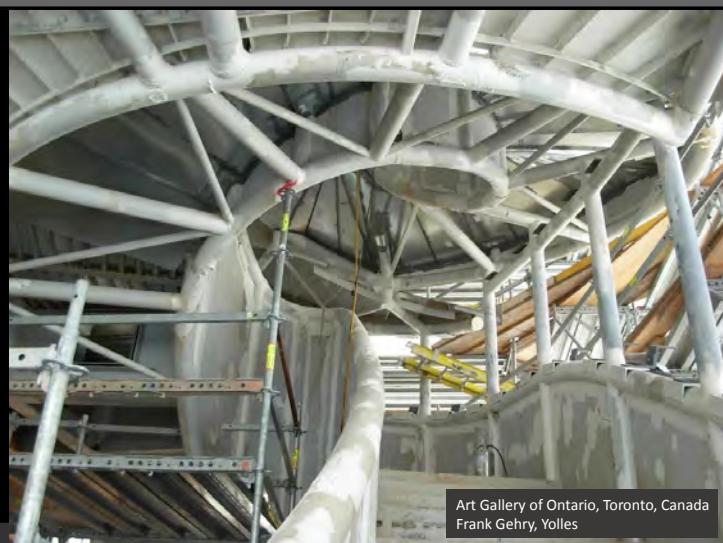


Art Gallery of Ontario, Toronto, Canada
Frank Gehry, Yolles
Fabrication and erection: Benson Steel

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Splicing bent tubes



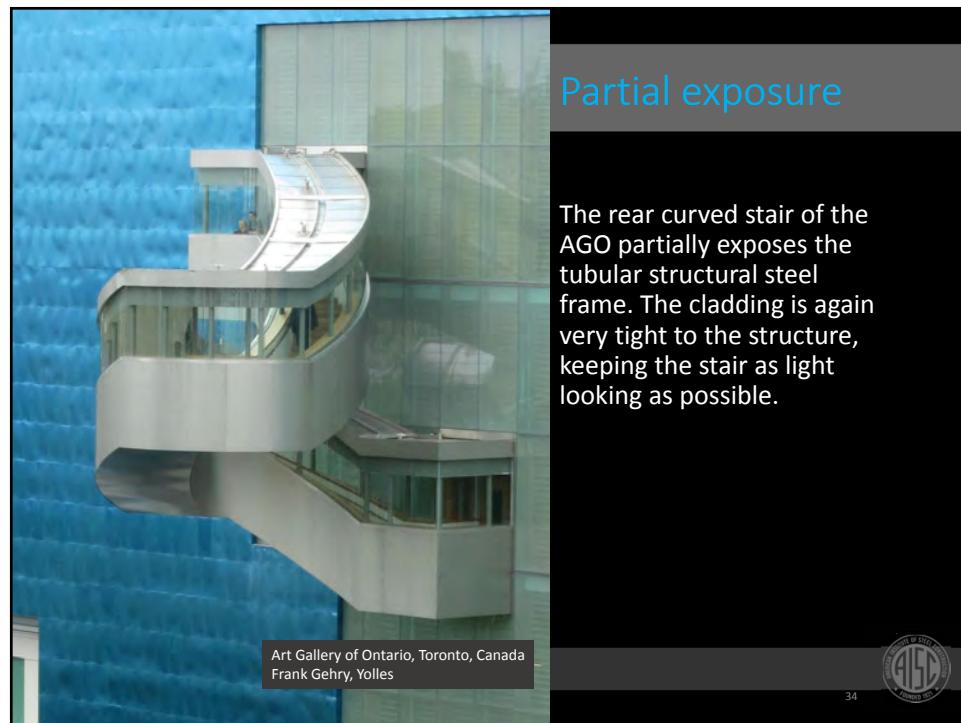
Art Gallery of Ontario, Toronto, Canada
Frank Gehry, Yolles

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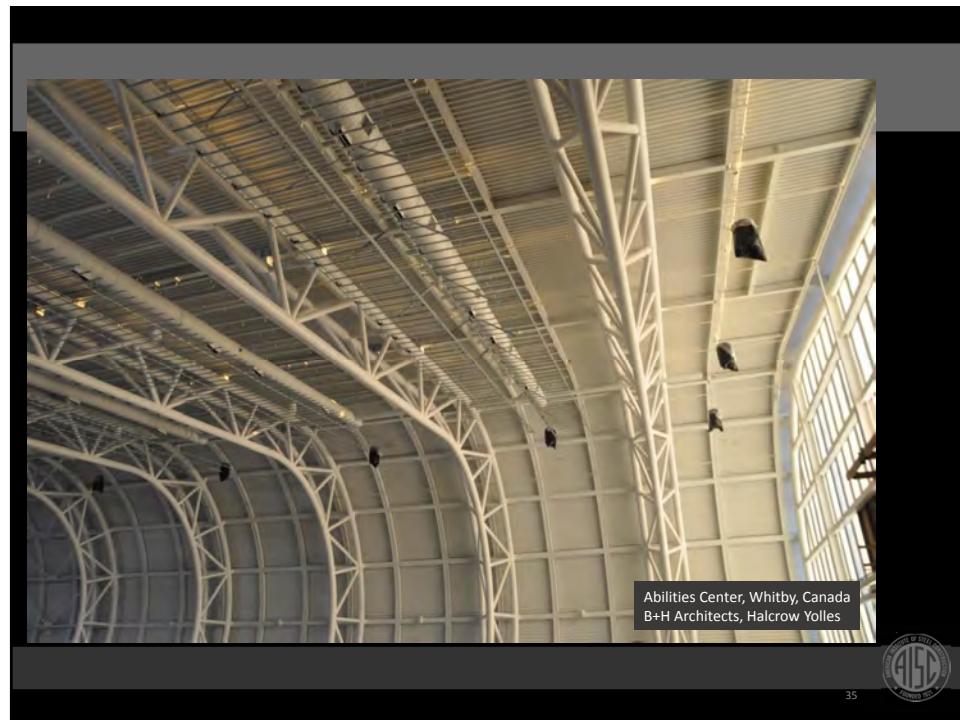
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Partial exposure
The rear curved stair of the AGO partially exposes the tubular structural steel frame. The cladding is again very tight to the structure, keeping the stair as light looking as possible.

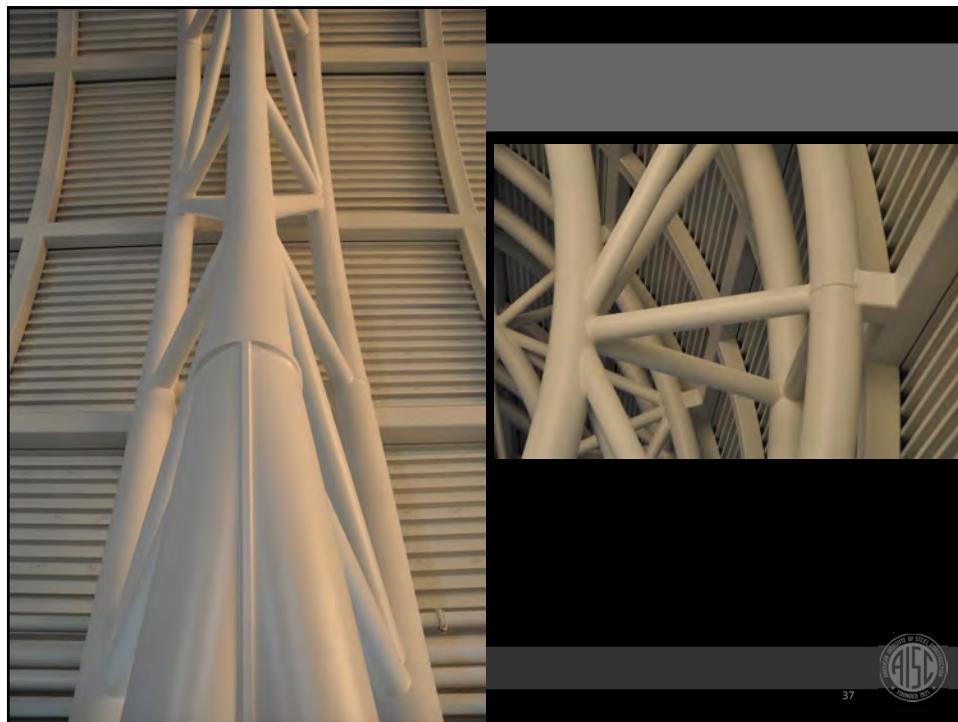
Art Gallery of Ontario, Toronto, Canada
Frank Gehry, Yolles



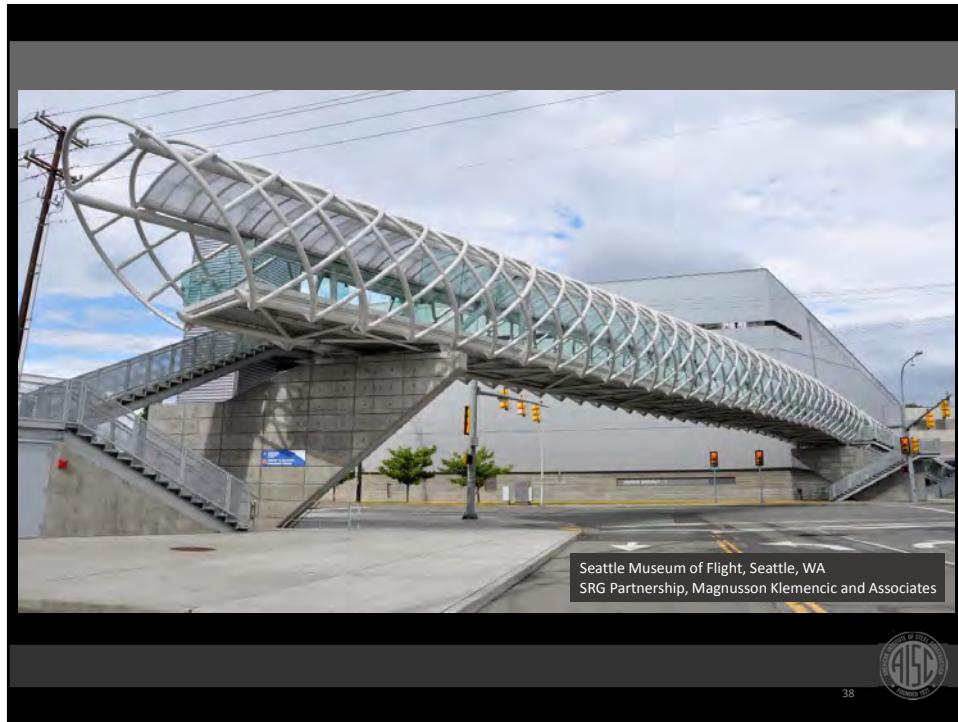
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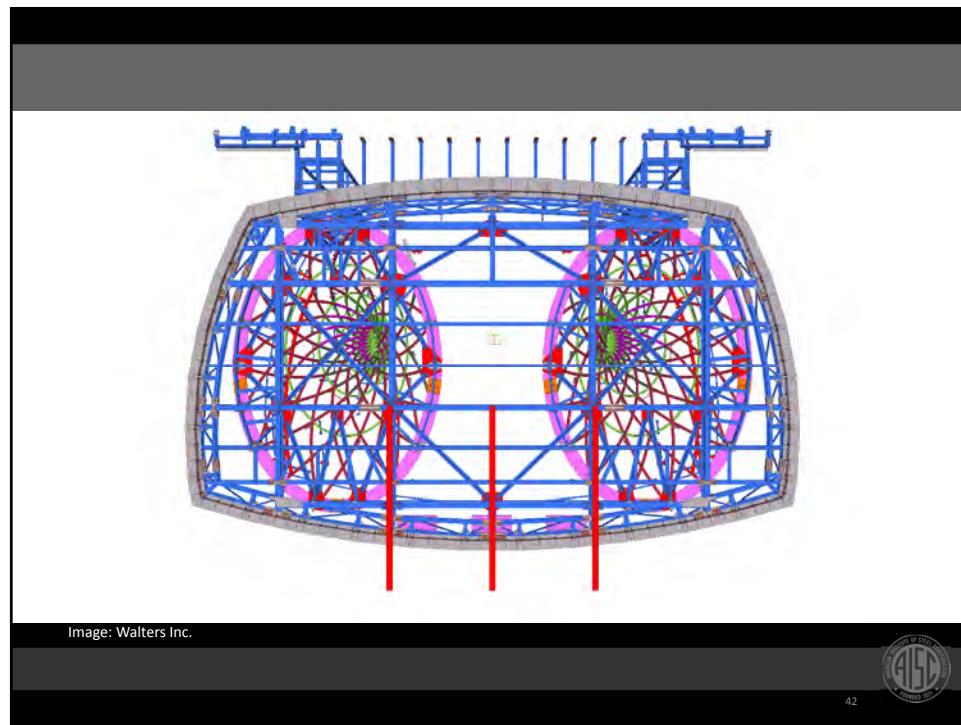
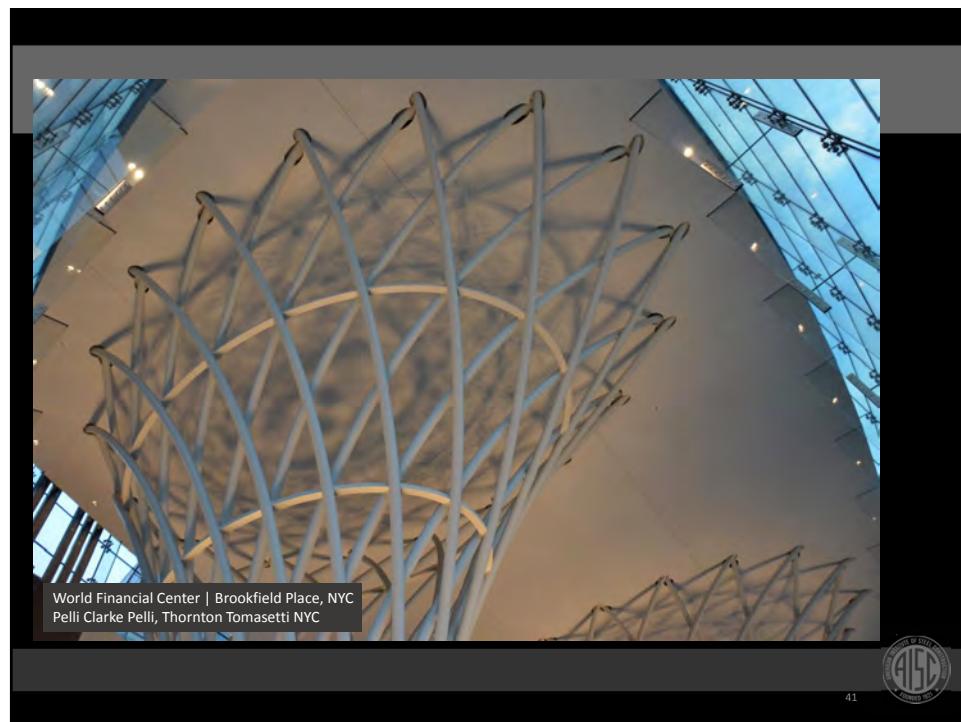


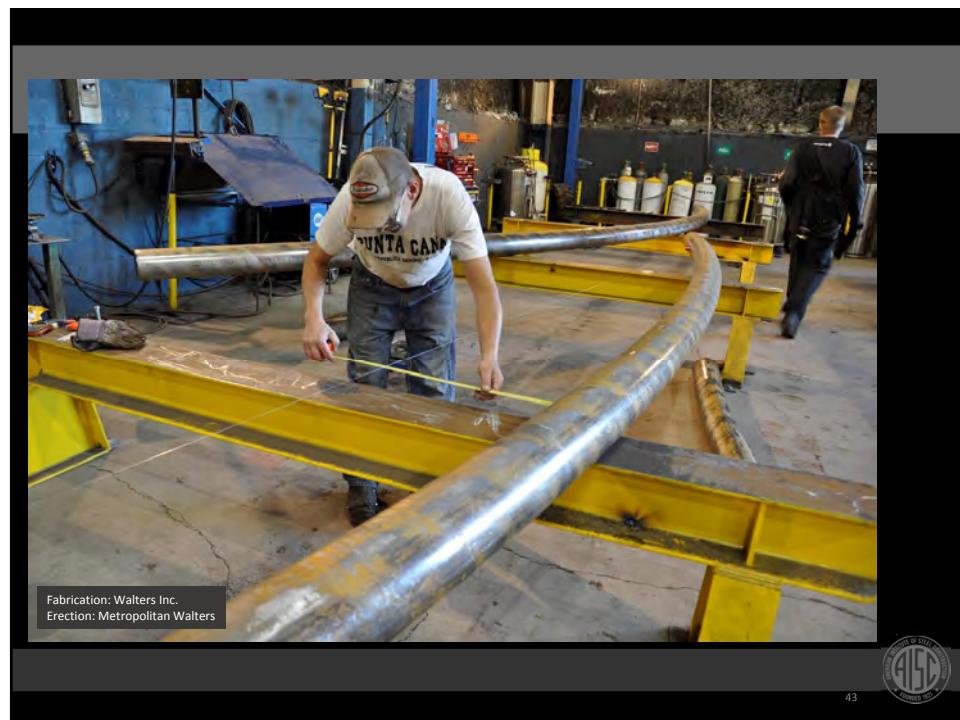
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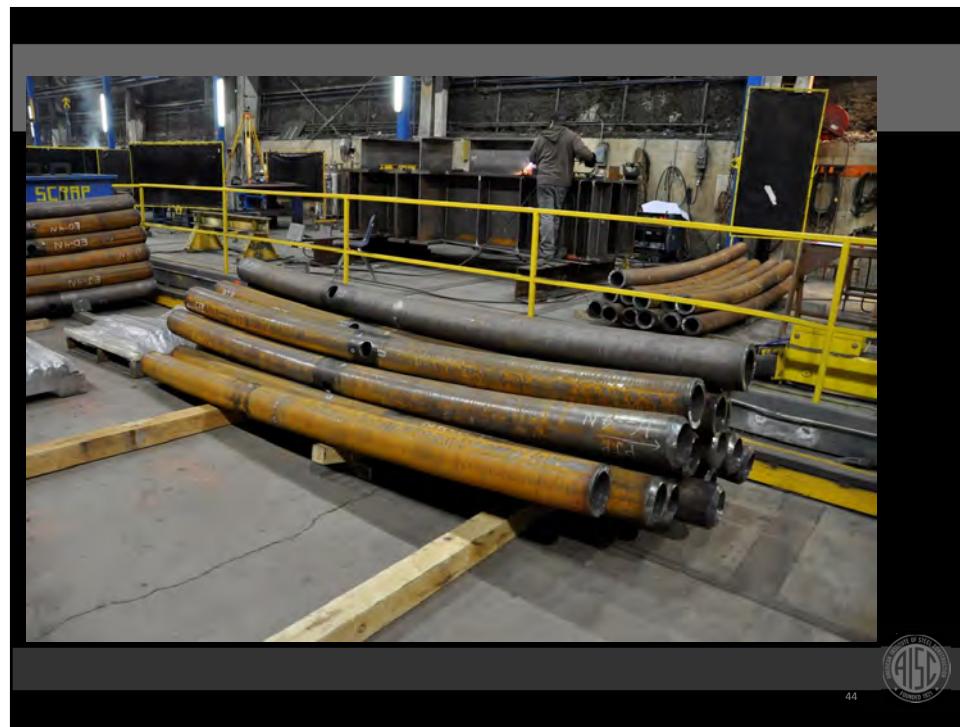
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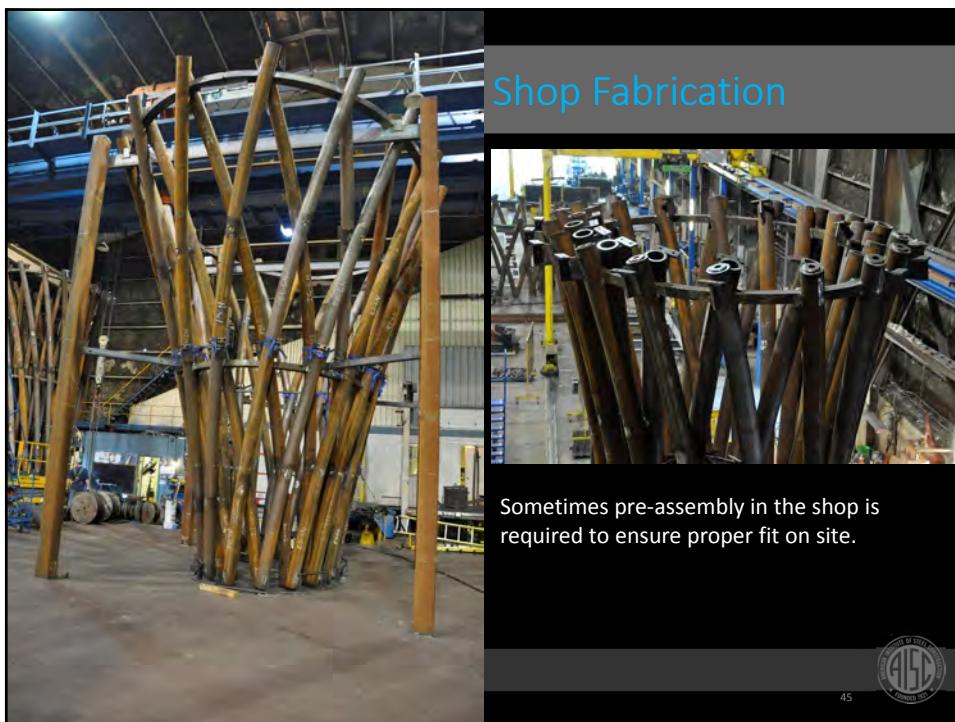


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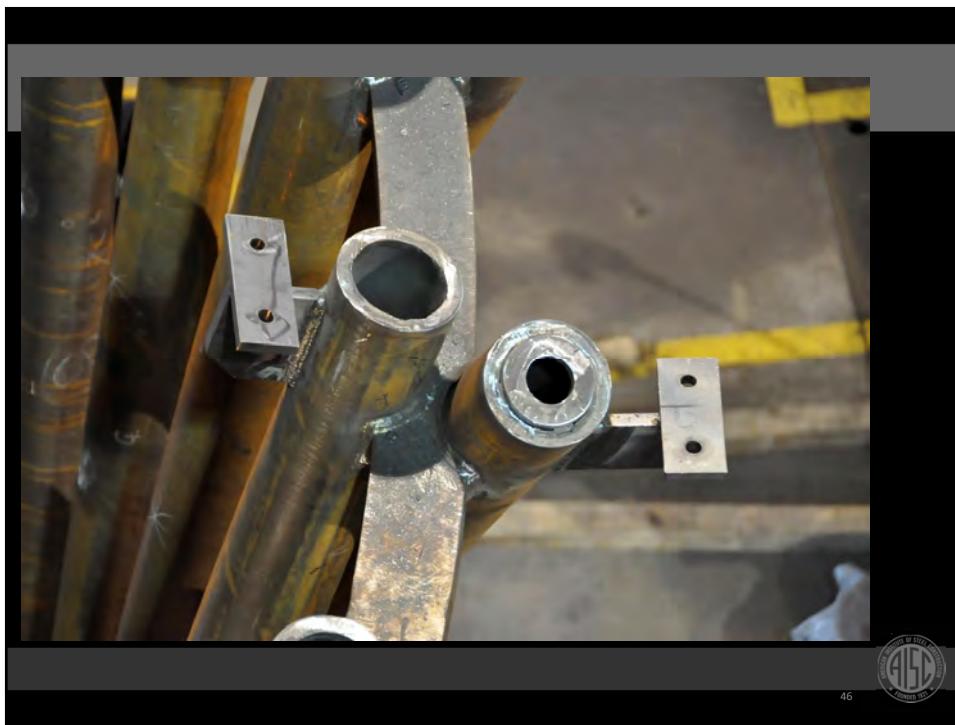


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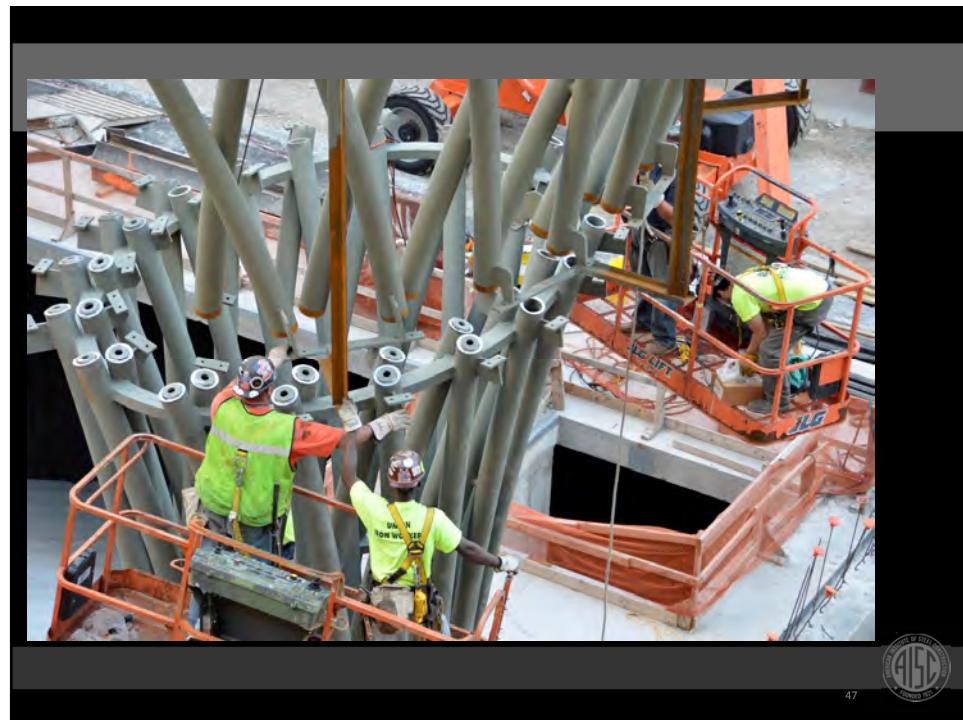


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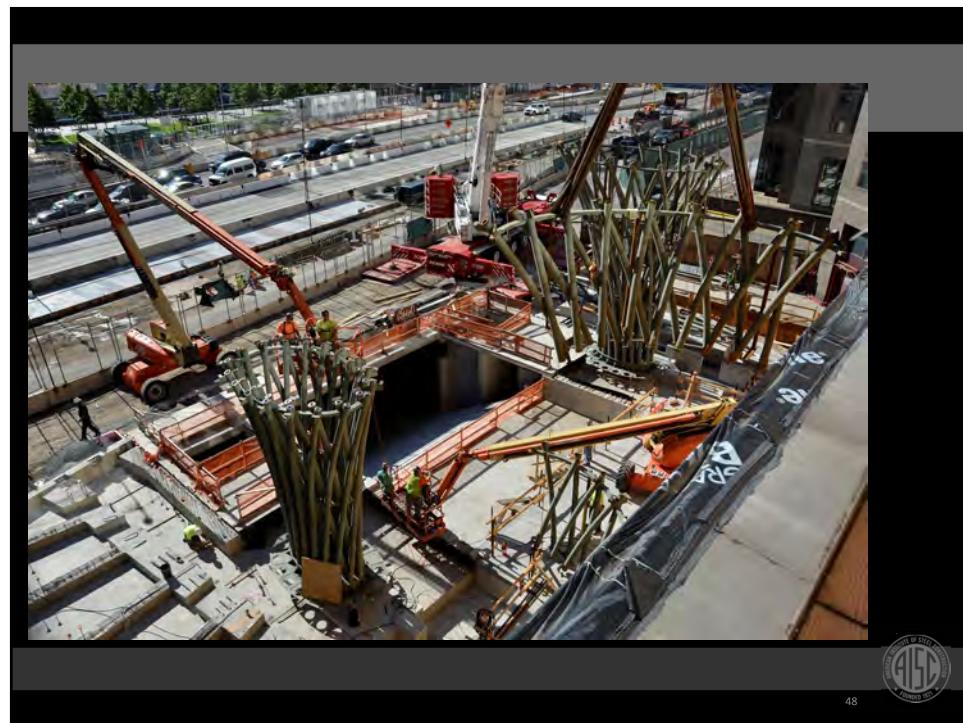


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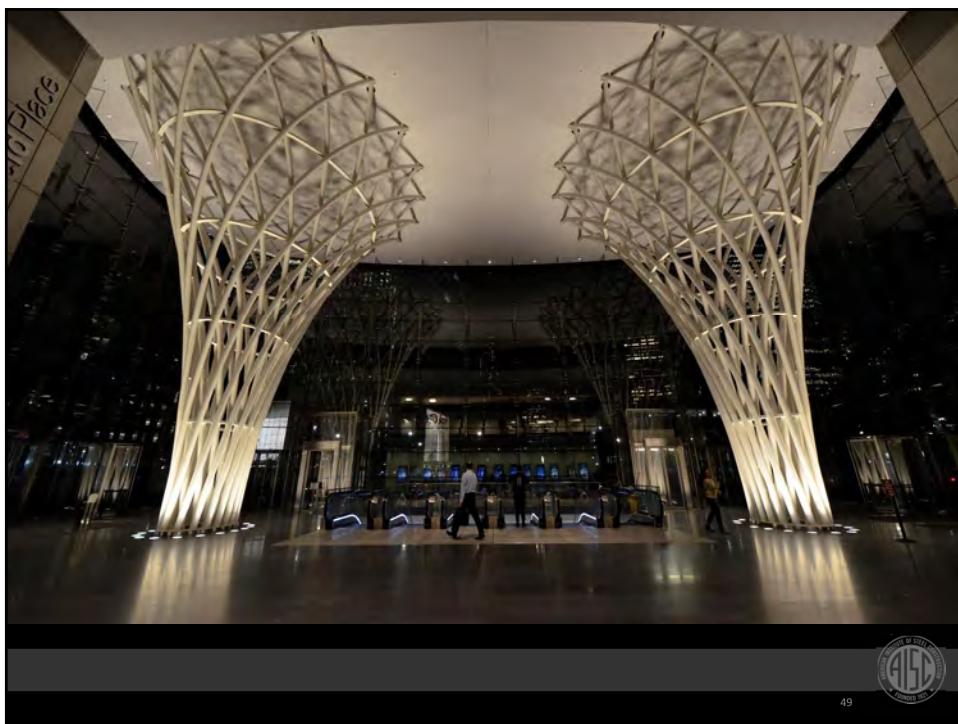


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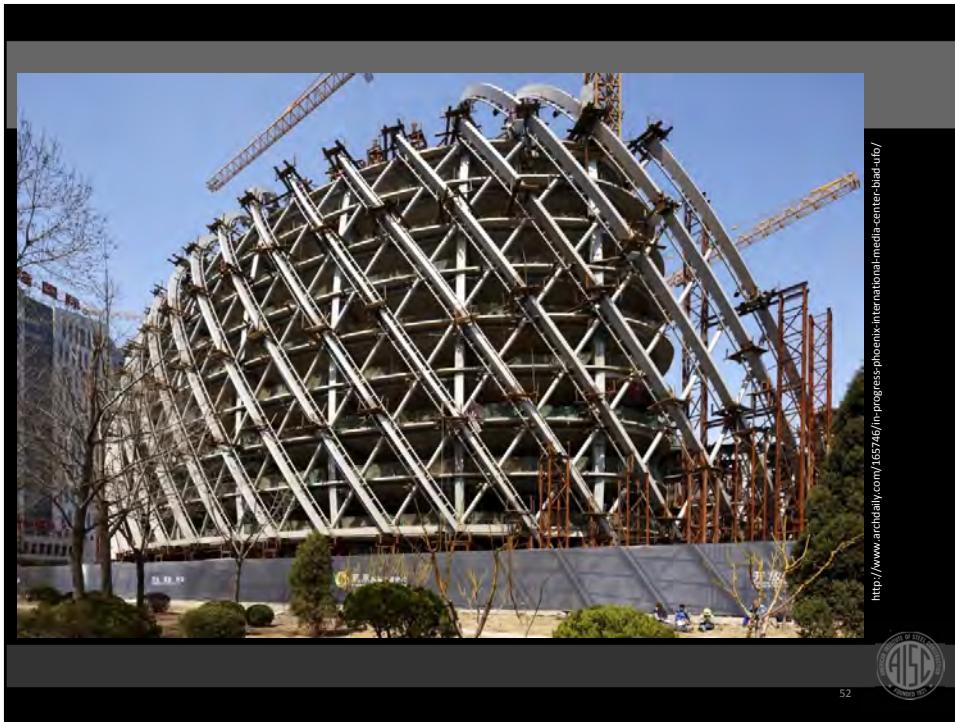
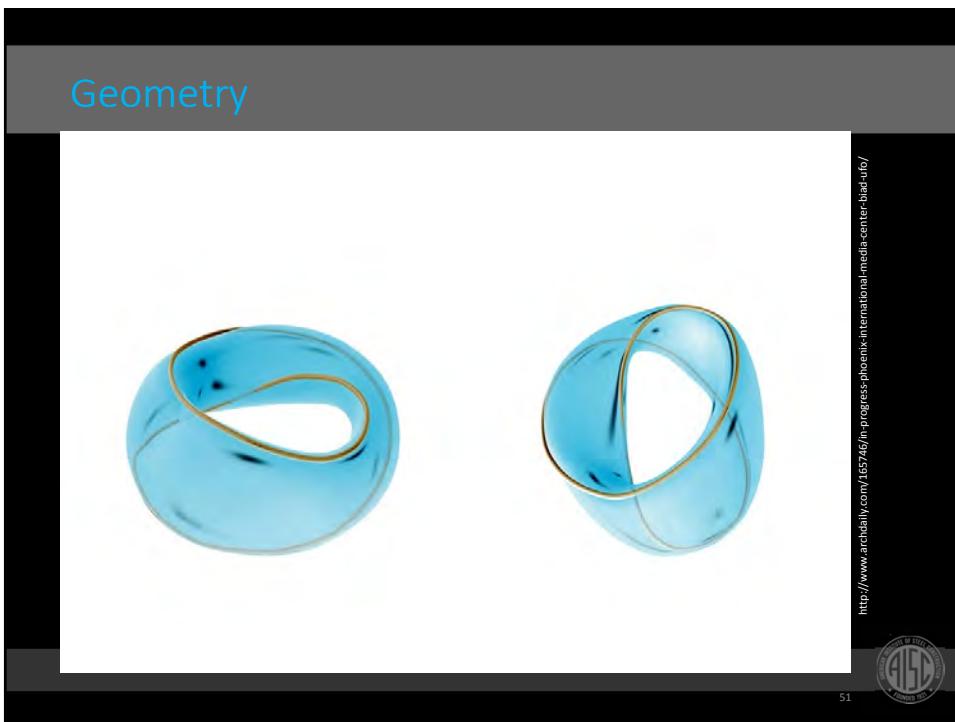


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Flying ramps in trusses



<http://www.archdaily.com/165746/in-progress-phoenix-international-media-center-blak-utq/>

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Multiple curvatures

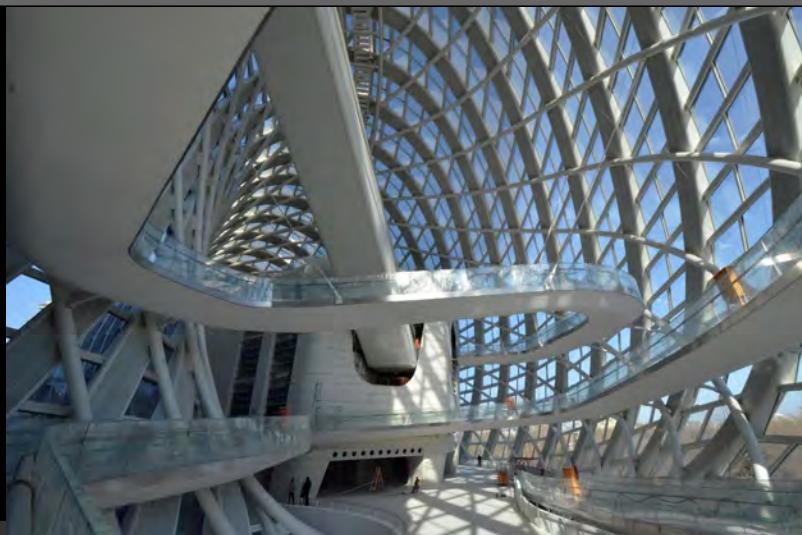


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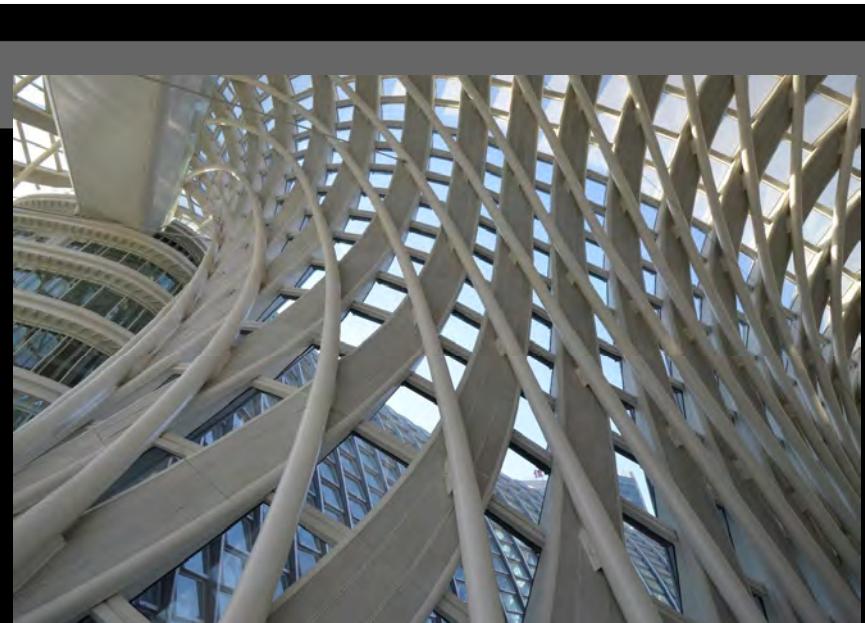
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Interior nearing completion

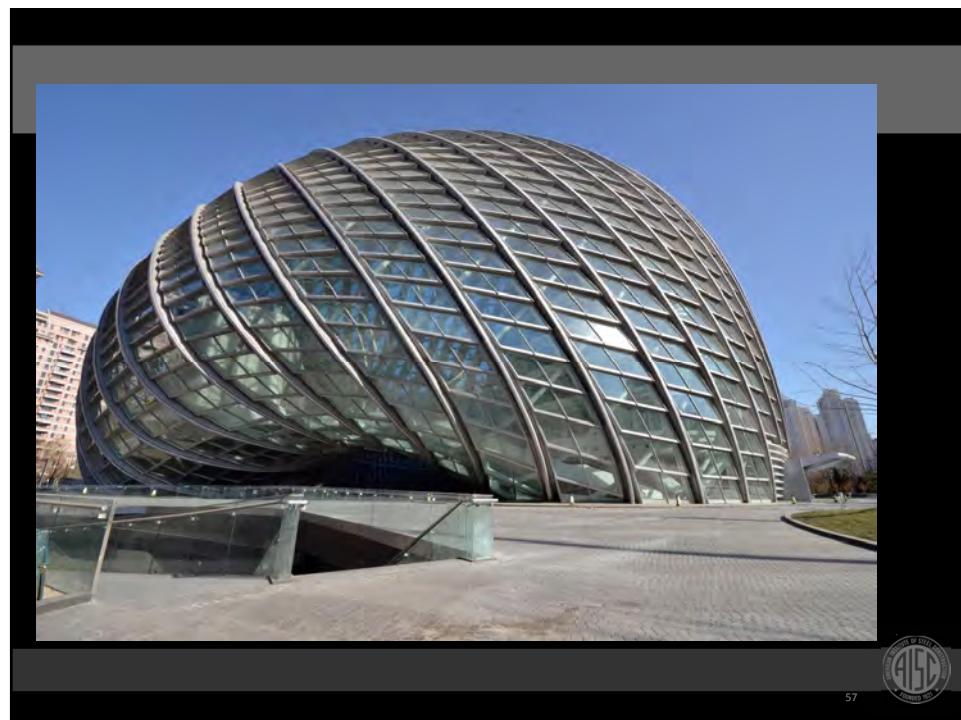


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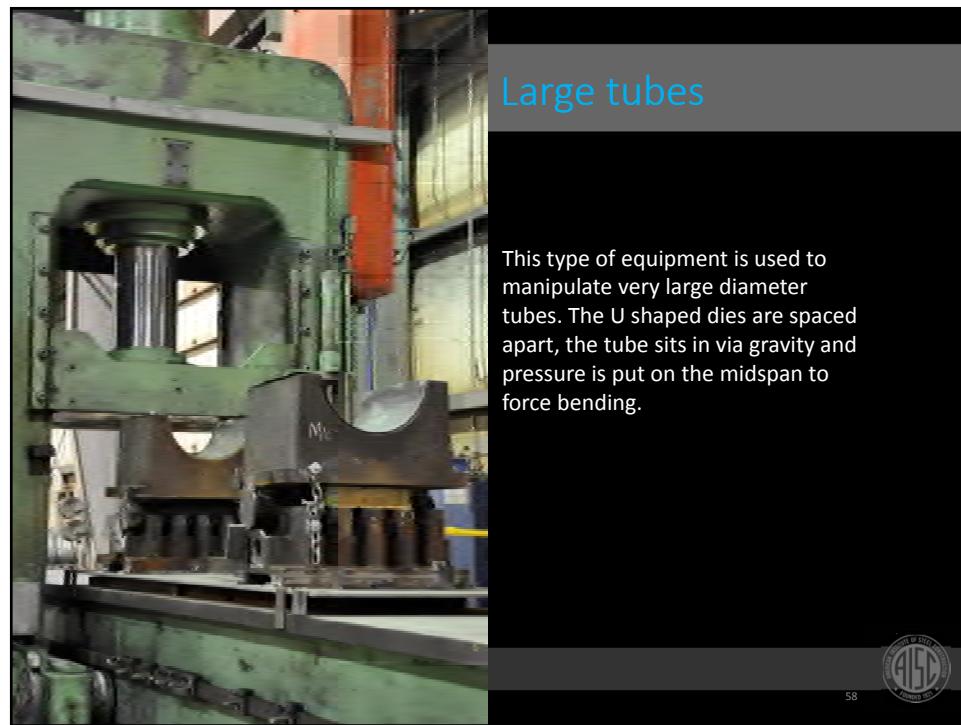


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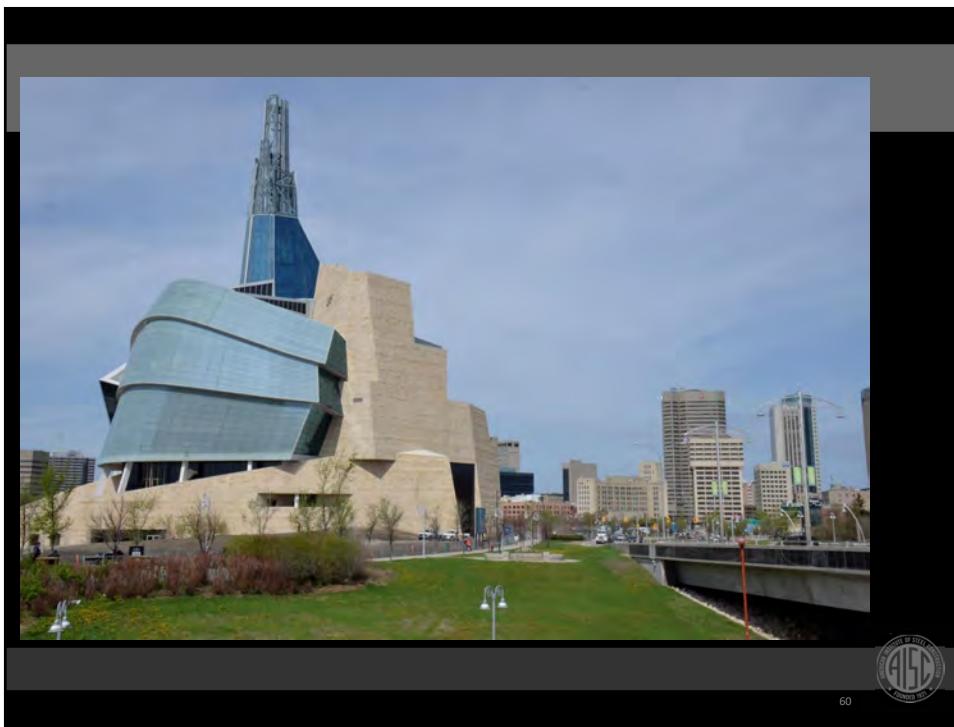


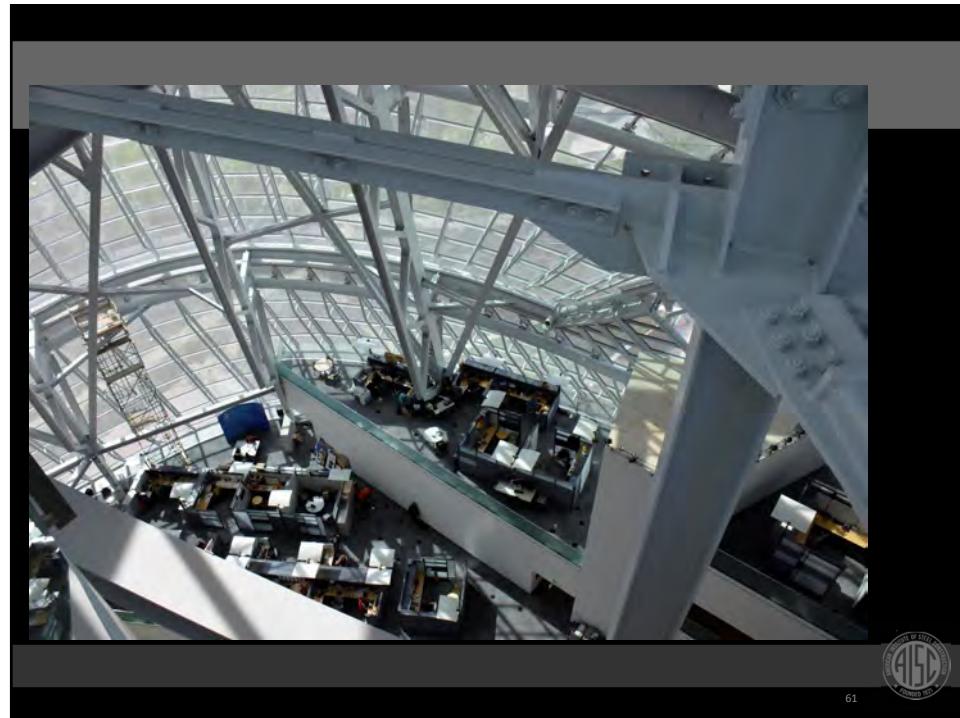
Large tubes

This type of equipment is used to manipulate very large diameter tubes. The U shaped dies are spaced apart, the tube sits in via gravity and pressure is put on the midspan to force bending.

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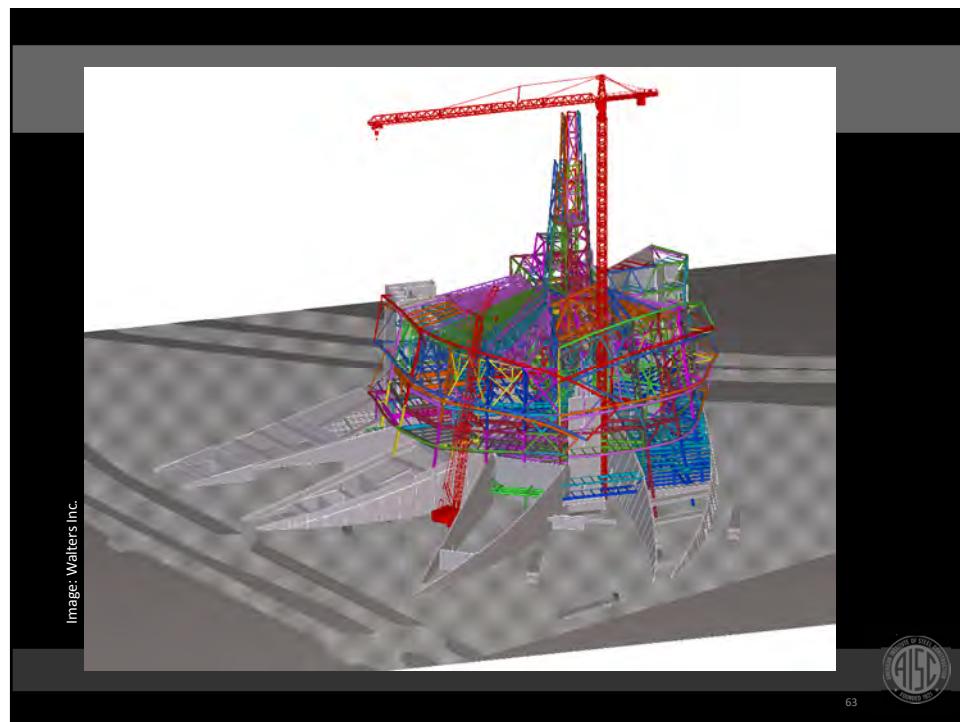


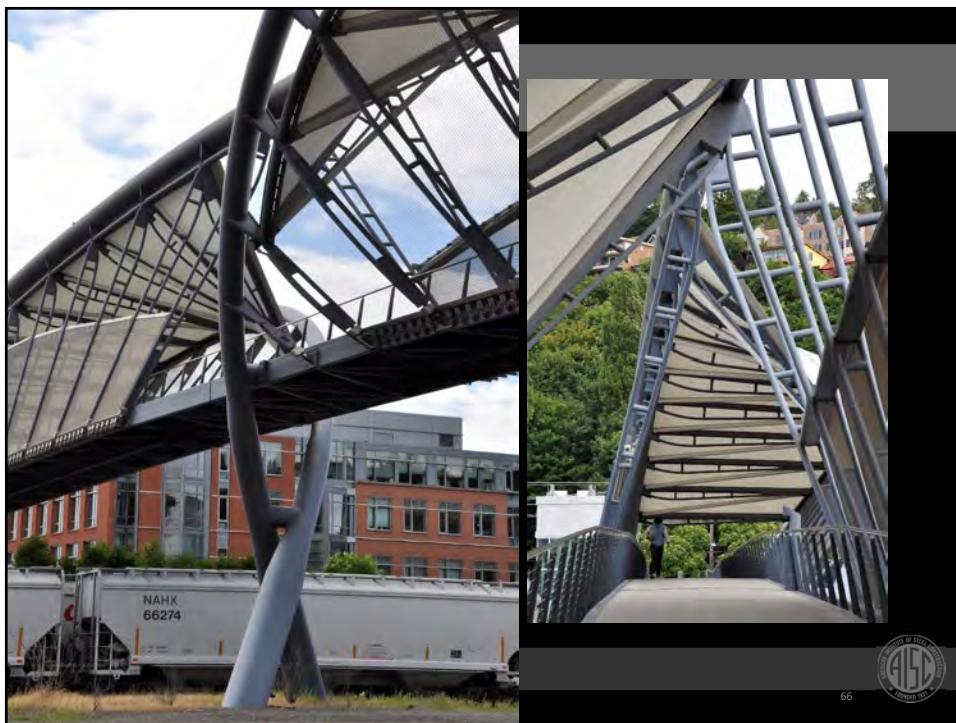
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Brake forming



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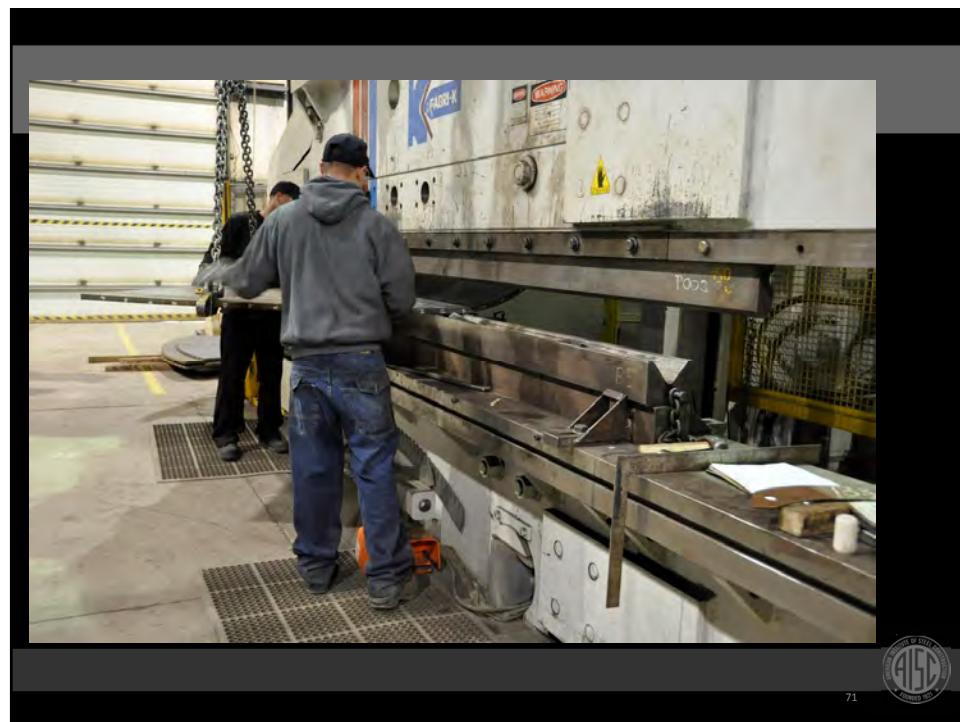


Marking the plates

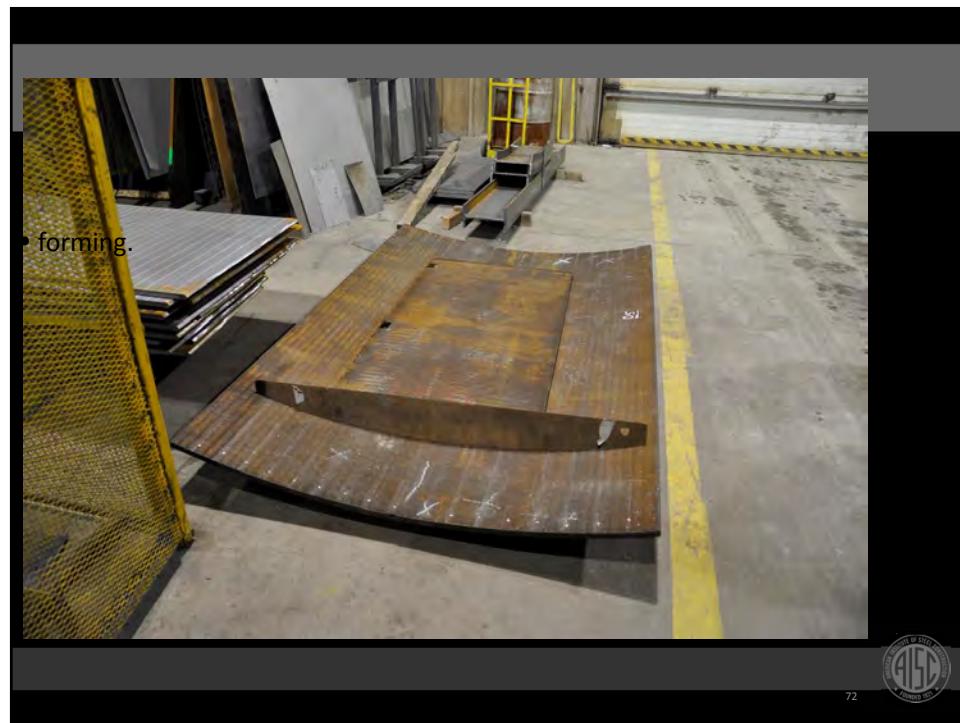


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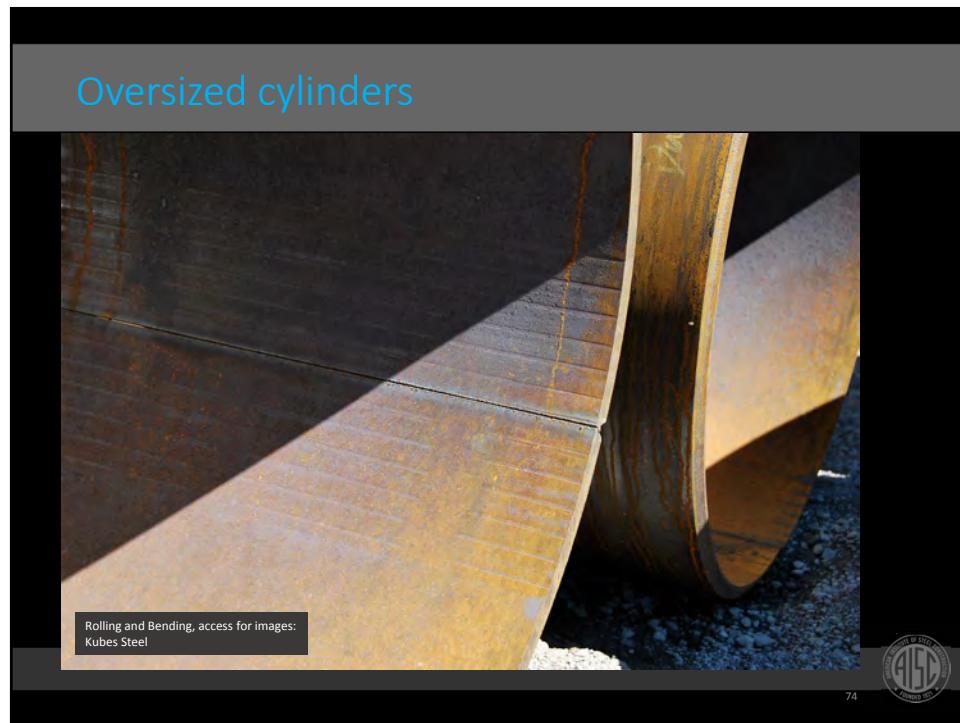
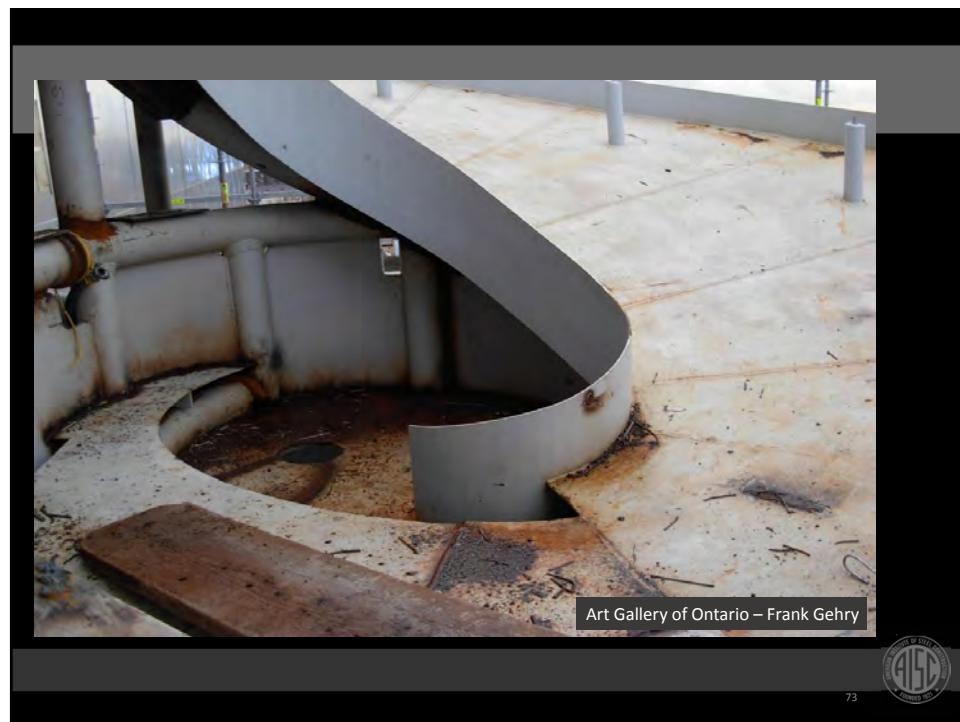


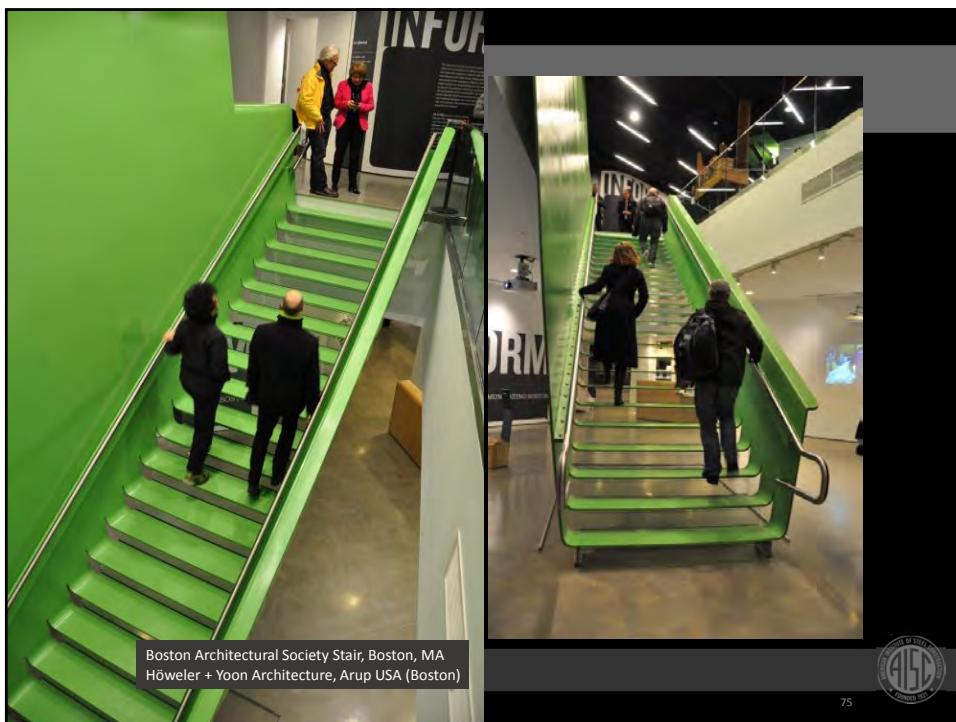
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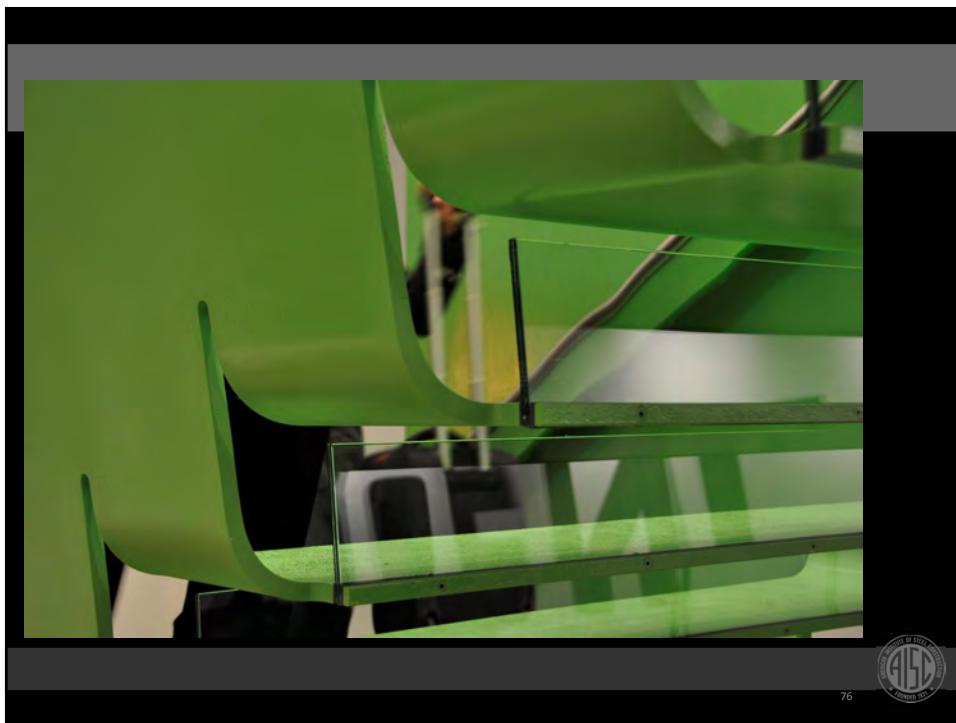
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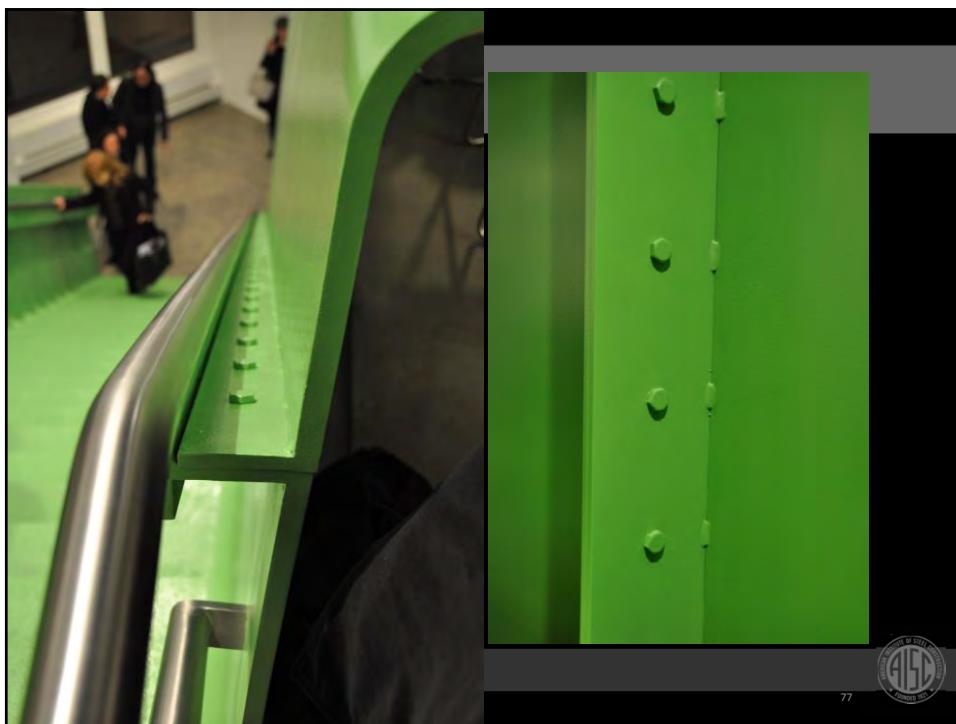


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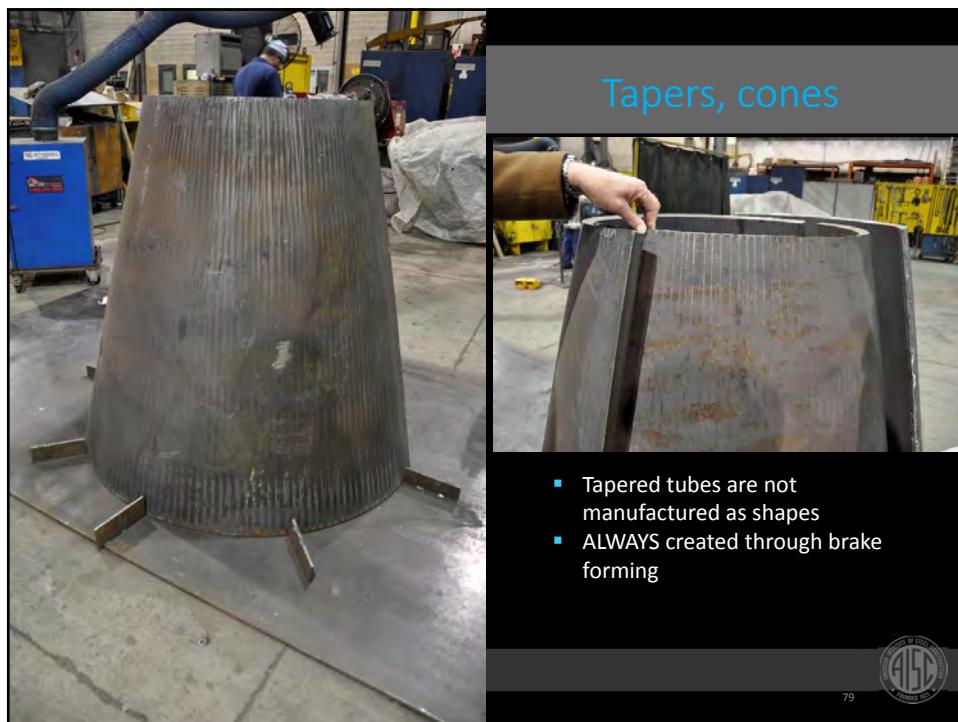


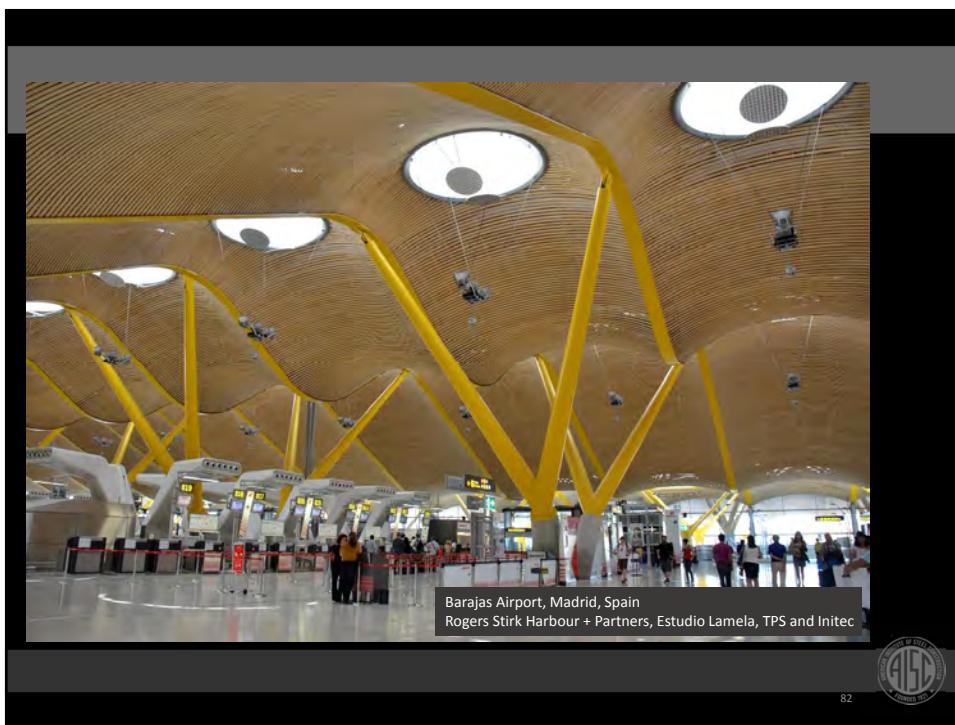
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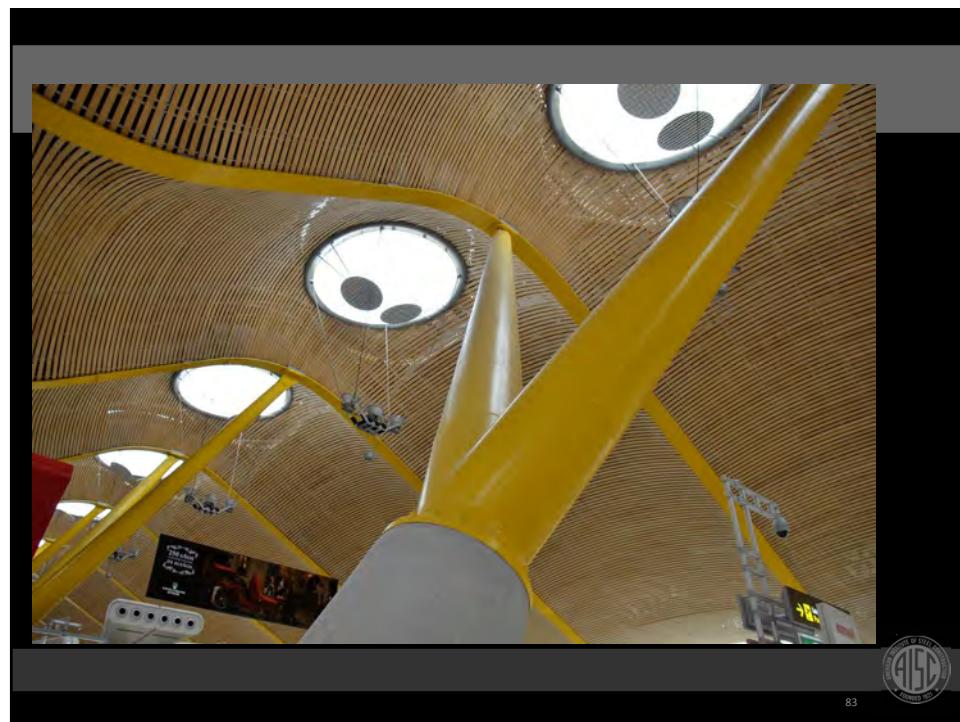


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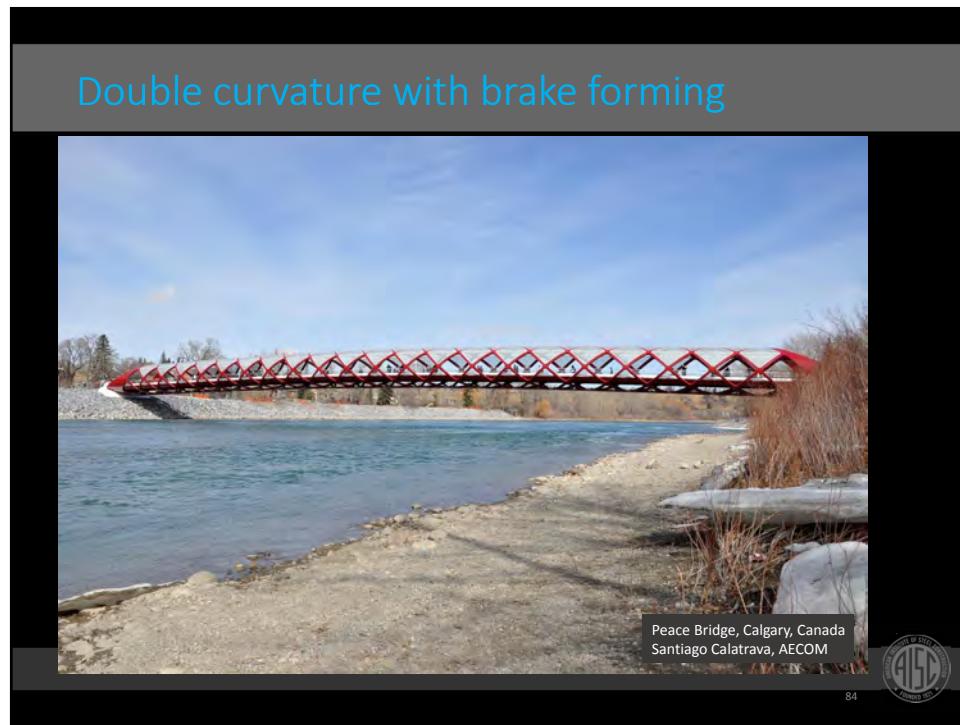






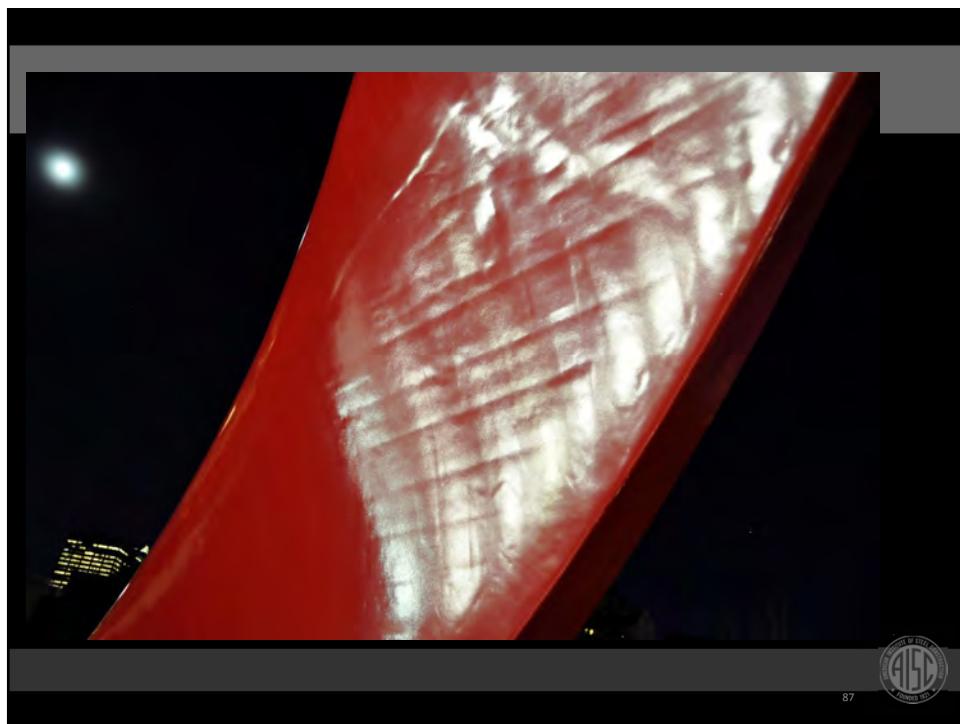


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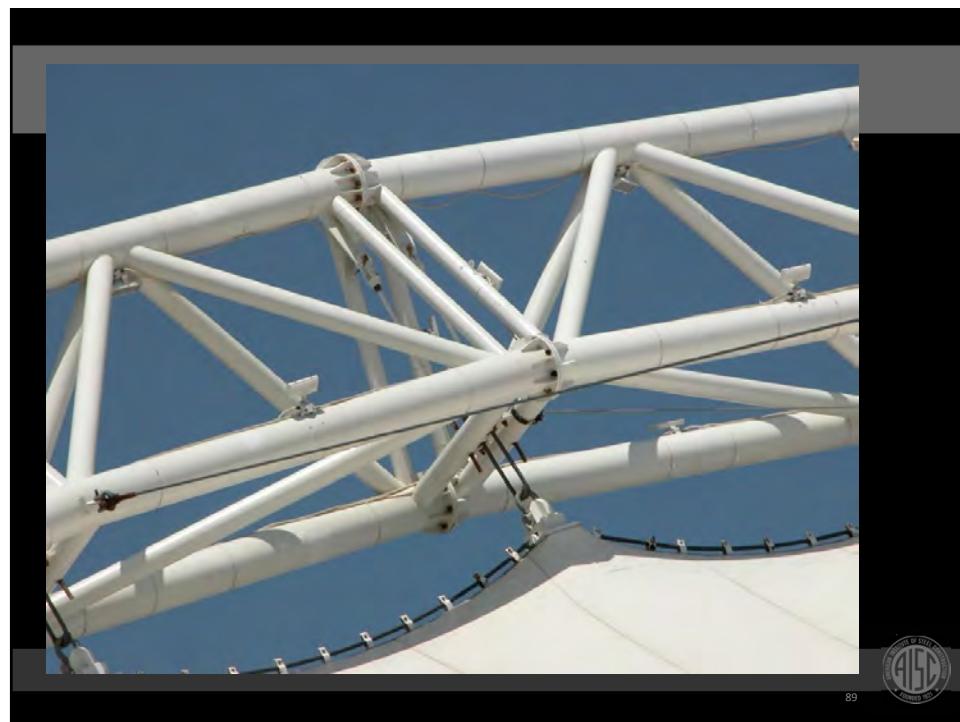


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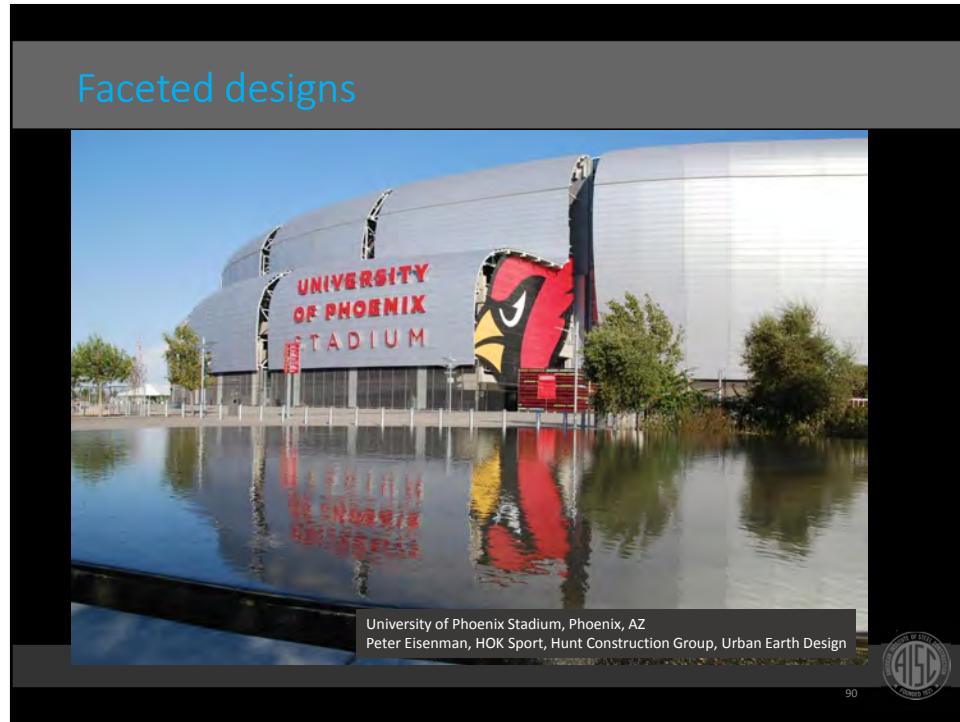


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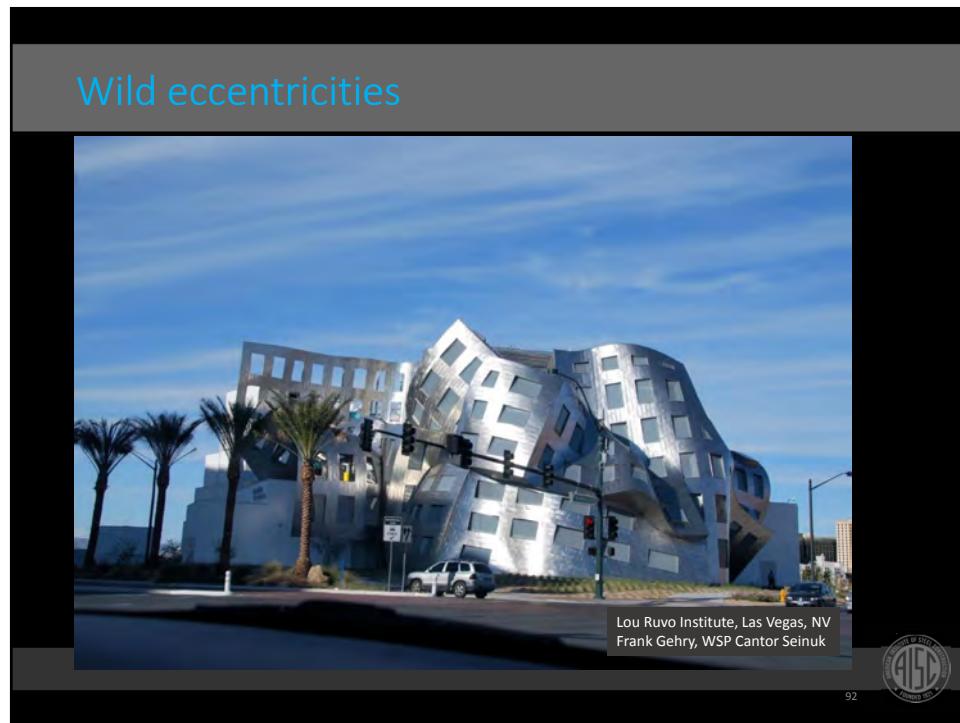
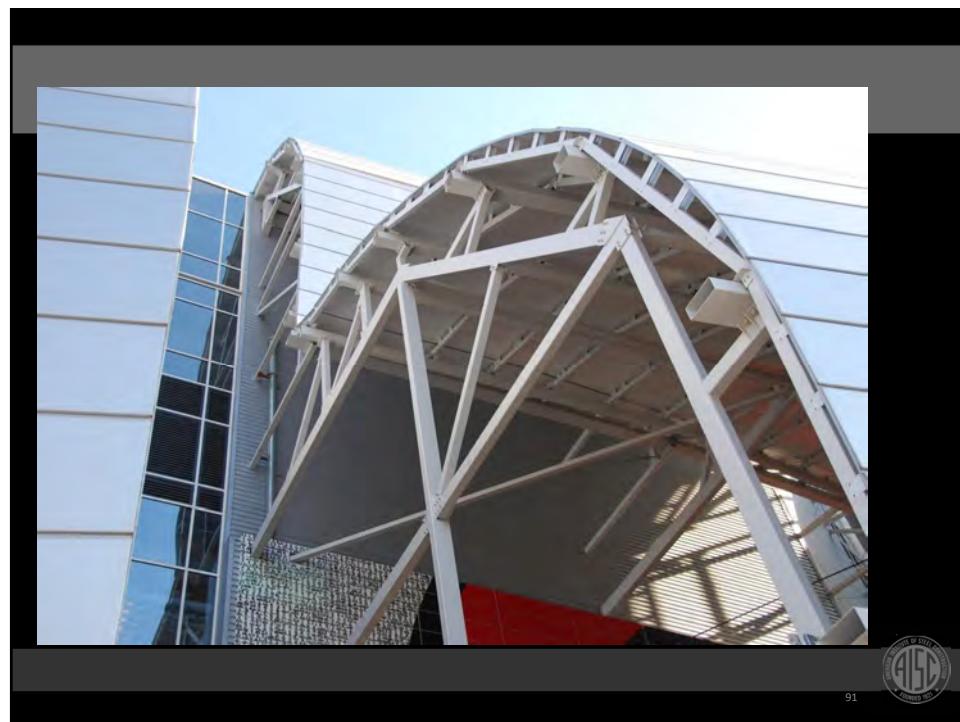
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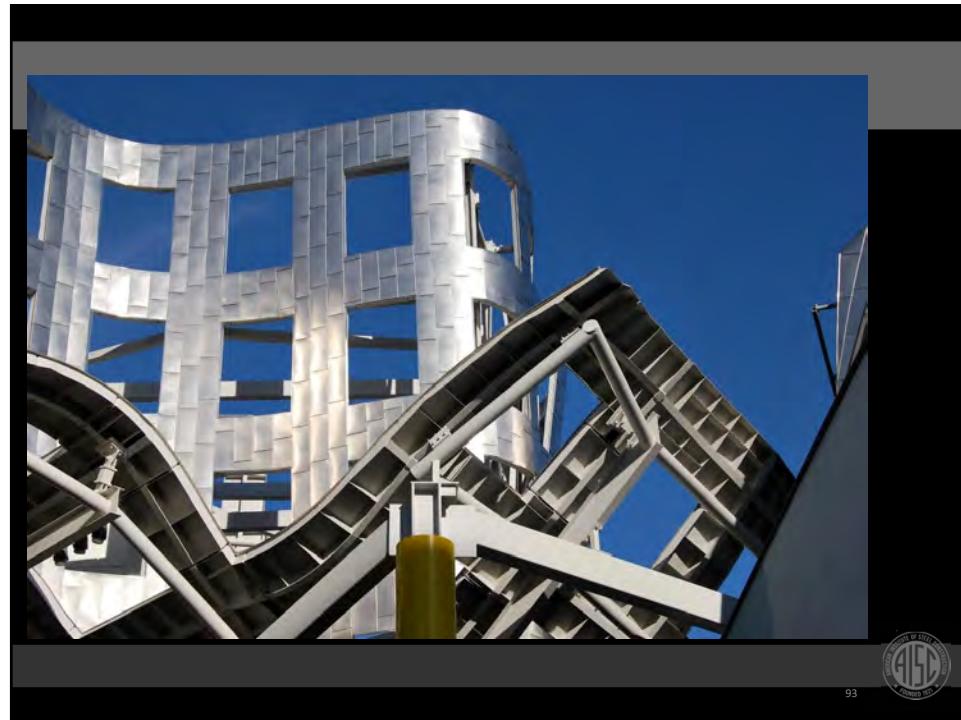


University of Phoenix Stadium, Phoenix, AZ
Peter Eisenman, HOK Sport, Hunt Construction Group, Urban Earth Design

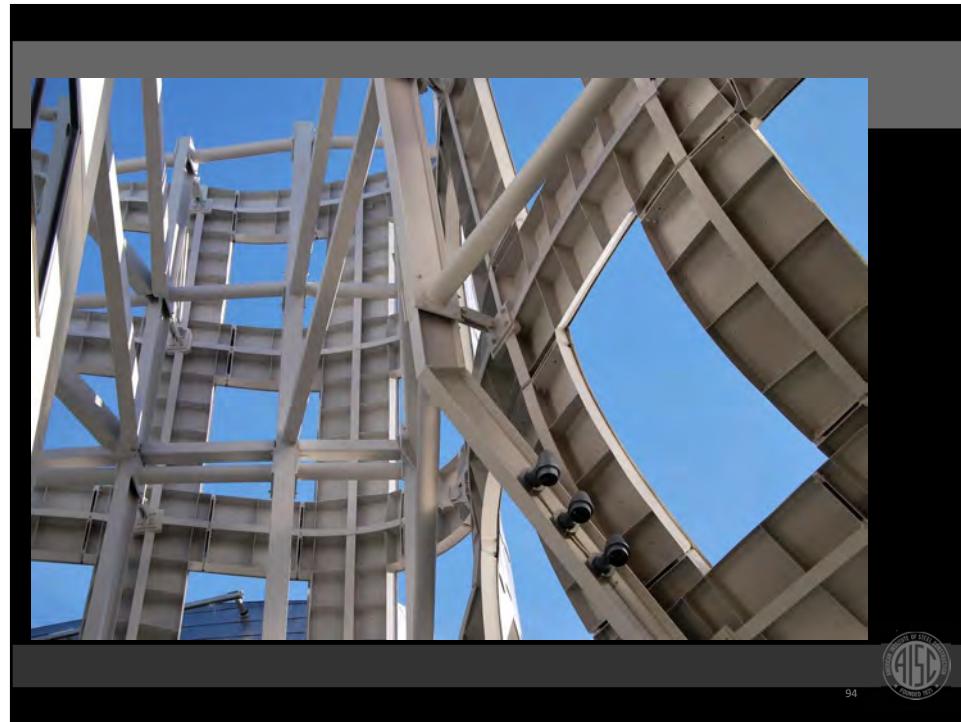
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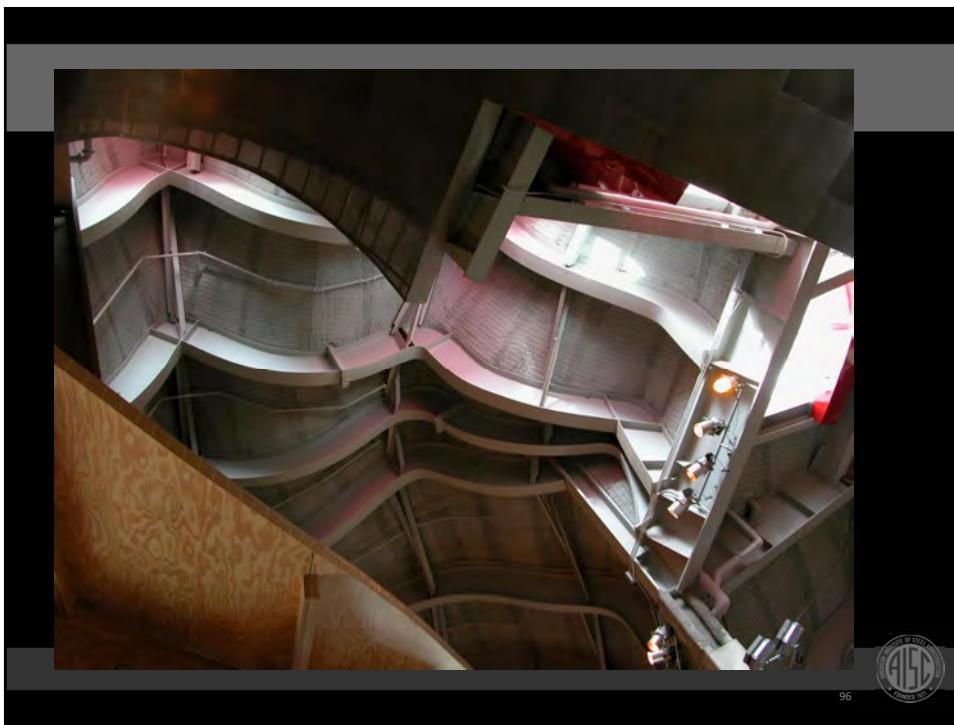


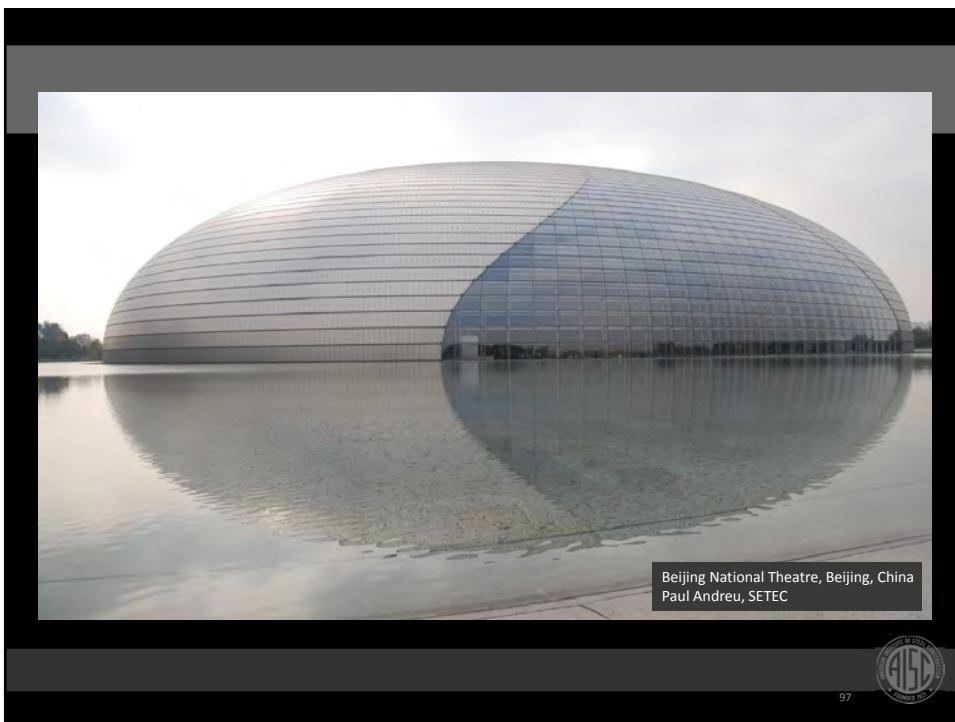
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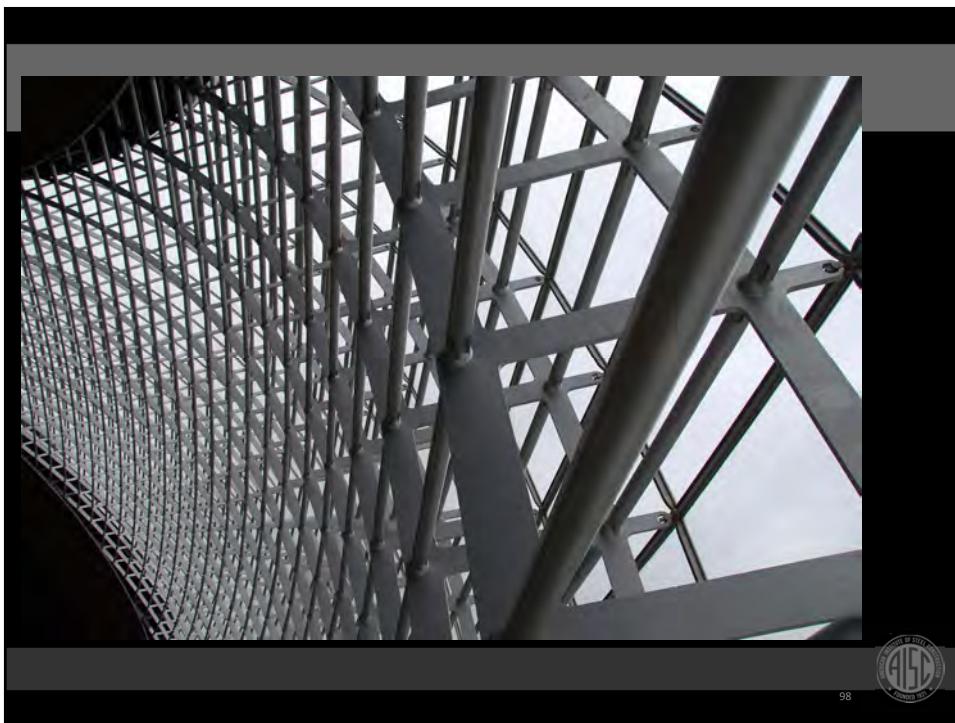
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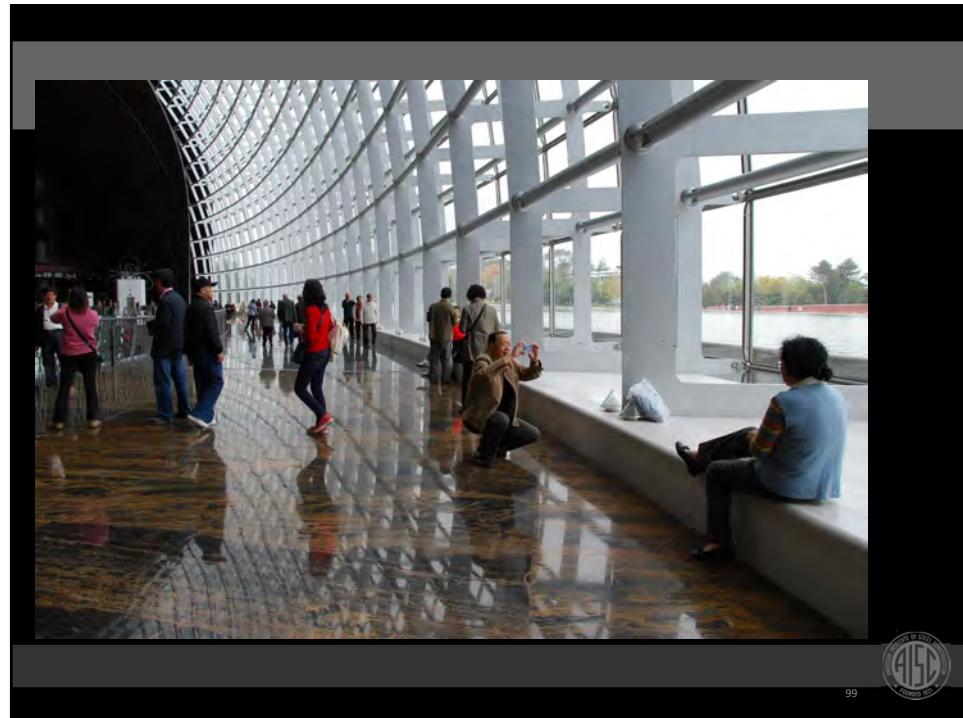


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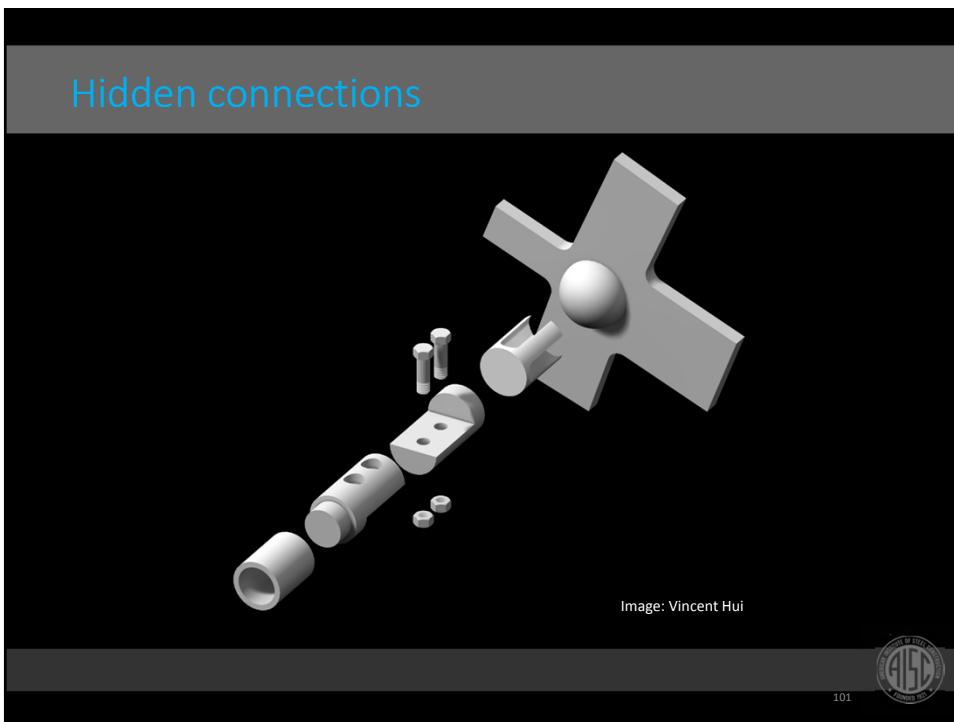


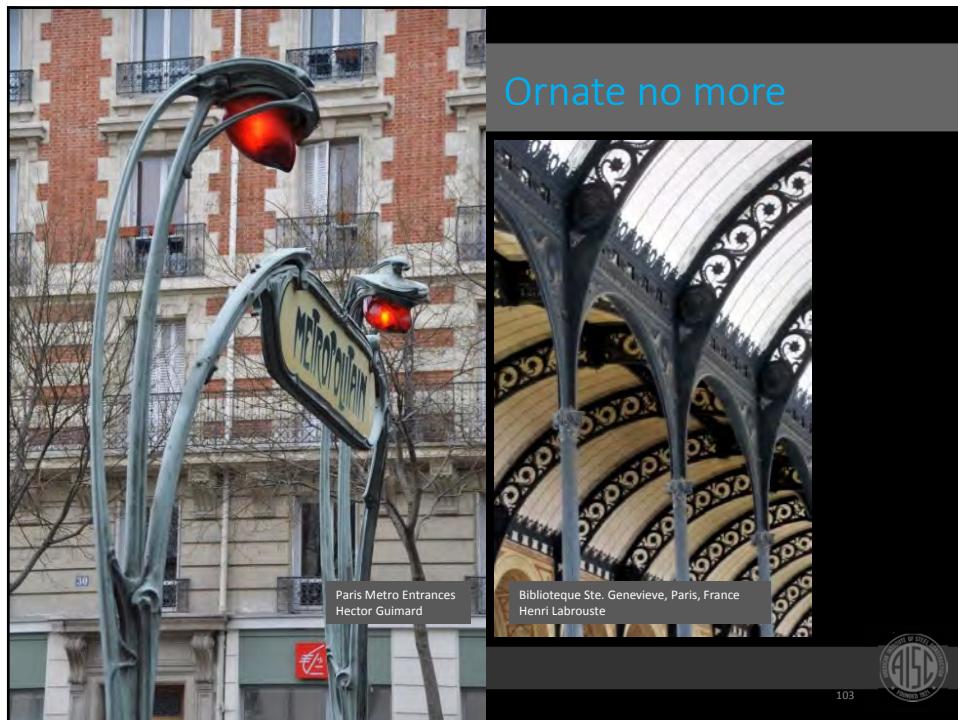
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Castings

- Used for special connections that join multiple members
- Can be one-of large pieces and larger end connectors formed with expendable molds (i.e. Structural)
- Can be smaller investment (lost wax) cast pieces made in great quantity (i.e. glazing attachments)
- Investment cast pieces can be highly detailed
- Can be solid or hollow depending on size and purpose
- Forging is also used but creates much simpler elements due to the almost crude nature of the process

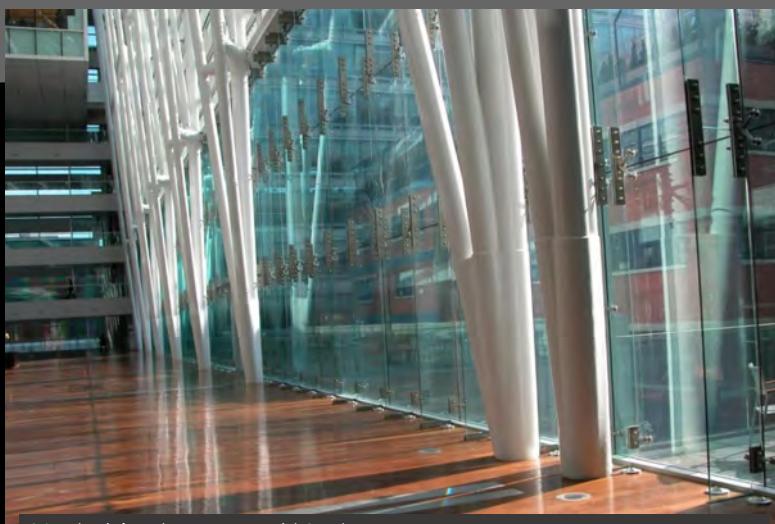
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Castings

- The sand used in expendable negative molds is collected, treated and reused to increase sustainability
- The tooling used for the positive molds:
 - Some use polystyrene which can only be used once
 - Some use pine wood which allow for multiple uses
 - Where production is increased, mahogany is used to increase the number of reuses of the tooling
- It is said that when the fabrication costs for a connection become 4 times as expensive as the materials used to create the connection, then castings begin to make economic sense.



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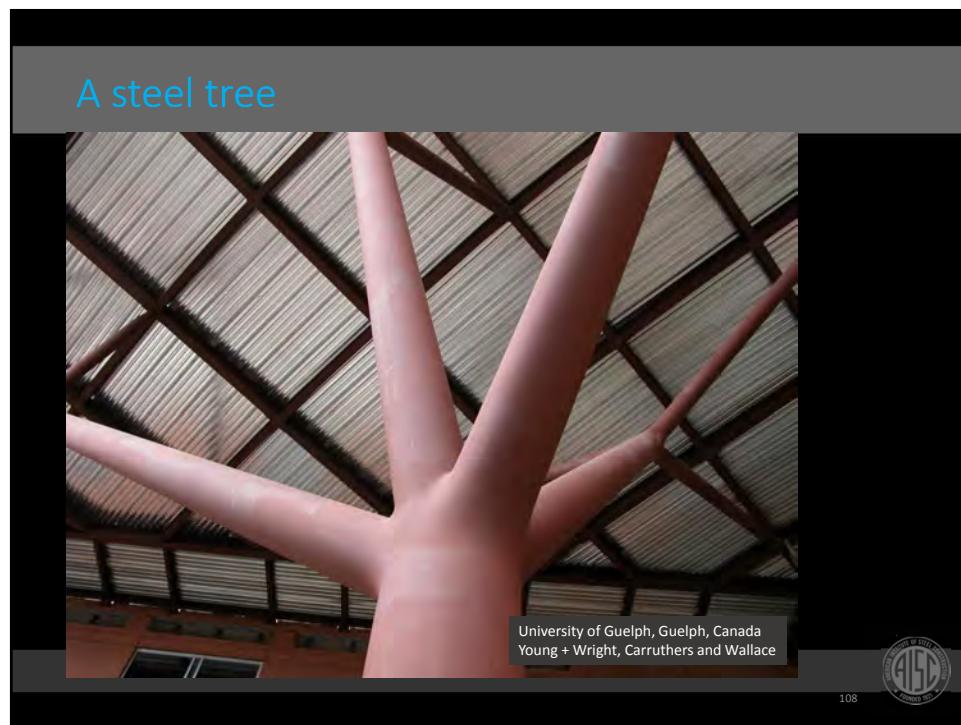


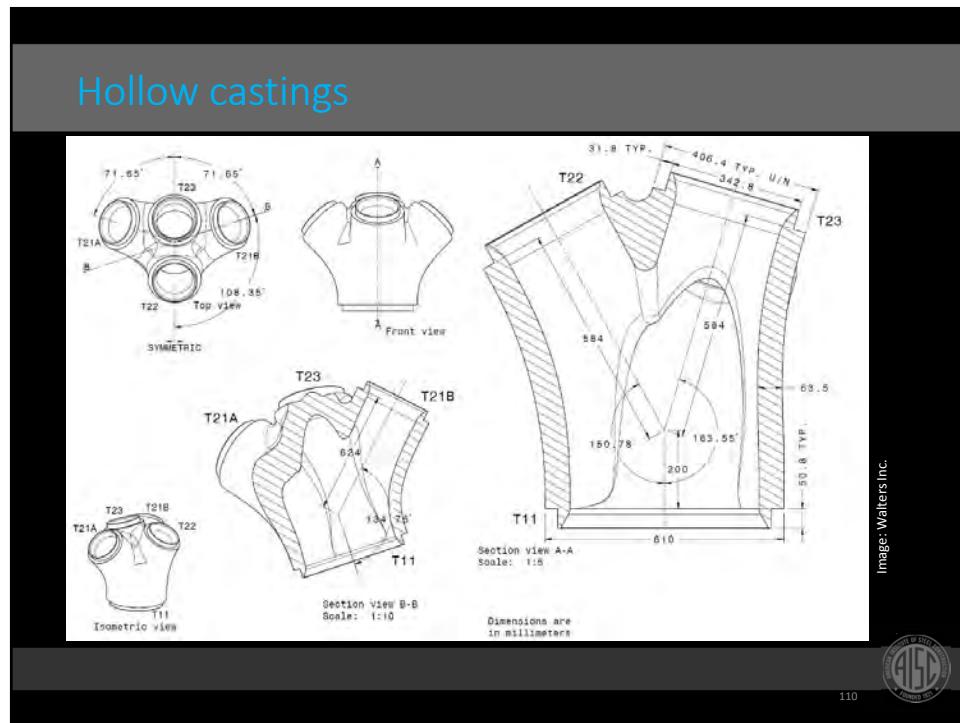
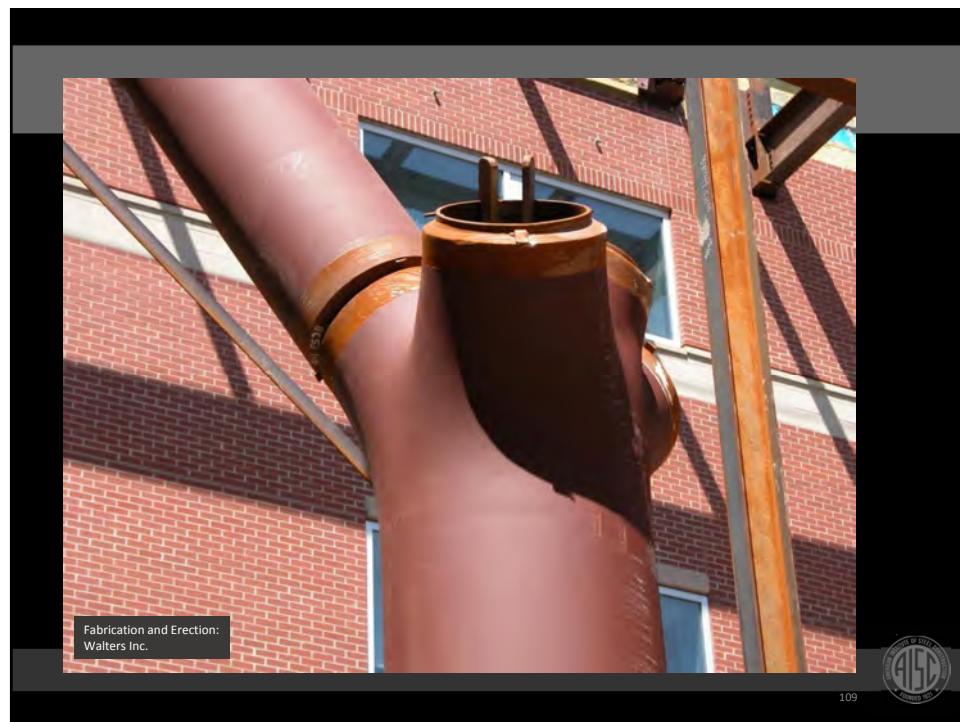
Caisse de Dépôt et Placements, Montréal, Canada
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Making the casting



Image: Walters Inc.

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Textured surface



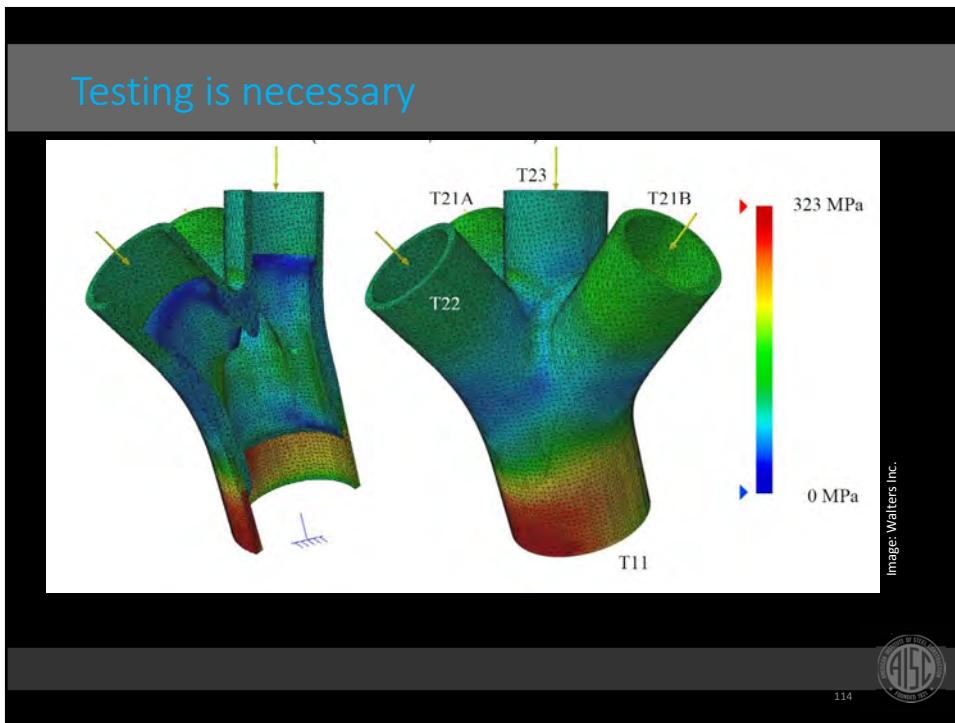
Image: Walters Inc.

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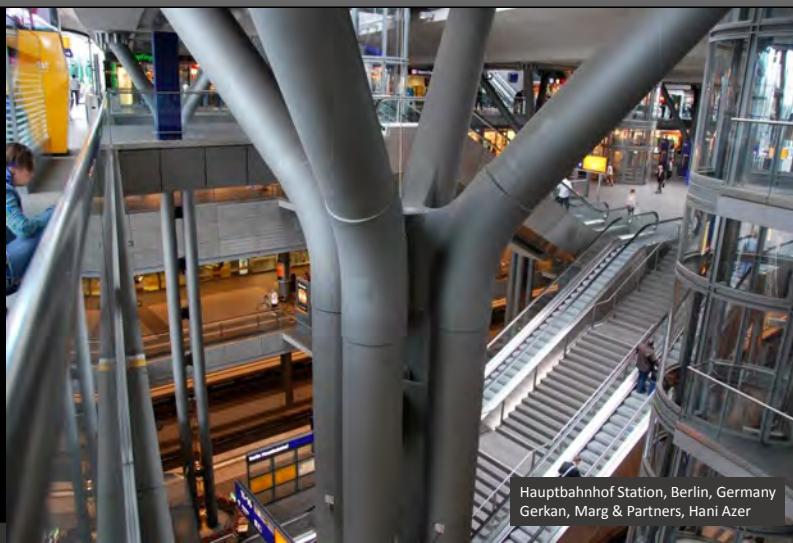
High gloss finish



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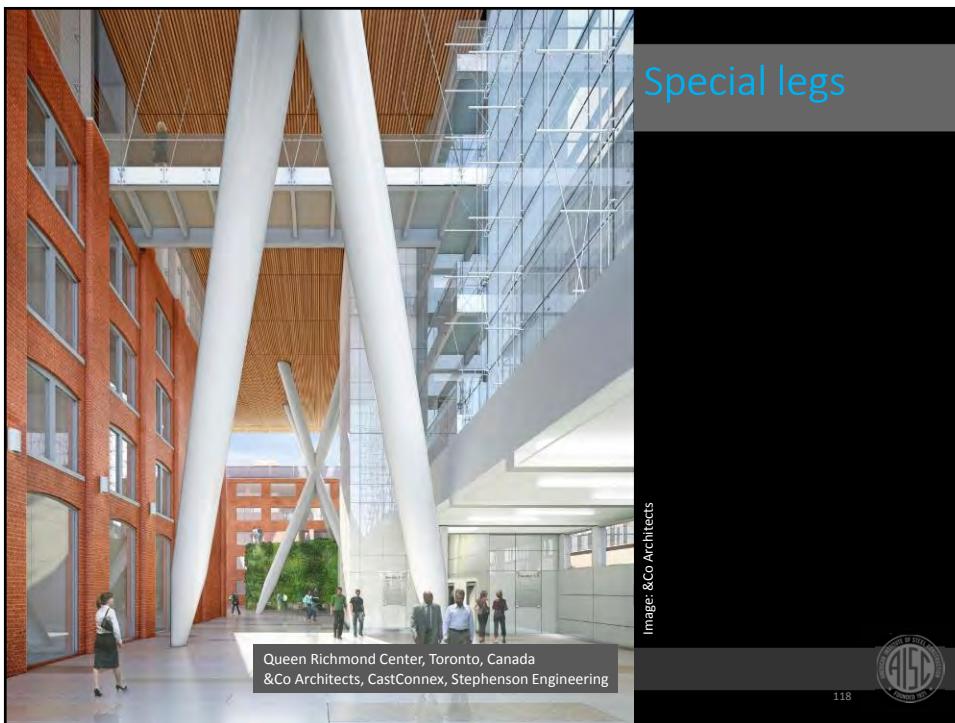


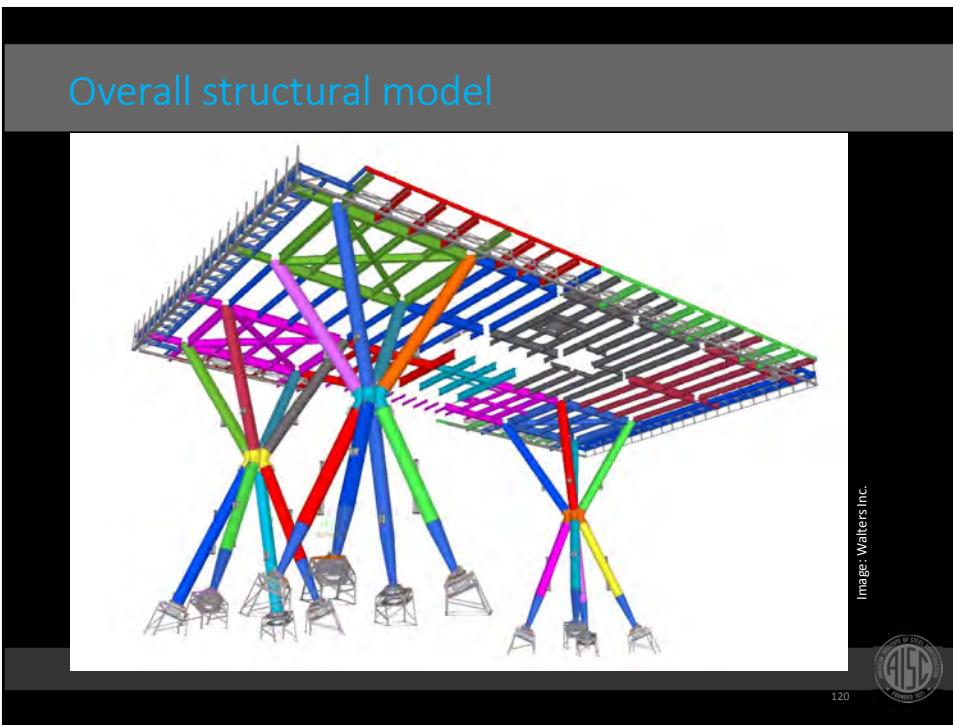
Showing the joint

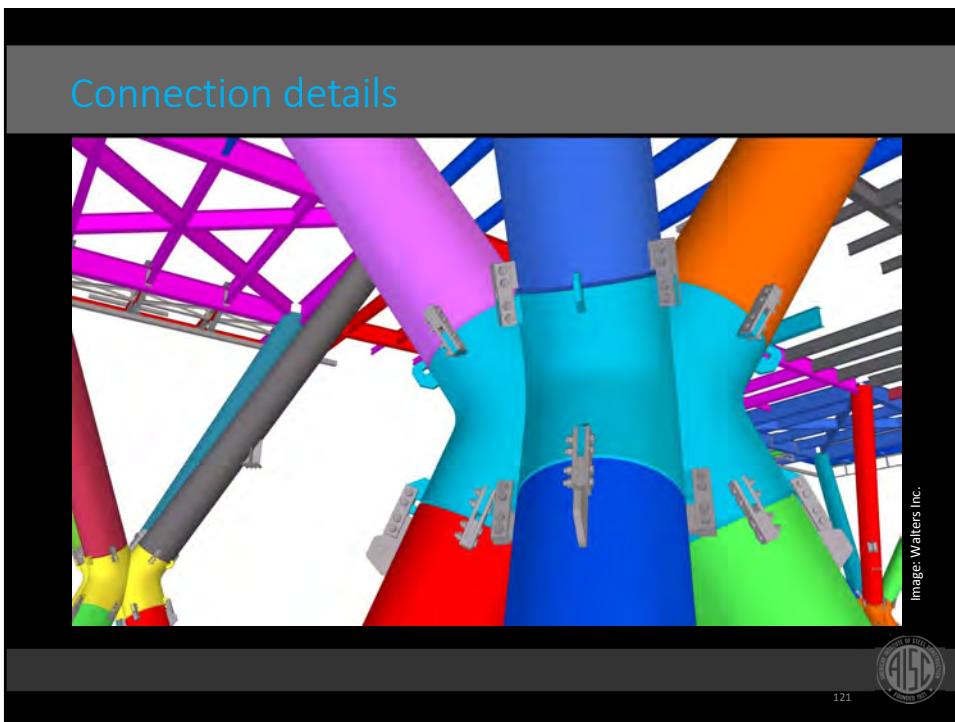


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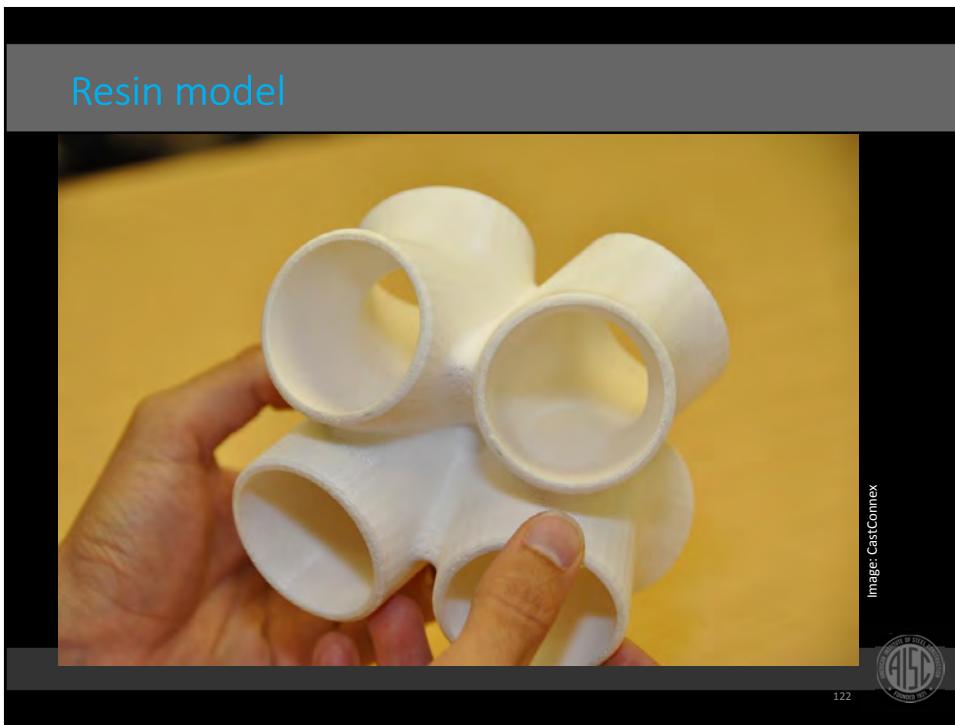






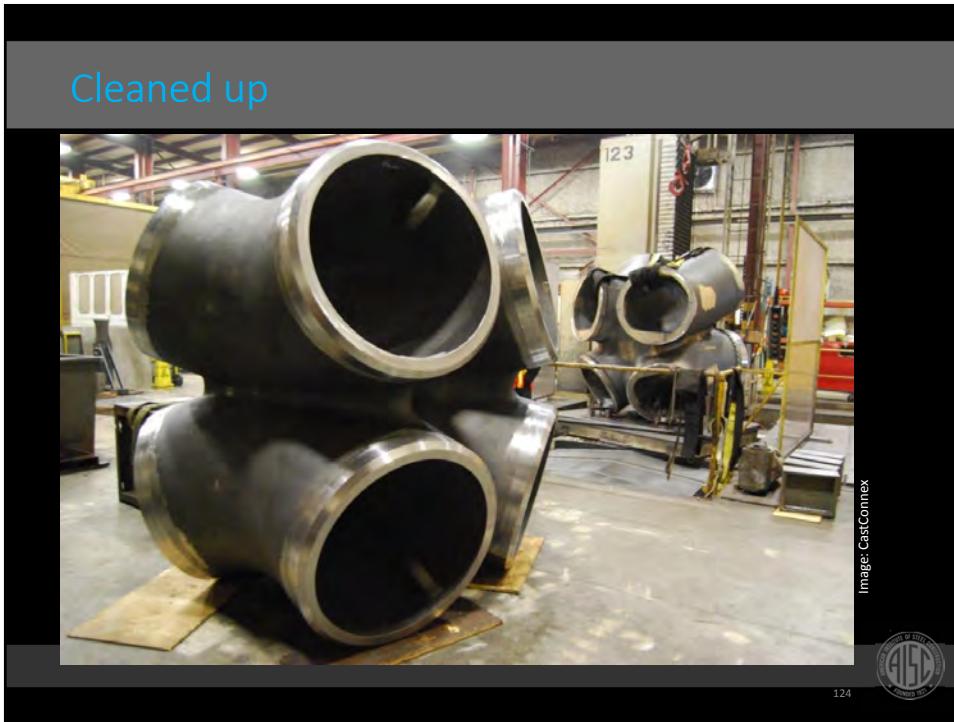


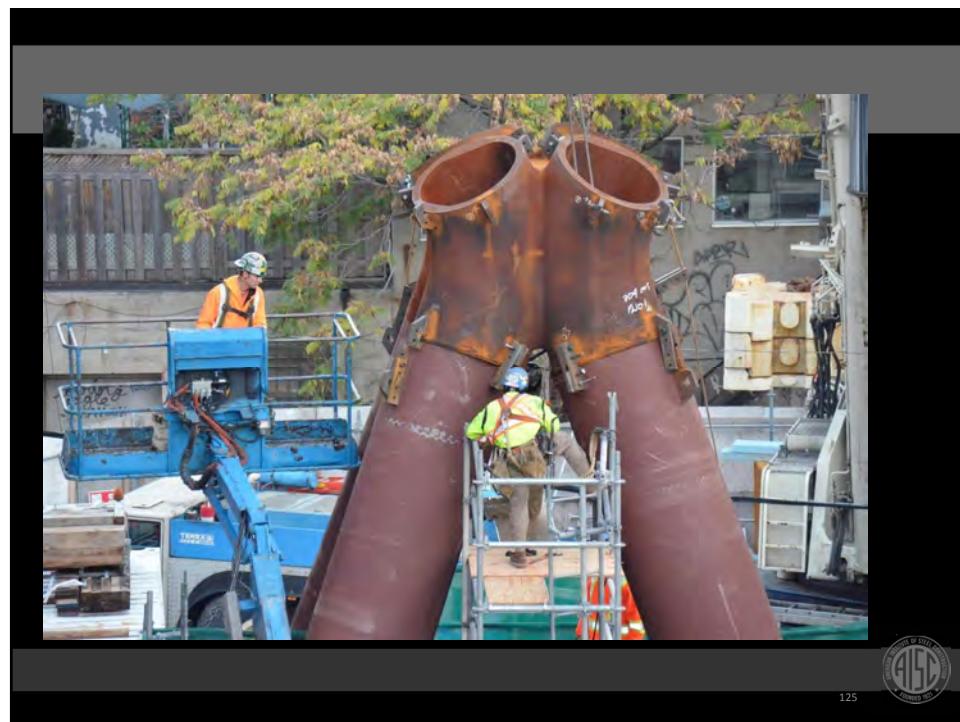
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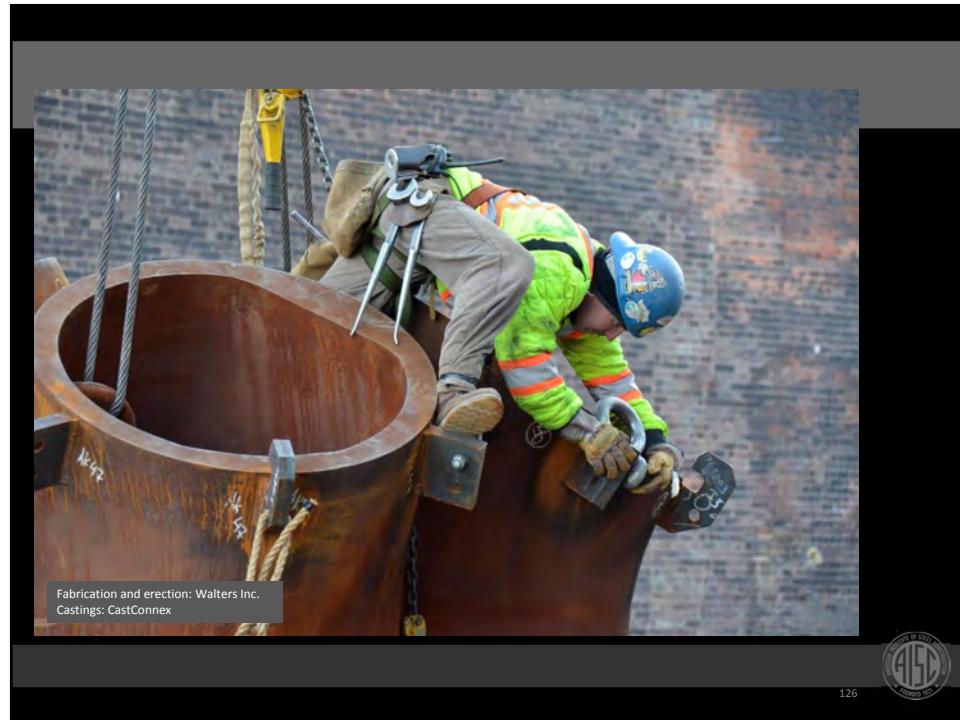
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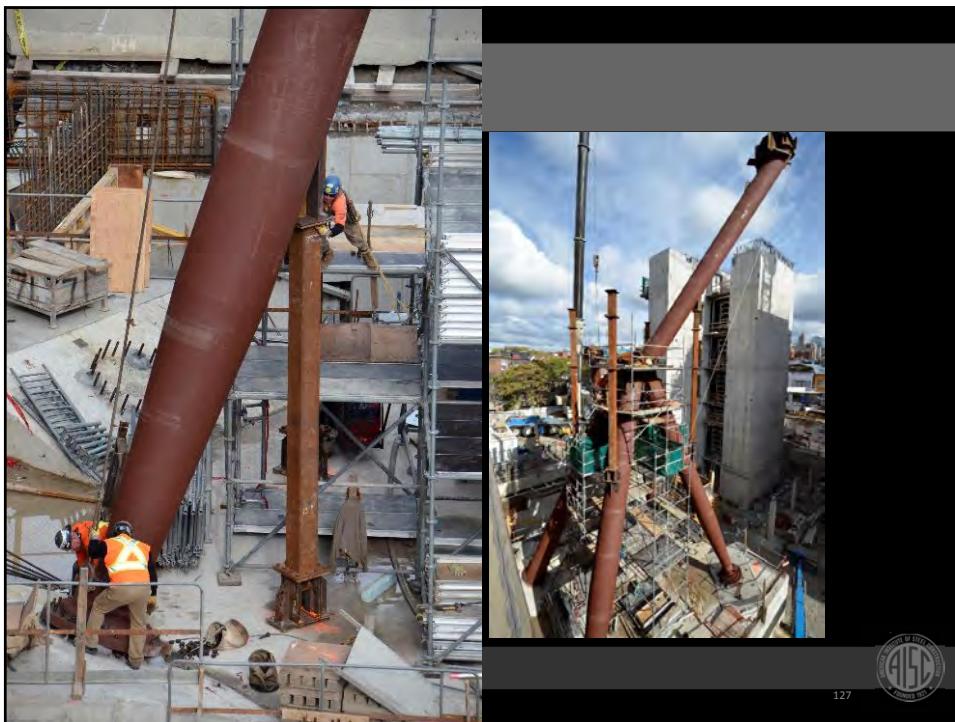


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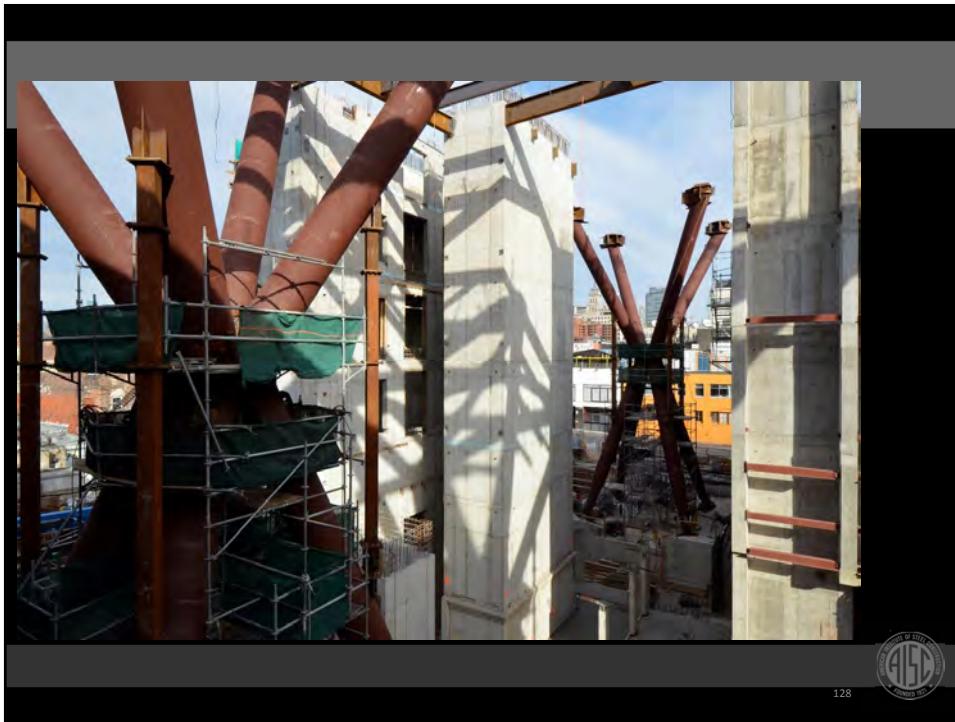


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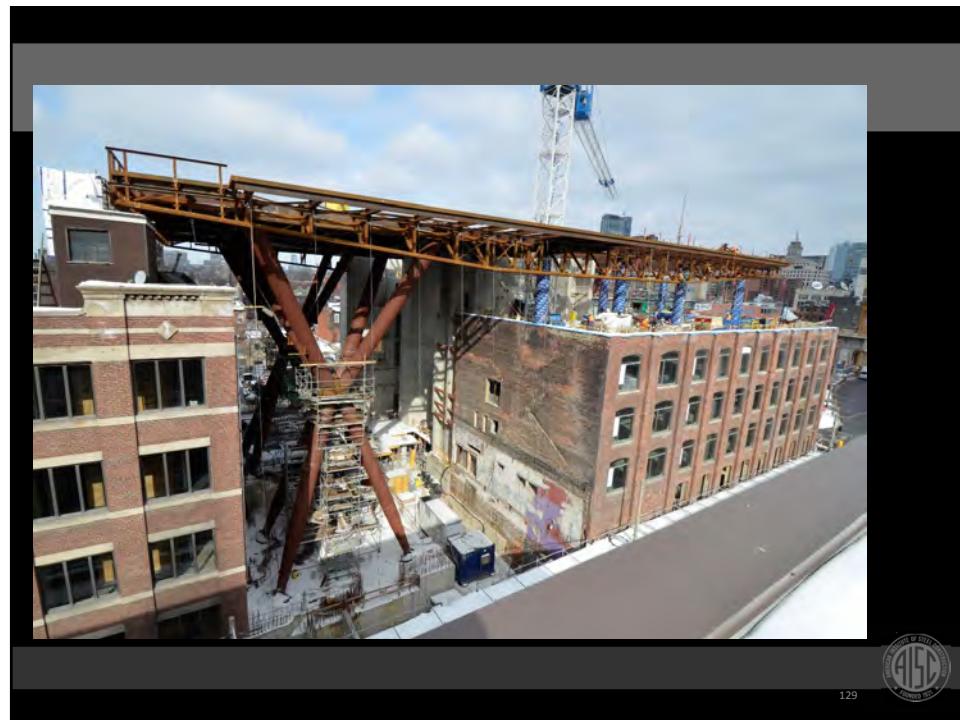


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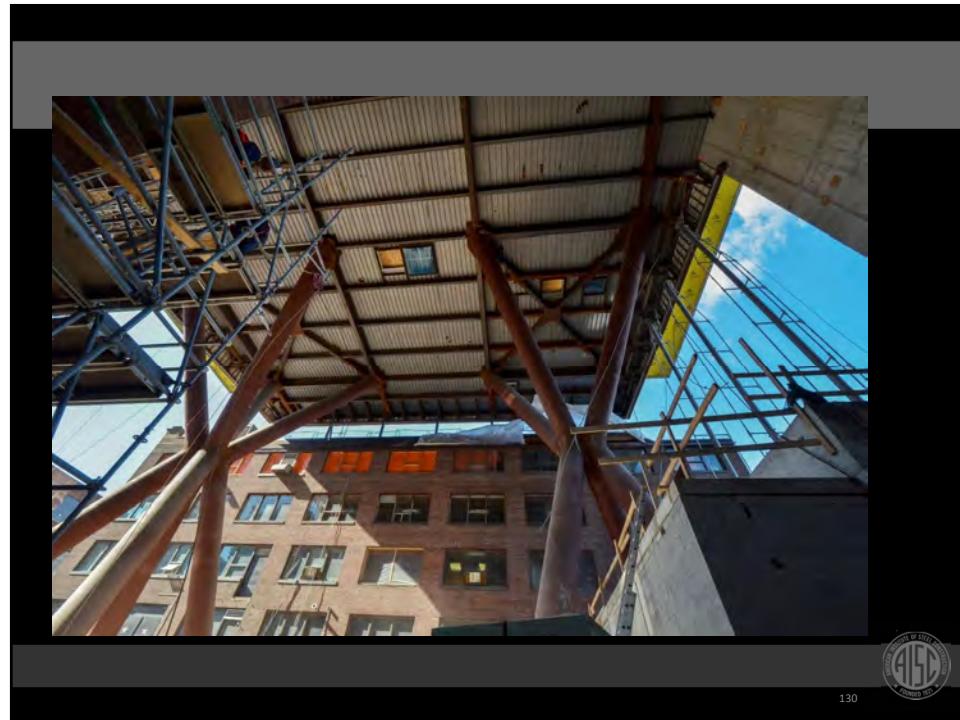


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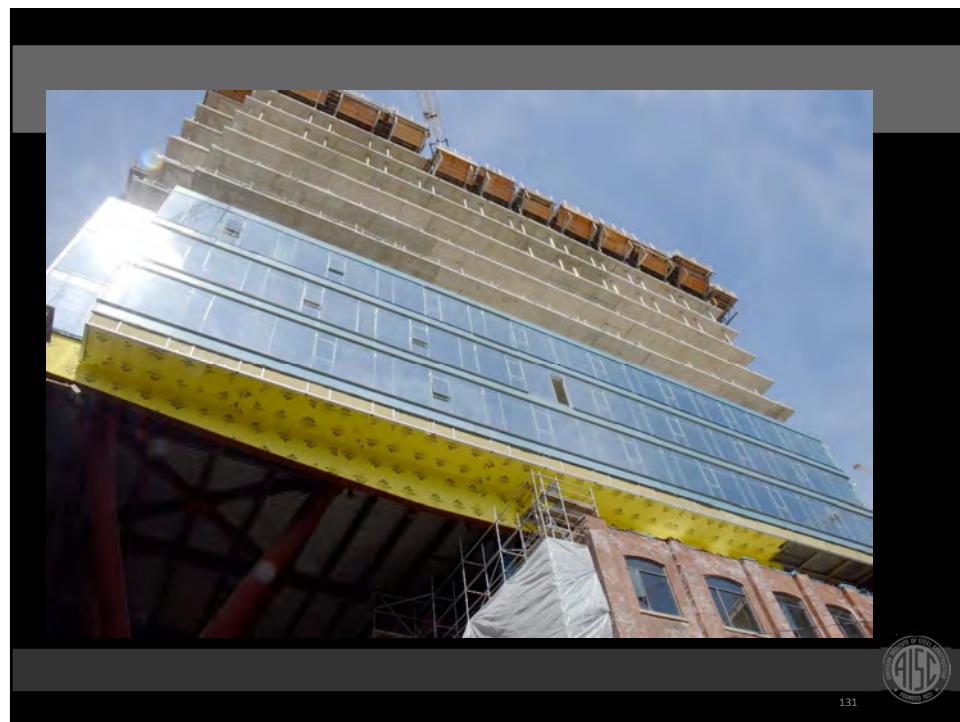


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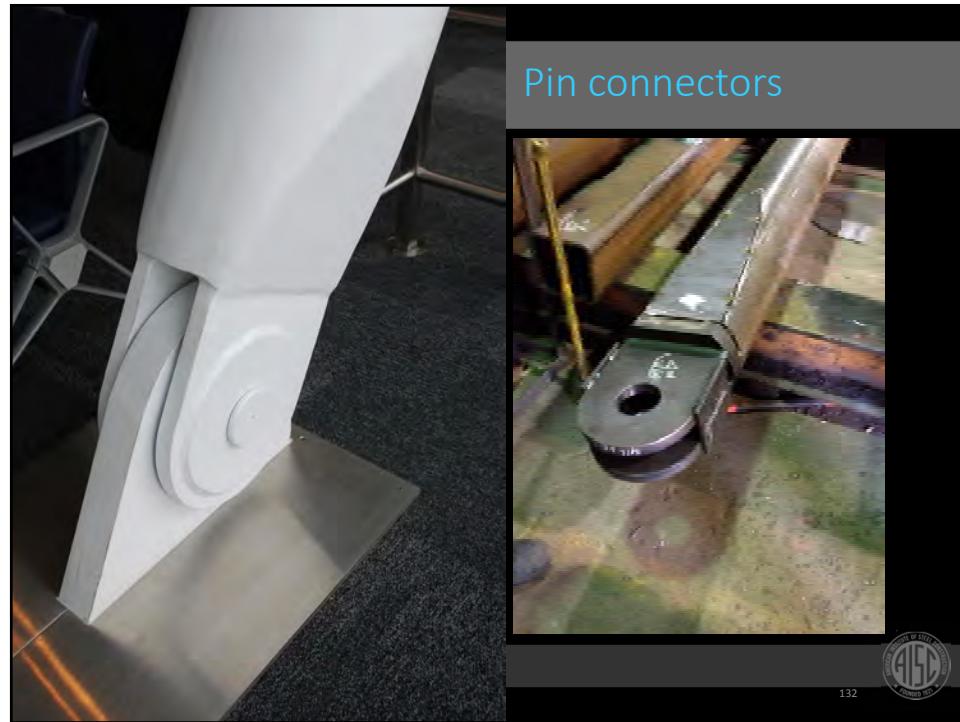


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Pin connectors – off the shelf projects



Image: CastConnex

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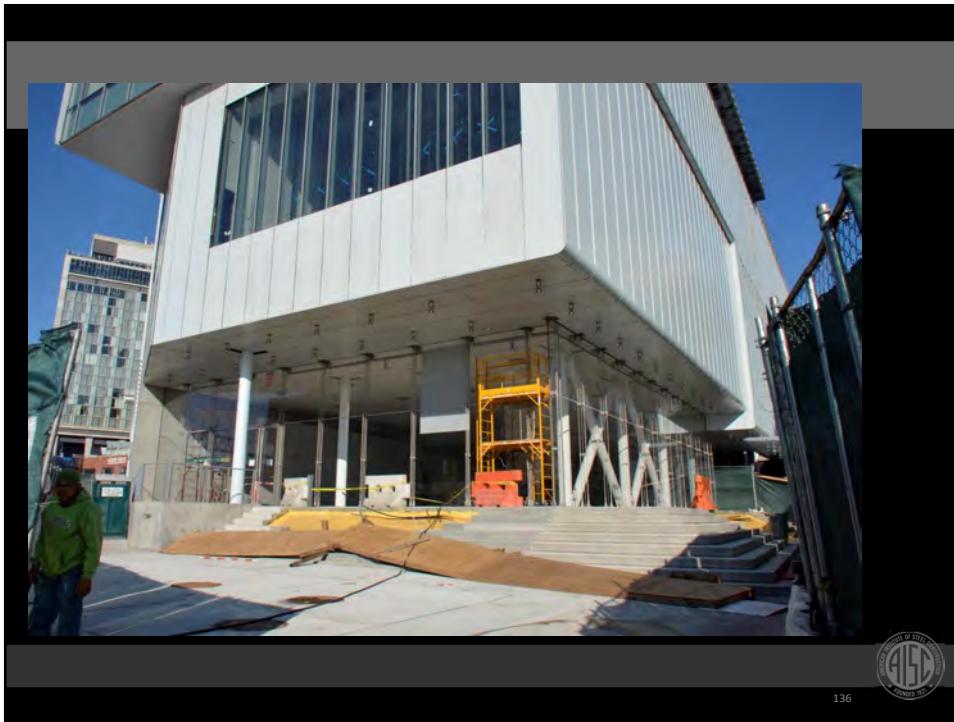
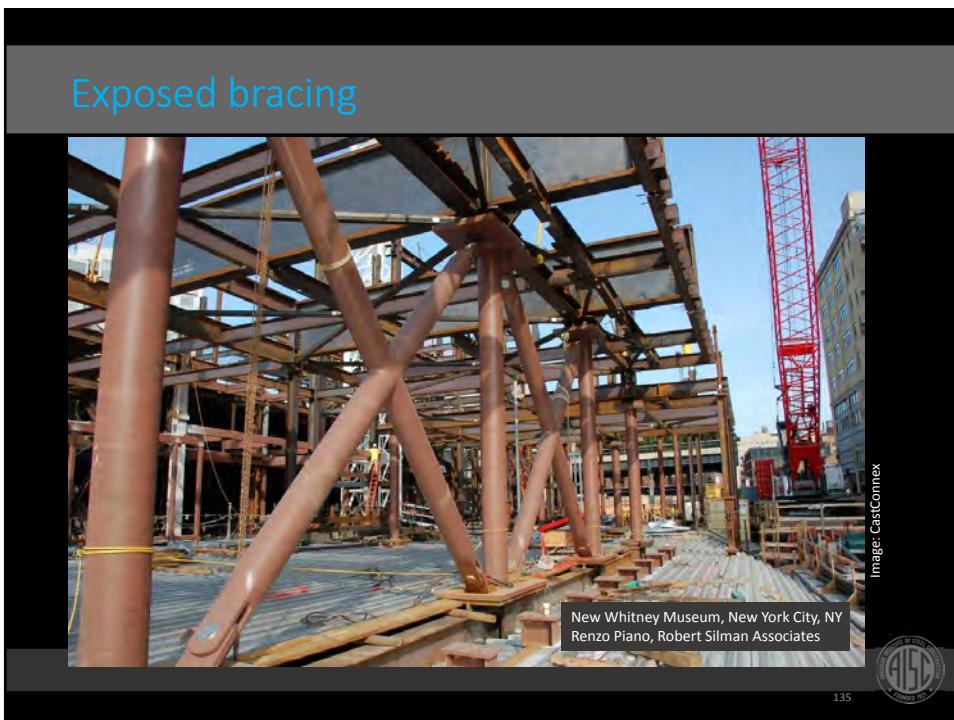
Mechanized welding

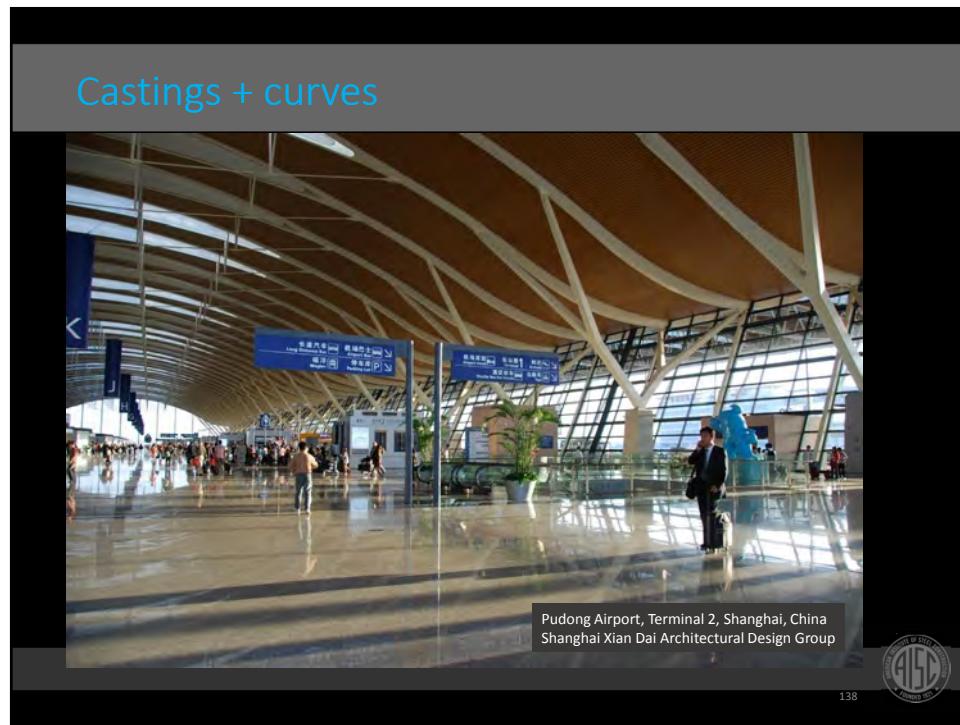


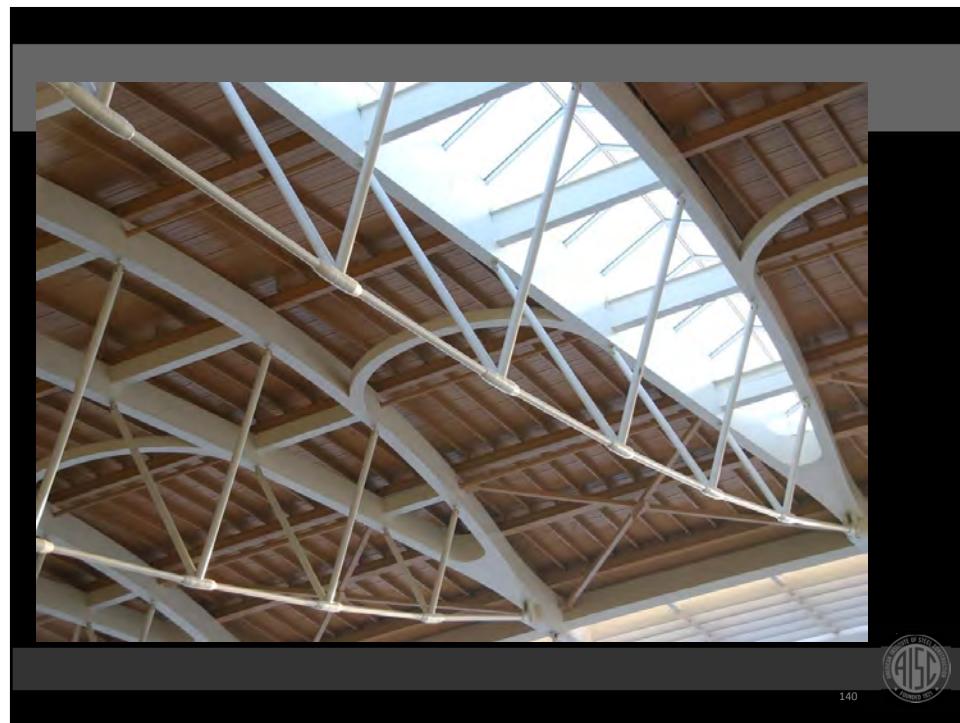
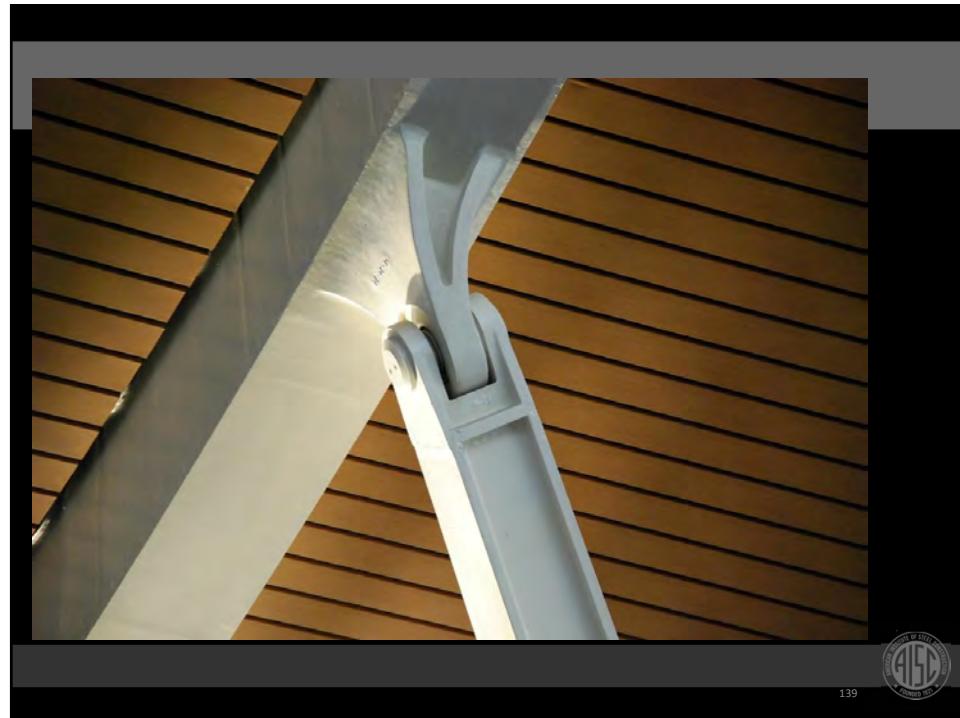
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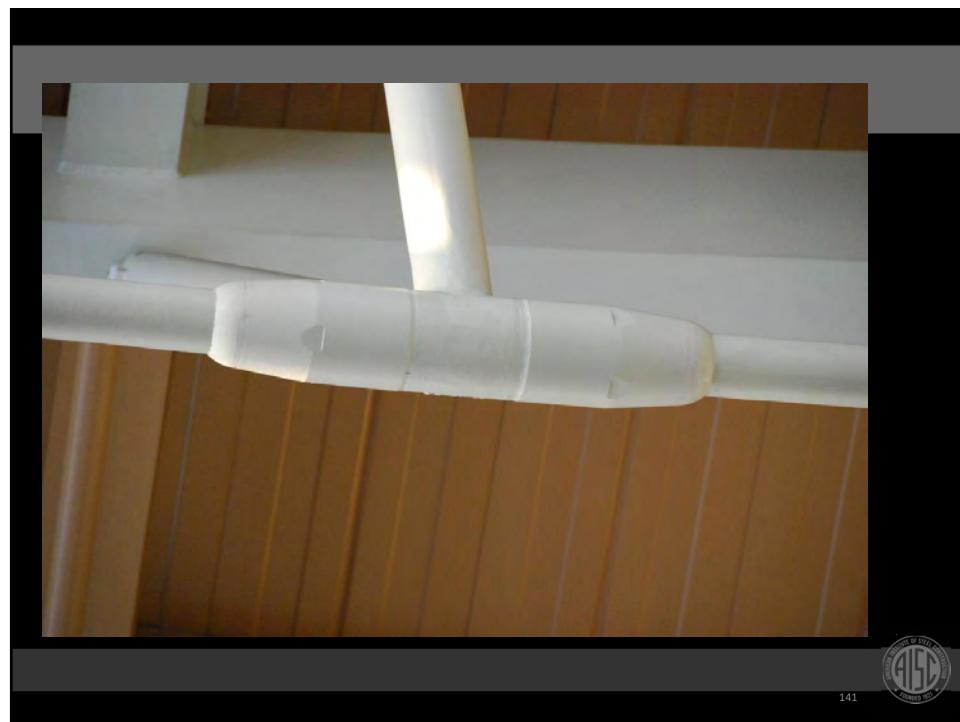
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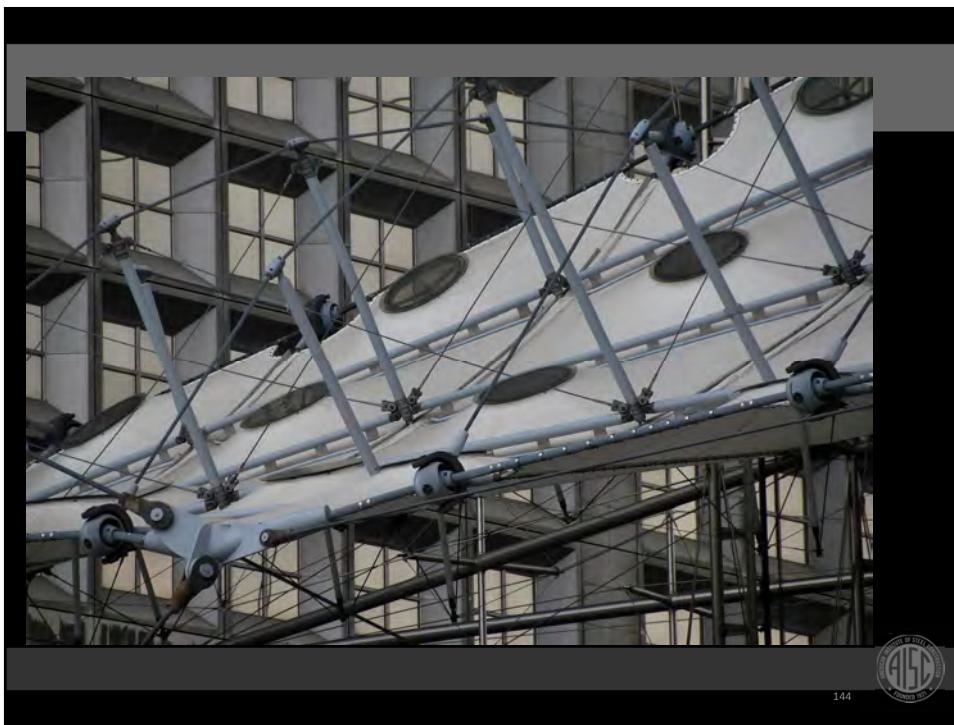
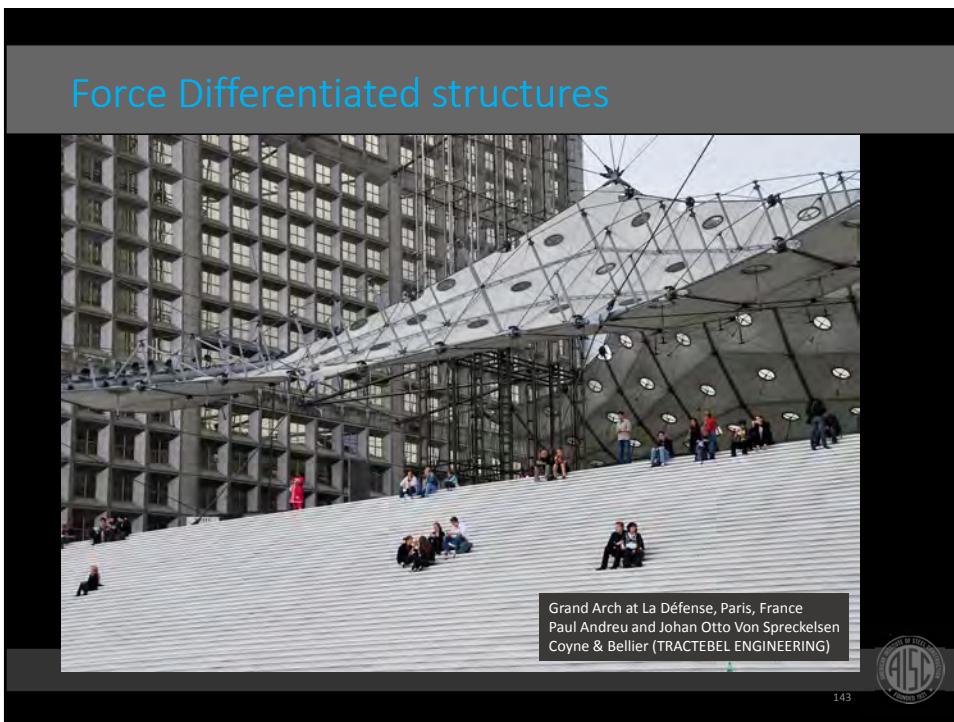


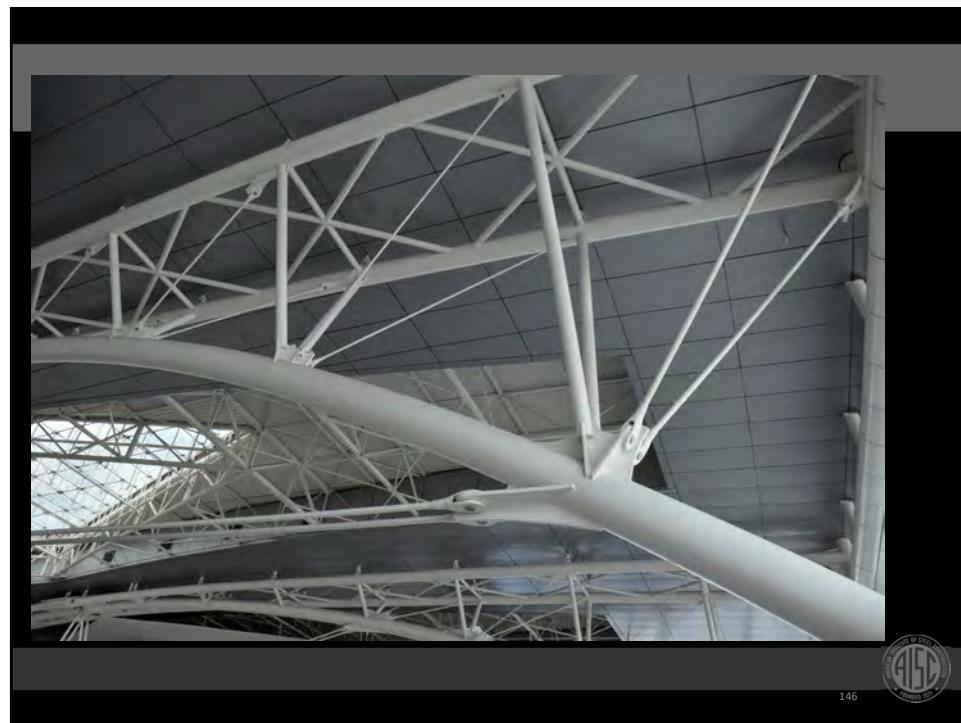


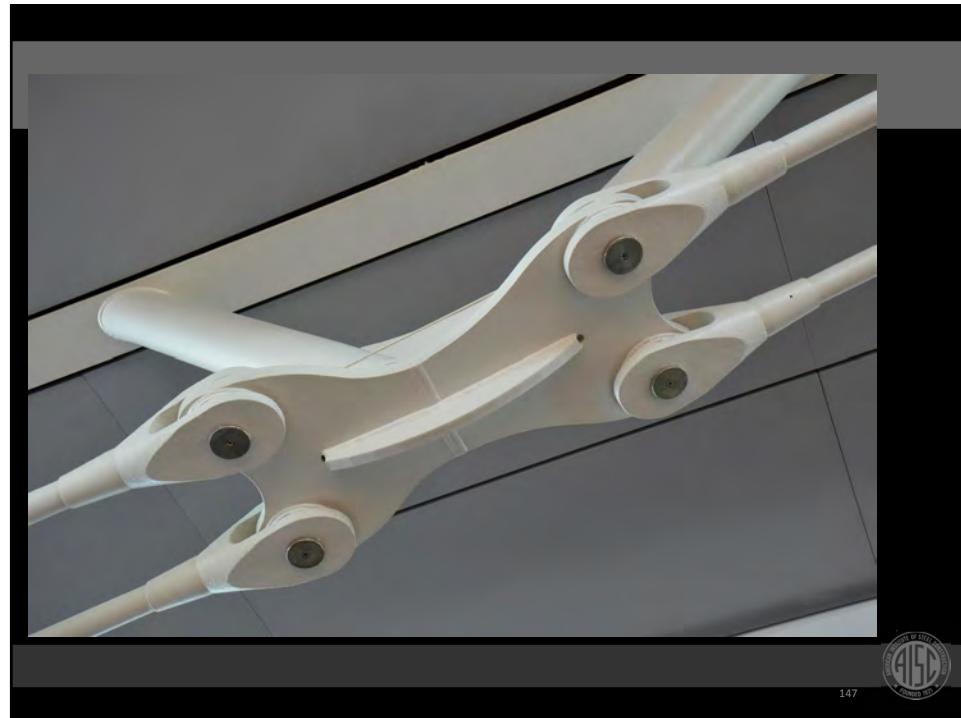




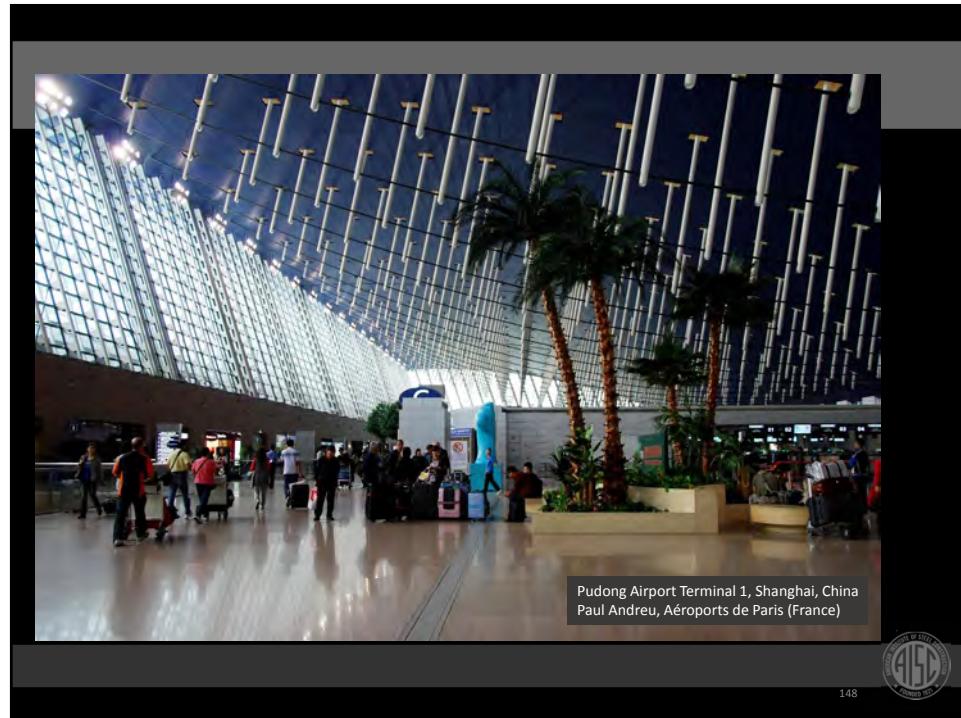








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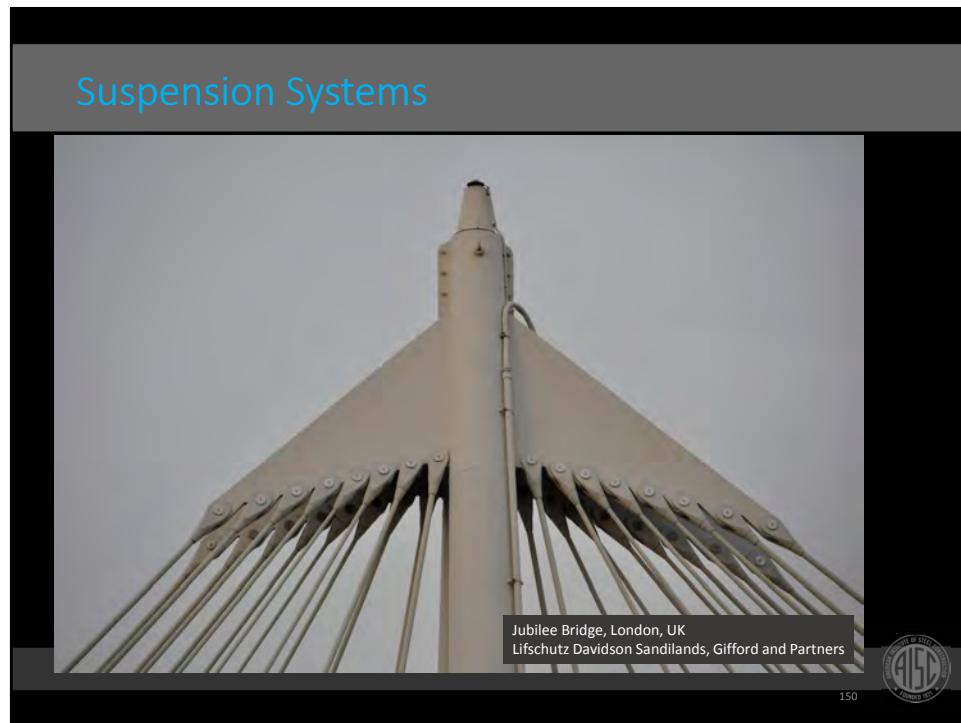
Pudong Airport Terminal 1, Shanghai, China
Paul Andreu, Aéroports de Paris (France)

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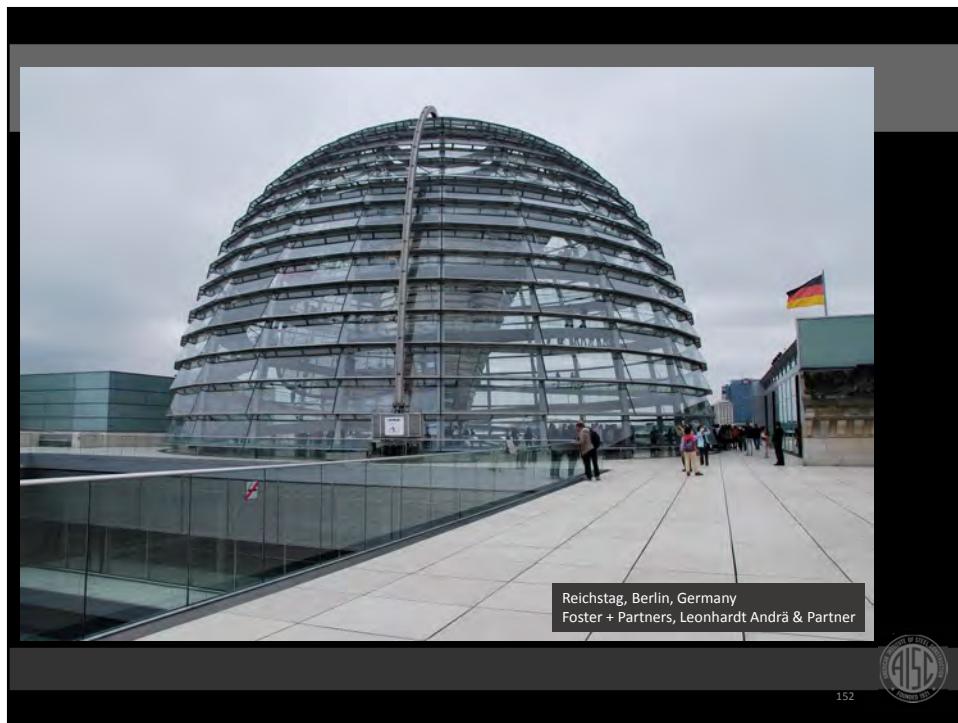


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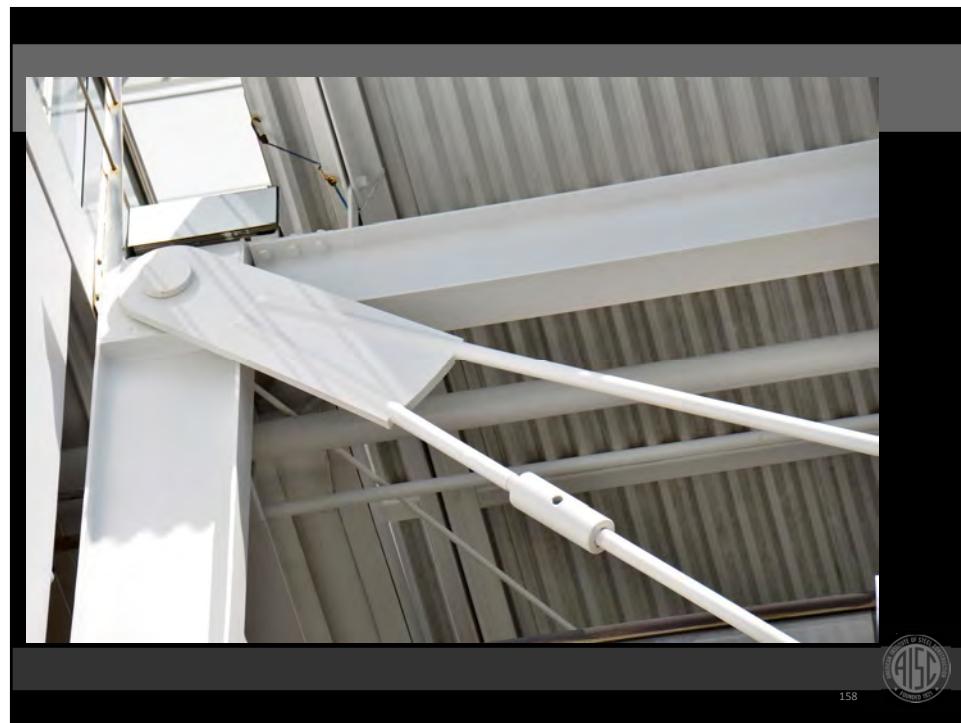


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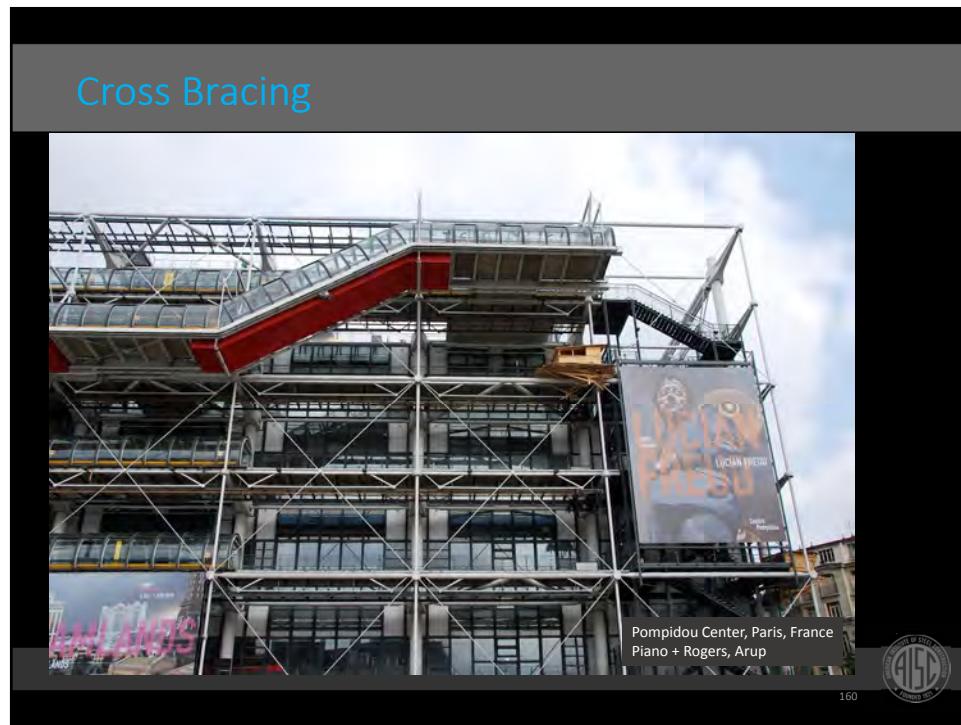
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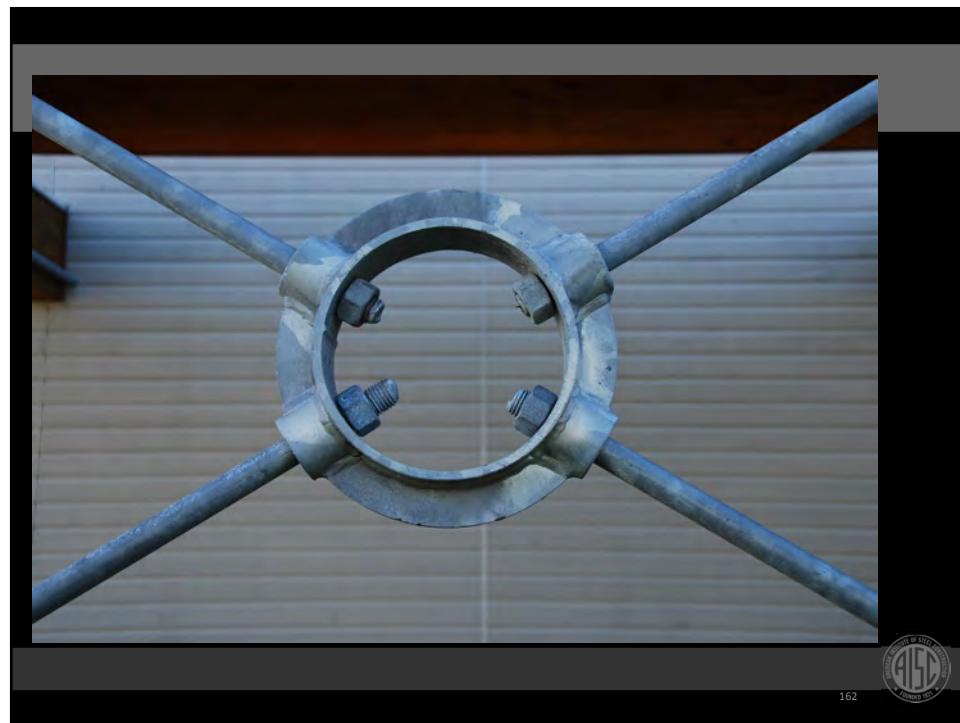
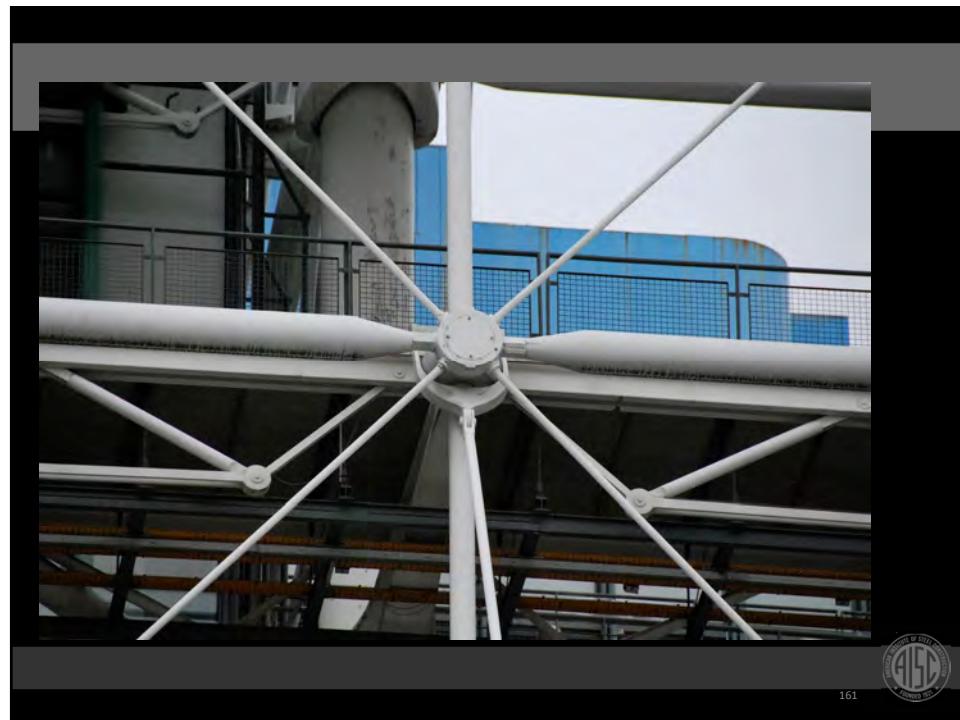


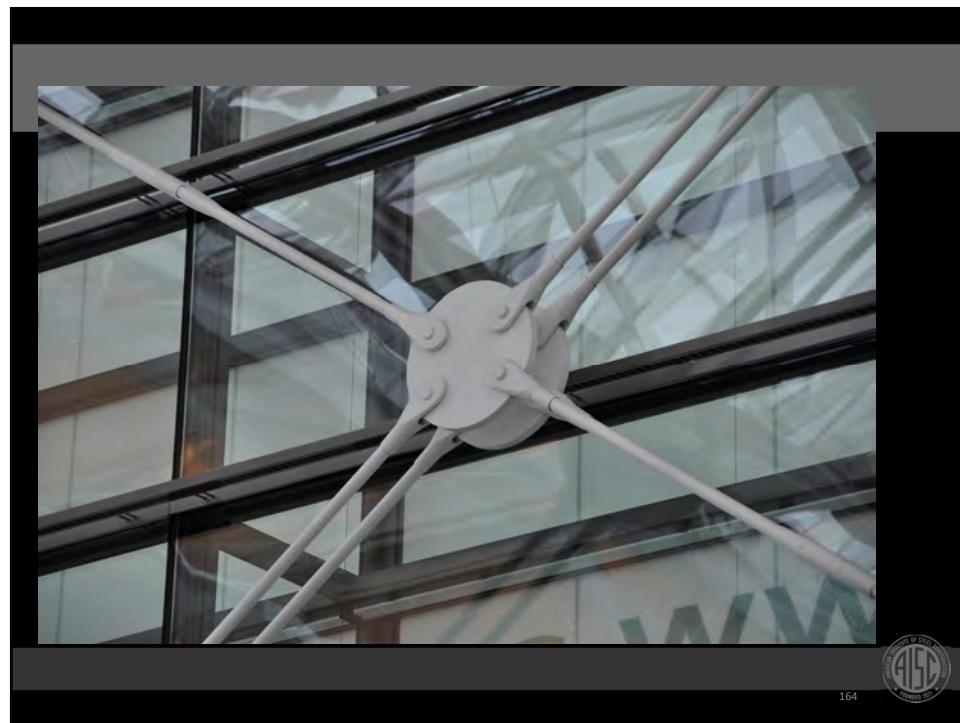
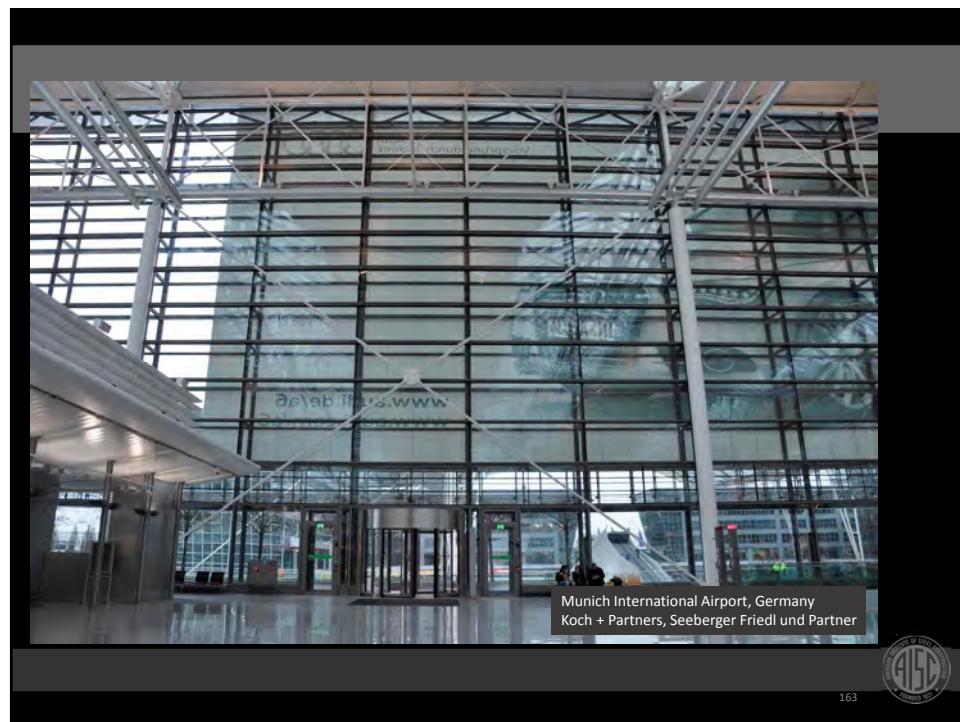
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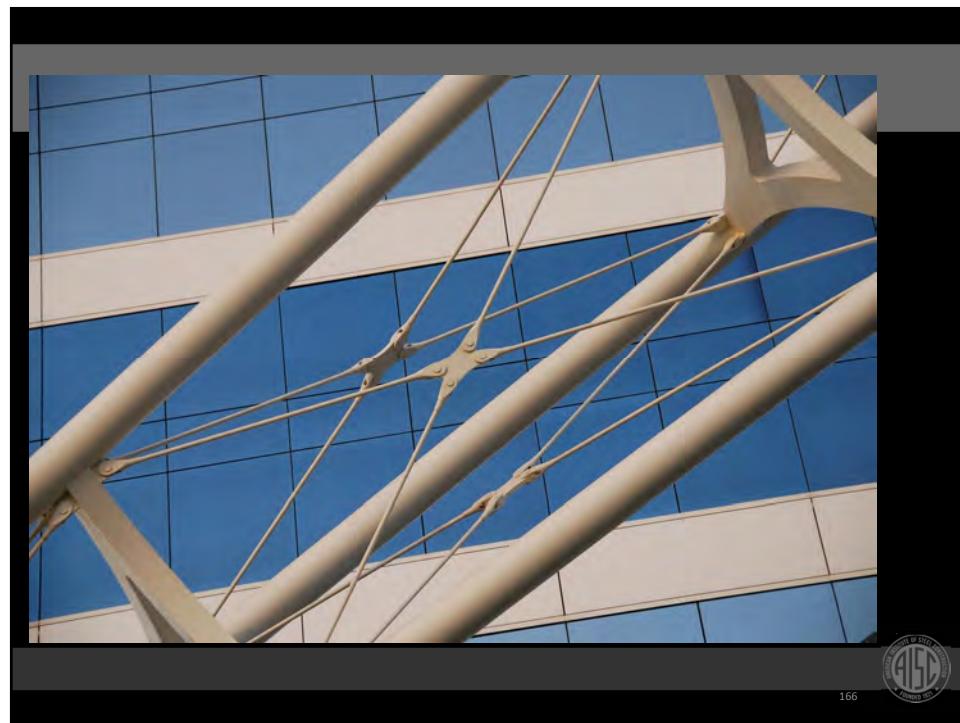
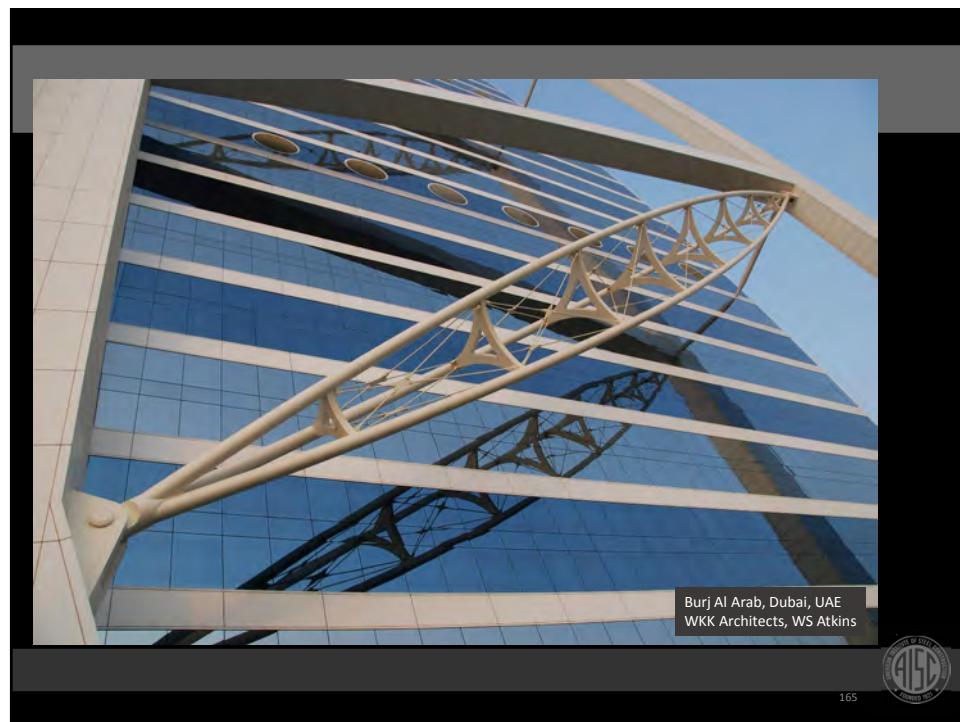


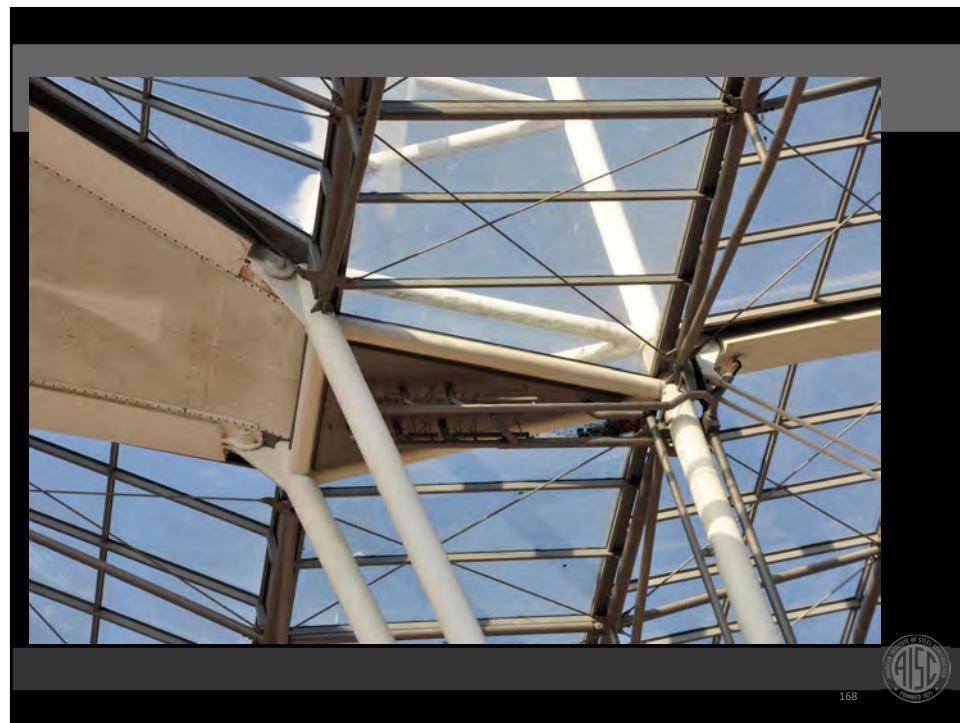
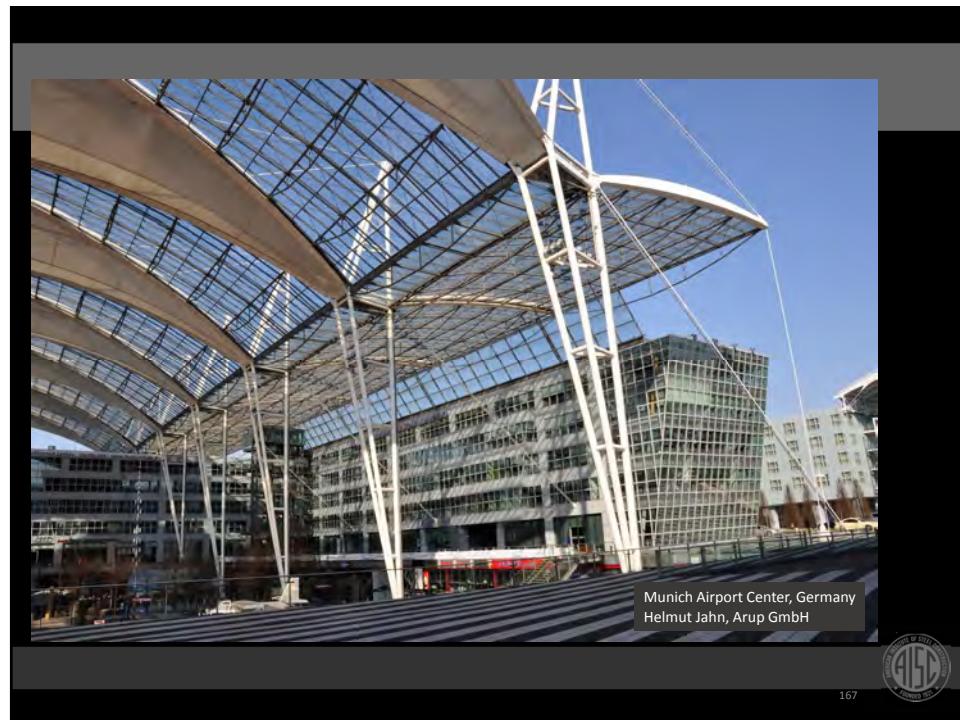
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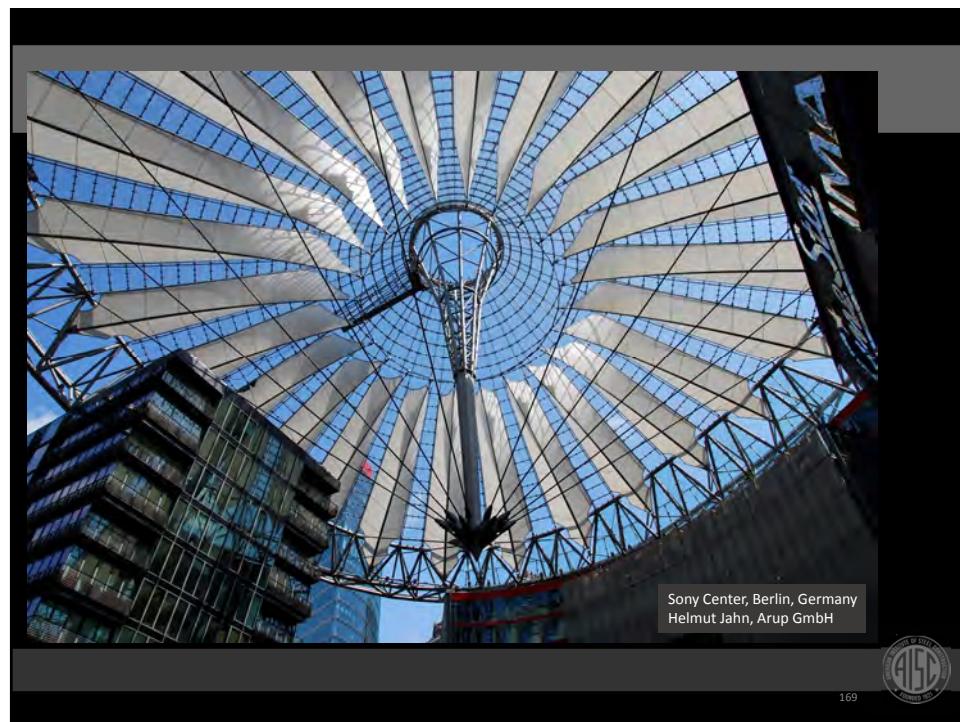












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Anything goes?

- Steel design today is far different than it was even 10 years ago
- Architects present fabricators and engineers with complex problems
- With a good understanding of the goals of the project, and the tools and standards available, high quality work is quite achievable!
- A high level of COMMUNICATION between the Architect, Engineer and Fabricator is essential!

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ARCHITECTURAL STEEL DESIGN

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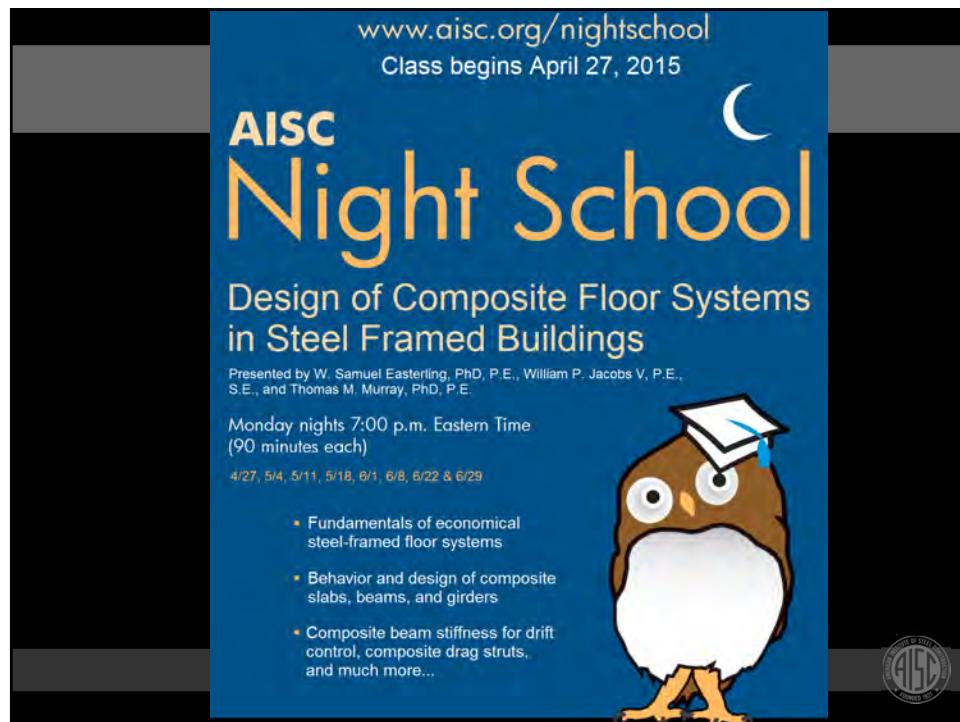


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The image shows the Chicago Metal Rolled Products Company logo, which features a stylized 'CM' monogram inside a circle. Below the logo, the company name "CHICAGO METAL ROLLED PRODUCTS COMPANY" is written in bold, black, sans-serif capital letters. Below the company name is a horizontal bar consisting of four photographs. From left to right: 1. An exterior view of a modern building with a curved glass and steel facade. 2. A industrial setting showing a large blue metal rolling machine. 3. A large, shiny metal pipe. 4. A worker in a hard hat standing next to a large metal structure.

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Survey at conclusion of webinar.

There's always a solution in steel.

