



Helmut Jahn

Munich Airport Center | Munich, Germany

STEEL

Architecturally
Exposed Structural
Steel
CONNECTIONS

Objectives

- Understand when bolted connections work with the AESS category.
- Understand when welded connections best serve the AESS category.
- Understand the limits on the practice of grinding of welds
- Understand the use of custom plate steel to achieve an AESS 4 category.
- Various approaches to making similar connections



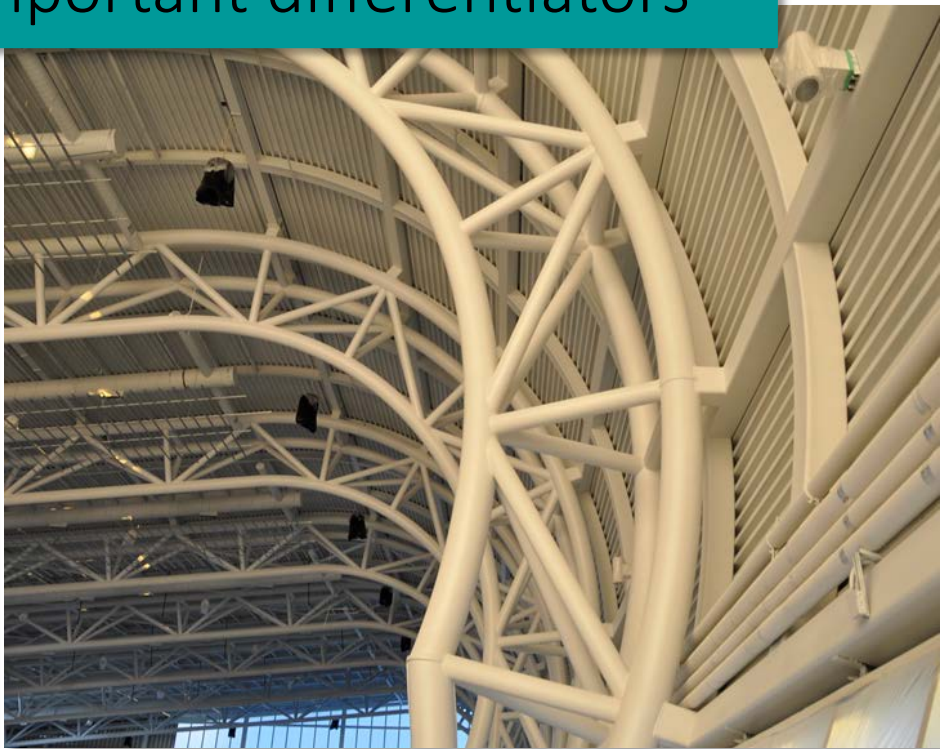
What is AESS?



- Architecturally Exposed Structural Steel is steel that has been purposefully left exposed
- It must fulfill structural functions
- It is normally part of the Architectural aesthetic of the space
- It usually requires detailing, finish and handling that requires more attention and care than regular structural steel
- It adds to the cost of the contract
- Proper application of the Category System will assist to make a smoother design and construction experience



Connection types are important differentiators

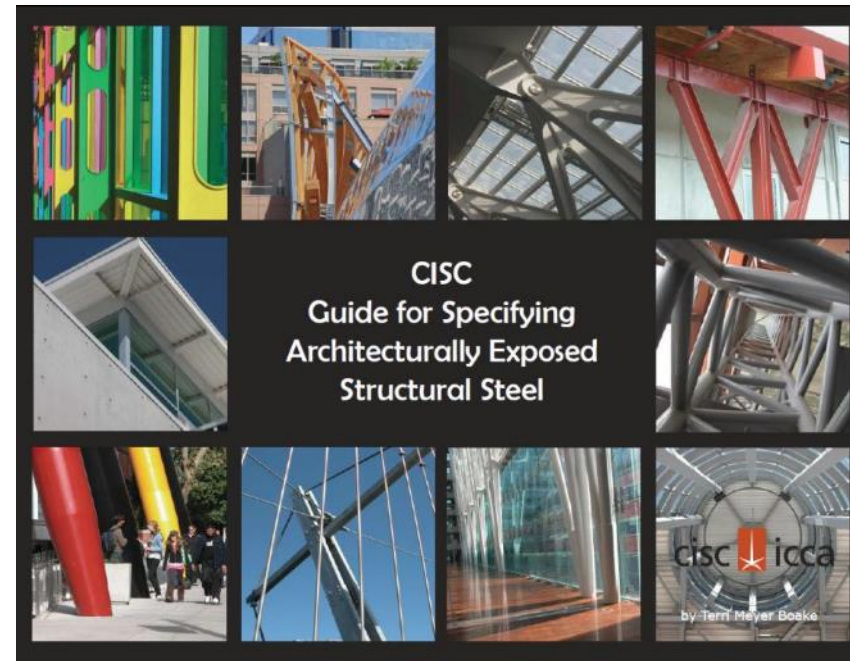


AESS: Primary Factors of influence

- Distance. Visibility.
- Connections mostly bolted or welded
- Tolerances required at fabrication and erection
- Access to detail to perform required finish

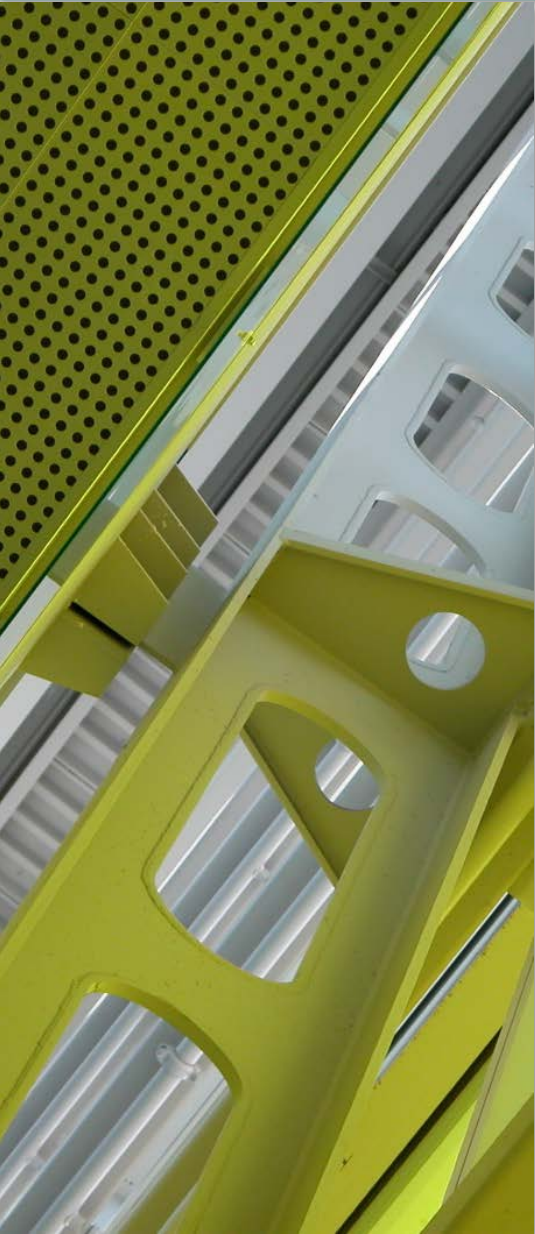
- Interior or exterior setting
- Paint finish, corrosion resistance, fire protection

- Degree of expression
- Size and shape of structural elements



Learning Outcomes and Objectives of the Session

- Understand when bolted connections work with the AESS category.
- Understand when welded connections best serve the AESS category.
- Understand the limits on the practice of grinding of welds
- Various approaches to making similar connections
- Use of discreet or hidden connections to save \$\$ over welded connections



What is AESS?



- Architecturally Exposed Structural Steel is steel that has been purposefully left exposed
- It must fulfill structural functions
- It is normally part of the Architectural aesthetic of the space
- It usually requires detailing, finish and handling that requires more attention and care than regular structural steel
- **It adds to the cost of the contract**
- *Proper application of the Category System will assist to make a smoother design and construction experience*



Standard Structural Steel

The initial point of technical reference is Standard Structural Steel as it is already an established and well-understood as a baseline in construction Specifications.

Predominant use of standard structural steel shapes, OWSJ, exposed decking



AESS 1 – Basic Elements

- the first step above Standard Structural Steel
- suitable for "basic" elements, which require enhanced workmanship
- should only require a low cost premium

Uses a lot of standard structural steel shapes, *some HSS, OWSJ*, exposed decking

Table 1 - AESS Category Matrix

AESS 1

Category

| Id | Characteristics |
|-----|----------------------------------|
| 1.1 | Surface preparation to SSPC-SP 6 |
| 1.2 | Sharp edges ground smooth |
| 1.3 | Continuous weld appearance |
| 1.4 | Standard structural bolts |
| 1.5 | Weld spatters removed |

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth

- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
- 3.3 HSS weld seam oriented for reduced visibility
- 3.4 Cross sectional abutting surface aligned
- 3.5 Joint gap tolerances minimized
- 3.6 All welded connections

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized

- C.1
- C.2
- C.3
- C.4
- C.5

| AESS C Custom Elements | AESS 4 Showcase Elements | AESS 3 Feature Elements <i>Viewed at a Distance ≤ 6 m</i> | AESS 2 Feature Elements <i>Viewed at a Distance > 6 m</i> | AESS 1 Basic Elements | SSS Standard Structural Steel |
|------------------------------|--------------------------------|--|---|-----------------------------|--|
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | optional | optional | optional | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | optional | optional | | | |
| | ✓ | | | | |
| | ✓ | | | | |
| | ✓ | | | | |
| | ✓ | | | | |
| | optional | optional | | | |
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Sample Use:

Estimated Cost Premium:

| | | | | | |
|------------------------------------|-------------------------------|--|---|--|---------|
| Elements with special requirements | Showcase or dominant elements | Airports, shopping centres, hospitals, lobbies | Retail and architectural buildings viewed at a distance | Roof trusses for arenas, retail warehouses, canopies | |
| Low to High (20-250%) | High (100-250%) | Moderate (60-150%) | Low to Moderate (40-100%) | Low (20-60%) | None 0% |



AESS 2 – Feature Elements < 6m/20ft

structure that is intended to be viewed at a distance > 6 m

The process requires basically good fabrication practices with enhanced treatment of welds, connection and fabrication details, tolerances for gaps, and copes

- Uses a lot of standard structural steel shapes, some HSS, exposed decking
- Bolted connections and unremediated welded connections

Table 1 - AESS Category Matrix

AESS 2

Category

- Id
- 1.1 Surface preparation to SSPC-SP 6
- 1.2 Sharp edges ground smooth
- 1.3 Continuous weld appearance
- 1.4 Standard structural bolts
- 1.5 Weld spatters removed
- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth
- 3.1 Mill marks removed
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|------------------------------|--------------------------------|--|---|-----------------------------|--|
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | ✓ | ✓ | ✓ | ✓ | |
| | optional | optional | optional | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | ✓ | ✓ | ✓ | | |
| | optional | optional | | | |
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Sample Use:

| | | | | | |
|------------------------------------|-------------------------------|--|---|--|--|
| Elements with special requirements | Showcase or dominant elements | Airports, shopping centres, hospitals, lobbies | Retail and architectural buildings viewed at a distance | Roof trusses for arenas, retail warehouses, canopies | |
|------------------------------------|-------------------------------|--|---|--|--|

Estimated Cost Premium:

| | | | | | |
|--------------------------|--------------------|-----------------------|------------------------------|-----------------|------------|
| Low to High (20-250%) | High (100-250%) | Moderate (60-150%) | Low to Moderate (40-100%) | Low (20-60%) | None 0% |
|--------------------------|--------------------|-----------------------|------------------------------|-----------------|------------|



AESS 3 – Feature Elements \leq 6m/20ft

structures that will be viewed at a distance \leq 6m

- suitable for "feature" elements – where the designer is comfortable allowing the viewer to see the *art of metalworking*
- welds should be generally smooth but visible and some grind marks would be acceptable
- *weld grinding is permitted but not encouraged*

- Increased use of HSS over standard structural shapes
- Some *curvature in members*
- More welded than bolted connections

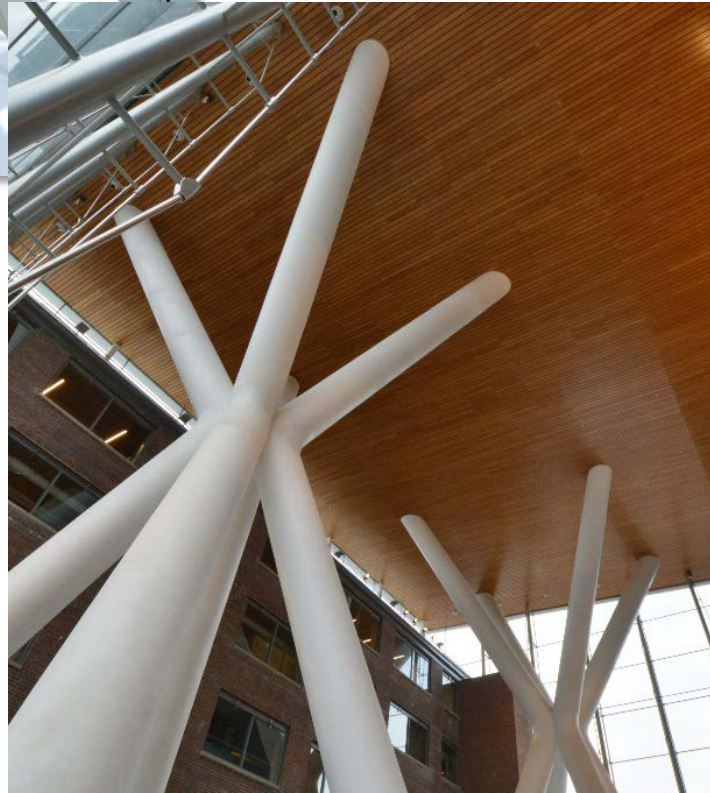
Table 1 - AESS Category Matrix

AESS 3

Category

| | AESS C <i>Custom Elements</i> | AESS 4 <i>Showcase Elements</i> | AESS 3 <i>Feature Elements</i> <i>Viewed at a Distance ≤ 6 m</i> | AESS 2 <i>Feature Elements</i> <i>Viewed at a Distance > 6 m</i> | AESS 1 <i>Basic Elements</i> | SSS <i>Standard Structural Steel</i> |
|--------------------------------|---|---|---|--|--|--|
| Id | <i>Characteristics</i> | | | | | |
| 1.1 | Surface preparation to SSPC-SP 6 | √ | √ | √ | √ | |
| 1.2 | Sharp edges ground smooth | √ | √ | √ | √ | |
| 1.3 | Continuous weld appearance | √ | √ | √ | √ | |
| 1.4 | Standard structural bolts | √ | √ | √ | √ | |
| 1.5 | Weld spatters removed | √ | √ | √ | √ | |
| 2.1 | Visual Samples | optional | optional | optional | | |
| 2.2 | One-half standard fabrication tolerances | √ | √ | √ | | |
| 2.3 | Fabrication marks not apparent | √ | √ | √ | | |
| 2.4 | Welds uniform and smooth | √ | √ | √ | | |
| 3.1 | Mill marks removed | √ | √ | | | |
| 3.2 | Butt and plug welds ground smooth and filled | √ | √ | | | |
| 3.3 | HSS weld seam oriented for reduced visibility | √ | √ | | | |
| 3.4 | Cross sectional abutting surface aligned | √ | √ | | | |
| 3.5 | Joint gap tolerances minimized | √ | √ | | | |
| 3.6 | All welded connections | optional | optional | | | |
| 4.1 | HSS seam not apparent | √ | | | | |
| 4.2 | Welds contoured and blended | √ | | | | |
| 4.3 | Surfaces filled and sanded | √ | | | | |
| 4.4 | Weld show-through minimized | √ | | | | |
| C.1 | | | | | | |
| C.2 | | | | | | |
| C.3 | | | | | | |
| C.4 | | | | | | |
| C.5 | | | | | | |
| <i>Sample Use:</i> | Elements with special requirements | Showcase or dominant element | Airports, shopping centres, hospitals, lobbies | Retail and architectural buildings viewed at a distance | Roof trusses for arenas, retail warehouses, canopies | |
| <i>Estimated Cost Premium:</i> | Low to High (20-250%) | High (100-250%) | Moderate (60-150%) | Low to Moderate (40-100%) | Low (20-60%) | None 0% |

AESS 4 – Showcase Elements



- used where the designer intends that the form is the only feature showing in an element
- All welds ground and filled edges are ground square and true
- All surfaces are sanded and filled. Tolerances are more stringent, generally to half of standard tolerance for standard structural steel

- Large amounts of custom plate work
- Remediated (and unremediated) welded connections
- Large custom castings
- Machined steel

Table 1 - AESS Category Matrix

AESS 4

Category

| Id | Characteristics |
|-----|---|
| 1.1 | Surface preparation to SSPC-SP 6 |
| 1.2 | Sharp edges ground smooth |
| 1.3 | Continuous weld appearance |
| 1.4 | Standard structural bolts |
| 1.5 | Weld spatters removed |
| 2.1 | Visual Samples |
| 2.2 | One-half standard fabrication tolerances |
| 2.3 | Fabrication marks not apparent |
| 2.4 | Welds uniform and smooth |
| 3.1 | Mill marks removed |
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| | |
|-----|--|
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|------------------------------|--------------------------------|--|---|-----------------------------|--|
| | √ | √ | √ | √ | |
| | √ | √ | √ | √ | |
| | √ | √ | √ | √ | |
| | √ | √ | √ | √ | |
| | √ | √ | √ | √ | |
| | optional | optional | optional | | |
| | √ | √ | √ | | |
| | √ | √ | √ | | |
| | √ | √ | √ | | |
| | √ | √ | √ | | |
| | √ | √ | √ | | |
| | optional | optional | | | |
| | √ | | | | |
| | √ | | | | |
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| | √ | | | | |

Sample Use:

| | | | | | |
|------------------------------------|-------------------------------|--|---|--|--|
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Estimated Cost Premium:

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|---|------------------------------------|--------------------------------|--|---|--|--|
| <i>Id</i> | | | Viewed at a Distance ≤ 6 m | Viewed at a Distance > 6 m | | |
| <i>Characteristics</i> | | | | | | |
| 1.1 Surface preparation to SSPC-SP 6 | | ✓ | ✓ | ✓ | ✓ | |
| 1.2 Sharp edges ground smooth | | ✓ | ✓ | ✓ | ✓ | |
| 1.3 Continuous weld appearance | | ✓ | ✓ | ✓ | ✓ | |
| 1.4 Standard structural bolts | | | | | | |
| 1.5 Weld spatters removed | | | | | | |
| 2.1 Visual Samples | | | | | | |
| 2.2 One-half standard fabrication tolerances | | | | | | |
| 2.3 Fabrication marks not apparent | | | | | | |
| 2.4 Welds uniform and smooth | | | | | | |
| 3.1 Mill marks removed | | ✓ | ✓ | | | |
| 3.2 Butt and plug welds ground smooth and filled | | ✓ | ✓ | | | |
| 3.3 HSS weld seam oriented for reduced visibility | | ✓ | ✓ | | | |
| 3.4 Cross sectional abutting surface aligned | | ✓ | ✓ | | | |
| 3.5 Joint gap tolerances minimized | | ✓ | ✓ | | | |
| 3.6 All welded connections | | optional | optional | | | |
| 4.1 HSS seam not apparent | | ✓ | | | | |
| 4.2 Welds contoured and blended | | ✓ | | | | |
| 4.3 Surfaces filled and sanded | | ✓ | | | | |
| 4.4 Weld show-through minimized | | ✓ | | | | |
| C.1 | | | | | | |
| C.2 | | | | | | |
| C.3 | | | | | | |
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| <i>Sample Use:</i> | Elements with special requirements | Showcase or dominant elements | Airports, shopping centres, hospitals, lobbies | Retail and architectural buildings viewed at a distance | Roof trusses for arenas, retail warehouses, canopies | |
| <i>Estimated Cost Premium:</i> | Low to High (20-250%) | High (100-250%) | Moderate (60-150%) | Low to Moderate (40-100%) | Low (20-60%) | None 0% |

Viewing distance is noted as the differentiating factor between the high and low end AESS Categories.



Grinding permitted \$\$

No Grinding!!

Basic Choices Impacting Economy

LESS EXPENSIVE

Bolting (Hex or TC)

“As is” welds

Standard steel shapes

Shop Fabrication and assembly

MORE EXPENSIVE

Extensive welding

Remediated (ground) welds

Custom steel shapes (plate)

Extensive site welding and assembly



Strategies to Encourage Economical Approaches

DISTANCE FACTOR

- If it is beyond 6m/20ft then precise finishes are a waste of time and \$\$
- “As is” welds are just fine at a distance
- Discreet or Hidden connections can be used instead of welded/remediated connections
- Easier to justify using standard steel shapes over custom
- Works with AESS 2 and 3 Categories



Strategies to Encourage Economical Approaches



COATING FACTOR

- If galvanizing is used for corrosion protection, it works well with less refined details
- Heavier intumescent protection negates the need for fine details and can mask aspects of the connection
- Deciding against a high or semi gloss coating at the outset of the project can help soften the details

Image: TheVeryMany

Strategies to Encourage Economical Approaches


MULTIPLICATION FACTOR

- If a connection detail is widely repeated it may be easier to set up jigs to ensure uniformity
- Can the number of unique connections be reduced?
- Can the cost of multiplying the number of connections dissuade the designer from requiring extensive weld remediation?



MULTIPLICATION FACTOR



A close-up photograph of a white metal structure, likely a guardrail or barrier, showing two welded joints. The welds are unremediated, appearing as rough, uneven, and somewhat irregular lines where the metal pieces meet. The background is a blurred asphalt road with white dashed lines, suggesting an outdoor setting.

Choice to use an unremediated welded connection.



The connection could have been done like this, for a significant cost increase.

MULTIPLICATION FACTOR



Stadium entrance canopy....

AESS 4

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized

Strategies to Encourage Economical Approaches

CHOOSING THE RIGHT AESS CATEGORY

- Not all projects need be designed to AESS 4
- Not all projects require the level of detailing suited to museums, galleries and even airports
- Even at AESS 3 and 4, the grinding of welds is **OPTIONAL**



AESS 4 “triggers”



- mostly custom sections, many created from plate material
- significant remediation of welding throughout the elements
- curved steel – although this may also be used in lower-category projects, it does add challenges
- use of large custom castings
- sharp corners on members (need plate vs rolled shapes for this)
- seamless appearance
- absence of W shapes
- splices between transportable sections done via welding (as opposed to bolting, hidden or discreet connections)
- often coordinated with cable-supported glazing systems, necessitating even tighter tolerances

Strategies to Encourage Economical Approaches

GOOD USE OF VISUAL SAMPLES

- Visual samples or mock-ups are available in the AESS spec as of AESS 2 and above
- Negotiate the connection details through the use of mock-ups (physical, partial, 3D printed, digital renders) to make highly educated and informed decisions about appearance and cost.



Definitions



Member refers to the discrete sections of steel, such as wide-flange (Universal) sections, hollow structural sections (HSS), angles, channels, rods or cables.

Element references the larger agglomerated pieces of a building. This includes trusses, beams and columns as they extend from one external connection point to the other. A small or uncomplicated element may be constituted simply by one steel member. In many AESS projects the additional complexity will require the assemblage of larger elements from a number of members.

Connection Types

Connections are of three basic types by virtue of their location and purpose:

Internal connections are those by which the *members* are joined to create a larger element. These are most normally the result of shop fabrication.

External connections connect *elements* to each other. These are most often completed on site. This includes, for example, the connection of a truss to its supporting column or a beam to a truss.

Splices are to be found when *elements* are too large to ship in one piece. These are often completed on site, either on the ground prior to lifting or in the air as erection proceeds.



Shop or site?



Welded connections will have the most economical results if fabricated in the shop

- Climate controlled environment
- Ease of access for welding operations
- Crane assist for abilities to turn and manipulate the pieces

Bolted connections are best suited to site situations

- Quick to do
- Shortest time on the crane
- Weather independent
- Less requirements for scaffolding and temporary shoring

Expressed or discreet



- Connections located **within** an AESS element tend to be done in ways that **suppress** the evidence of the connection.
- Connections **between** AESS elements will **choose the level and nature** of the expression of the connection.
- **Splices** are special connections that discreetly happen within sections of elements where the act of connecting is intended to be hidden.

Bolted Connections




- Often preferred by steel contractors for site erection
- Often used when a more technical look is desired (architecturally driven)
- Simple alignment and tolerance tightening can create quite beautiful looking bolted connections
- Choose between regular hex head or TC (tension control) bolts
- Ensure that all of the bolt heads are placed uniformly in the connection

Zero cost premium to specify the head side of the bolt!



- AESS 2**
- 2.1 Visual Samples
 - 2.2 One-half standard fabrication tolerances
 - 2.3 Fabrication marks not apparent
 - 2.4 Welds uniform and smooth





This could have been welded at a much higher cost, but the tight tolerances make this a good looking connection and cheaper/faster to do on site.

AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth



Canadian Museum for Human Rights | Winnipeg, Canada

DISTANCE FACTOR

+

FINISH FACTOR

viewing distance

Galvanized steel infers texture and roughness in the detailing





Aesthetic intention was to achieve roughness so the connection details can be softened to reflect that, saving money. The large gusset plates feed INTO the aesthetic.


- AESS 2**
- 2.1 Visual Samples
 - 2.2 One-half standard fabrication tolerances
 - 2.3 Fabrication marks not apparent
 - 2.4 Welds uniform and smooth

Lifting plate remains as part of the look, saving \$

AESTHETIC FACTOR

- AESS 2**
- 2.1 Visual Samples
 - 2.2 One-half standard fabrication tolerances
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 - 2.4 Welds uniform and smooth

Aesthetic intention was to achieve roughness



The front of the project allocated more \$ on the relatively invisible welded tube to tube connections as continuity was critical to the look.

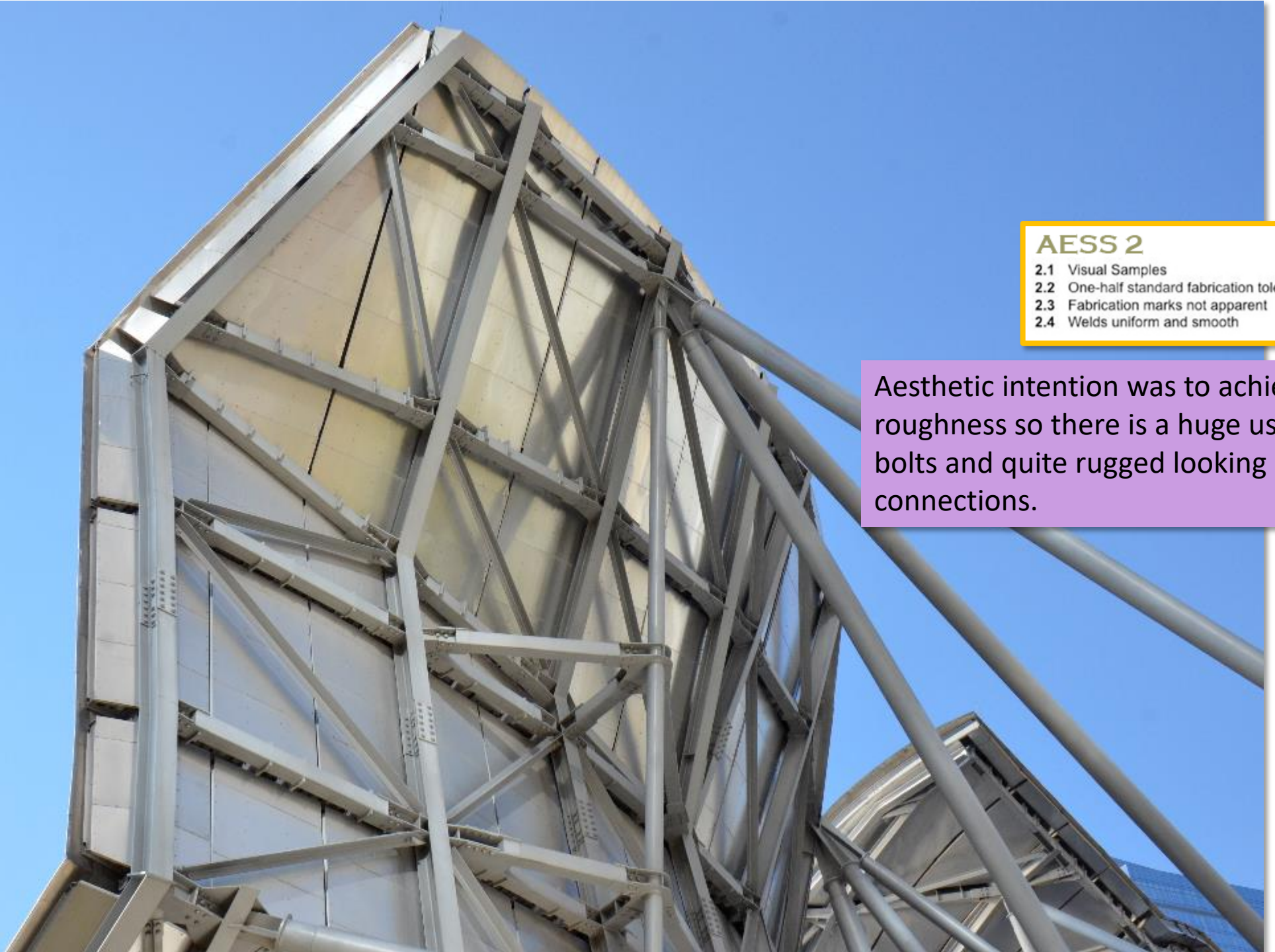
Pritzker Pavilion | Chicago, IL

viewing distance



Even so, no weld remediation due to the distance factor!

viewing distance



AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth

Aesthetic intention was to achieve roughness so there is a huge use of bolts and quite rugged looking connections.

AESTHETIC FACTOR

A close-up photograph of a complex steel structure, likely part of a building's facade or interior framework. The structure consists of multiple intersecting steel beams and plates, all finished with a smooth, light-colored paint. The joints are secured with hex head bolts, and the welds are uniform and smooth, demonstrating high-quality fabrication. The background shows a wooden panel, possibly part of the building's interior or a temporary structure.

AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth

Hex head bolts. No weld remediation. Works with Gehry's Deconstructivist design.



Arboretum | Penn State University

AESS 3

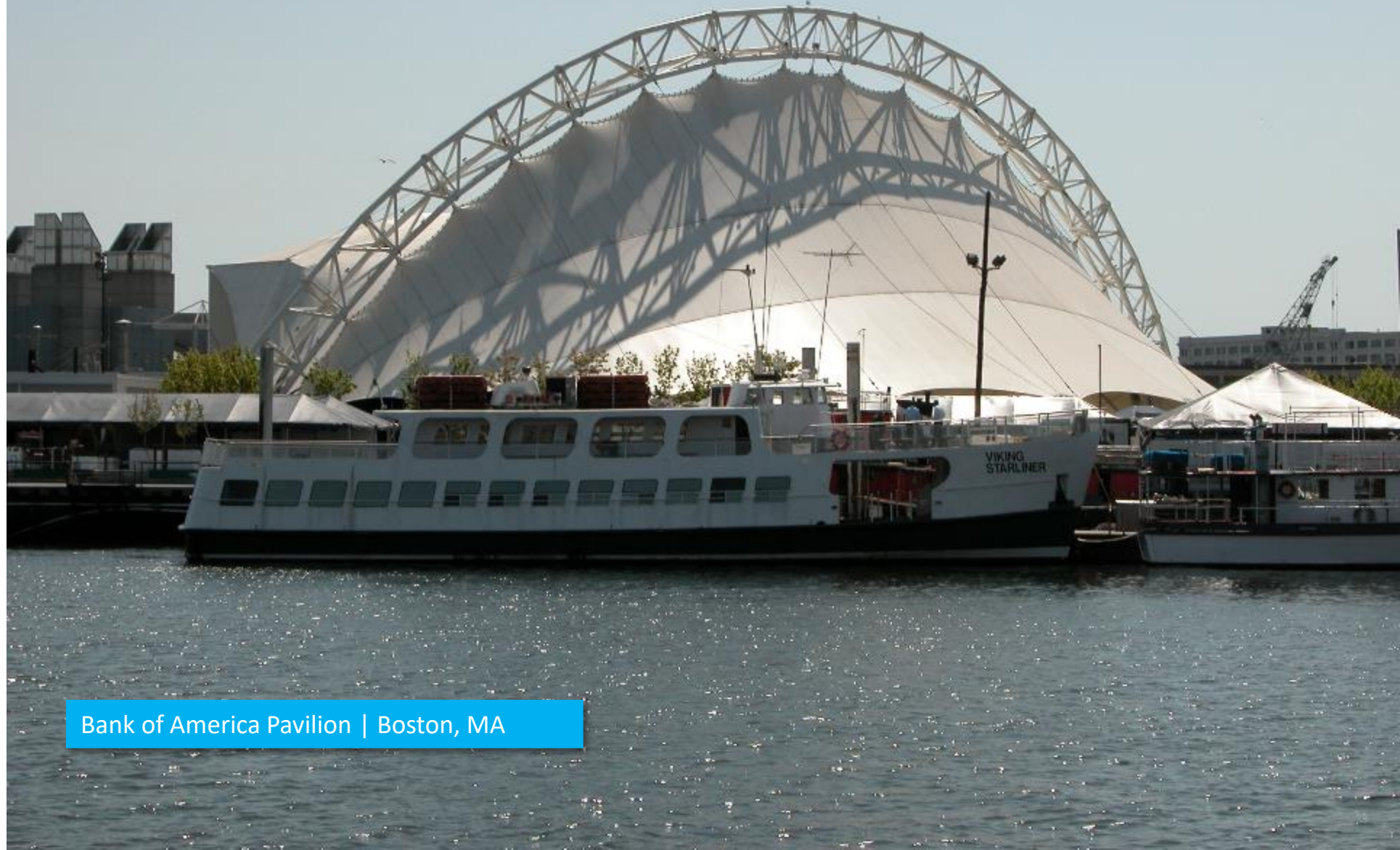
- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
- 3.3 HSS weld seam oriented for reduced visibility
- 3.4 Cross sectional abutting surface aligned
- 3.5 Joint gap tolerances minimized
- 3.6 All welded connections

Pairing the channels allows for a simple bolted connection through the plate



DISTANCE FACTOR

viewing distance



Bank of America Pavilion | Boston, MA

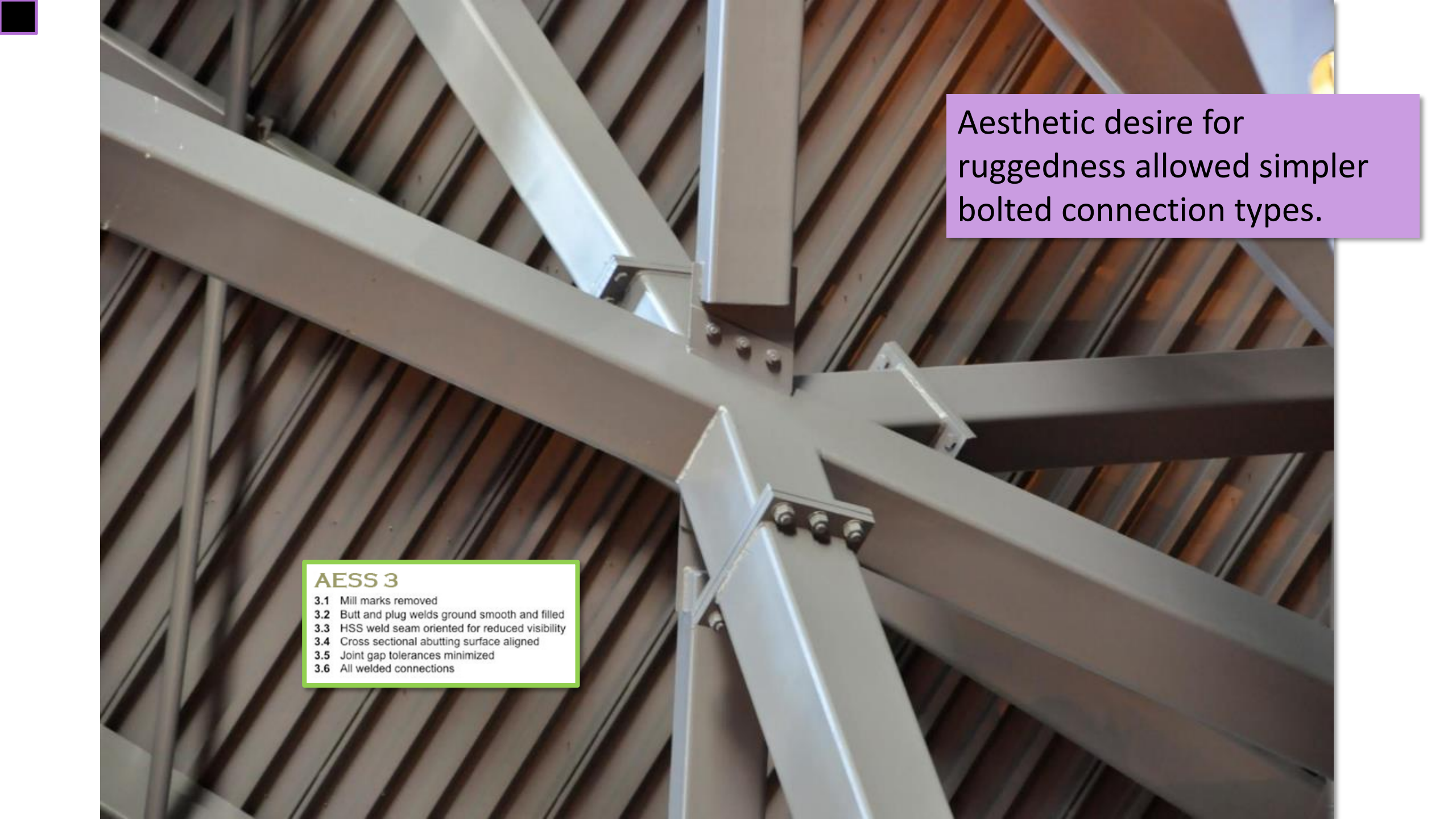


Distance factor at work!
Very simple bolted end plates combined with straight section trusses.

AESTHETIC FACTOR



Canadian War Museum | Ottawa, Canada



Aesthetic desire for ruggedness allowed simpler bolted connection types.


AESS 3

- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
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- 3.4 Cross sectional abutting surface aligned
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- 3.6 All welded connections

viewing distance



Lillis School of Business | Eugene, OR



Simple bolted connections. Bolt head orientation planned.

AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth

viewing distance



National Airport | Washington, DC



AESS 3

- 3.1 Mill marks removed
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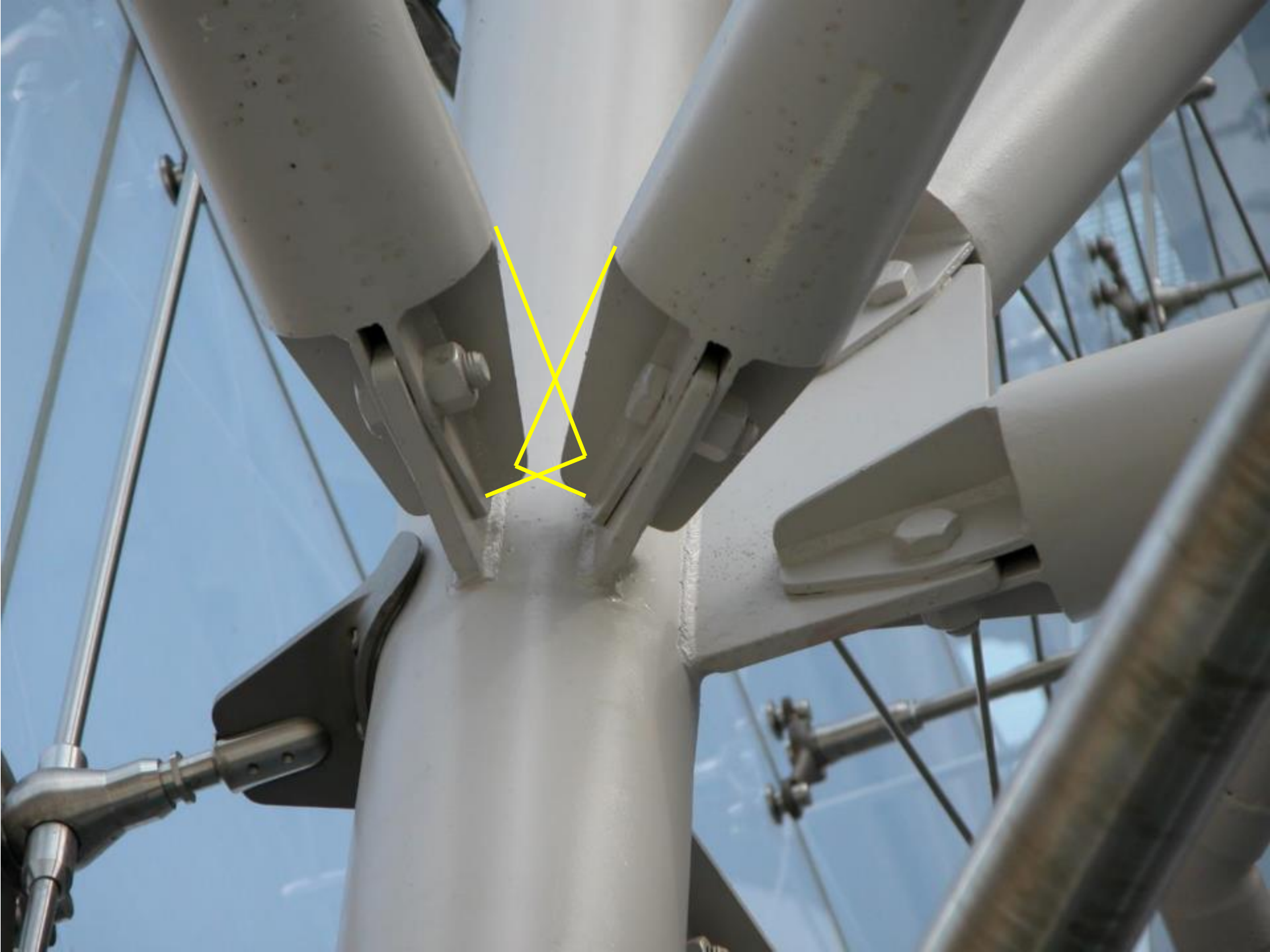


Rose Center for Space | New York, NY

A close-up photograph of a white metal joint on a ship's mast. The joint consists of several cylindrical sections meeting at a central point, secured with bolts and nuts. The background shows a clear blue sky and the rigging of the ship. A green-bordered callout box is overlaid on the lower-left portion of the image, containing a list of technical specifications.

AESS 3


- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
- 3.3 HSS weld seam oriented for reduced visibility
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- 3.5 Joint gap tolerances minimized
- 3.6 All welded connections



FINISH FACTOR

Federation Square | Melbourne, Australia

This is an open air project in a humid environment. Galvanization used as a finish – inferring a more rugged aesthetic and suitable detailing.



Galvanized steel infers texture and roughness in the detailing

AESS 3

- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
- 3.3 HSS weld seam oriented for reduced visibility
- 3.4 Cross sectional abutting surface aligned
- 3.5 Joint gap tolerances minimized
- 3.6 All welded connections













San Francisco Courthouse | Morphosis











CalTrans Los Angeles | Morphosis





ONE WAY

Green directional sign with white text and arrows pointing up and down.



STAFF ONLY
8'11" 2" CLEARANCE



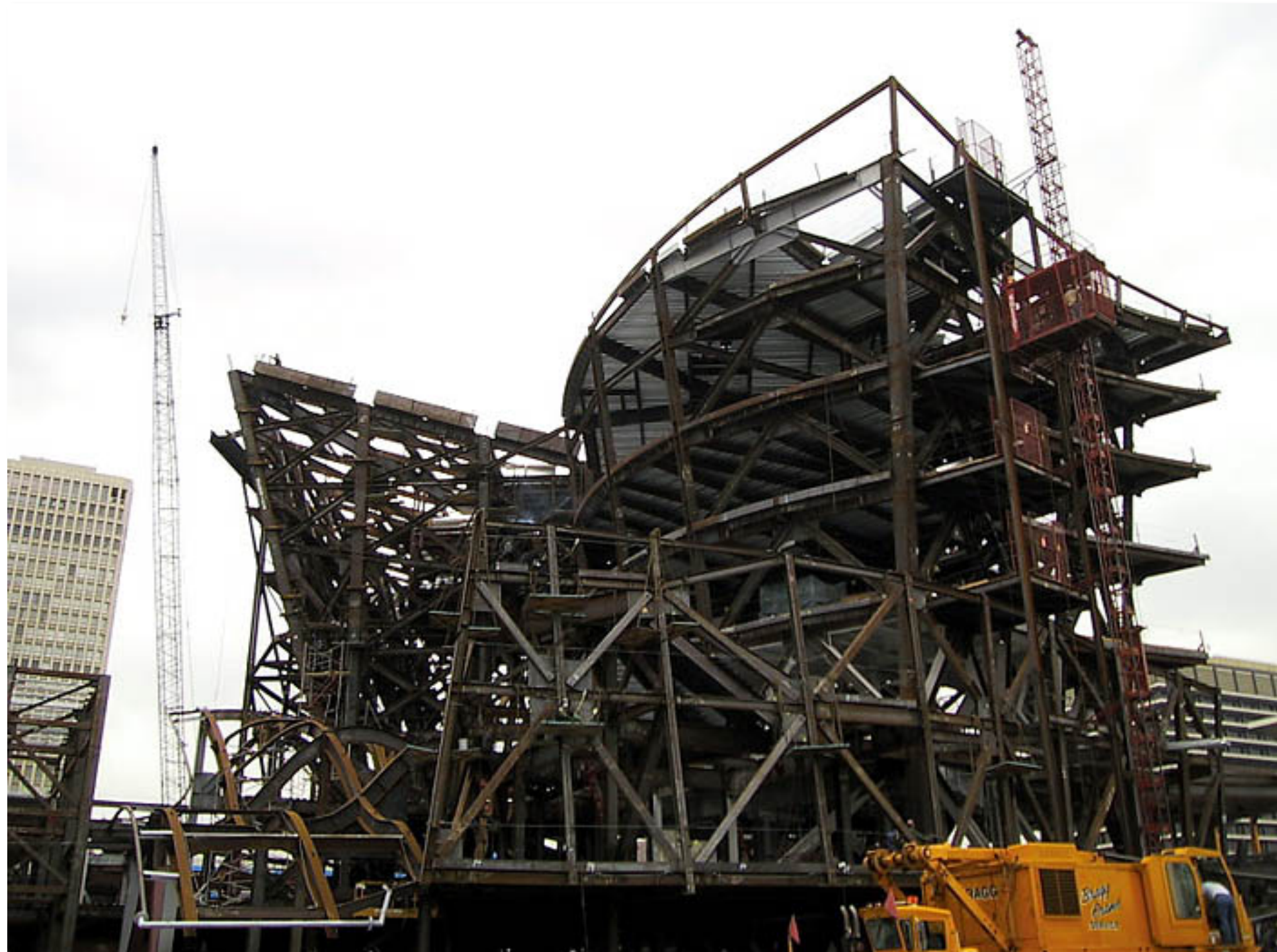




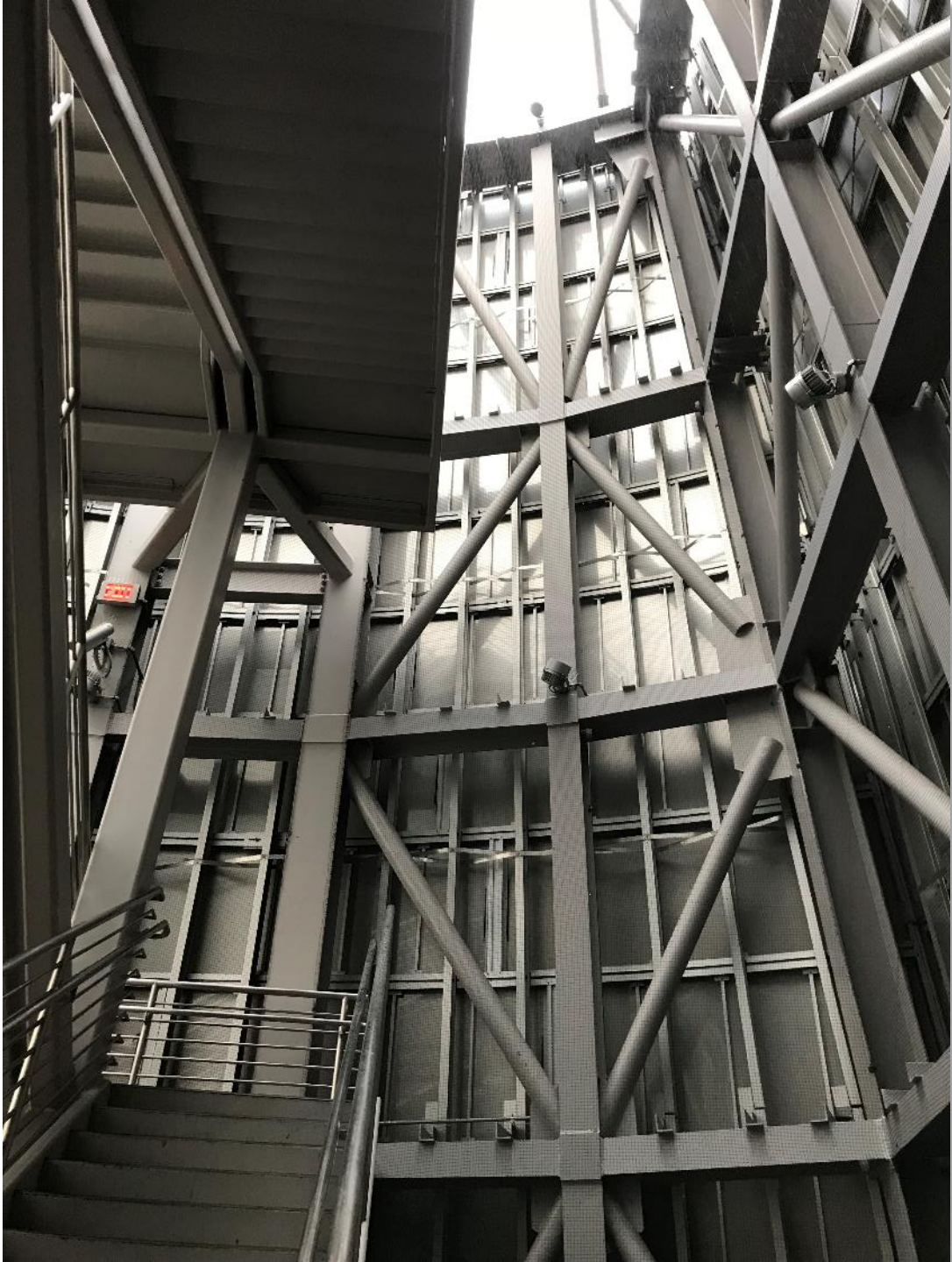


Disney Concert Hall, Los Angeles | Frank Gehry









Weld Remediation

This is the BIGGEST question!

The AESS level determines whether or not you are permitted to grind welds

AESS 1 and 2 – no weld grinding permitted due to use and distance factors

AESS 3 and 4 – grinding permitted, but...

- THINK CAREFULLY ABOUT THE DETAILS TO DECIDE IF IT IS ACTUALLY NECESSARY
- Neatly done welds can often be left “as is”
- DISTANCE TO VIEW can solve many potential grinding needs
- Grinding should be essential to the creation of smooth curves and not considered routine
- Grinding requires the construction of safe working platforms and ease of access on site





Weld seam oriented?







A close-up photograph of a metal joint, likely a pipe or structural component. The joint is made of a light-colored metal, possibly aluminum or stainless steel. It features a central weld seam that runs vertically through the center of the joint. The weld seam is oriented vertically, which is a design choice to reduce its visibility. The joint is supported by a yellow metal bracket or fixture. The background is a dark, textured surface.

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viewing distance



Pedestrian Bridge | Auckland, NZ



A close-up photograph of a square tube intersection. The tubes are painted white and show signs of rust. A weld joint is visible at the intersection, with a dark, recessed area on the back side. The background shows a wooden deck.

Square tubes intersecting,
higher cost detail.

Note back side inset so less
expensive to detail!
Obviously there is a
preferred view side.

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Use smaller tubes on the web members to allow a shoulder for the fillet weld.


AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth

AESS 3

- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
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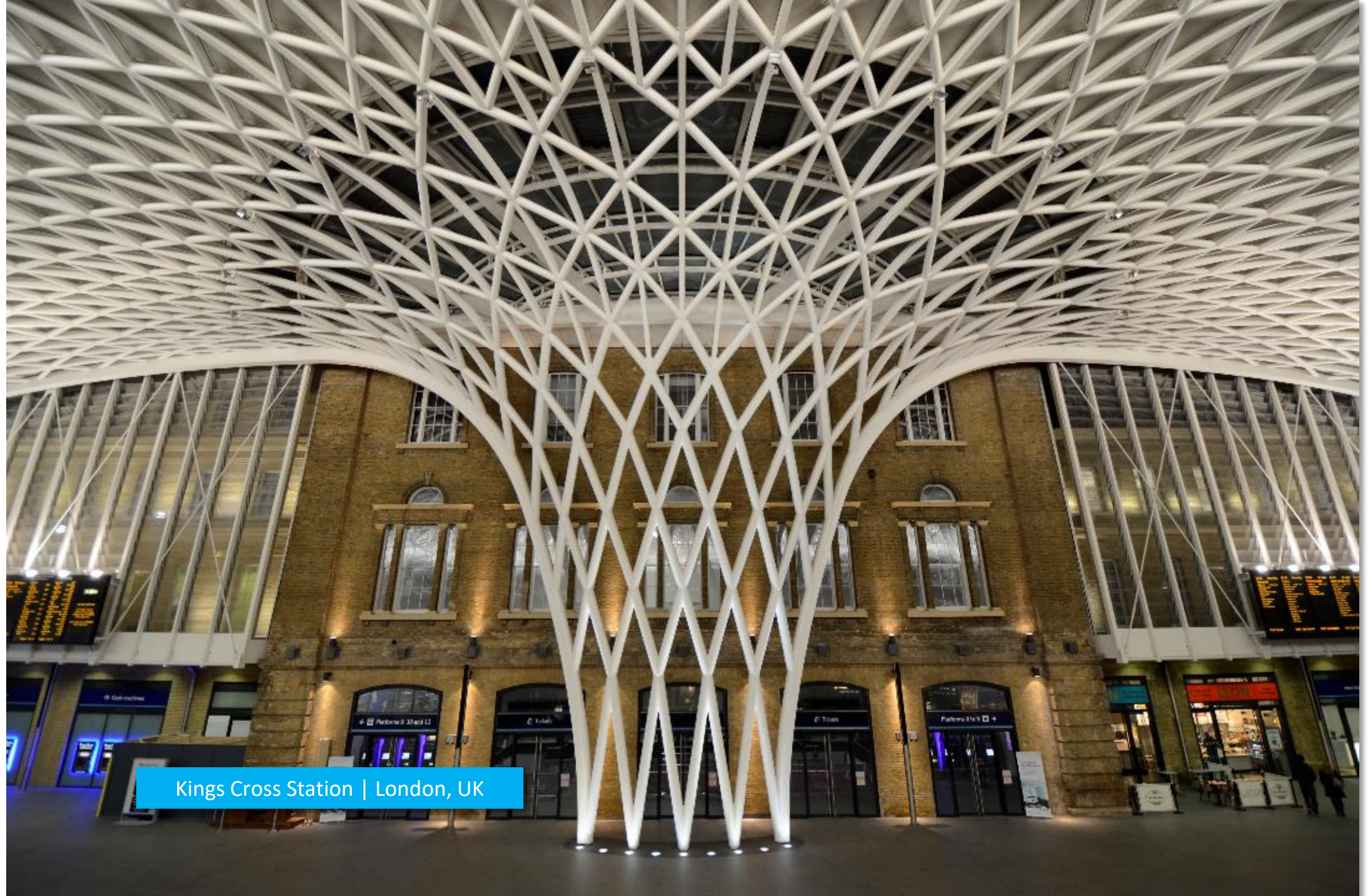


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viewing distance



Kings Cross Station | London, UK





This is NOT up too high to see...

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This is up too high to see.

AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth





| 14:00 Platforms | Arrivals | 14:00:01 |
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Pass Book

Pass Book

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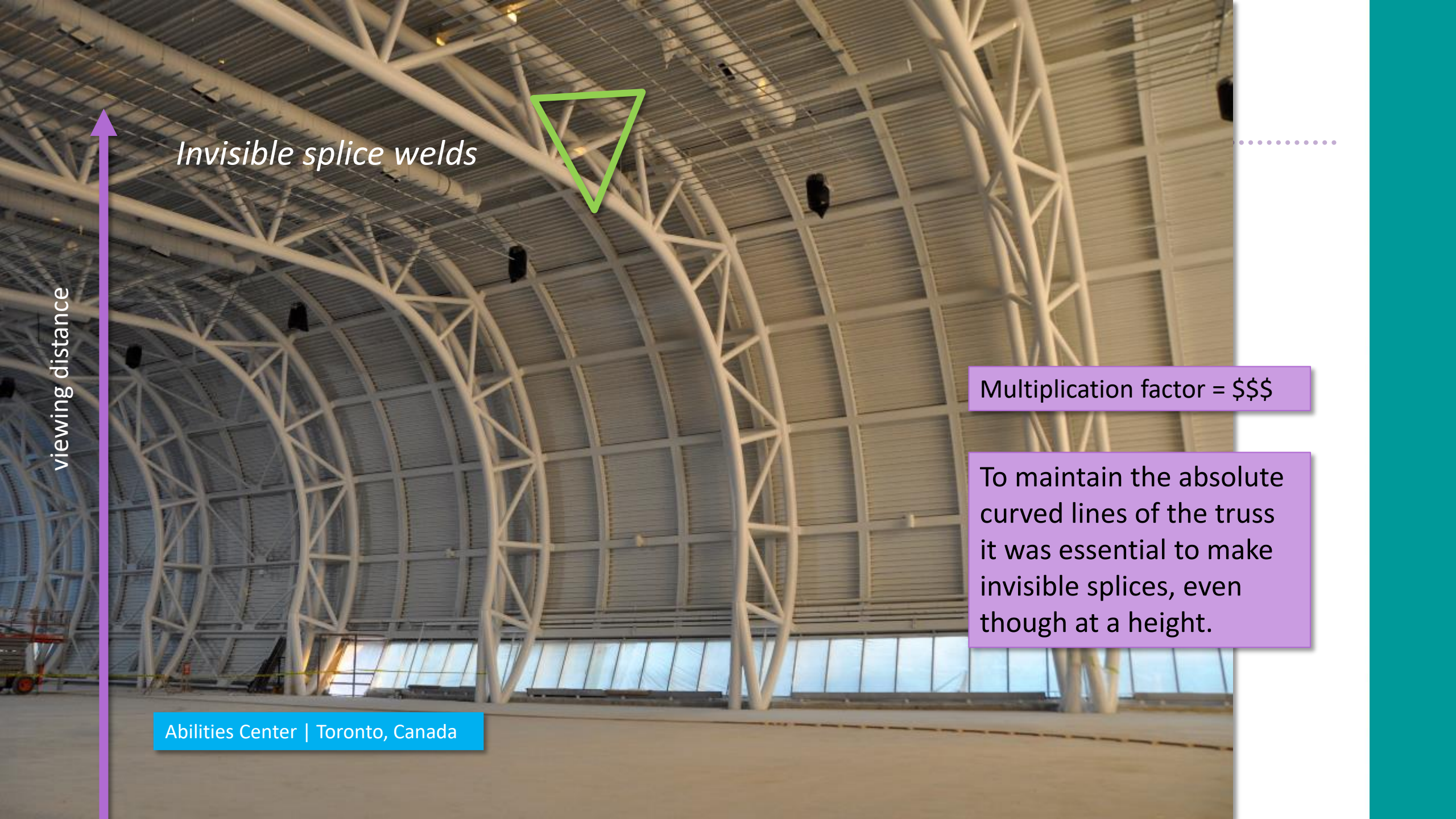
Roy Thomson Hall | Toronto, Canada



Multiplication factor = \$\$\$

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Invisible splice welds



viewing distance

Multiplication factor = \$\$\$

To maintain the absolute curved lines of the truss it was essential to make invisible splices, even though at a height.

Abilities Center | Toronto, Canada

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*Invisible splice welds
...somewhere?*

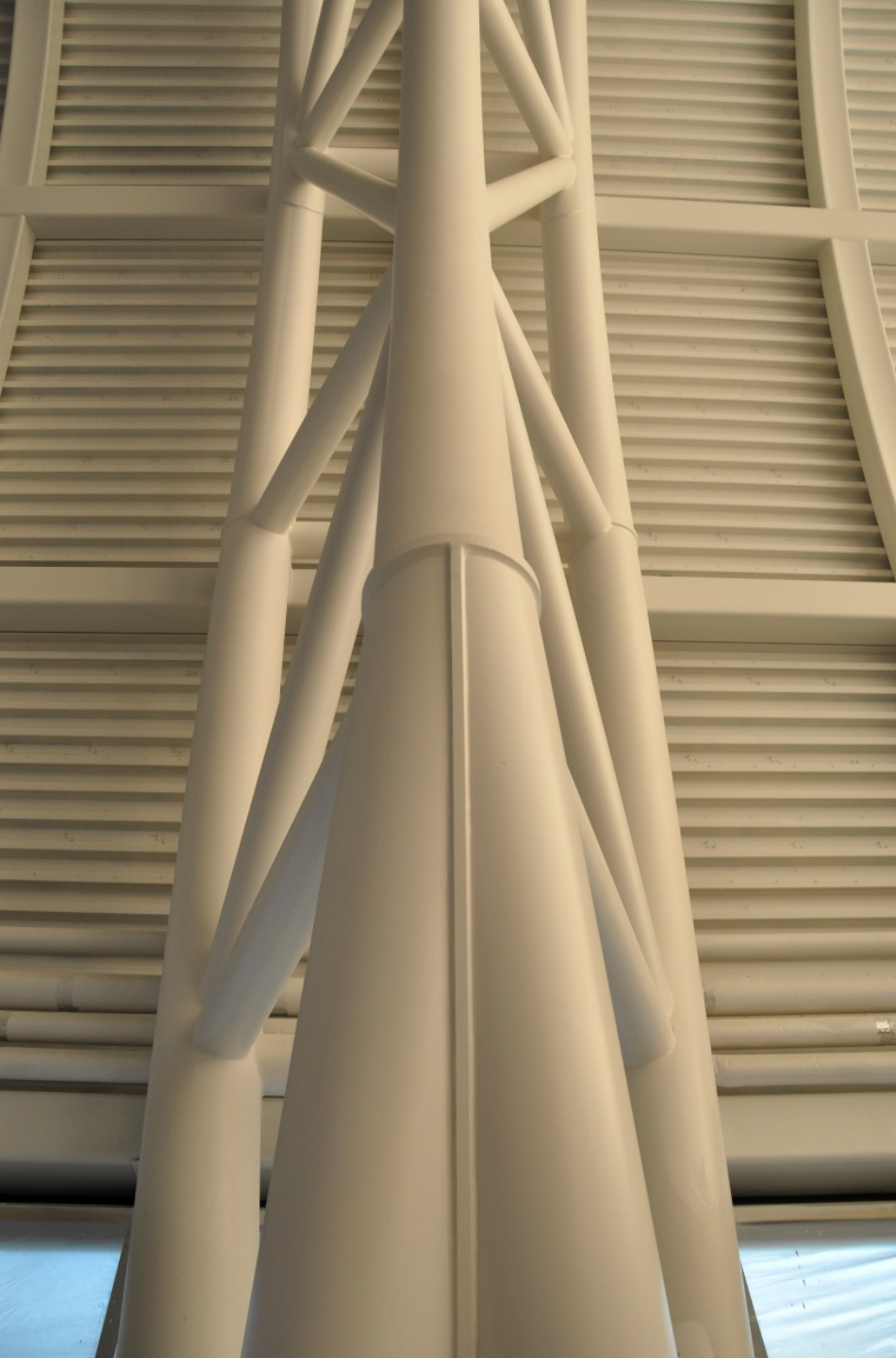
In this case the high end welded connections were essential to the look of the truss.



Shop welding

Site welding

Unremediated site welds are at the back of the truss so hidden from view.



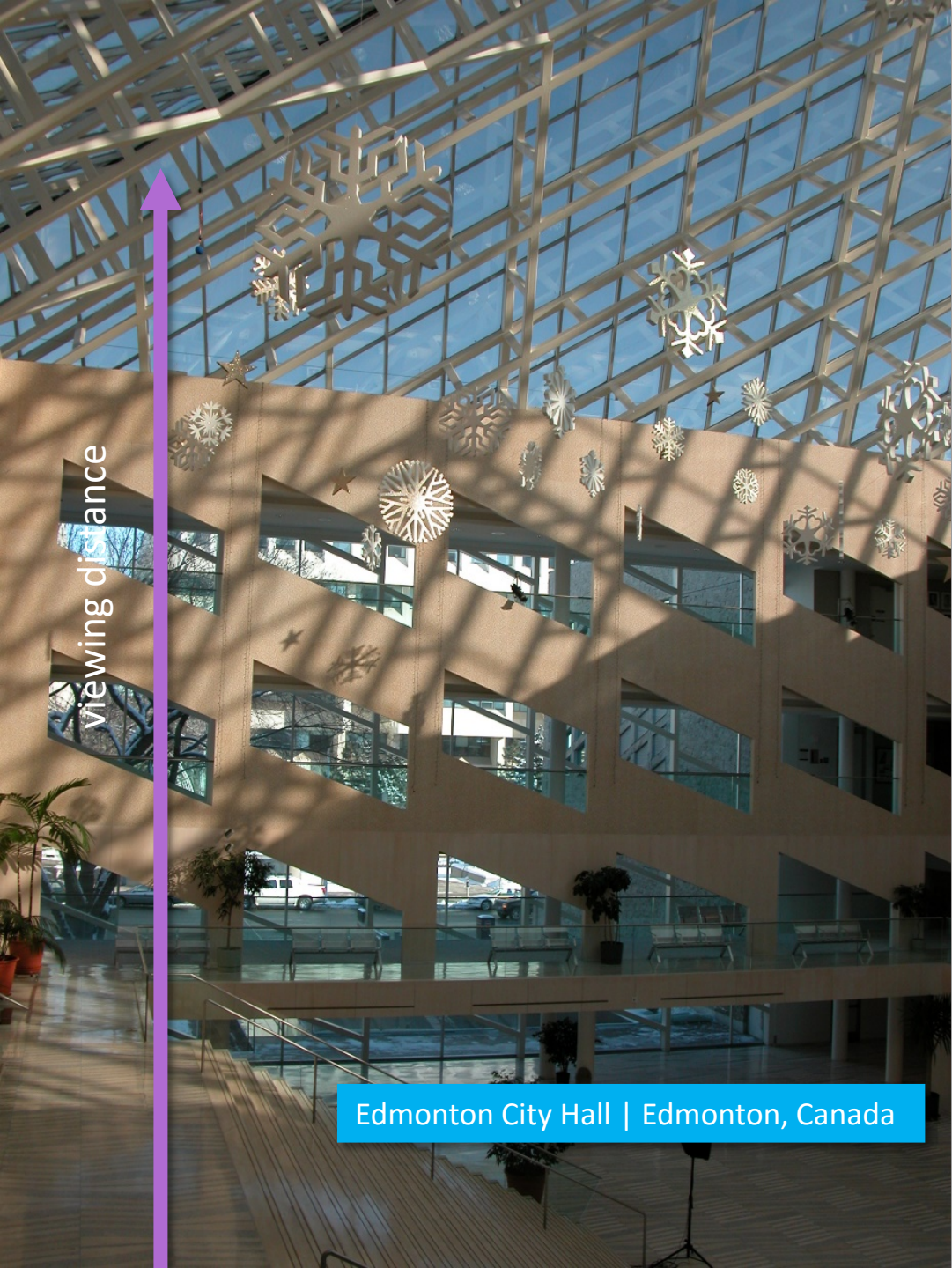
The level of detailing was important as the trusses were readily viewed at human eye level.

They were also within touching distance.

Given the sheer quantity, costs were a factor.

Use of a plate to join the round HSS legs created a nice shadow line and reduced grinding.






viewing distance

Edmonton City Hall | Edmonton, Canada



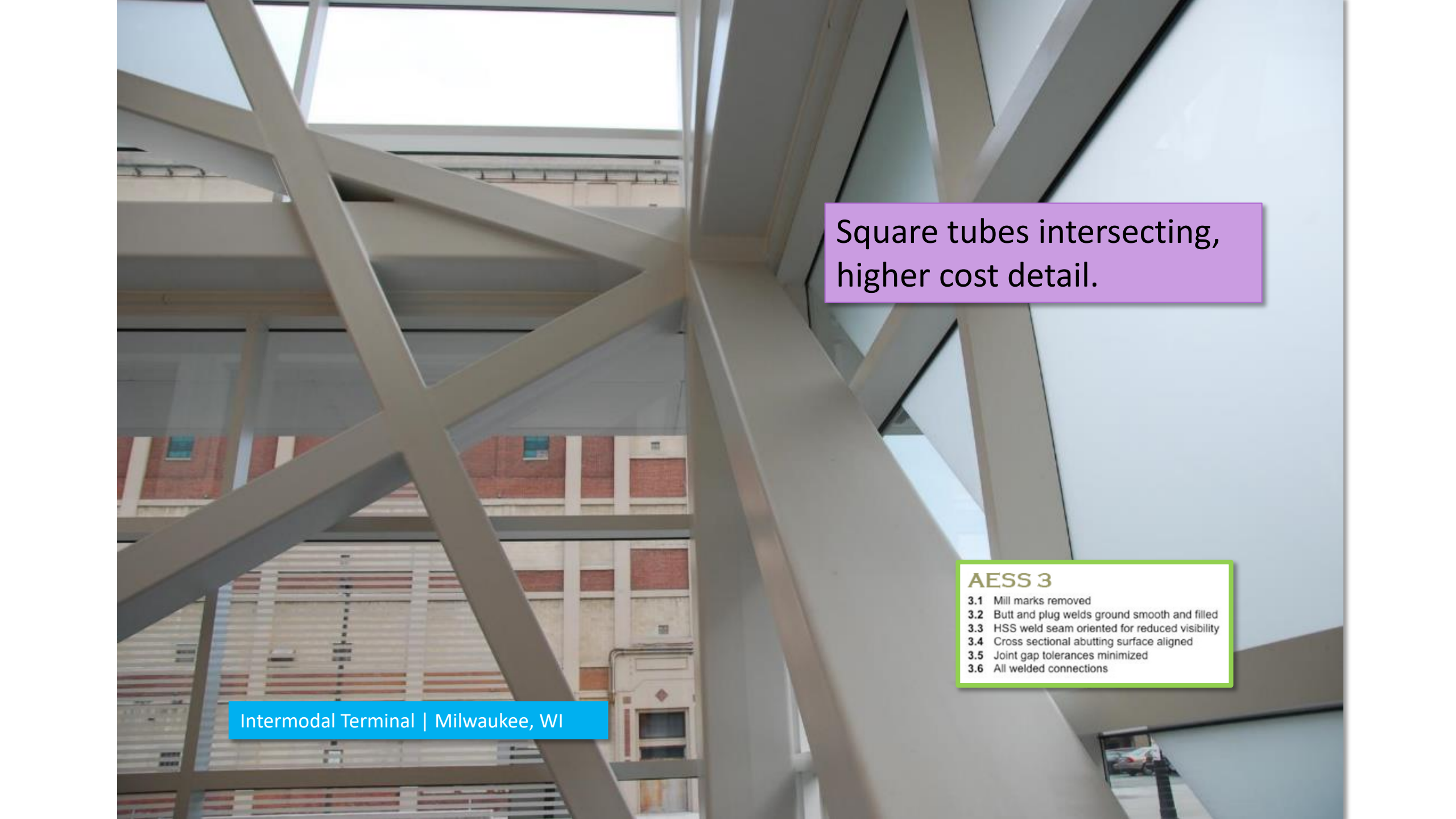
viewing distance



Distance to view negated
the need for fastidious
finishing and alignment.

AESS 3

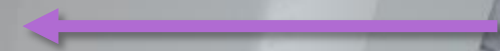
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Square tubes intersecting,
higher cost detail.

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Intermodal Terminal | Milwaukee, WI



*Weld seam
should have
been oriented
to hide it*





Seattle Museum of Flight | Seattle, WA

A close-up photograph of a white metal bridge railing joint. The railing consists of several thick, cylindrical posts connected by a horizontal rail. The joints are welded, and the weld seams are visible, showing a textured, slightly raised appearance. The background is a blurred view of a road with white dashed lines, suggesting the railing is part of a bridge or overpass structure.

Multiplication factor = \$\$\$

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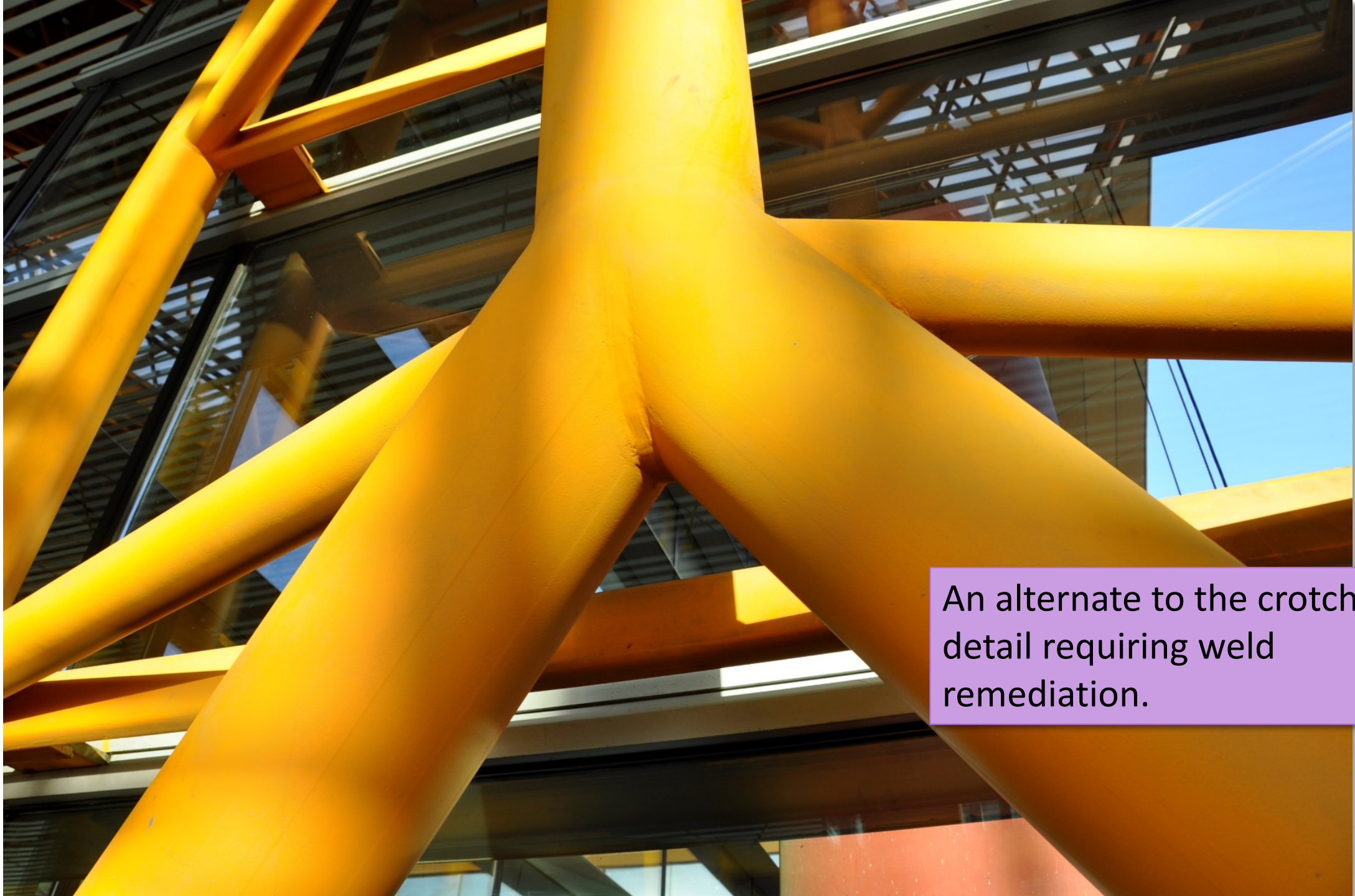
International Airport | Beijing, China





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An alternate to the crotch detail requiring weld remediation.

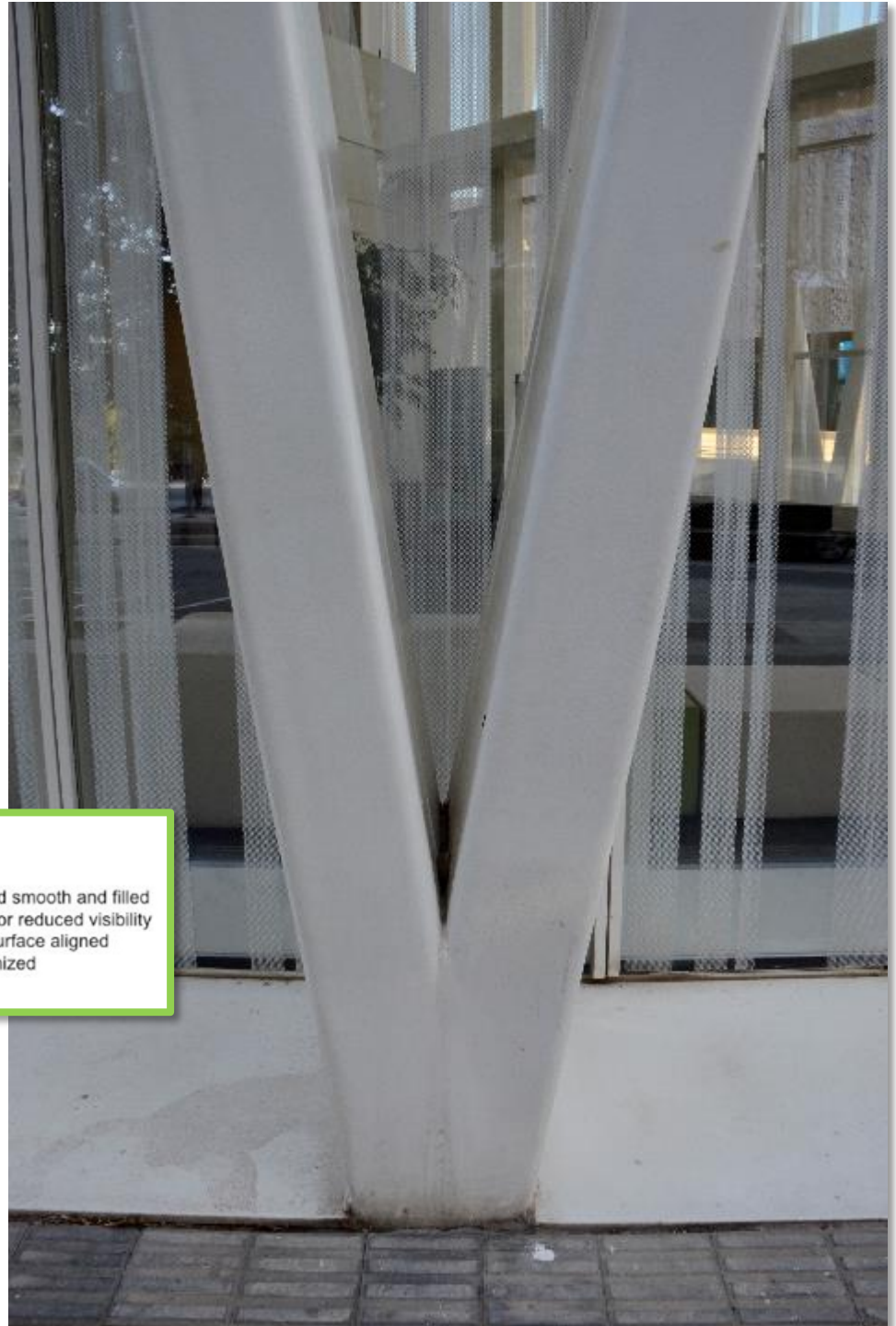


Perth Stadium | Perth, Australia

A close-up photograph of a highly polished metal joint, likely a pipe or structural component. The metal has a bright, reflective surface with visible highlights and shadows. The joint is a complex, multi-faceted connection. A text box is overlaid on the lower right portion of the image.

AESS 4

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized



- AESS 3**
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Torre Diagonale 00 | Barcelona

Making Splices

Usually done between sections of larger elements

Usually the result of transportation limitations

Usually intended to be as unobtrusive as possible

Downplay the connection

Three normal ways when dealing with HSS:

- COMPLETELY REMEDIATED SPLICE BY WELDING TO THE POINT OF INVISIBILITY
- HIDDEN CONNECTION USING BOLTS AND A COVER PLATE
- DISCREET CONNECTION WITH EXPOSED BOLTS



Side plates for temporary support prior to welding
Need to be removed, remediated

Weld designed for eventual grinding

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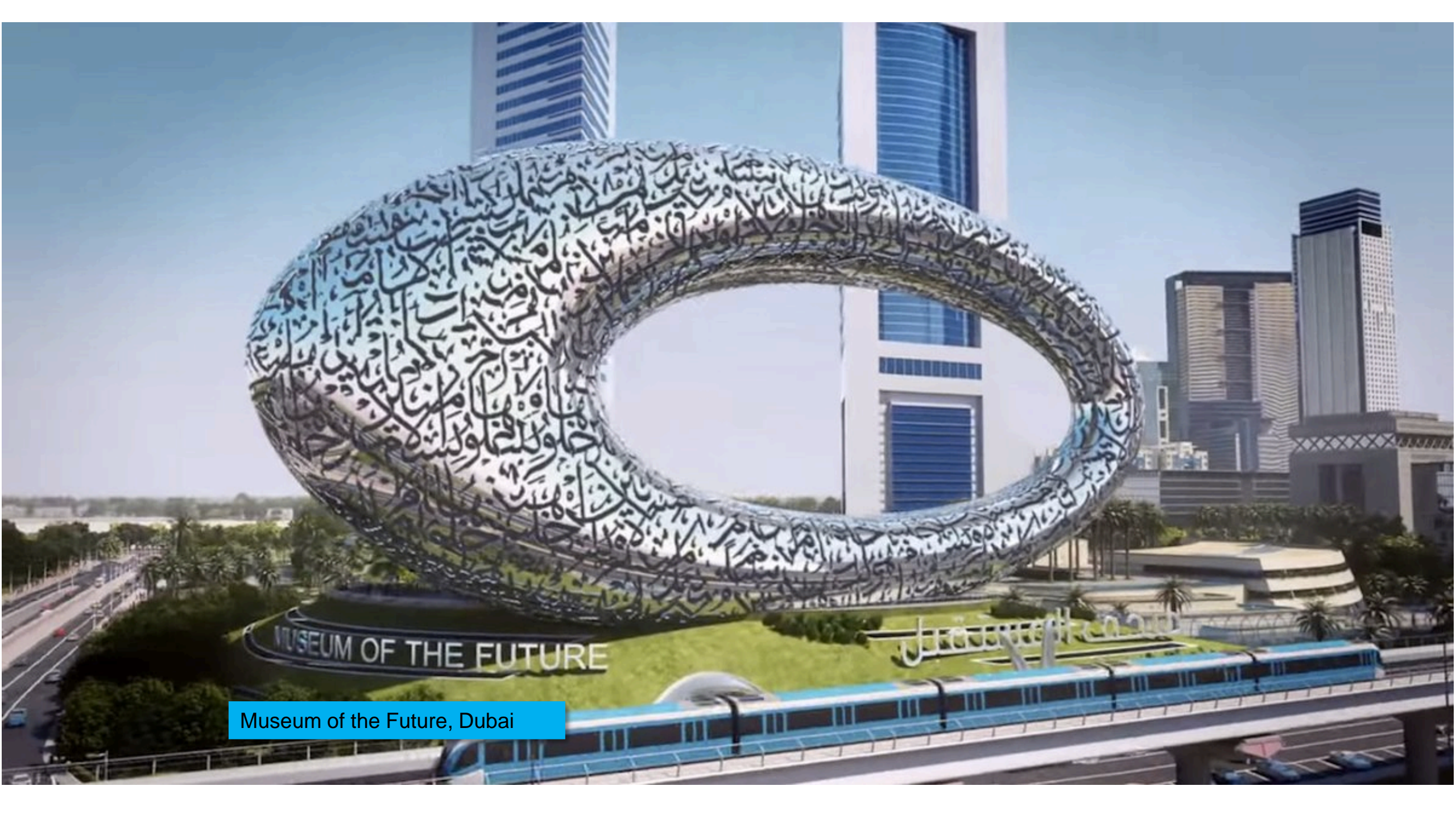
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Much more difficult to grind a round surface well

Economically driven connection design is looking for ways to avoid doing this for site splices.



- Welded joints are planned for.
- If the intention is to grind away the weld, the V joints need to be enlarged.
- Welds are structural and may not be removed at whim.



Museum of the Future, Dubai



محف
RE المستقبل

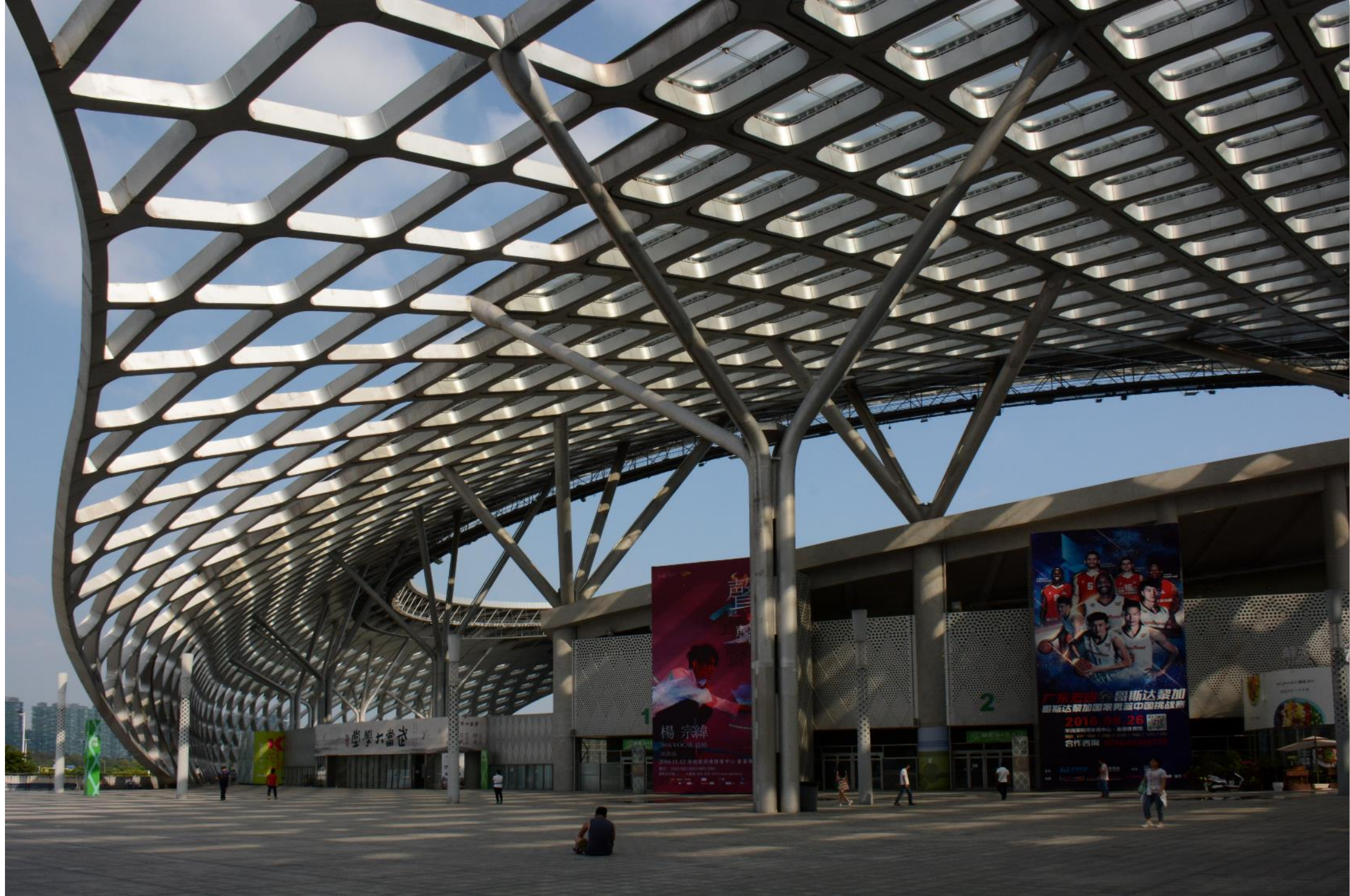








Shenzhen Bay Sports Complex



杨宗緯
2016.11.12 全国巡回演唱会
2016.11.12 全国巡回演唱会

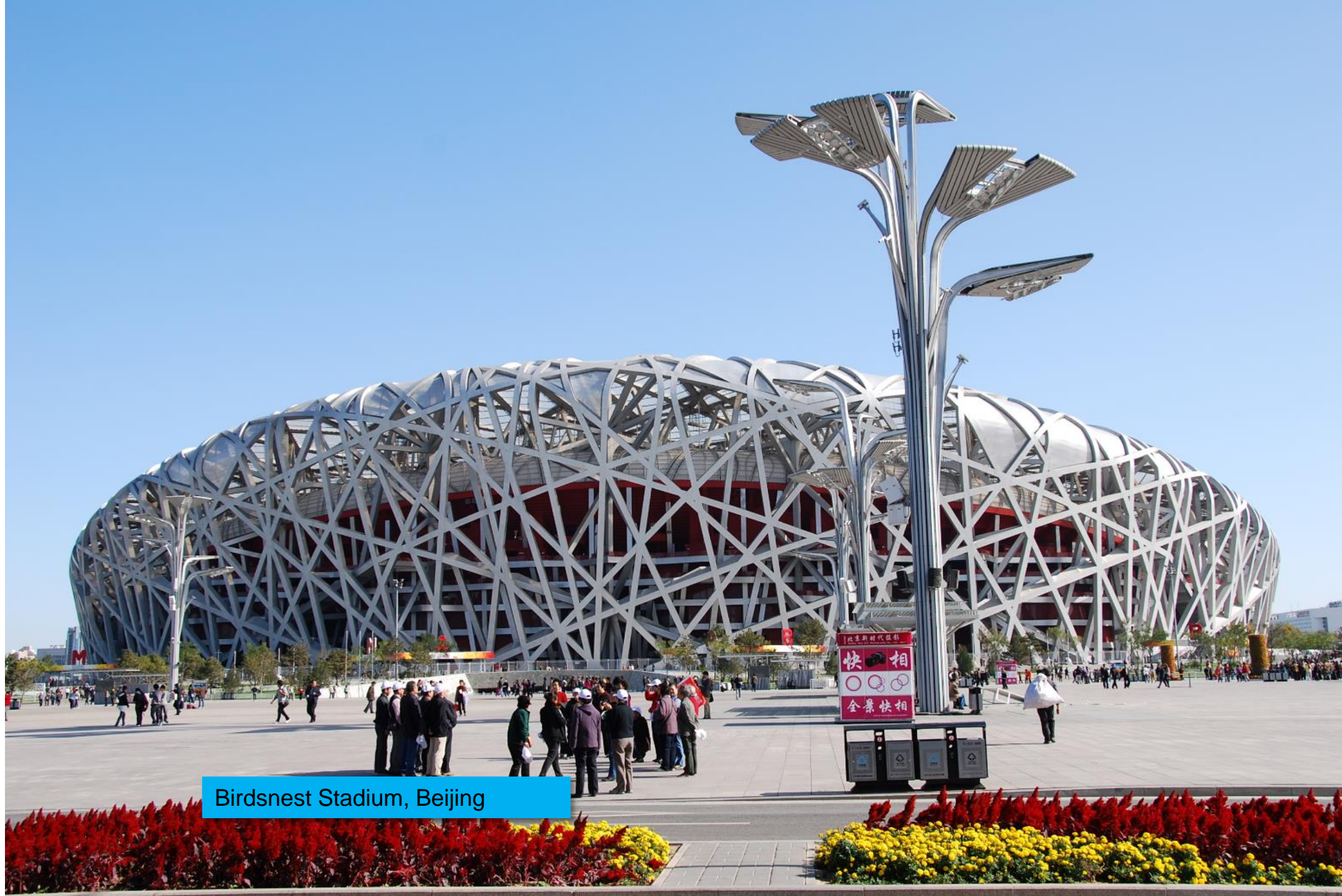
广东男篮 客场 哥斯达黎加
哥斯达黎加国家队 中国挑战赛
2016.09.26
中国篮球职业联赛中心 篮球世界杯
合作商

大包
小包
小包







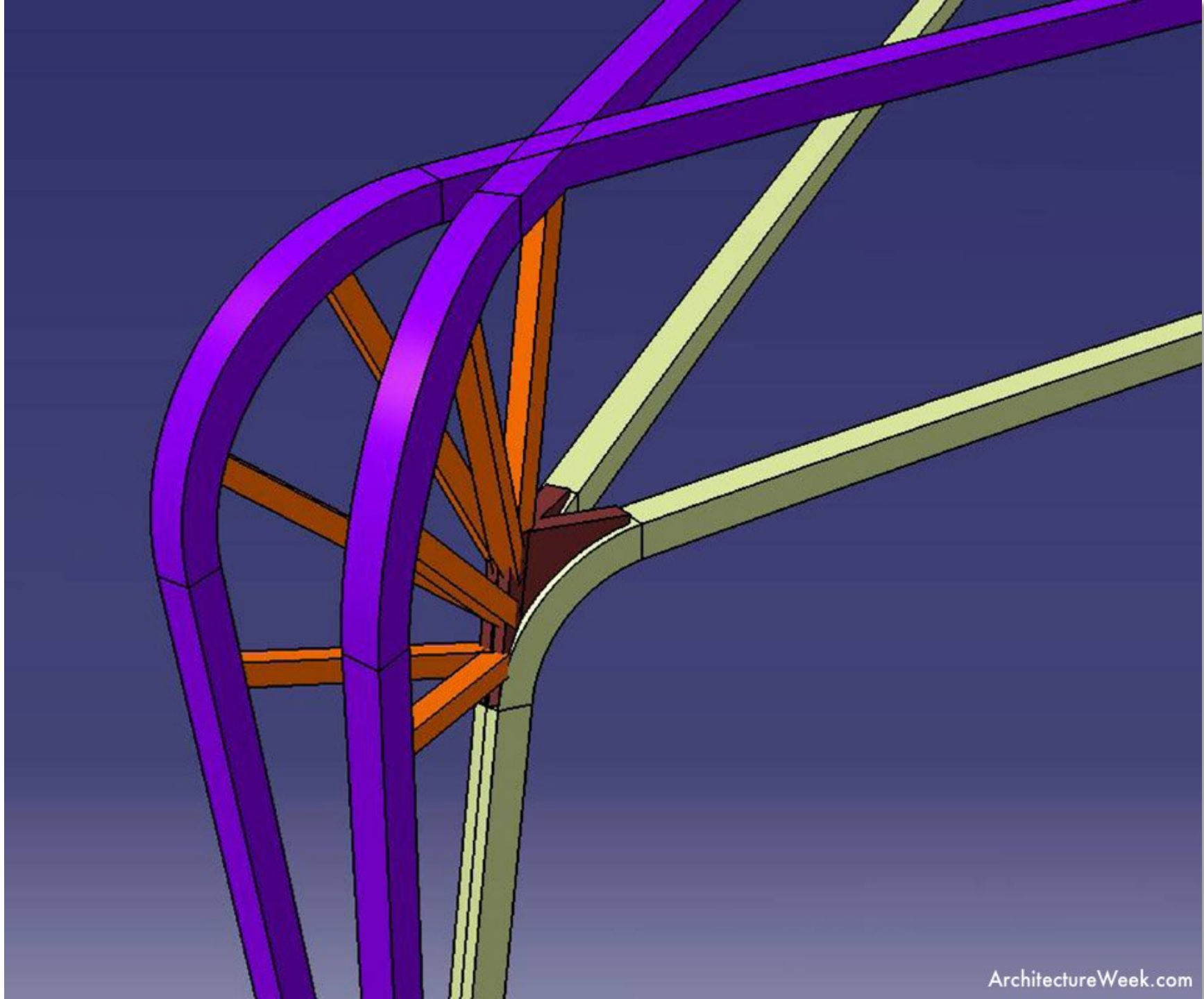


Birdsnest Stadium, Beijing



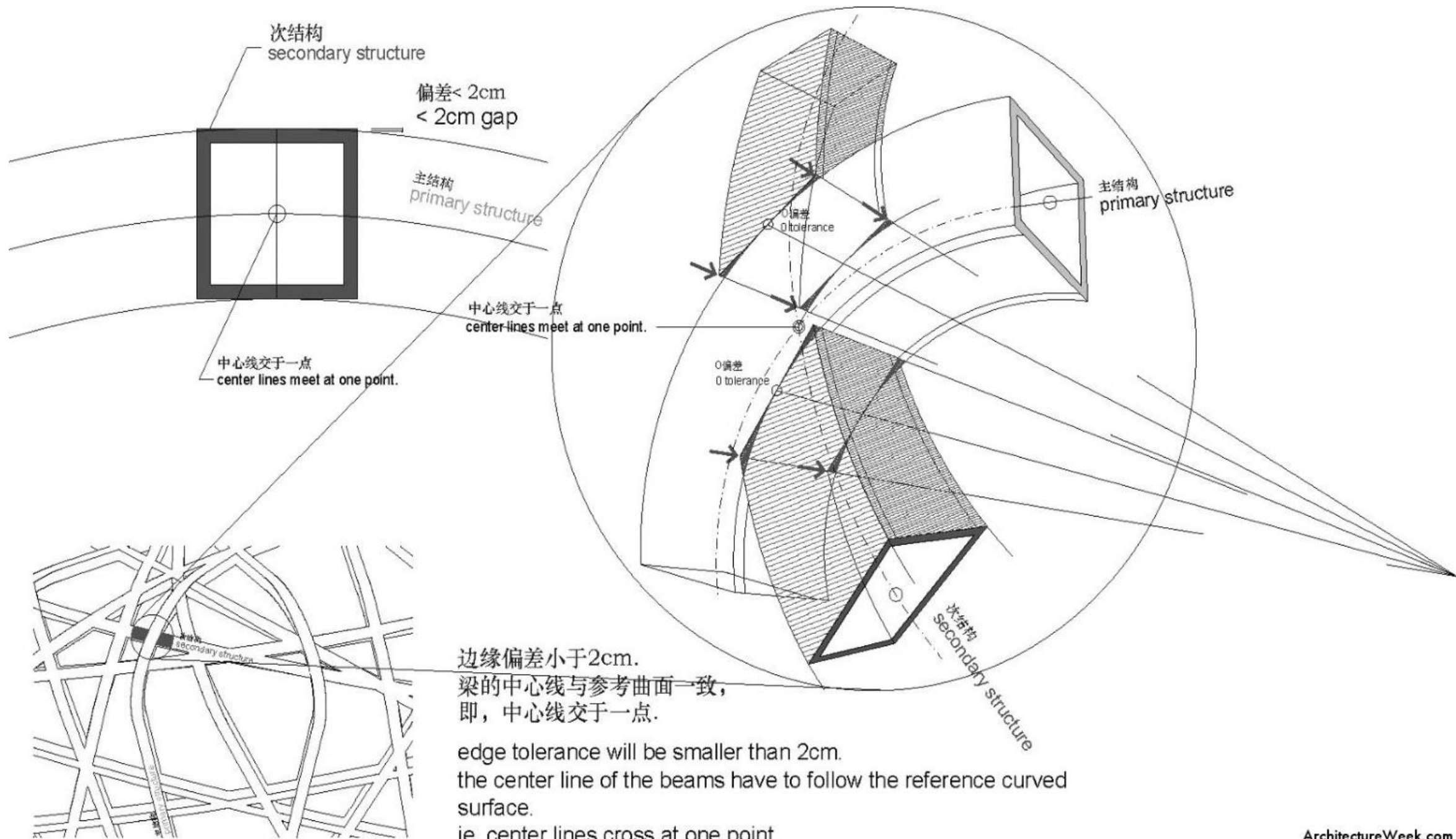
















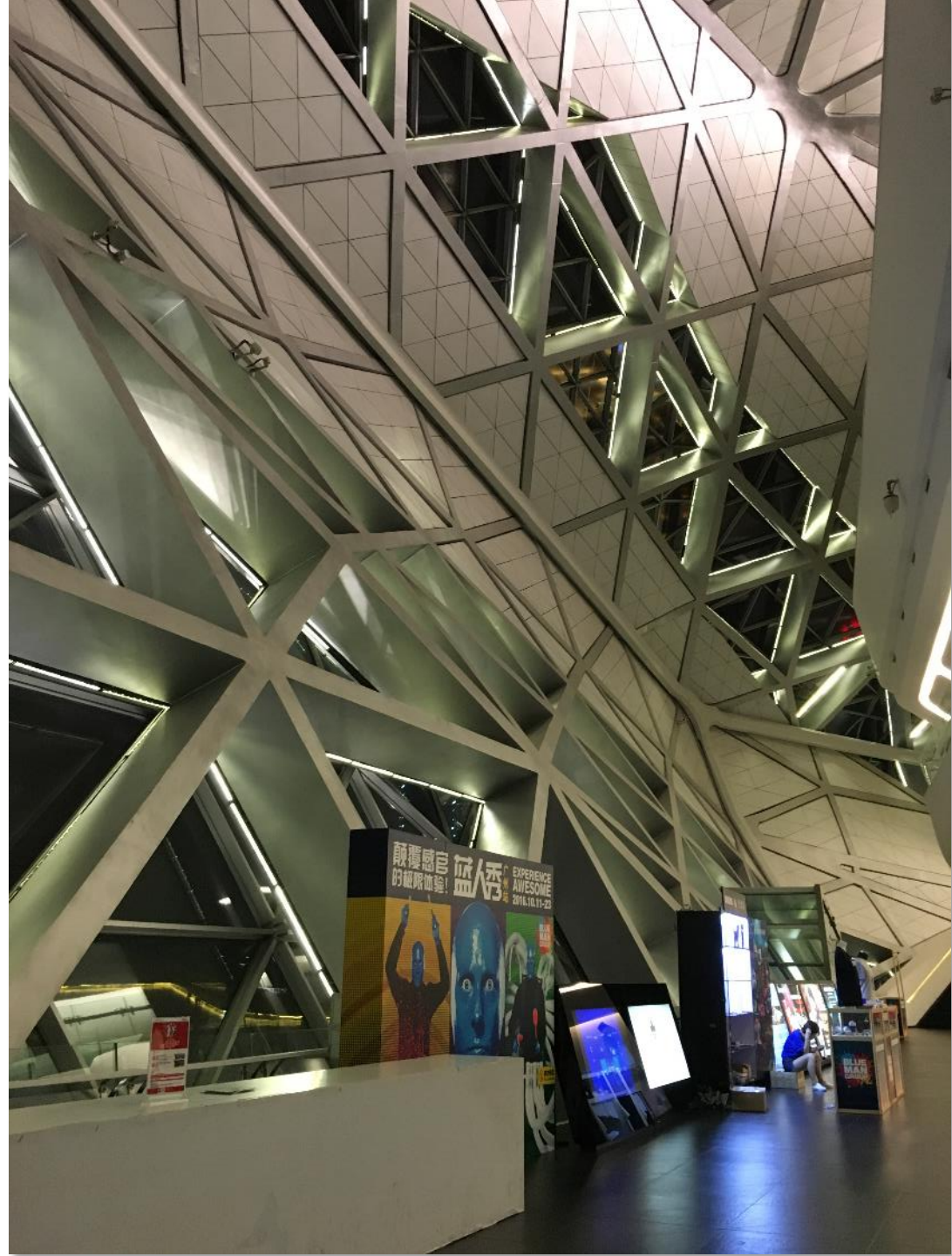
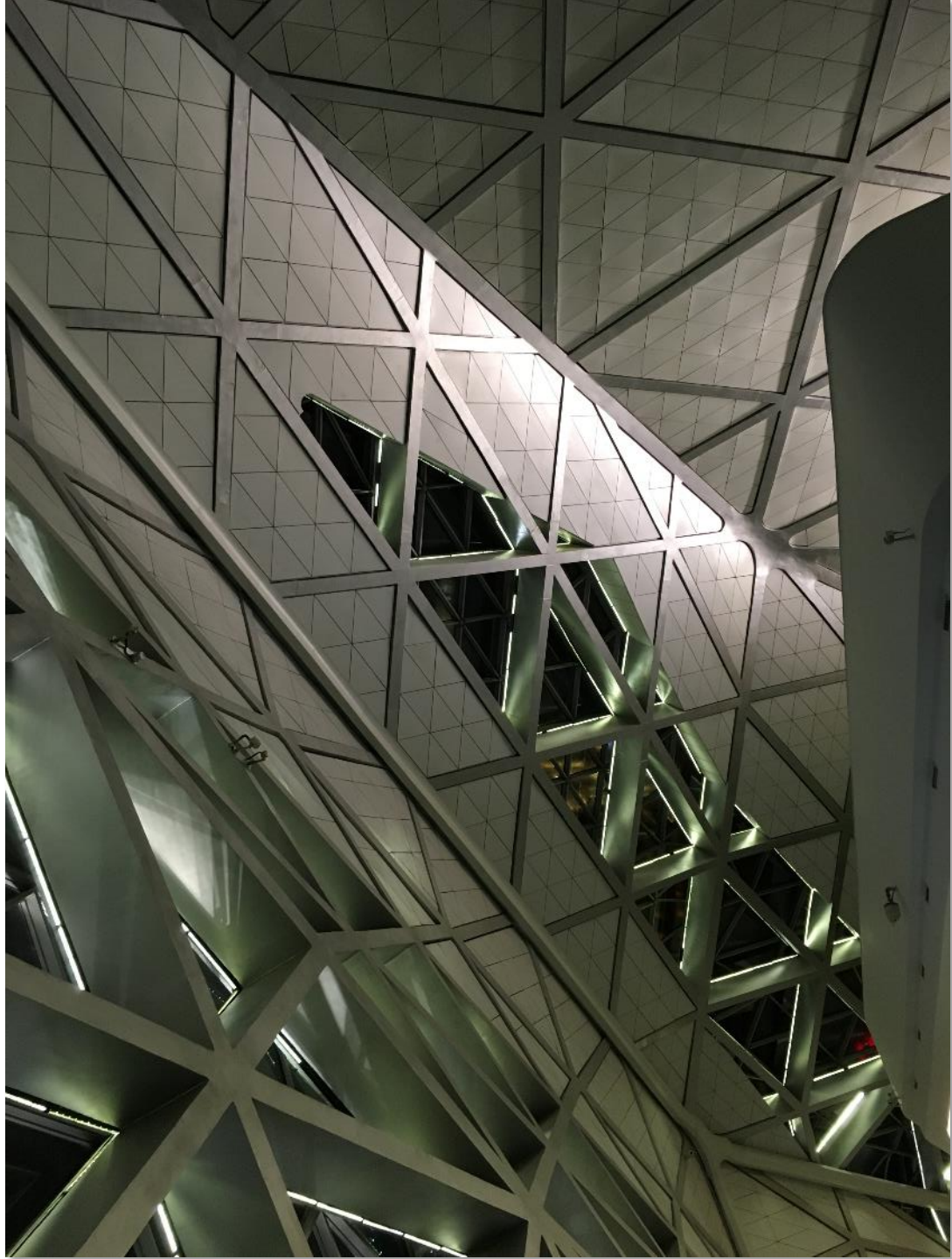
Guangzhou Opera House | Zaha Hadid













World Financial Center Entry Pavilion | New York City, NY

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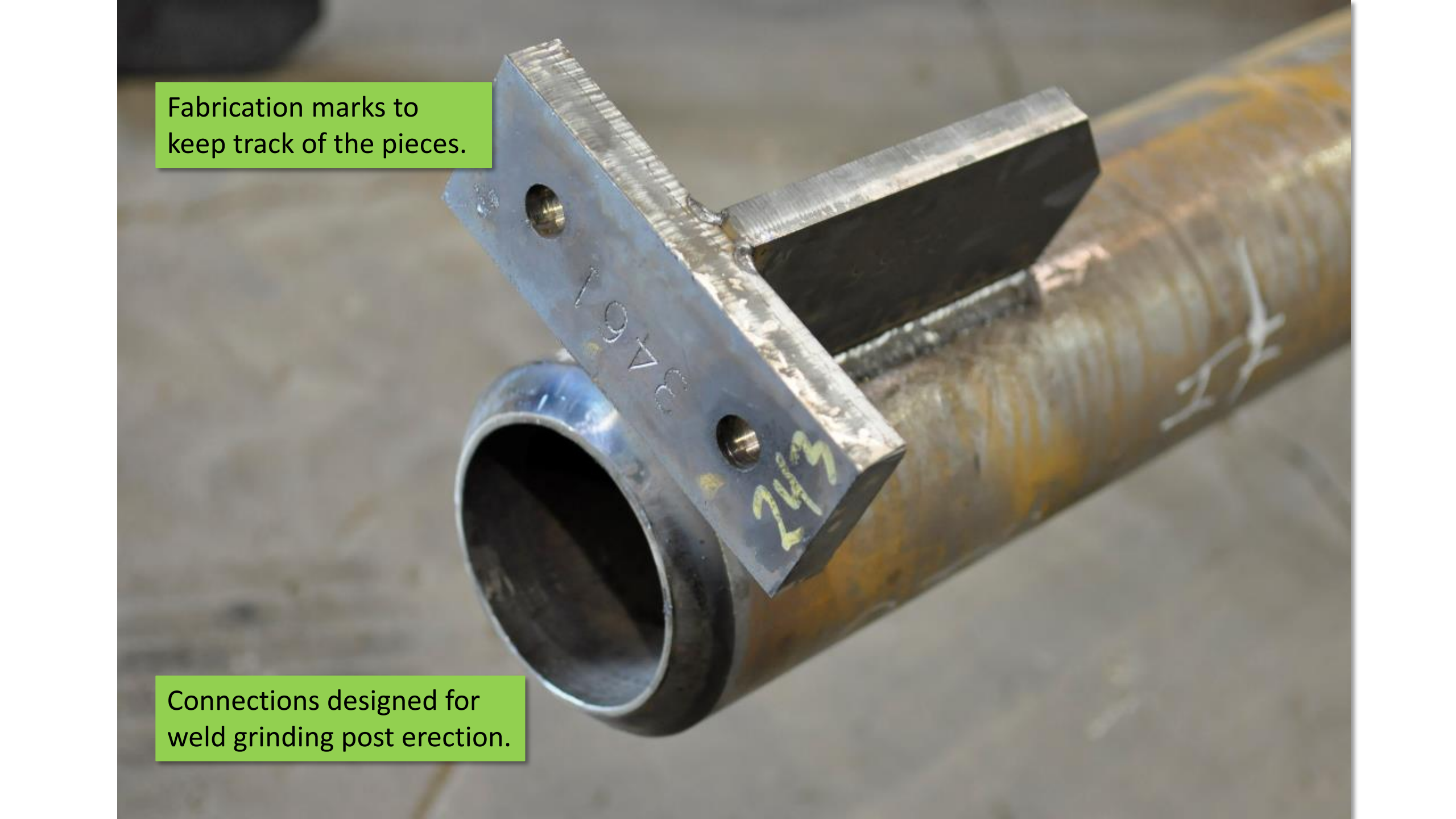


Maximum shop fabrication!

A close-up photograph of industrial metal components. Two vertical tubes are visible, with a horizontal tube connecting them. The tubes are held together by metal brackets or temporary connectors. The scene is set in a workshop, with a yellow safety line visible in the background. The metal surfaces show signs of use and welding.

Access for welding between the tubes was very tight, but doable.

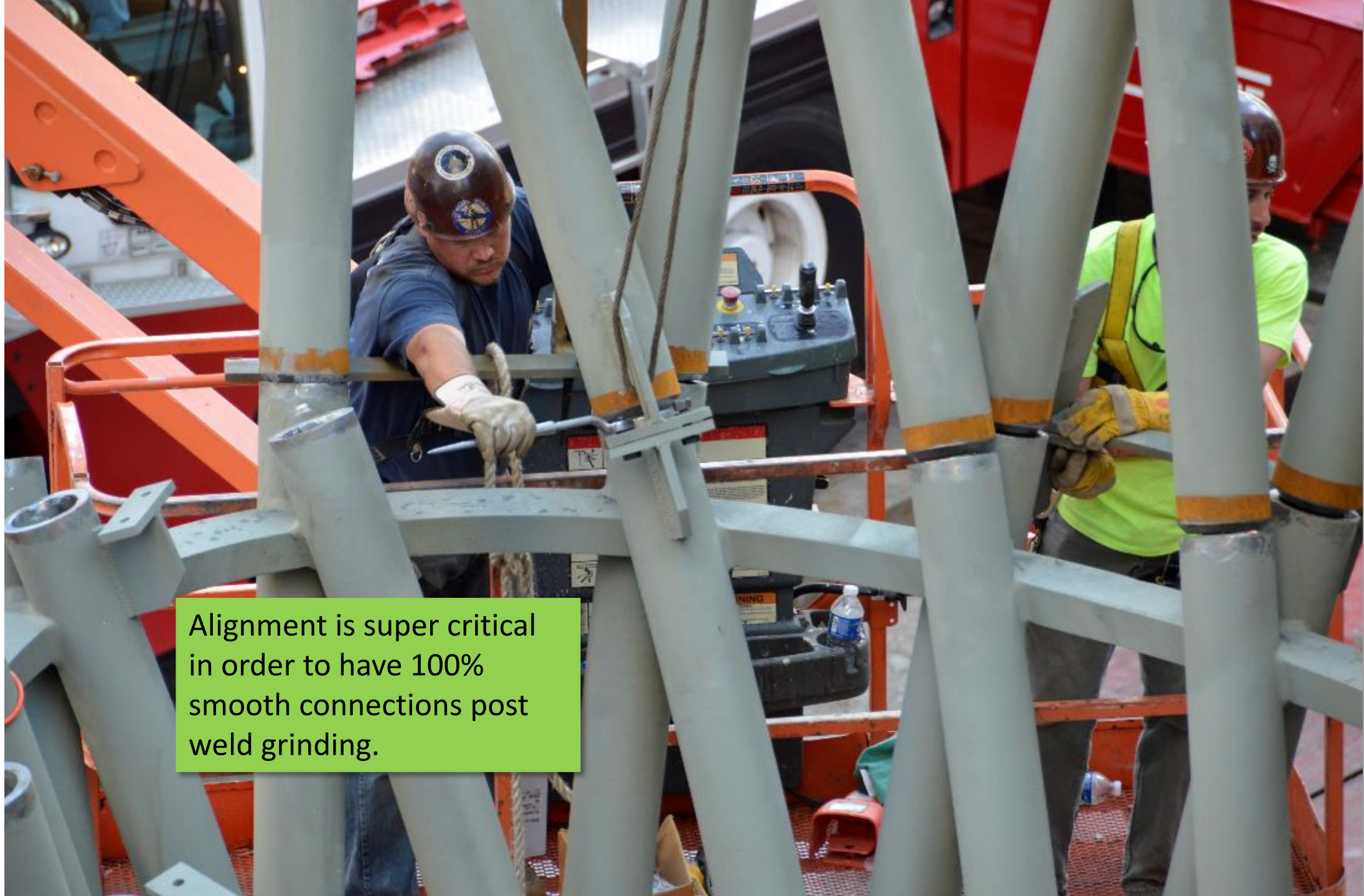
Temporary connectors will need to be removed and remediated.




Fabrication marks to keep track of the pieces.

Connections designed for weld grinding post erection.





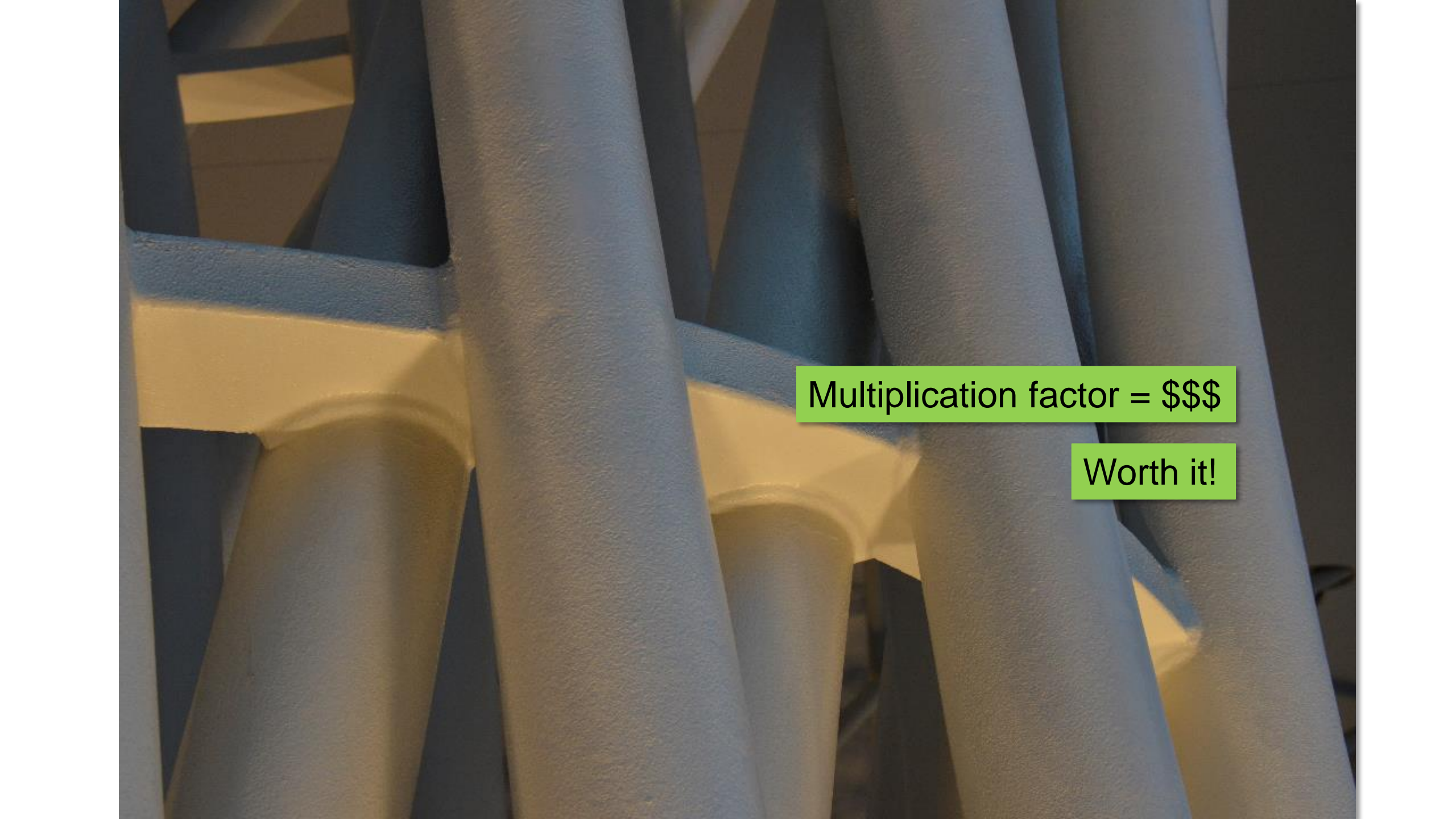
Alignment is super critical in order to have 100% smooth connections post weld grinding.



Budget for full scaffolding to allow ironworkers a safe/stable platform for weld completion.

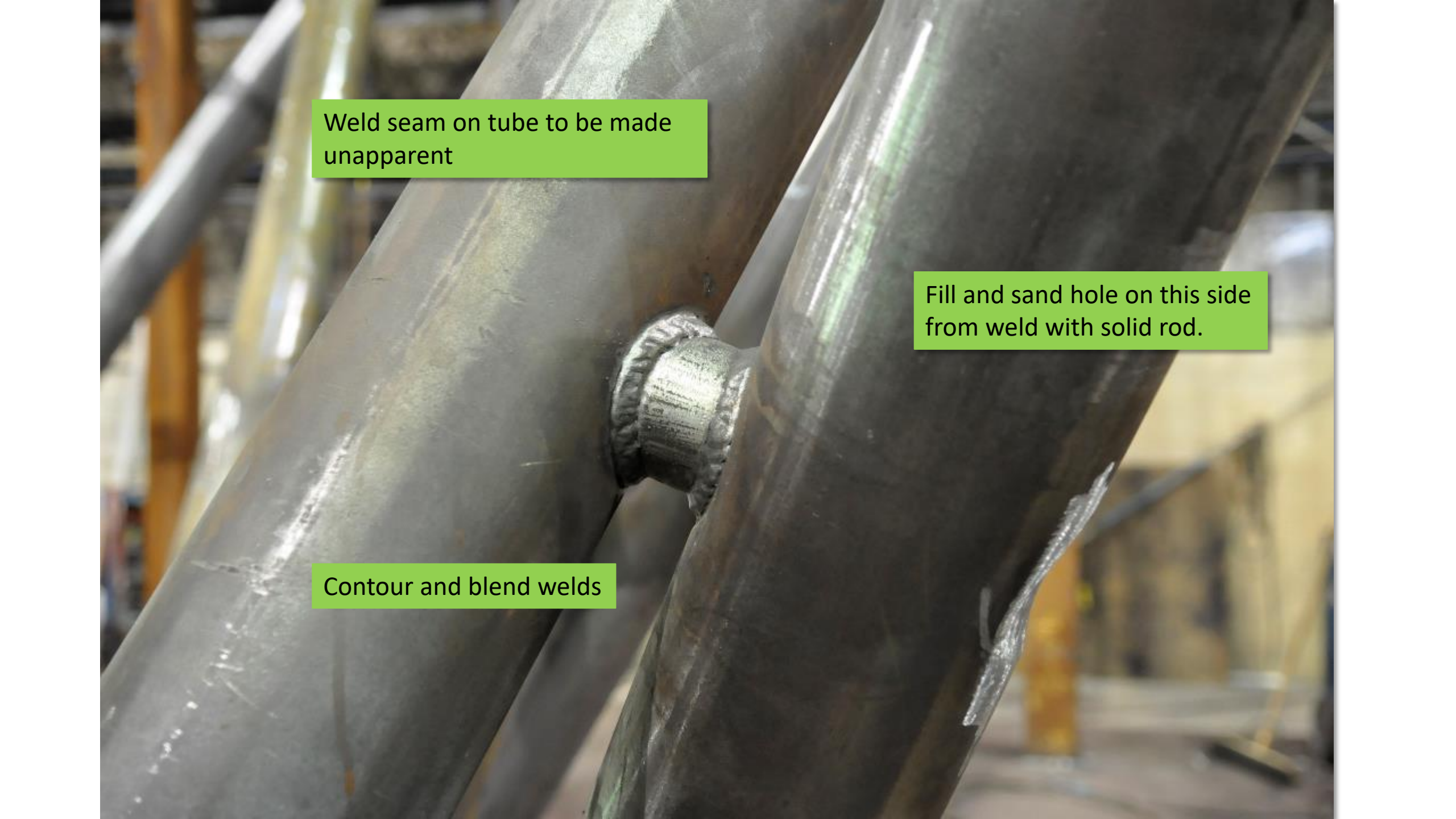


Multiplication factor = \$\$\$



Multiplication factor = \$\$\$

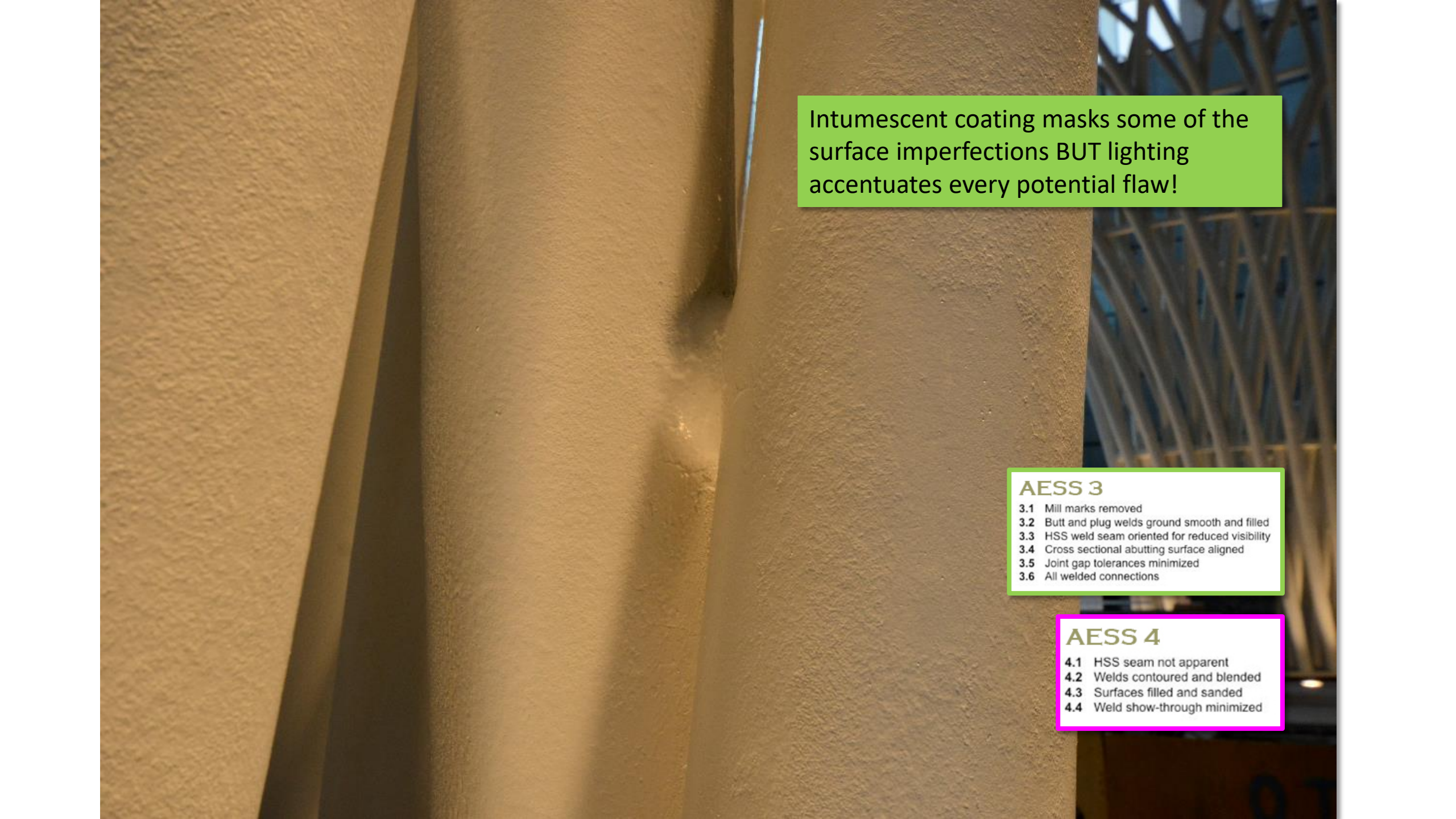
Worth it!

A close-up photograph of a metal tube joint. The tube is dark grey and has a weld seam around its circumference. A hole is visible in the tube, and a small amount of material is protruding from it. The background is a blurred industrial setting.

Weld seam on tube to be made unapparent

Fill and sand hole on this side from weld with solid rod.

Contour and blend welds



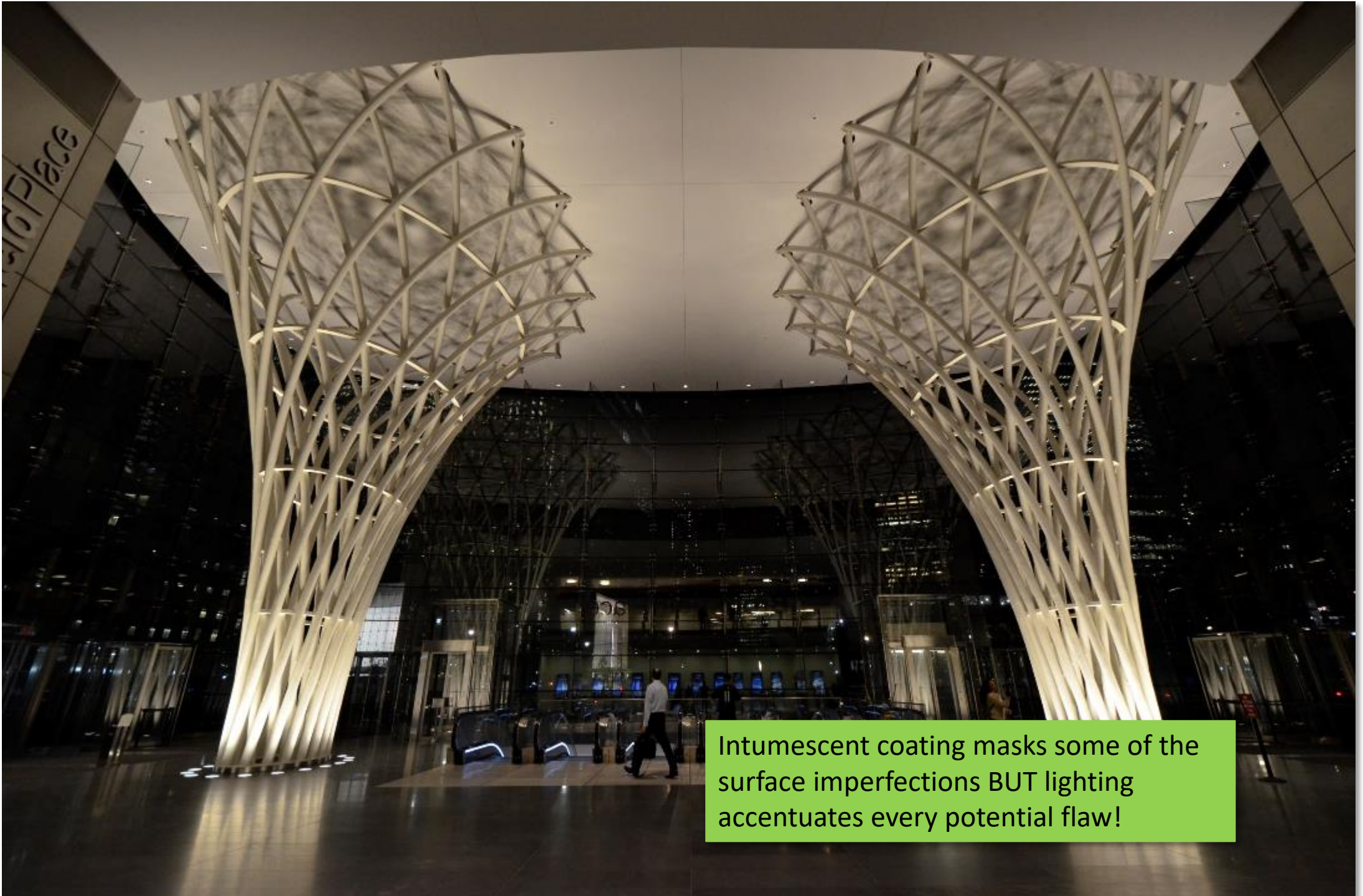
Intumescent coating masks some of the surface imperfections BUT lighting accentuates every potential flaw!

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Santiago Calatrava

PATH Station | New York City

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- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized

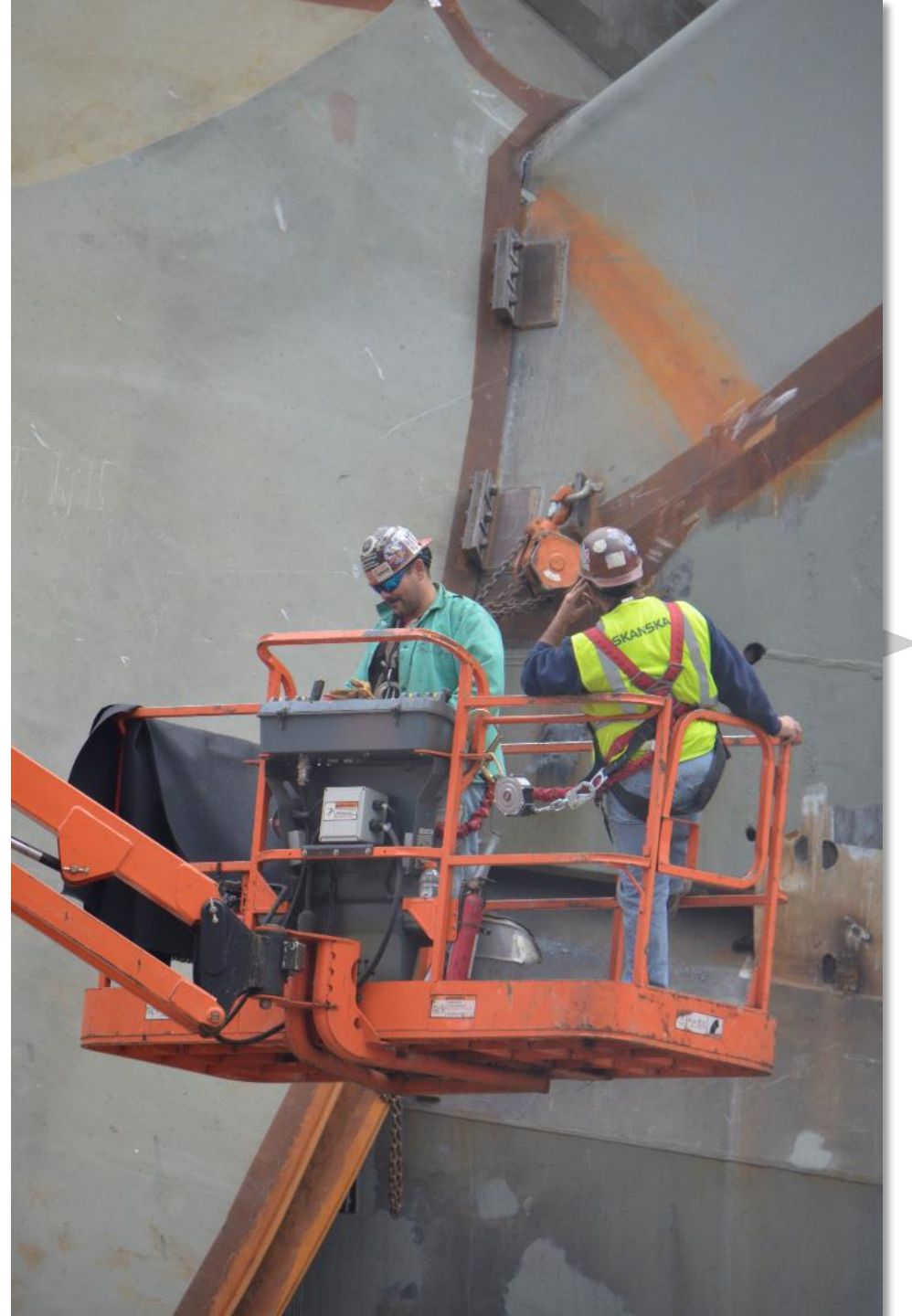
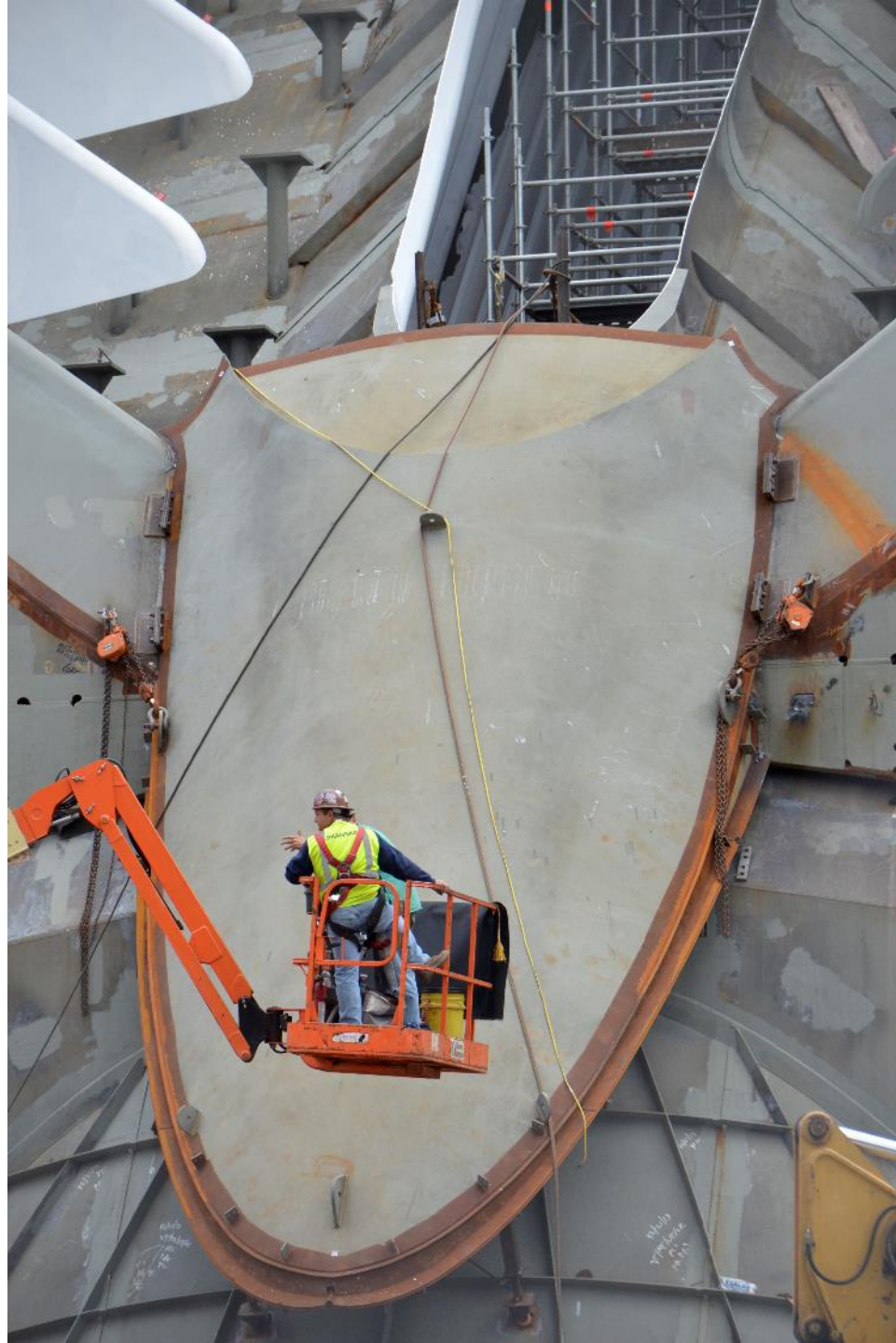














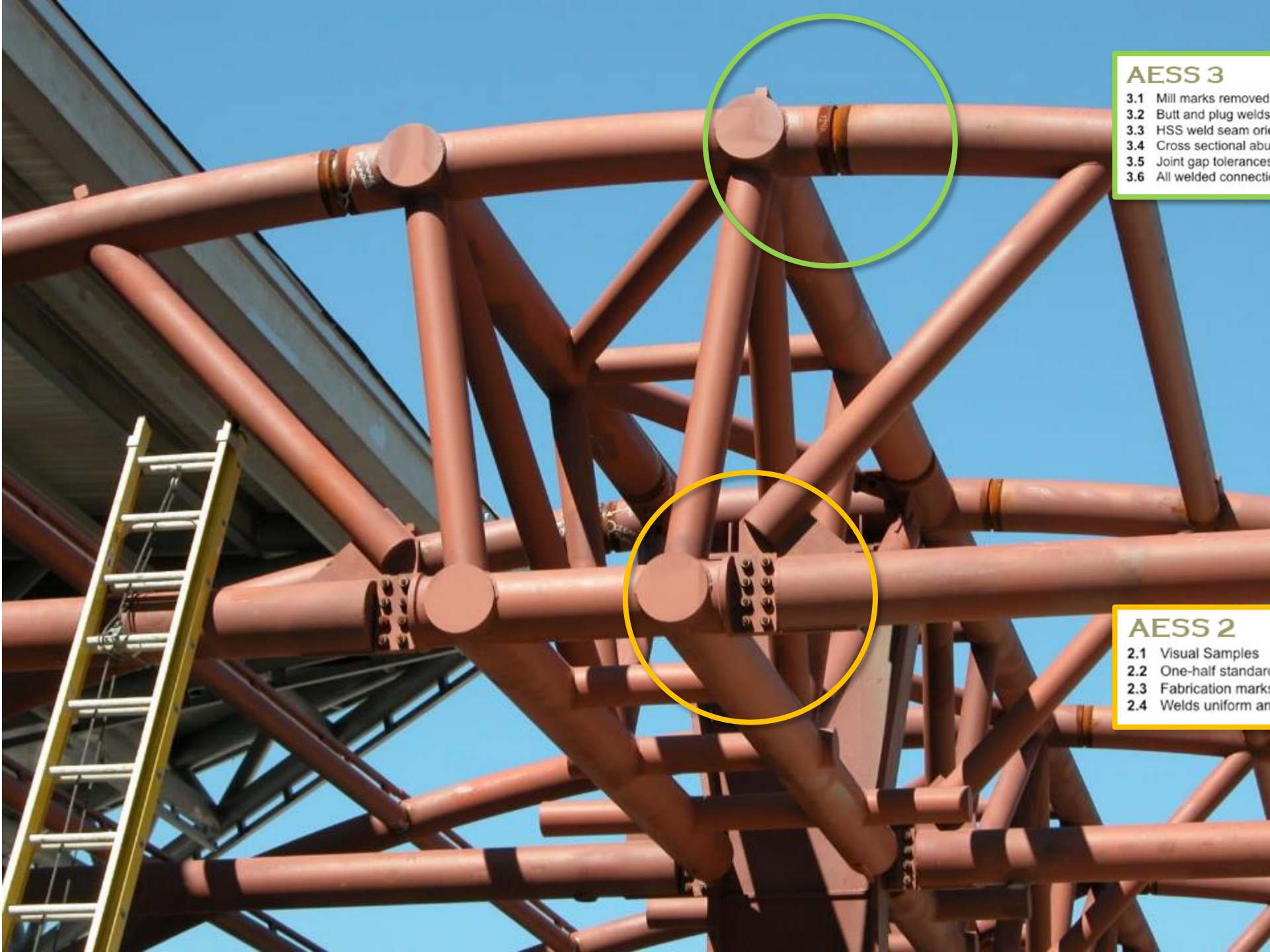
WORLD TRADE CENTER



Discreet Connections

- Use exposed bolts
- Create a visually trim line with the placement of the bolts
- Keeps the aesthetic intention of the structure
- Much quicker and less expensive to do than a fully welded connection
- Can add visual interest to the structure
- Done to connect larger shippable elements



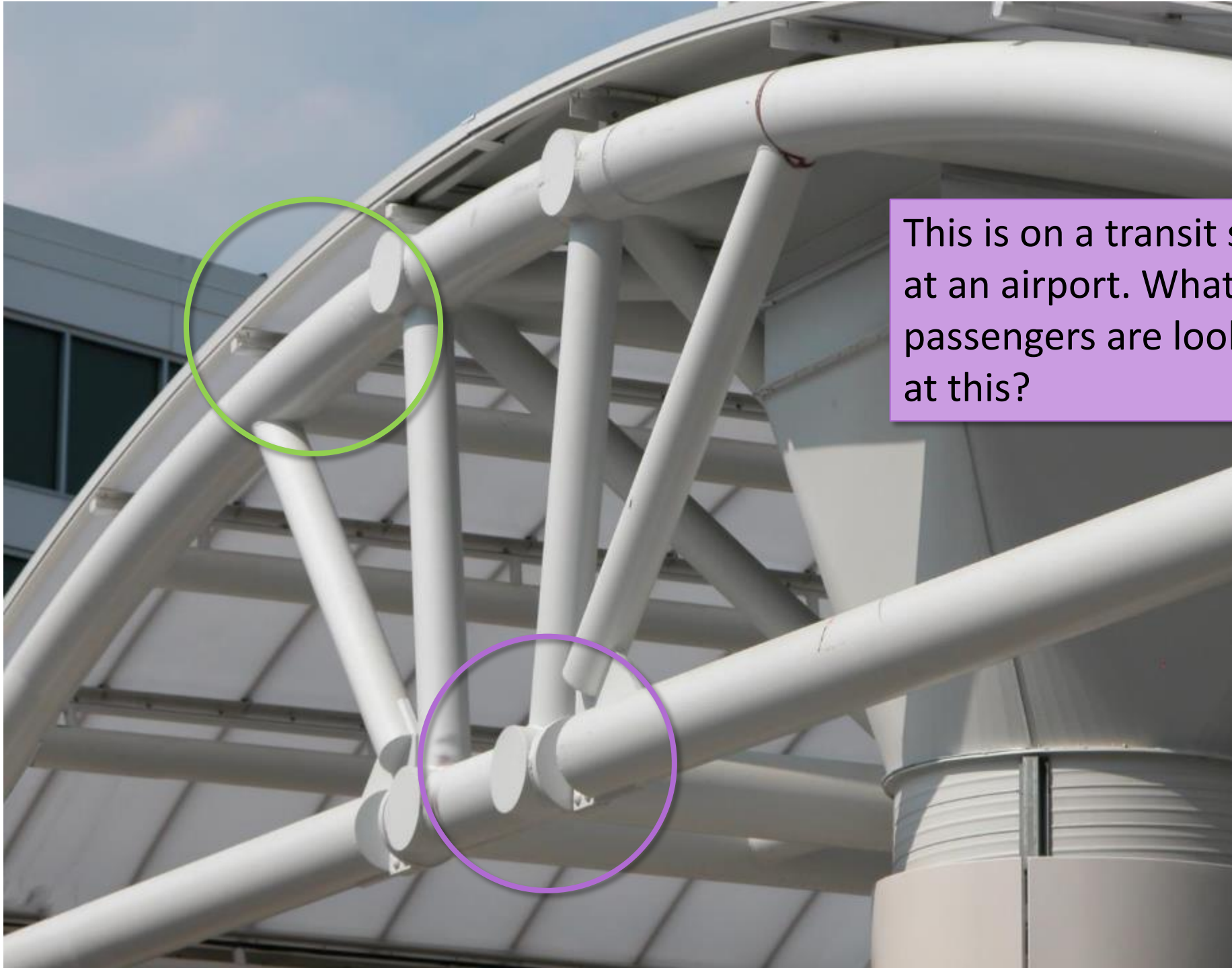


AESS 3

- 3.1 Mill marks removed
- 3.2 Butt and plug welds ground smooth and filled
- 3.3 HSS weld seam oriented for reduced visibility
- 3.4 Cross sectional abutting surface aligned
- 3.5 Joint gap tolerances minimized
- 3.6 All welded connections

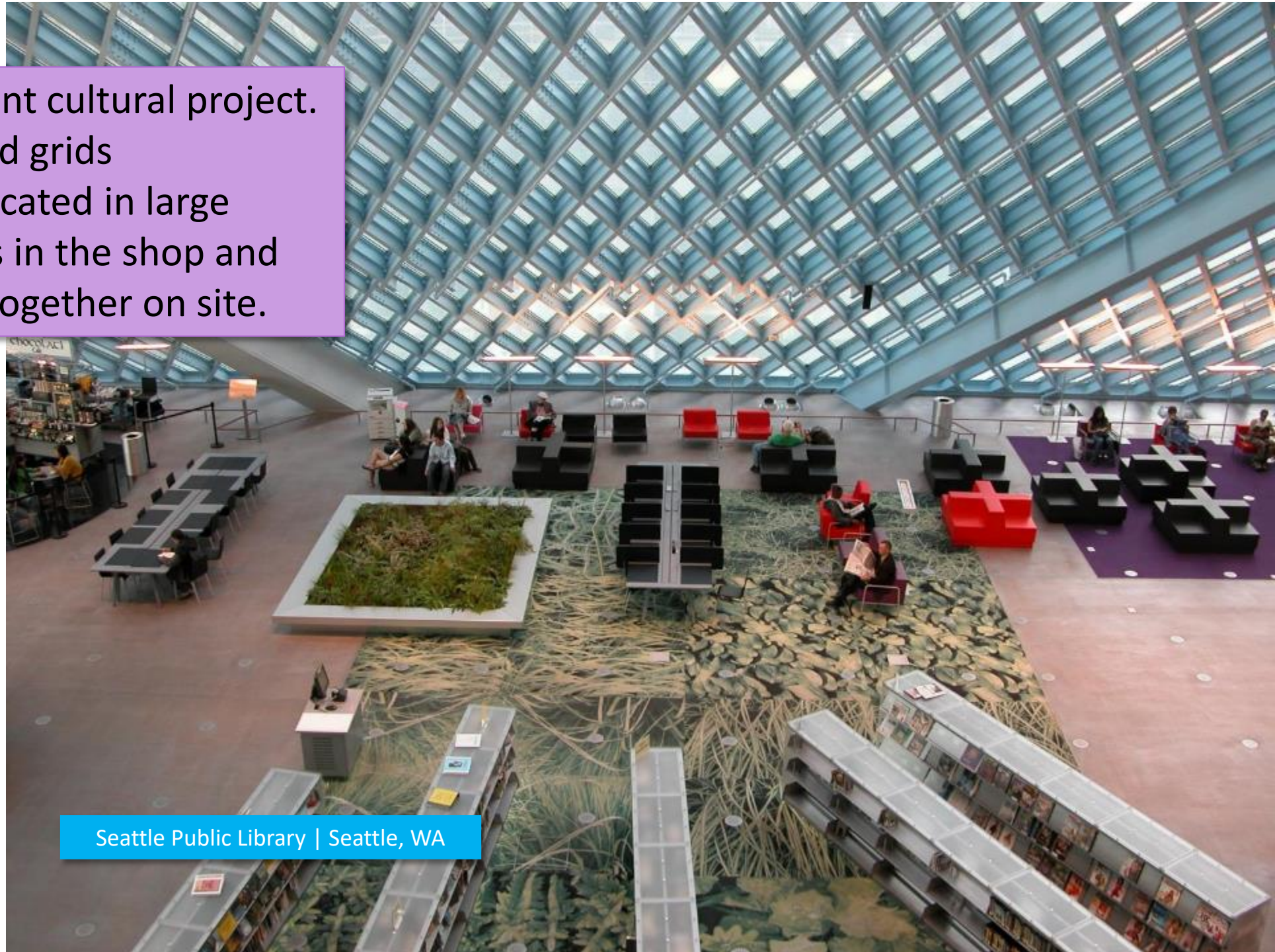
AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth



This is on a transit shelter at an airport. What passengers are looking up at this?

Important cultural project.
Diamond grids
prefabricated in large
sections in the shop and
bolted together on site.

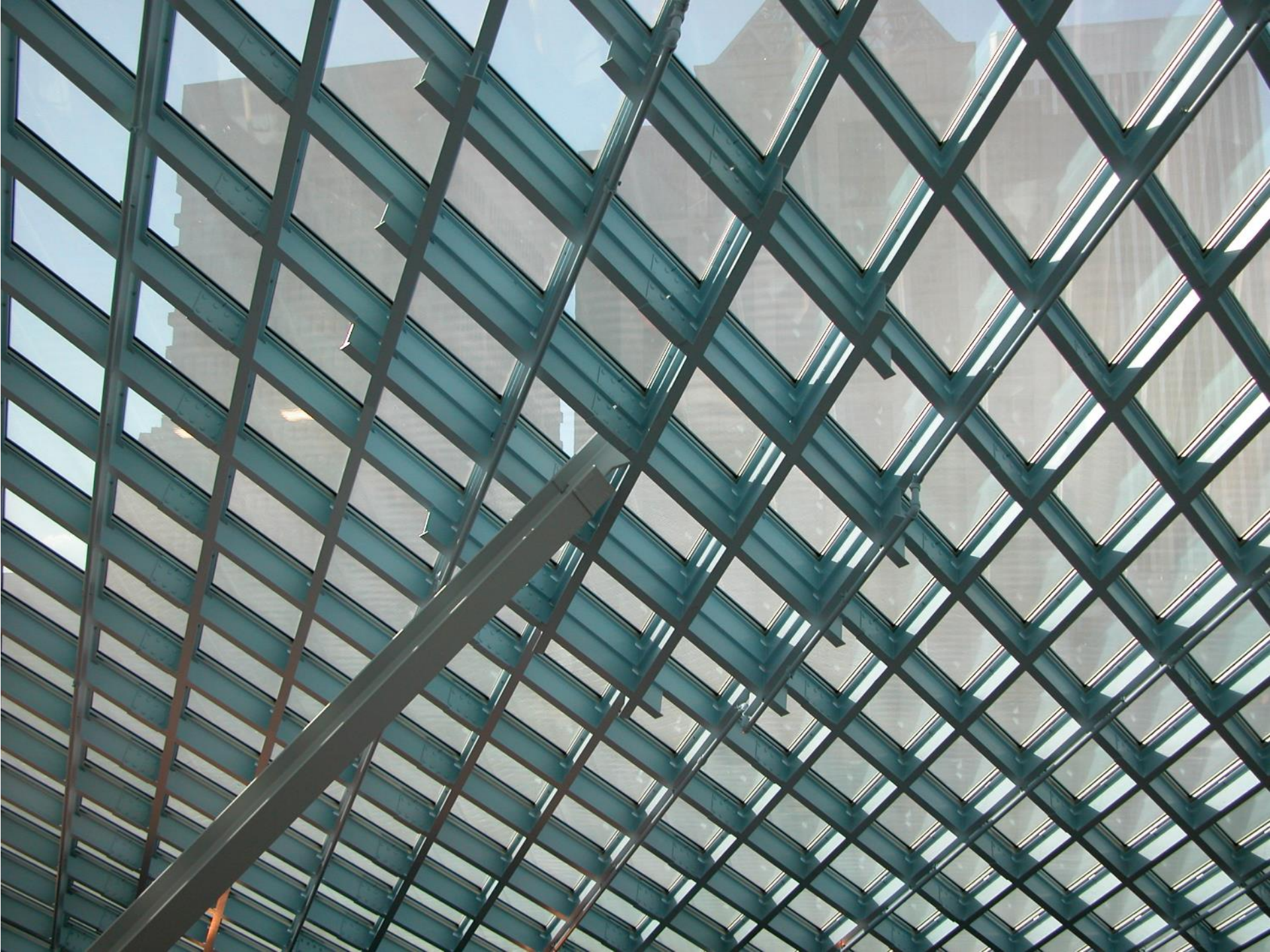


Seattle Public Library | Seattle, WA



AESS 3

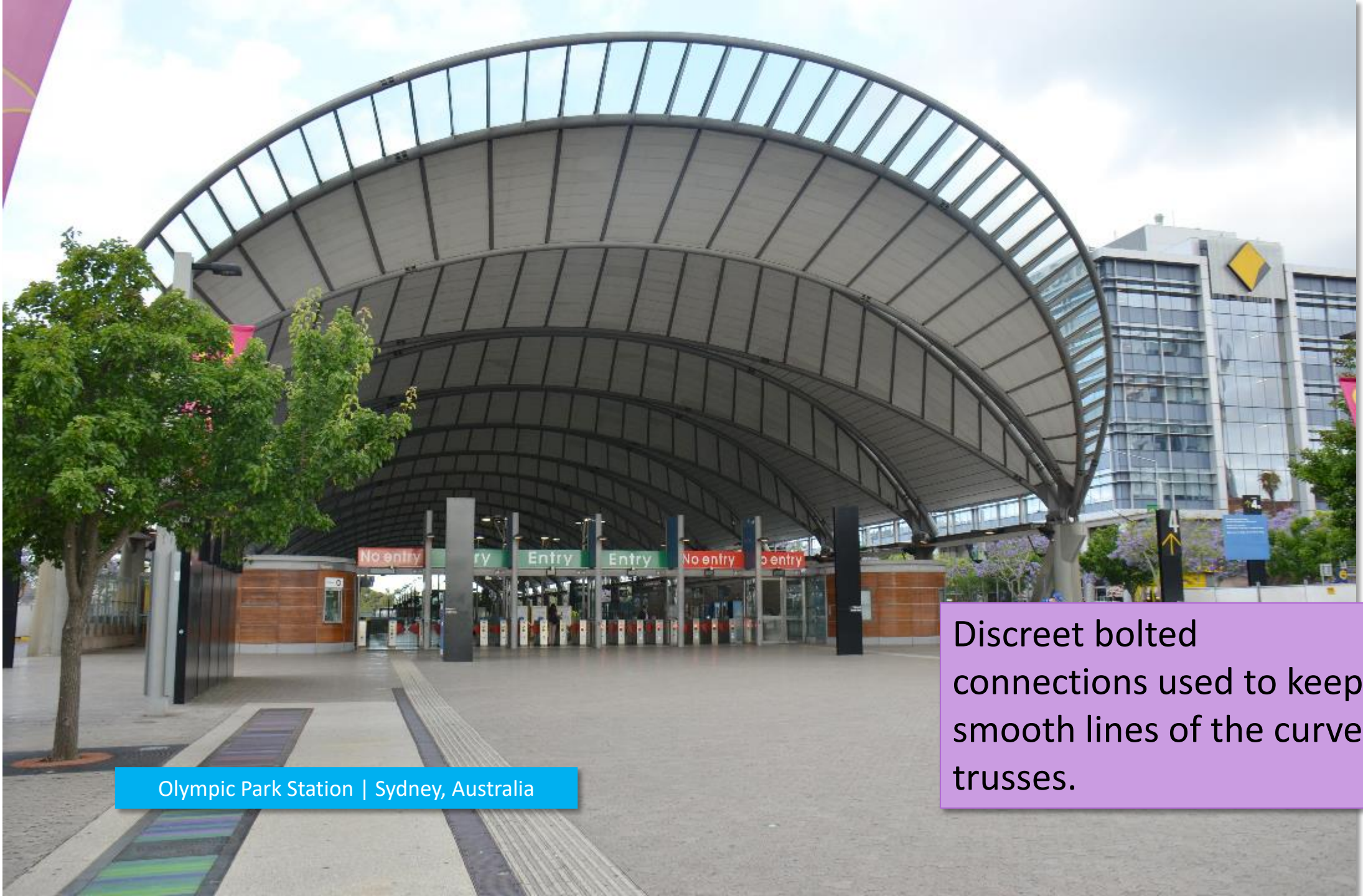
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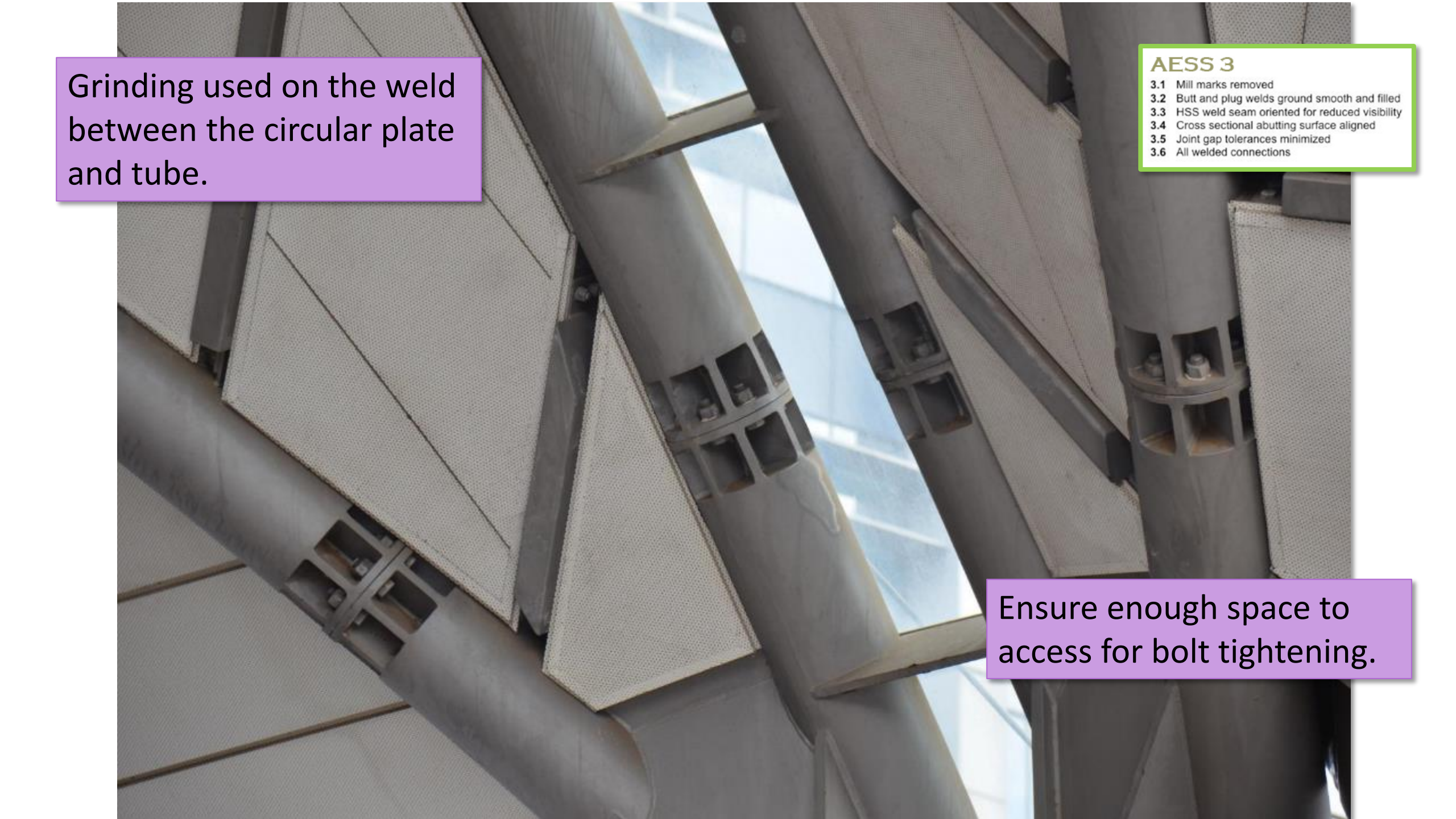






Olympic Park Station | Sydney, Australia

Discreet bolted connections used to keep smooth lines of the curved trusses.



Grinding used on the weld between the circular plate and tube.

AESS 3

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Ensure enough space to access for bolt tightening.

Office Building at Potsdamer Platz | Berlin, Germany



AESS 3

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Renzo Piano

Art Institute of Chicago









Masdar City | Abu Dhabi, UAE





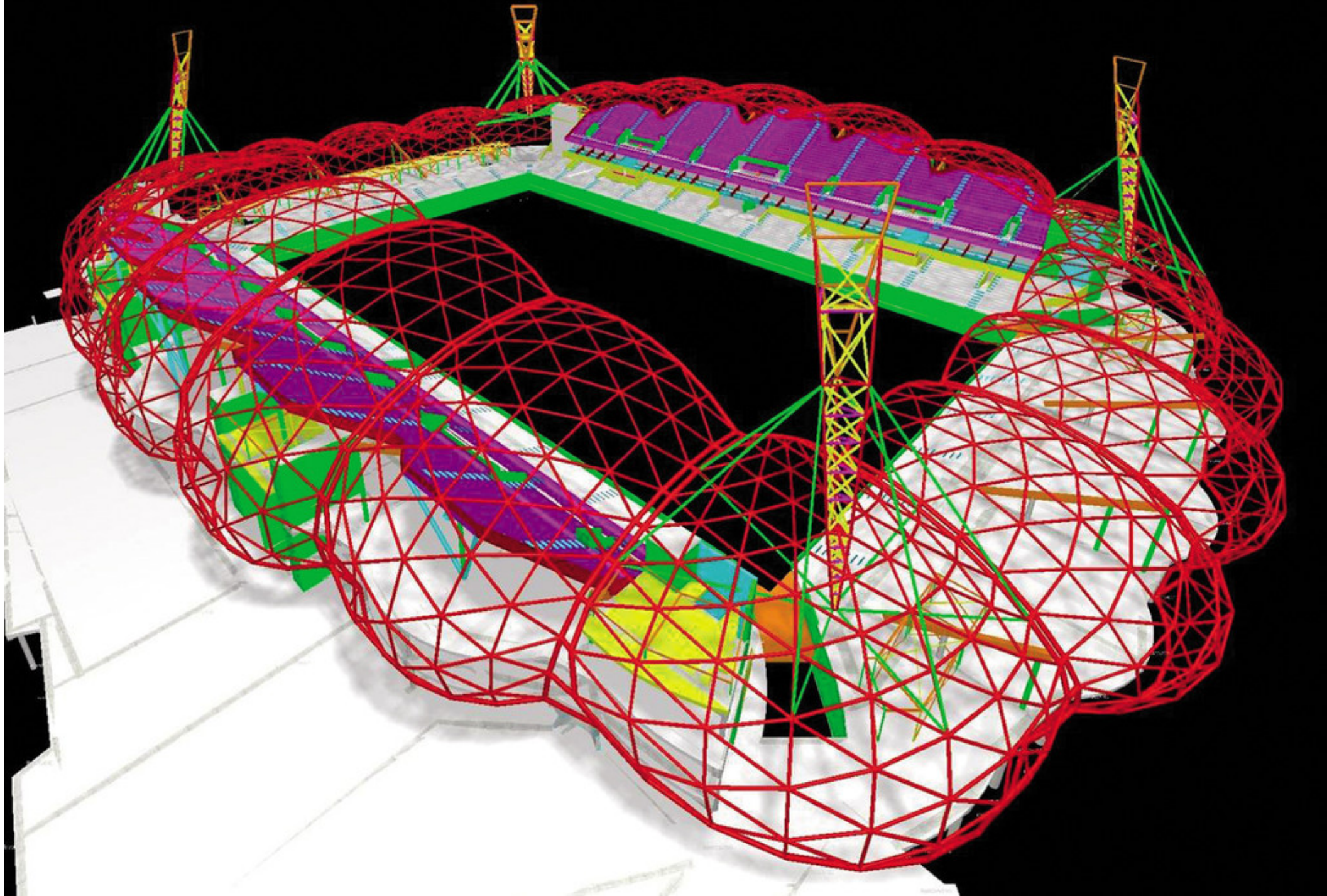
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Melbourne Stadium



Image: Arup



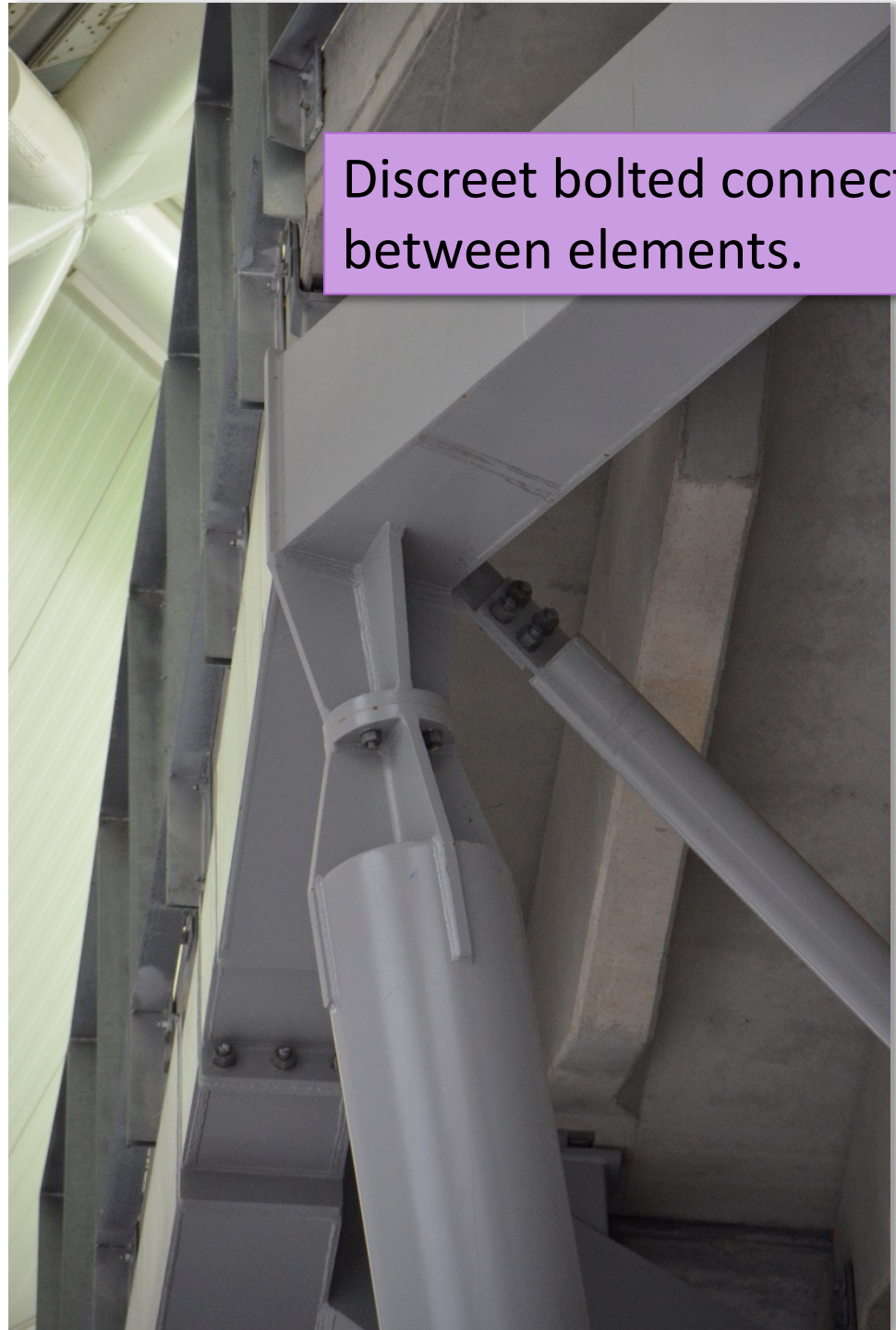
Discreet bolted connections between elements.



Discreet bolted connections between elements simplified on the interior/underside.



viewing distance



Discreet bolted connections between elements.



Southern Railway Station | Melbourne





viewing distance





viewing distance



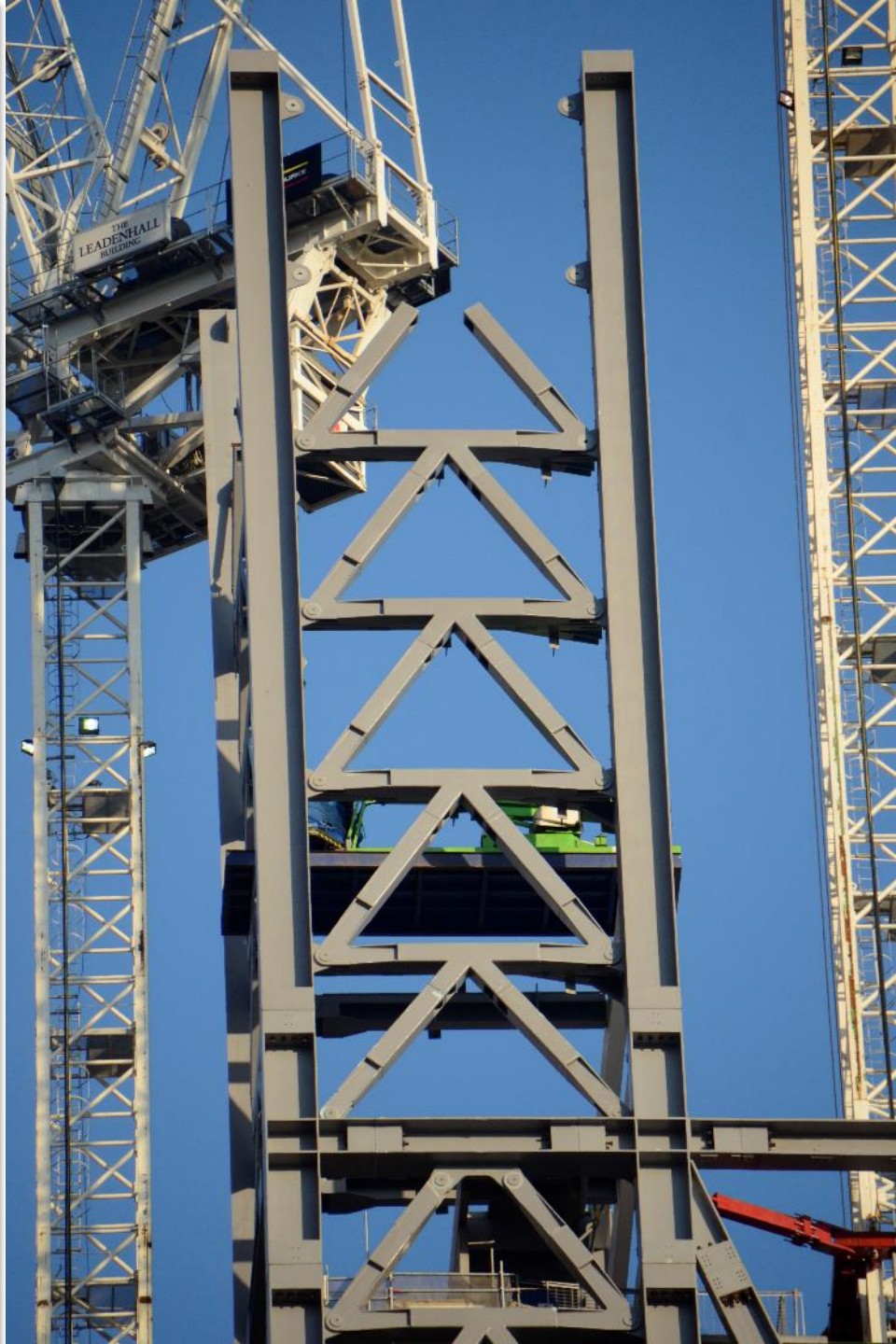


Discreet bolted connections
between elements.
Unremediated welds.





Leadenhall Building | London



AESS 3

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Detail MUST allow adequate space to perform bolting operations!







Theatre | Melbourne, Australia



Detail/orient to prevent water from collecting in the holes!

AESS 4

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized



100 Eleventh Avenue | New York, NY



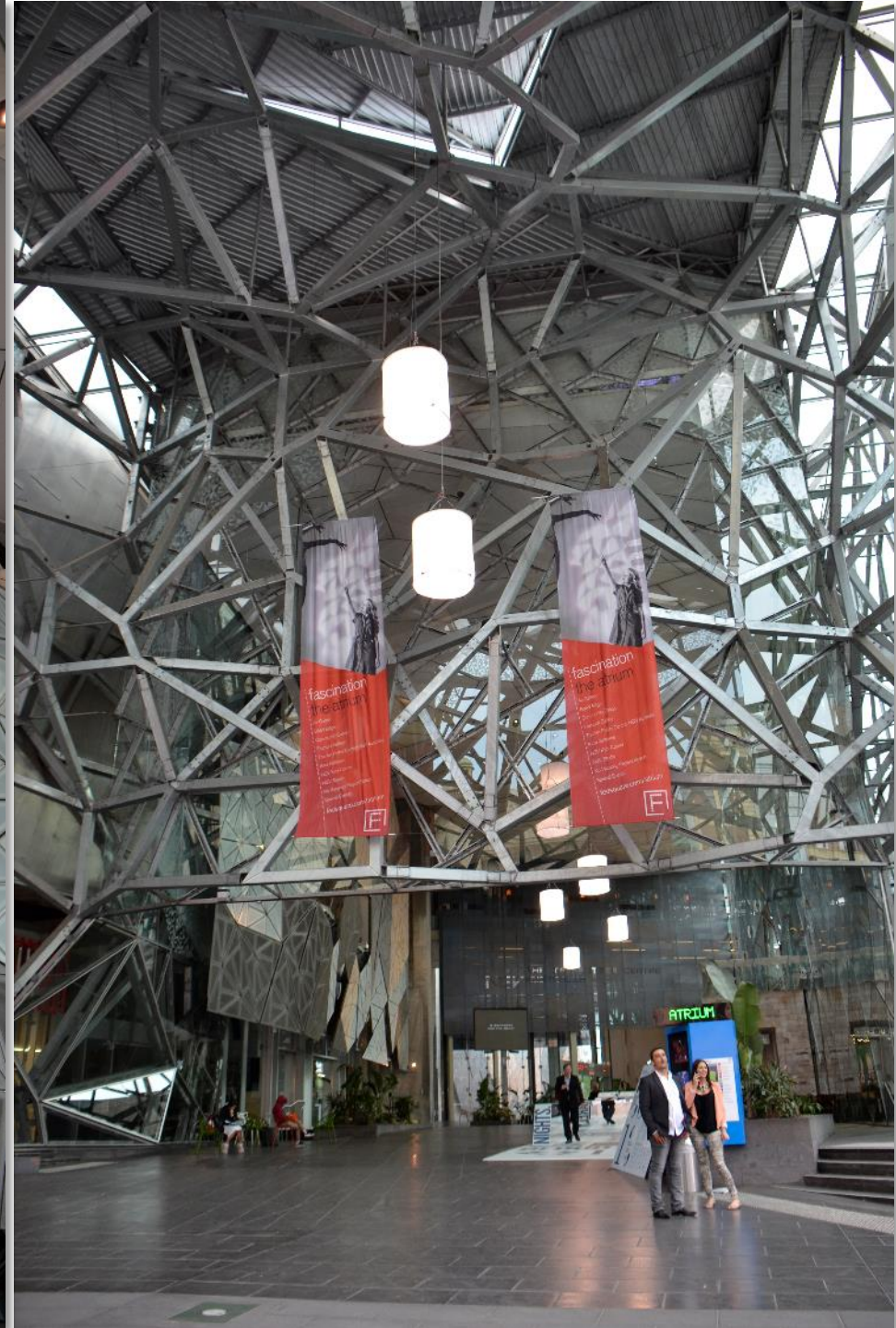
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Bates Smart Architects

Federation Square | Melbourne, Australia



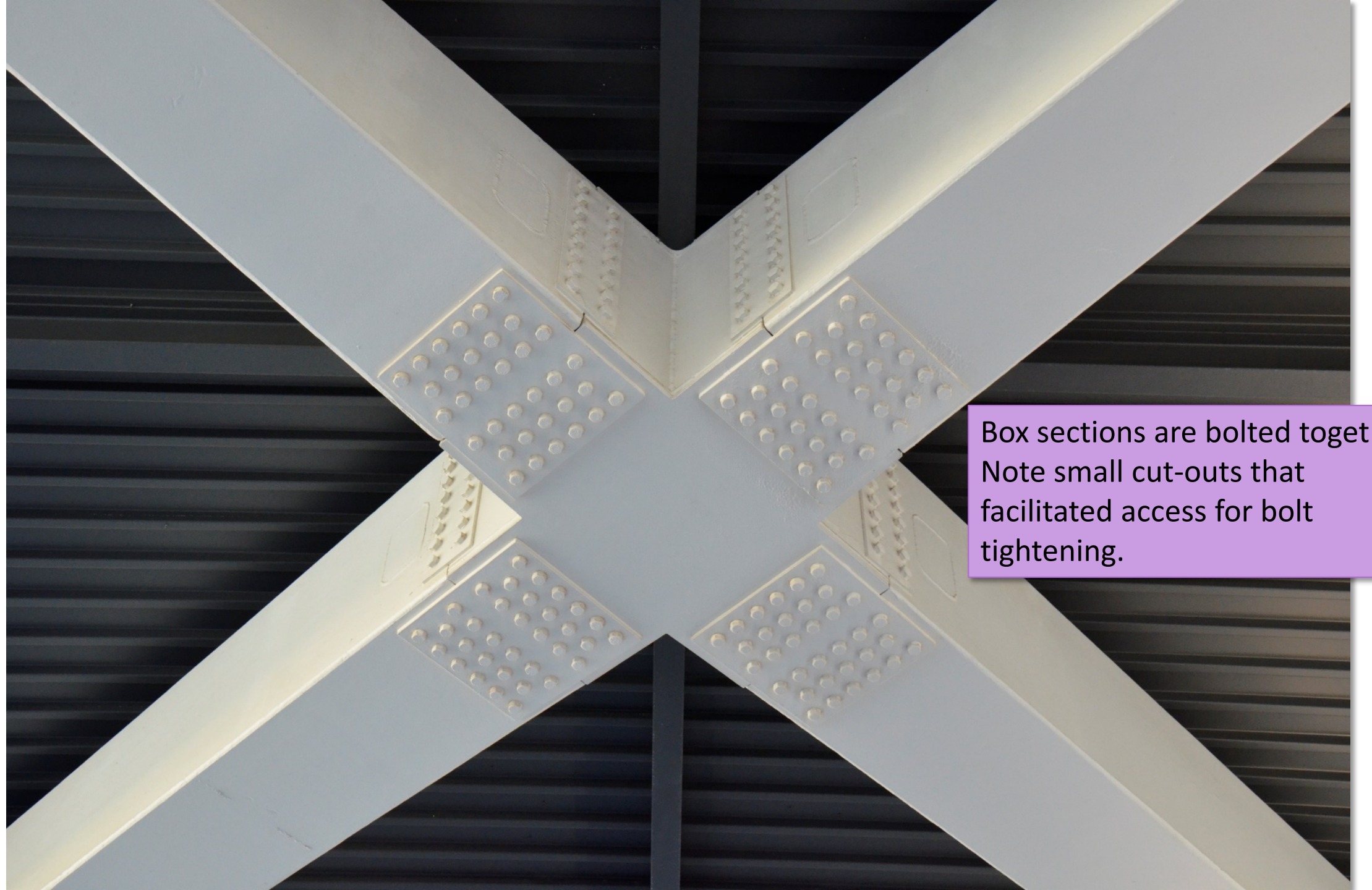




viewing distance



Train Station - Valencia, Spain



Box sections are bolted together. Note small cut-outs that facilitated access for bolt tightening.

Hidden Connections



Where site welding might be problematic, make parties aware that bolted connections may be effectively “hidden”







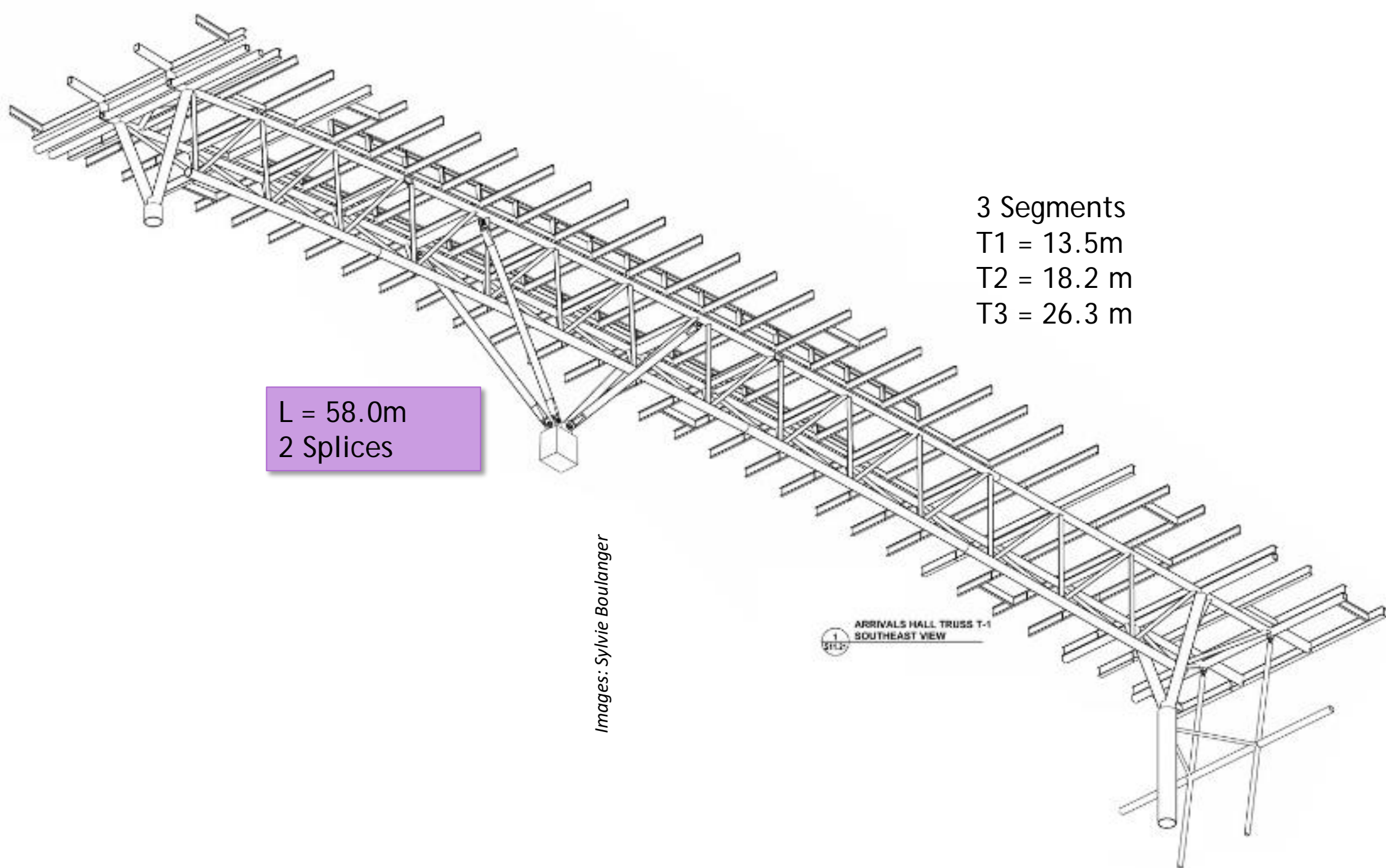




If grinding of the cover plate is avoided, this can also be used in AESS2 situations!

Images: Sylvie Boulanger





L = 58.0m
2 Splices

3 Segments
T1 = 13.5m
T2 = 18.2 m
T3 = 26.3 m

Images: Sylvie Boulanger

ARRIVALS HALL TRUSS T-1
1
SOUTH EAST VIEW



AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
- 2.3 Fabrication marks not apparent
- 2.4 Welds uniform and smooth




This detail is located well overhead.
Tack welds suffice for fixing the cover plate into position.
Filler compounds with light sanding can complete the detail prior to painting.





Sydney Olympic Stadium

Tickets

A close-up photograph of several white PVC pipes joined at a central point. The pipes are arranged in a star-like pattern. The joints are sealed with a translucent, slightly yellowish sealant. There is some dark staining or residue around the joints, particularly on the right side. The background is a grey, vertically-ribbed surface.

Given the exterior application it is critical to seal the joints against moisture penetration



The Shed – New York City




Images: Scott Lomax





Small discreet panels allow access for bolting.



Reveals are detailed at the splice points to remove the need for remediated welded connections.

Image: Scott Lomax





The Vessel – New York City



The hidden connections on The Vessel allowed for faster erection and zero shoring requirements.



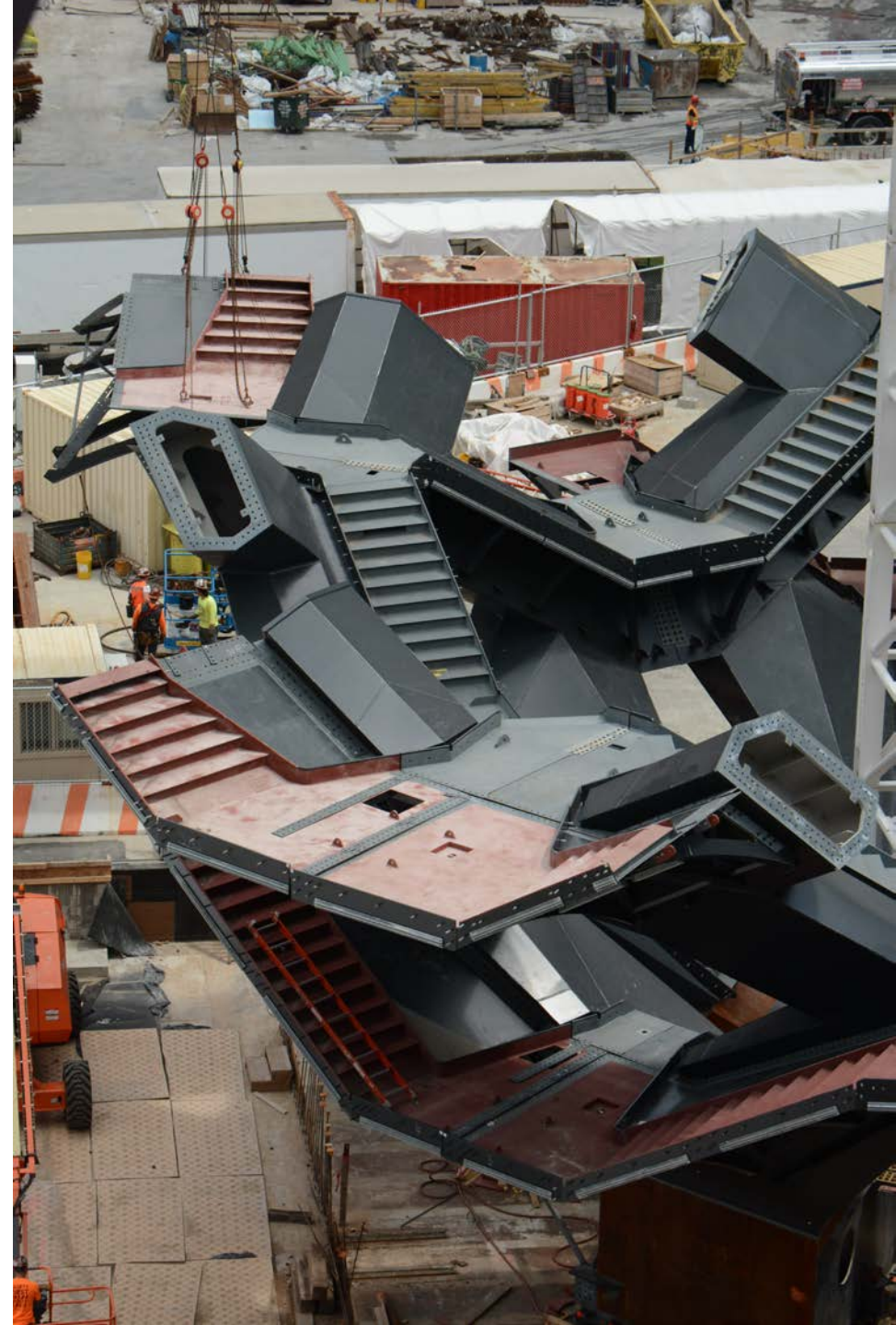


Image: Heatherwick Studios



End Connectors – Pin Connections

- Becoming a standardized detail
- Used where rotation is desired during the erection process
- Transfers only vertical and horizontal forces
- Not moment resisting





Pompidou Center | Paris, France





Bullring Shopping Center | Barcelona, Spain



Heathrow Airport | London



viewing distance

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AESS 3

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Multiplication factor = \$\$\$

Barajas Airport | Madrid, Spain

AESS 2

- 2.1 Visual Samples
- 2.2 One-half standard fabrication tolerances
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- 2.4 Welds uniform and smooth



2 plates on left
3 plates on right
Added thicknesses equal!

AESS 2

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Add an extra disk of steel to provide adequate thickness for shear but not increase the overall thickness of the incoming tension members.

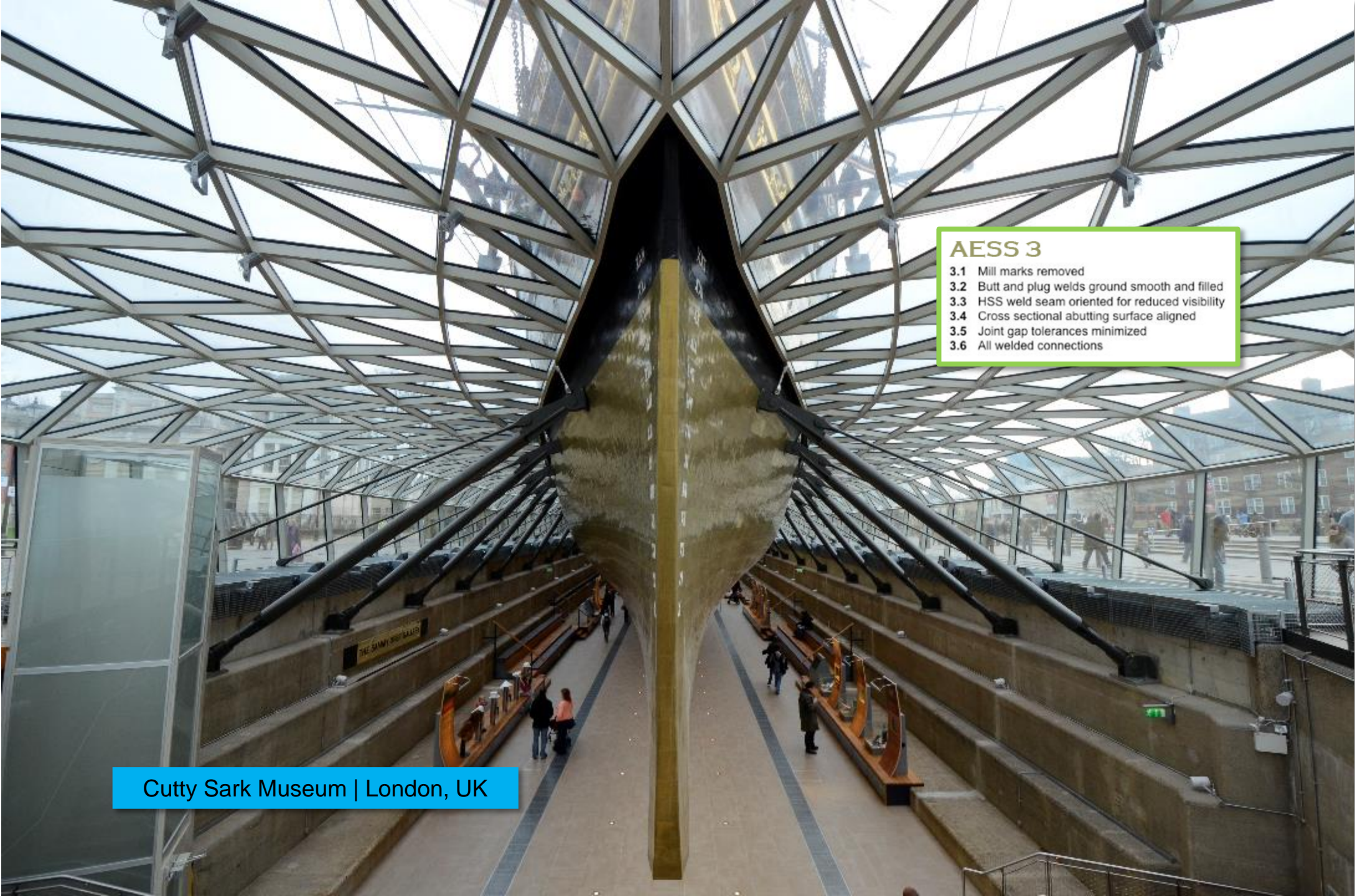


Ottawa International Airport | Ottawa, Canada



AESS 3

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Cutty Sark Museum | London, UK



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Neo Bankside Housing | London



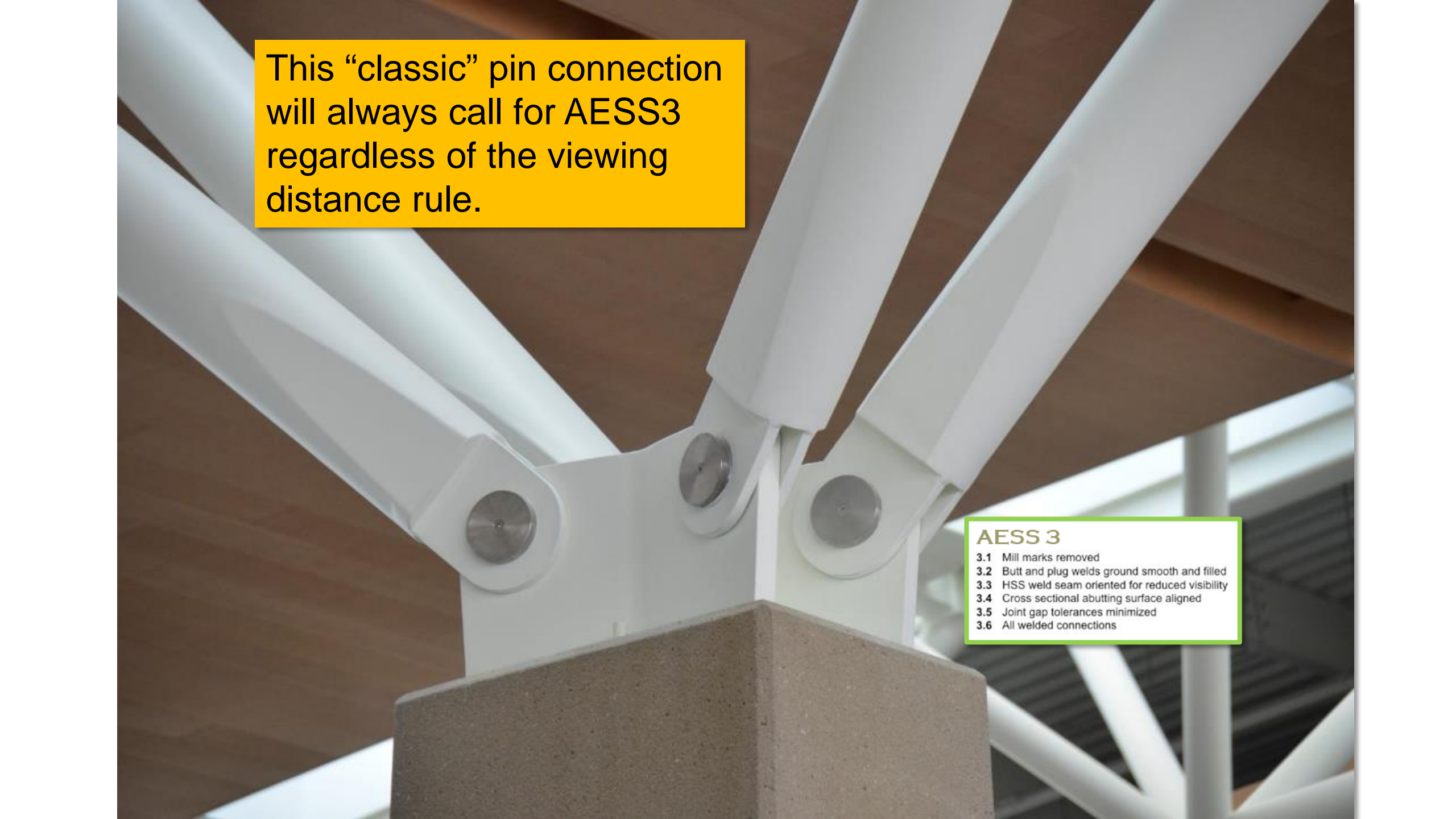
- AESS 4**
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viewing distance

AESS 2

- 2.1 Visual Samples
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Calgary International Airport | Calgary, Canada



This “classic” pin connection will always call for AESS3 regardless of the viewing distance rule.

AESS 3

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Southern Rail Station, Melbourne | Grimshaw



Notice that the sum of the widths of the sets of plates is roughly equal.



Tensile Connections



- Dealing with an entirely different language due to the slenderness of the members
- Connections for rods versus cables
- Mediating the overall size of the small diameter members as they connect to larger structural types
- Predominantly either:
 - End connections (PINS) that use clevises
 - Center points of cross bracing

Tensile Connections Components

End Condition: usually a clevis

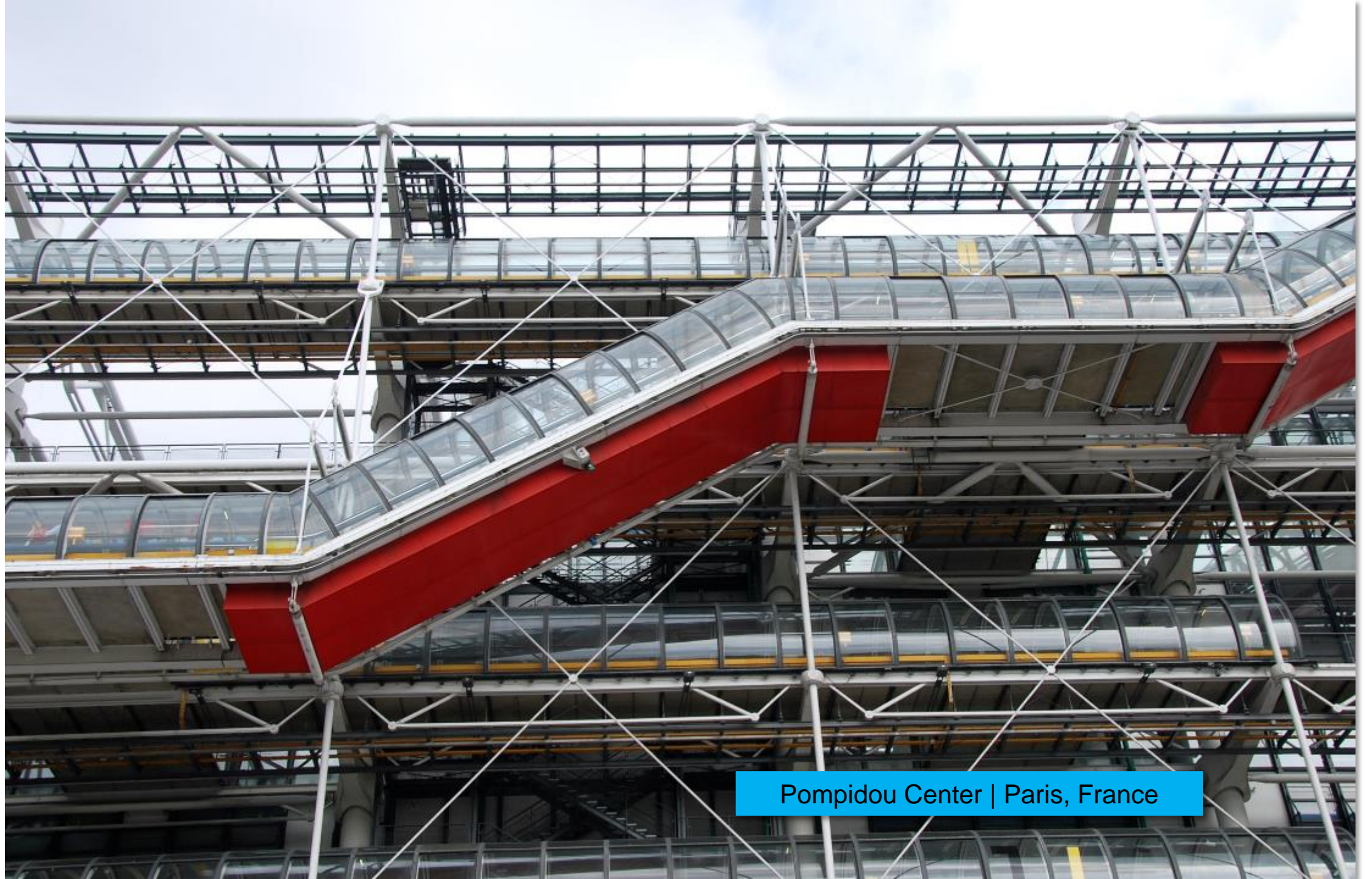
Tightening mechanisms

- Turnbuckle if along its span
- Bolts if used in conjunction with a centre X connection

Member

- Cable: can be galvanized or stainless steel as a function of aesthetic requirements or corrosion resistance for exterior; can be encased in a sheathing for weather protection; these can be extremely long
- Rods: solid steel; will need corrosion protection if exterior; limited in length





Pompidou Center | Paris, France





Munich International Airport

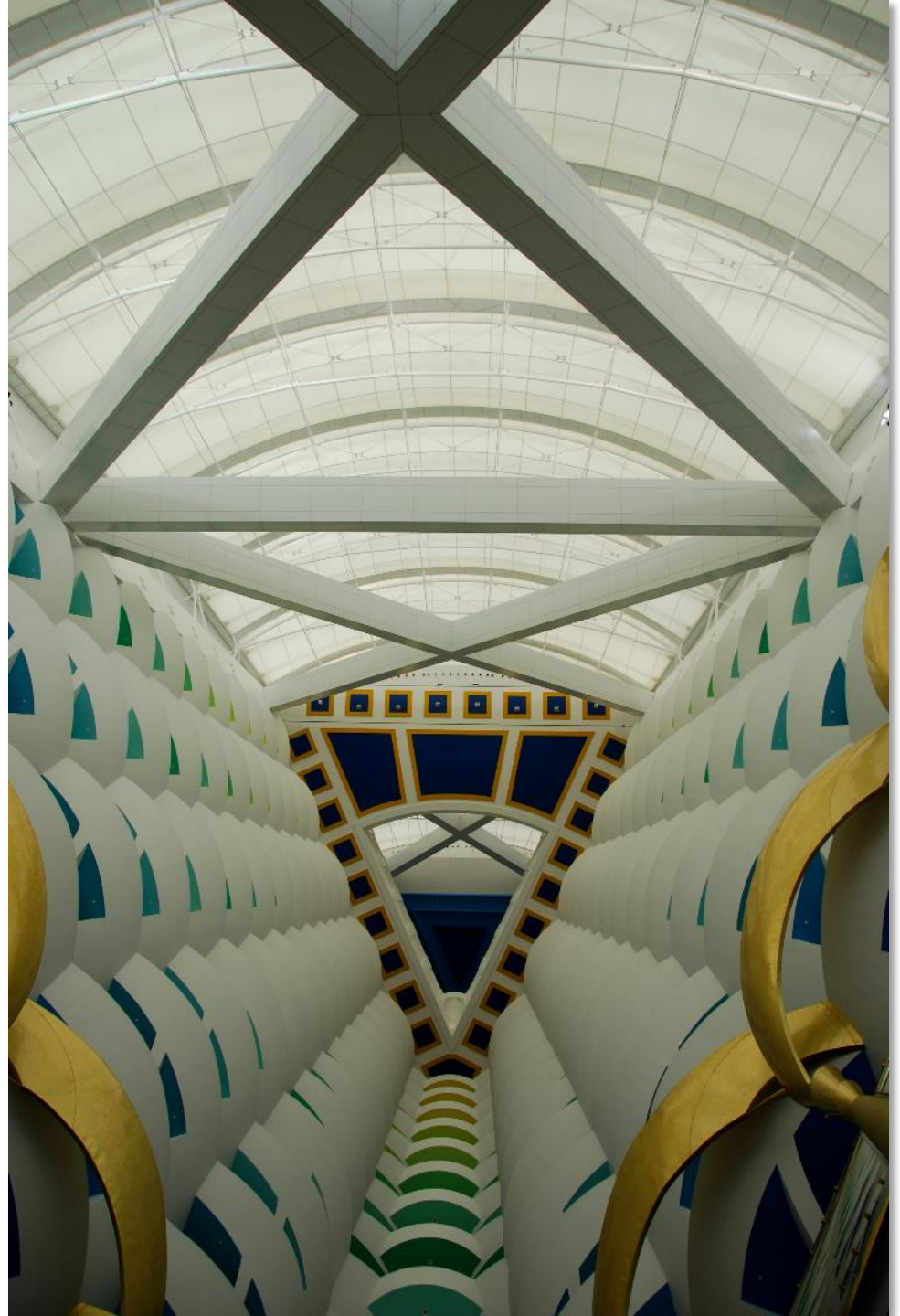






Burj Al Arab, Dubai









University Building at Laval





Reichstag | Berlin, Germany

AESS 4

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Kurilpa Bridge | Brisbane, Australia



AESS 3

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Jubilee Bridge | London



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viewing distance



Sony Center | Berlin, Germany



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International Airport | Porto, Portugal



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How to Create a Corner

When the “corners” on an HSS tube are too rounded for the desired aesthetic, and crispness is desired

Usually the point when custom fabrication of the members using plate steel is required

Major decision on the corner will impact cost”!

- \$ - Inset corner allows fillet welding
- \$\$ - butt corner with unremediated welds
- \$\$\$ - butt corner with fully ground welds







Siemens Crystal | London, UK

Offset plates:

- Allows for a simple fillet weld
- No weld grinding
- Added visual detail or shadow line

AESS 4

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
- 4.3 Surfaces filled and sanded
- 4.4 Weld show-through minimized



Newseum | Washington, DC



AESS 4

- 4.1 HSS seam not apparent
- 4.2 Welds contoured and blended
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A close-up photograph of a mechanical assembly, likely part of a window or door system. The assembly features several stainless steel cables (HSS) connected to a grey metal frame. The cables are secured with various metal components, including a central rectangular plate and several cylindrical connectors. The background shows a window with a white arrow pointing left and a sign that reads "BEST FOR PUSHER FEEDING".

AESS 4

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Plate allows for very crisp corners.

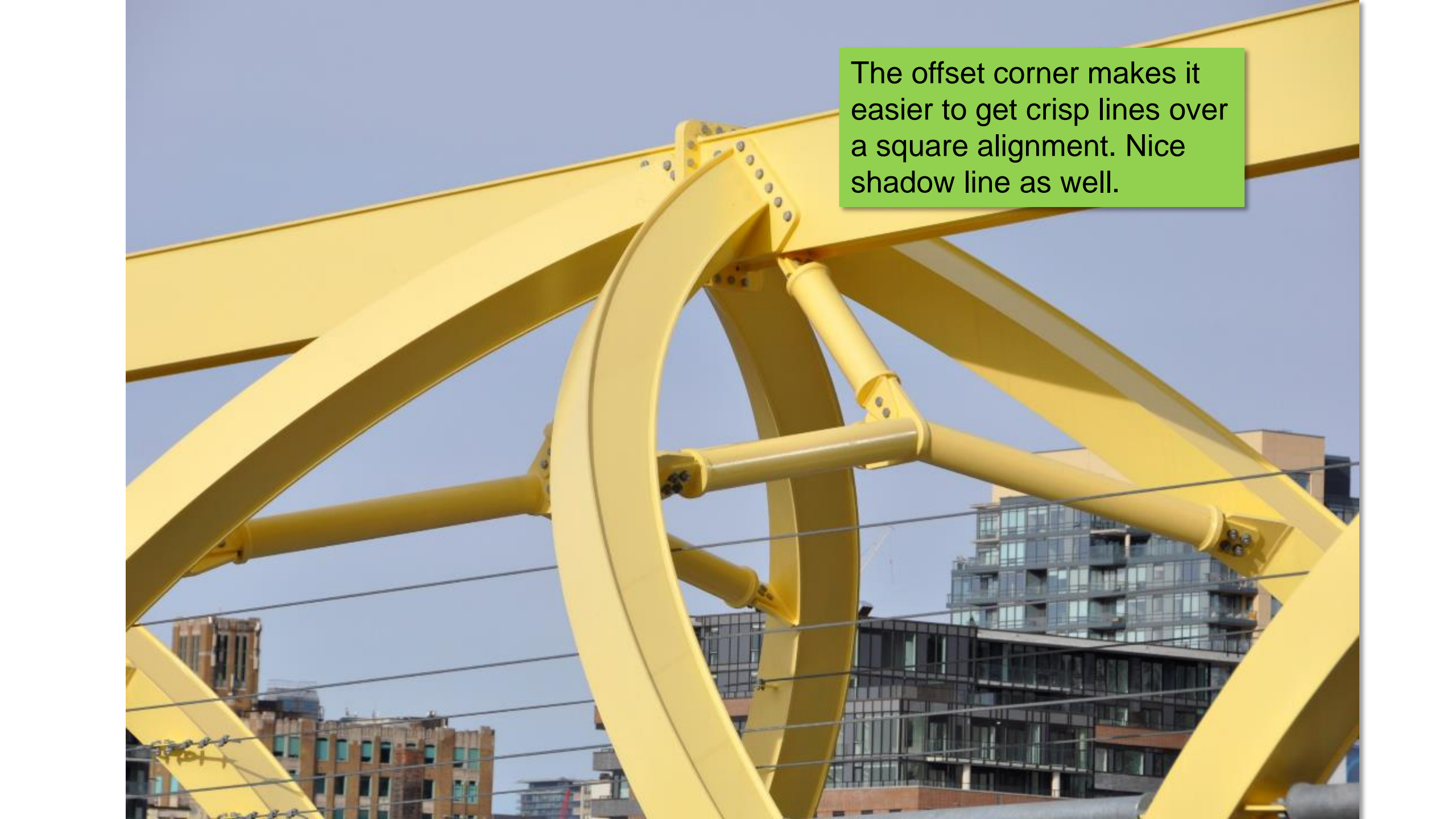


Puentes de Luz | Toronto

AESS 4

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Although some bolting used, the double curvature of the rolled plates kicked this into AESS4

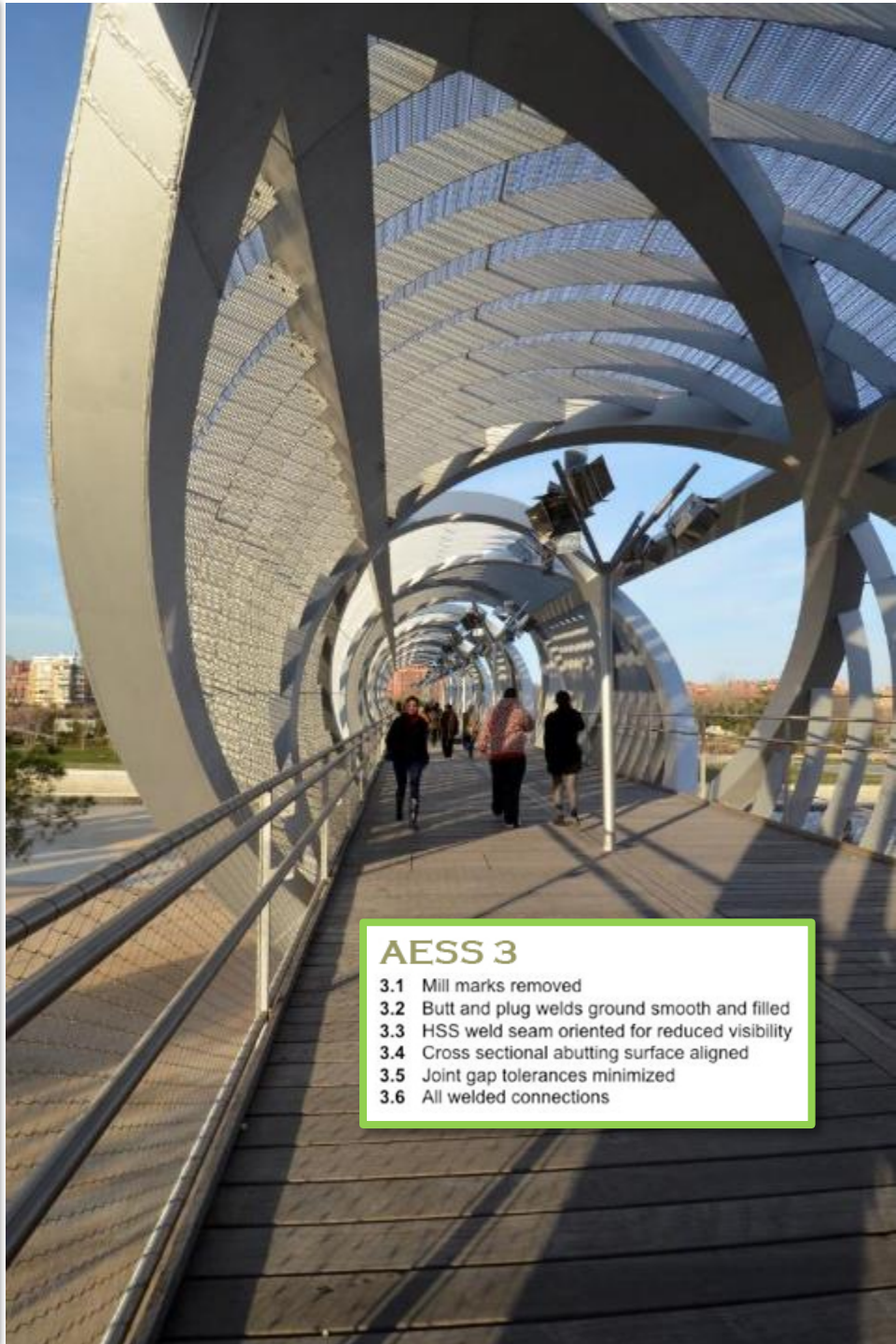


The offset corner makes it easier to get crisp lines over a square alignment. Nice shadow line as well.



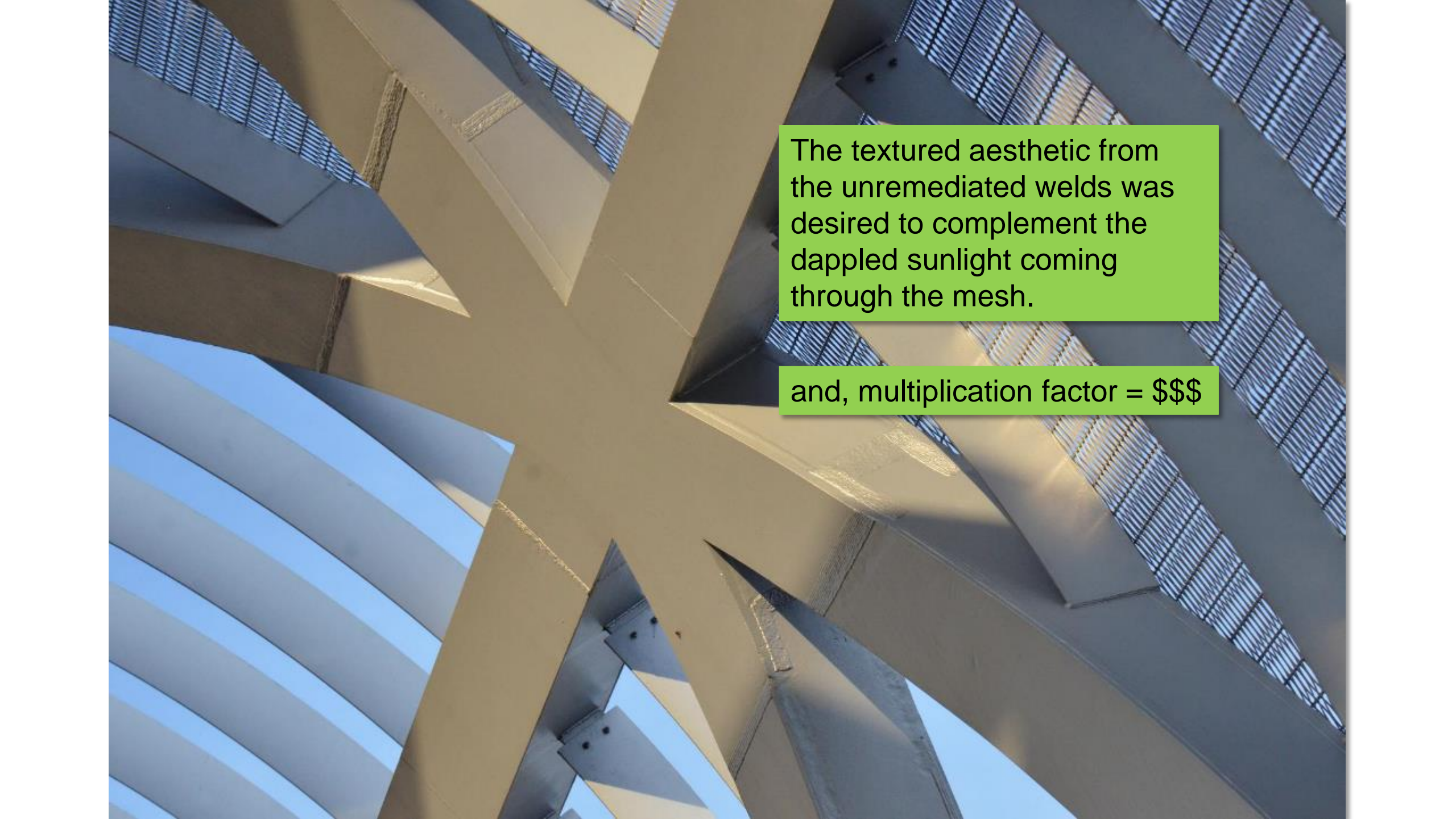
Arganzuela Bridge | Madrid, Spain

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The textured aesthetic from the unremediated welds was desired to complement the dappled sunlight coming through the mesh.

and, multiplication factor = \$\$\$

viewing distance



Cannon Street Station | London, UK



AESS 3

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viewing distance







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viewing distance



Discreet
connection



Renzo Piano

The Shard | London, UK








Renzo Piano

New York Times | New York, USA





Rogers Stirk Harbour + Partners

Leadenhall Building | London, UK









Aranguren + Gallegos Arquitectos

ABC Museum | Madrid, Spain



Safety Issues – Bolting vs Welding



- Easier, faster and SAFER to bolt on site
- Welding at height is full of risk
- Must ensure a safe working environment for ironworkers
- Must create secure platforms
- Provide for pre-heating and weather enclosures
- Add to the cost of the contract but reduces worker deaths and injuries

Minimal welding platforms





Welding platforms for ALL welded connections

Winterized enclosures for cold weather working





Massive multi storey scaffold to provide secure access



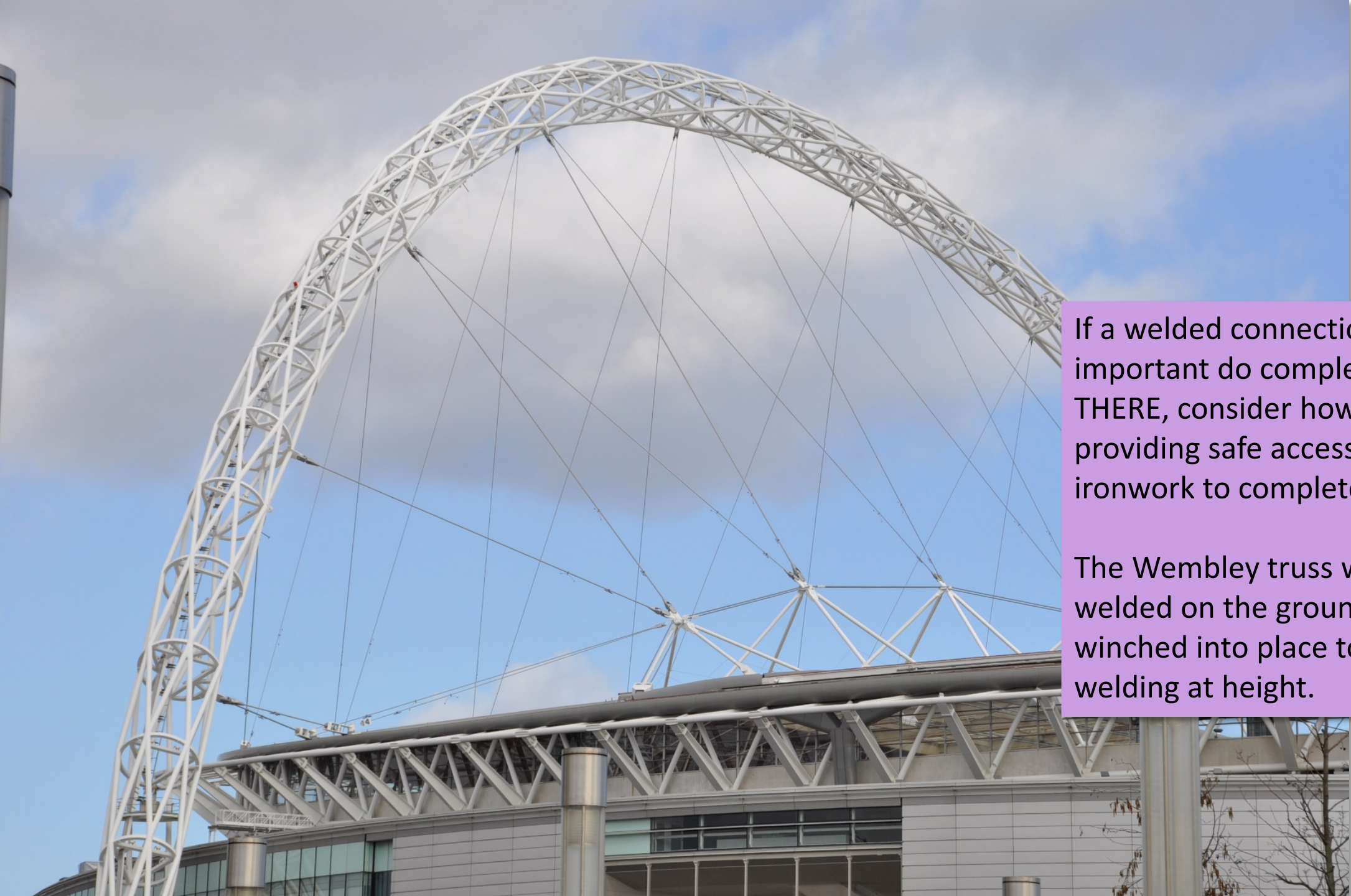
Custom fabricated reusable platforms to facilitate safe access for highly repetitive work.

P456/W skid #

516-70/S
- 1/2 x 100
51-157
722-WO
MADE IN CHINA

E/W P017 21

(2)



If a welded connection is important do complete WAY UP THERE, consider how you are providing safe access for the ironwork to complete this work.

The Wembley truss was fully welded on the ground and then winched into place to avoid welding at height.