Helmut Jahn

Munich Airport Center | Munich, Germany

STEEL

Architecturally Exposed Structural Steel CONNECTIONS

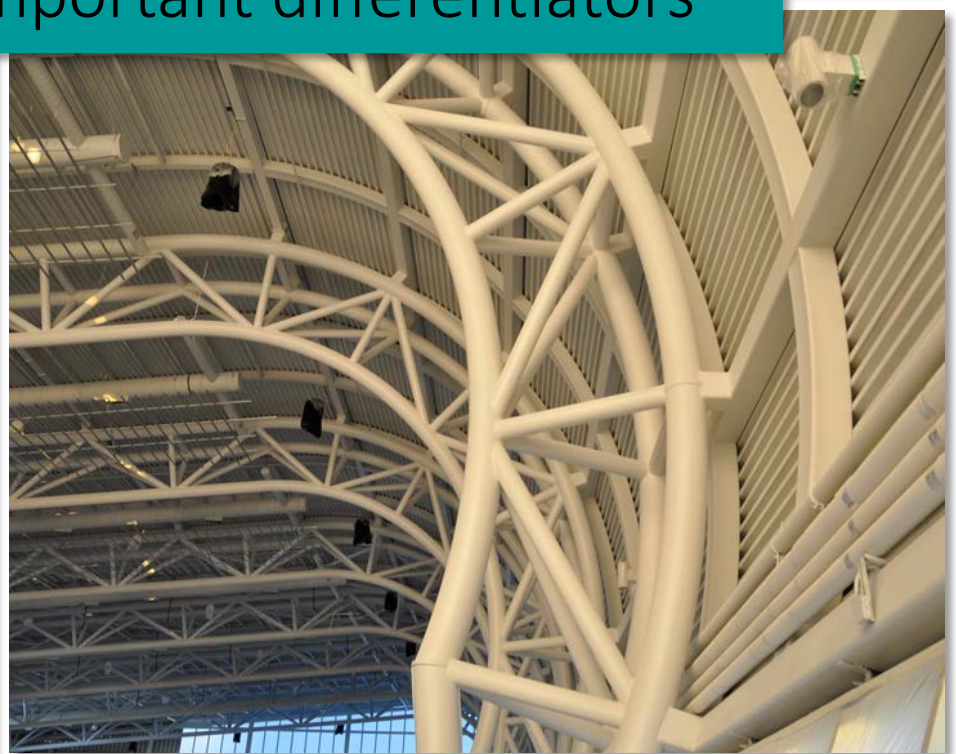
Objectives

- 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

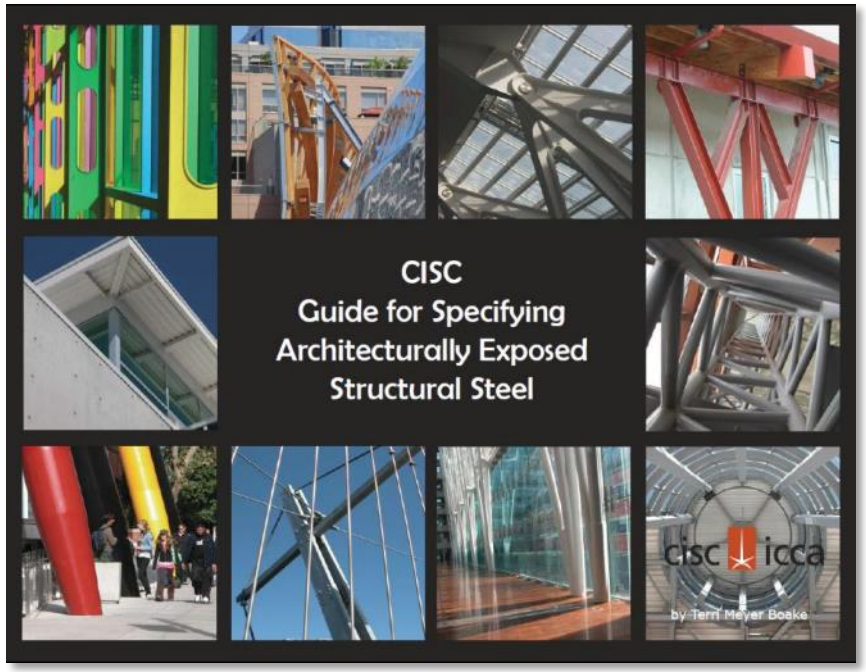


AESS: Primary Factors of influence

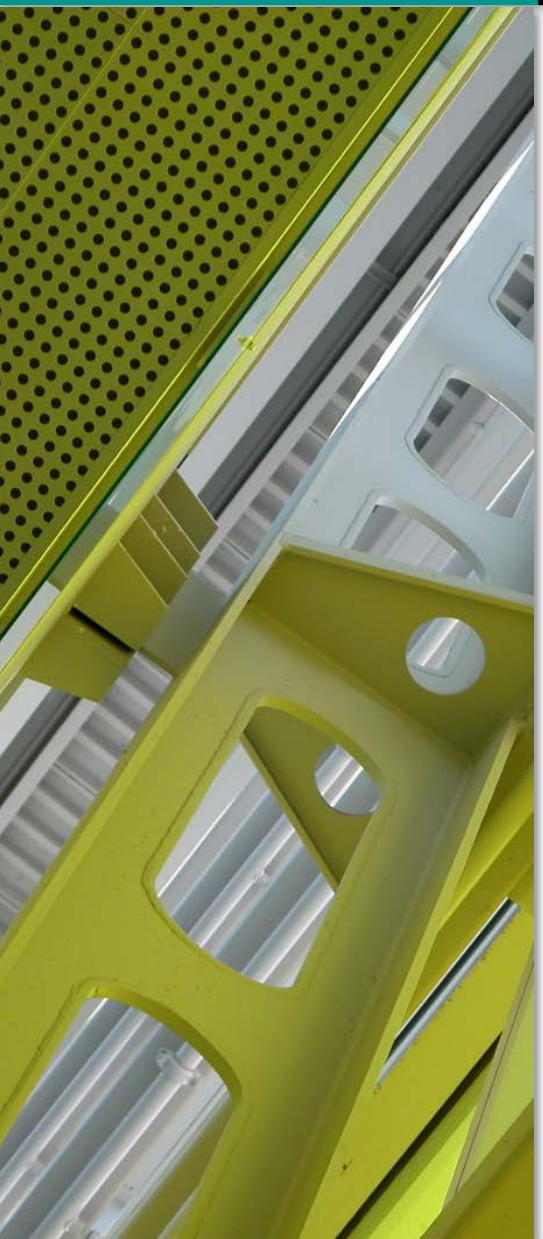
- Distance. Visibility.
- Connections mostly bolted or welded
- Tolerances required at fabrication and erection
- Access to detail to perform required finish

- 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
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- 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

Id	Characteristics	AESS C *Custom Elements*	AESS 4 *Showcase Elements*	AESS 3 *Feature Elements* *Viewed at a Distance ≤ 6 m*	AESS 2 *Feature Elements* *Viewed at a Distance > 6 m*	AESS 1 *Basic Elements*	SSS *Standard Structural Steel*
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							
	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 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

Id	Characteristics	AESS C *Custom Elements*	AESS 4 *Showcase Elements*	AESS 3 *Feature Elements* *Viewed at a Distance ≤ 6 m*	AESS 2 *Feature Elements* *Viewed at a Distance > 6 m*	AESS 1 *Basic Elements*	SSS *Standard Structural Steel*
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		√				
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	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 ≤ 6m/20ft

structures that will be viewed at a distance ≤ 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

Id	Characteristics	AESS C *Custom Elements*	AESS 4 *Showcase Elements*	AESS 3 *Feature Elements* *Viewed at a Distance ≤ 6 m*	AESS 2 *Feature Elements* *Viewed at a Distance > 6 m*	AESS 1 *Basic Elements*	SSS *Standard Structural Steel*
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		√	√			
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3.4	Cross sectional abutting surface aligned		√	√			
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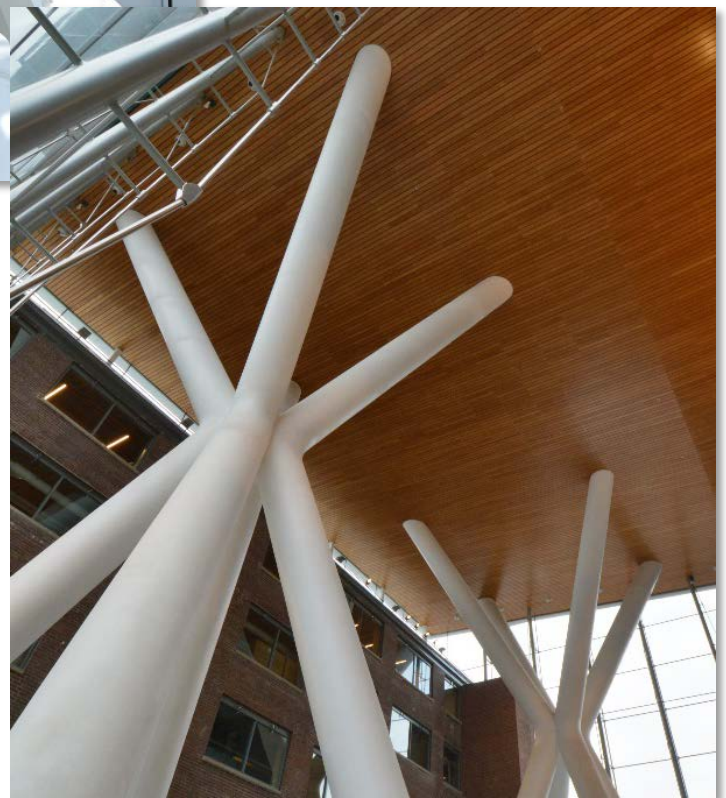
Sample Use:		Elements with special requirements	Showcase or dominant element	Airports, shopping centres, hospitals, lobbies	Retail and architectural buildings viewed at a distance	Roof trusses for arenas, retail warehouses, canopies	
Estimated Cost Premium:		Low to High (20-250%)	High (100-250%)	Moderate (60-150%)	Low to Moderate (40-100%)	Low (20-60%)	None 0%

AESS 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

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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			
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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	MORE EXPENSIVE
Bolting (Hex or TC)	Extensive welding
“As is” welds	Remediated (ground) welds
Standard steel shapes	Custom steel shapes (plate)
Shop Fabrication and assembly	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

Image: TheVeryMany

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

Strategies to Encourage Economical Approaches

MULTIPLICATION FACTOR

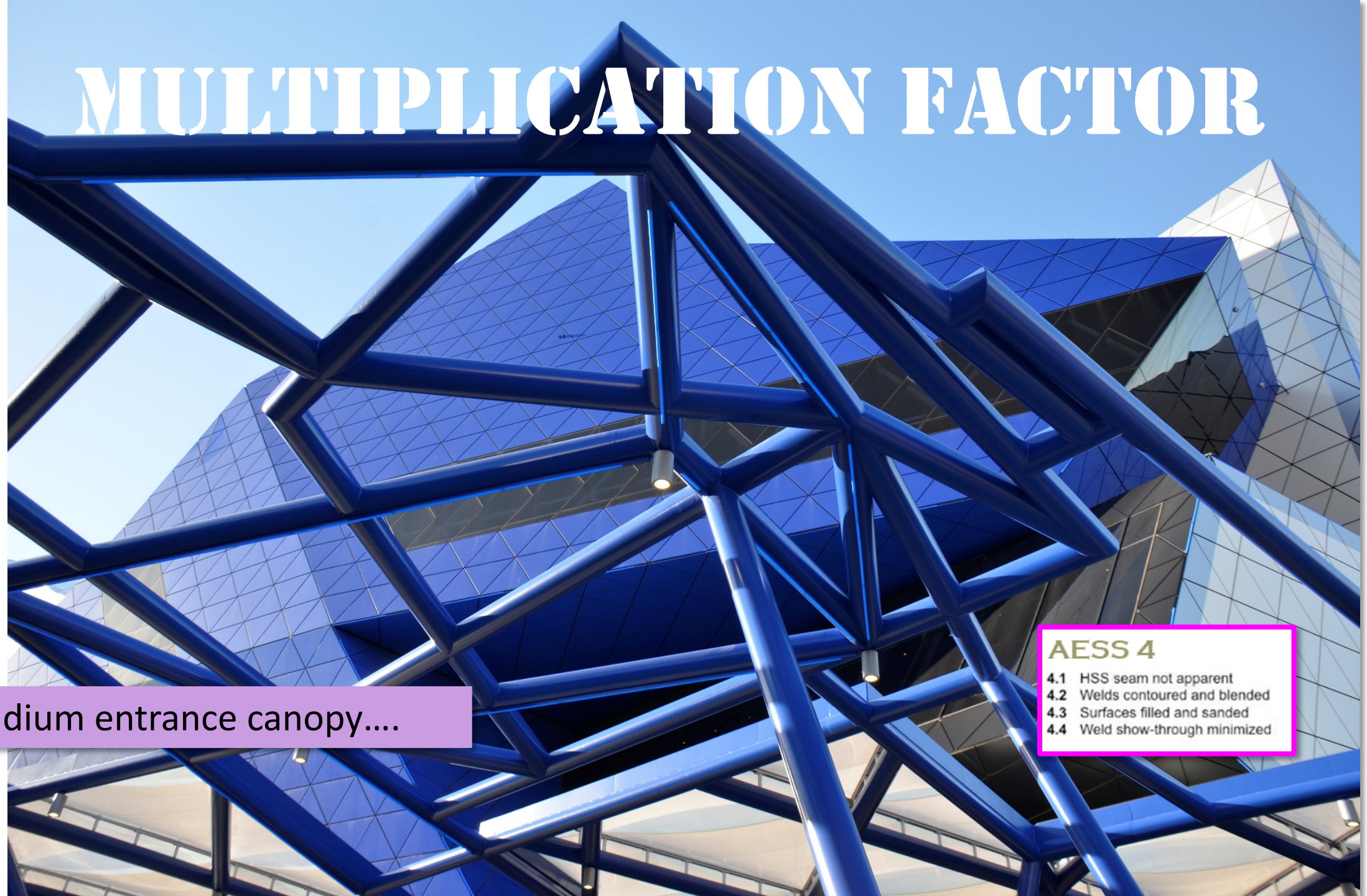
- If a connection detail is widely repeated it may be easier to set up jigs to ensure uniformity
- Can the number of unique connections be reduced?
- Can the cost of multiplying the number of connections dissuade the designer from requiring extensive weld remediation?

MULTIPLICATION FACTOR


Choice to use an unremediated welded connection.

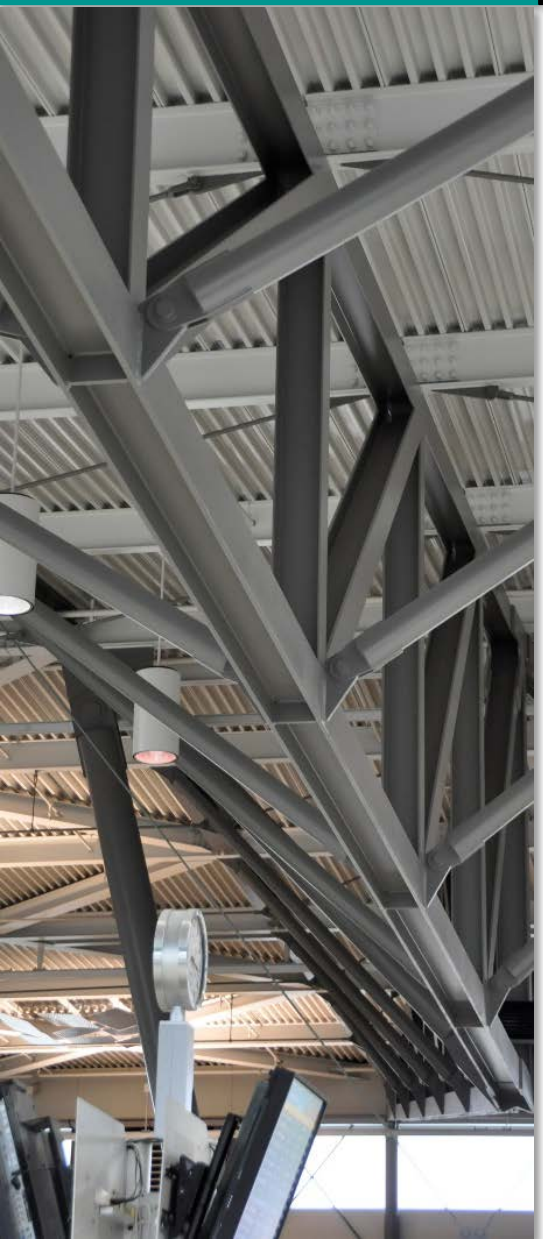
The connection could have been done like this, for a significant cost increase.

MULTIPLICATION FACTOR



Stadium entrance canopy….

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

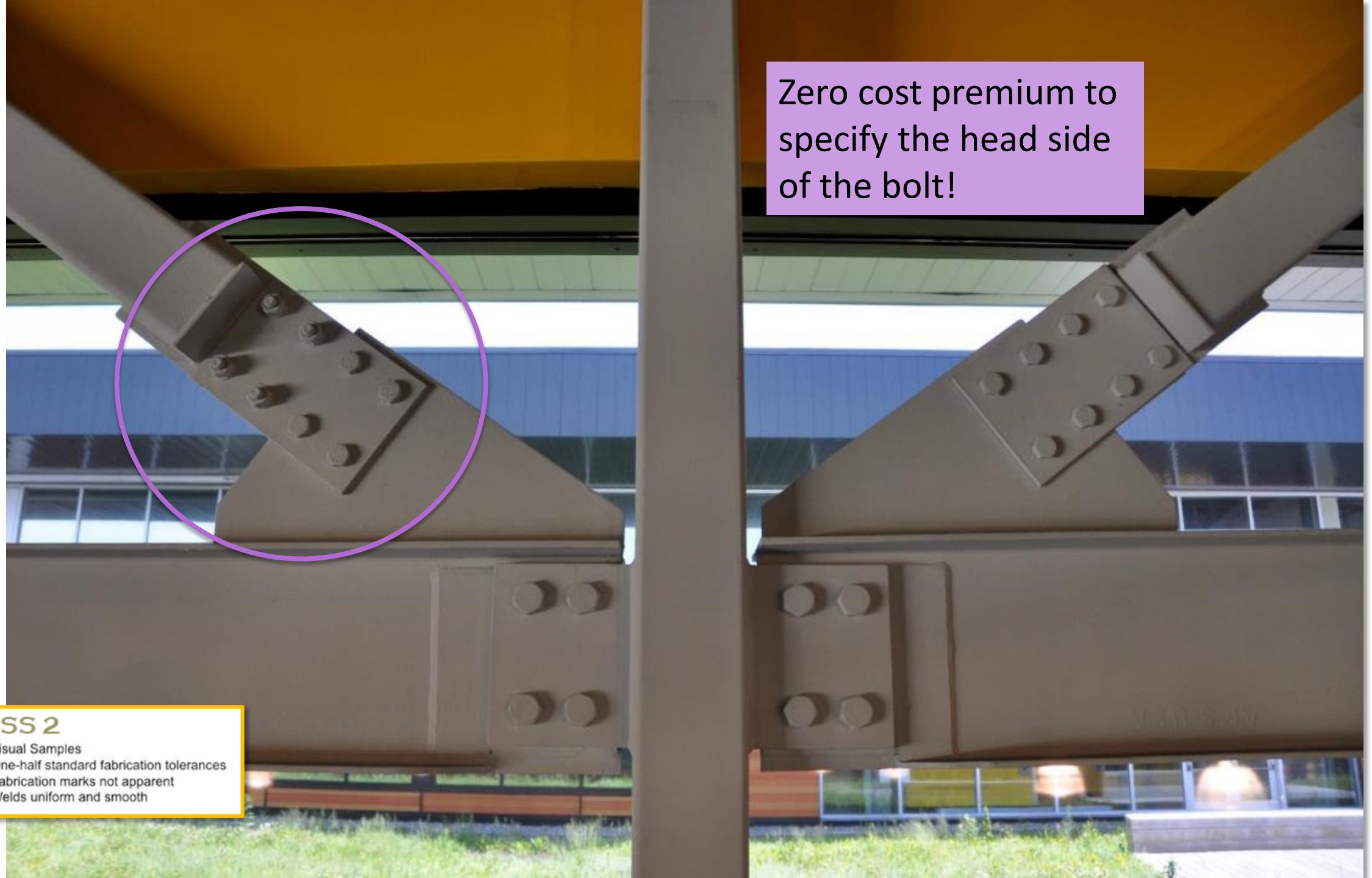
- Quick to do
- Shortest time on the crane
- Weather independent
- Less requirements for scaffolding and temporary shoring

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

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.

Canadian Museum for Human Rights | Winnipeg, Canada

DISTANCE FACTOR

+

FINISH FACTOR

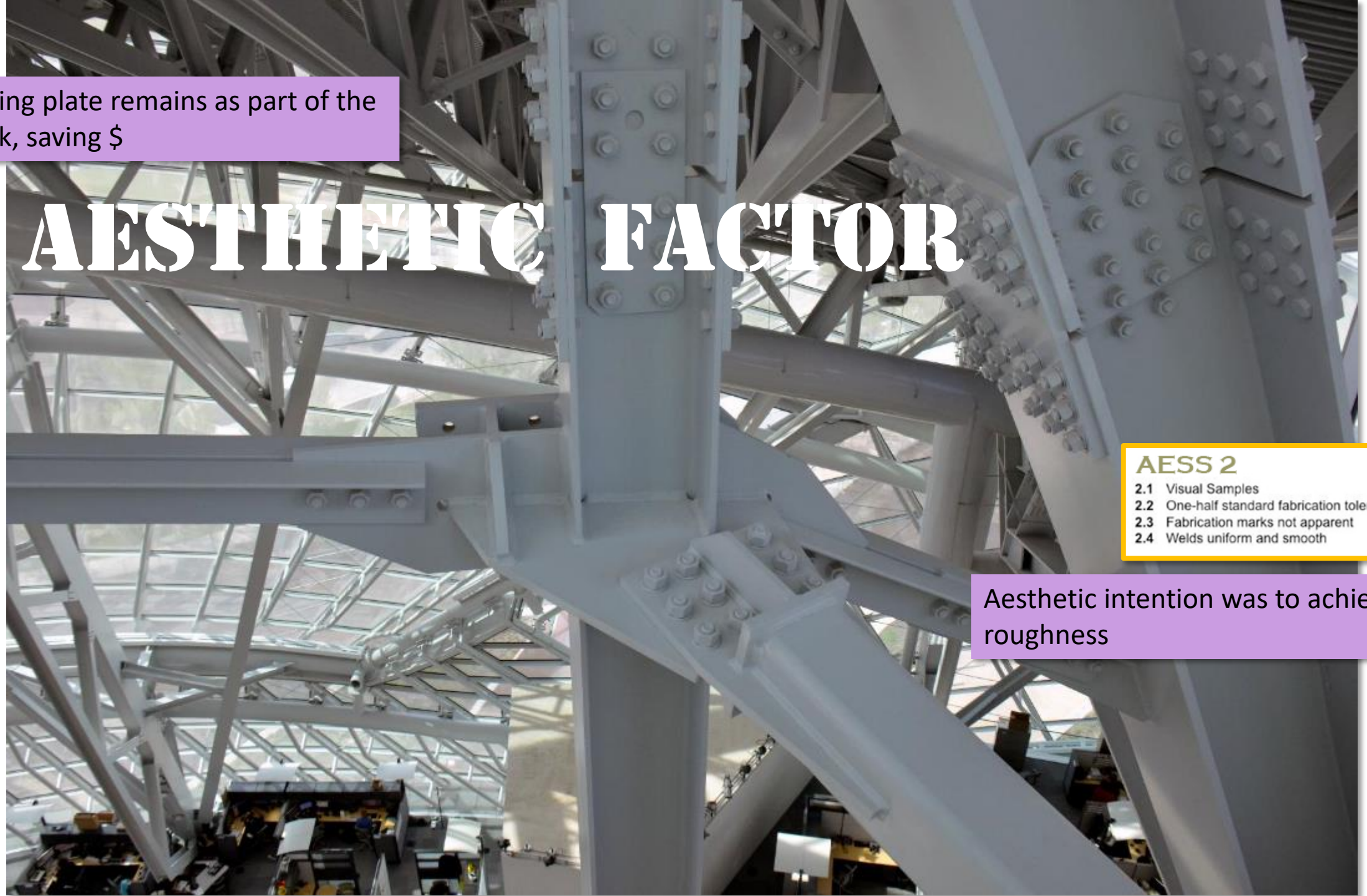
viewing distance

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
2.3 Fabrication marks not apparent
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

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

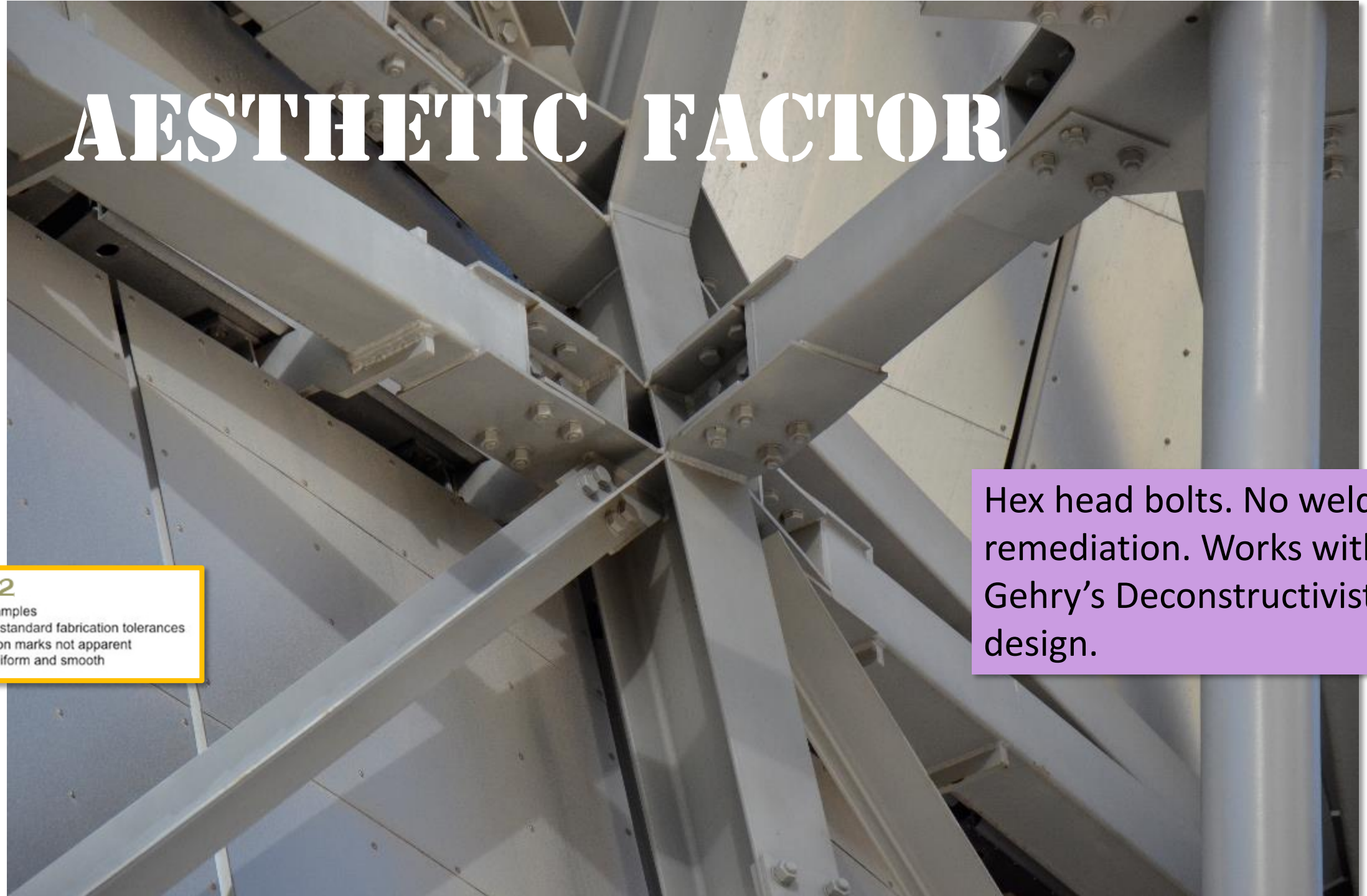
viewing distance

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



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.

viewing distance

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
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3.6 All welded connections

Rose Center for Space | New York, NY

AESS 3

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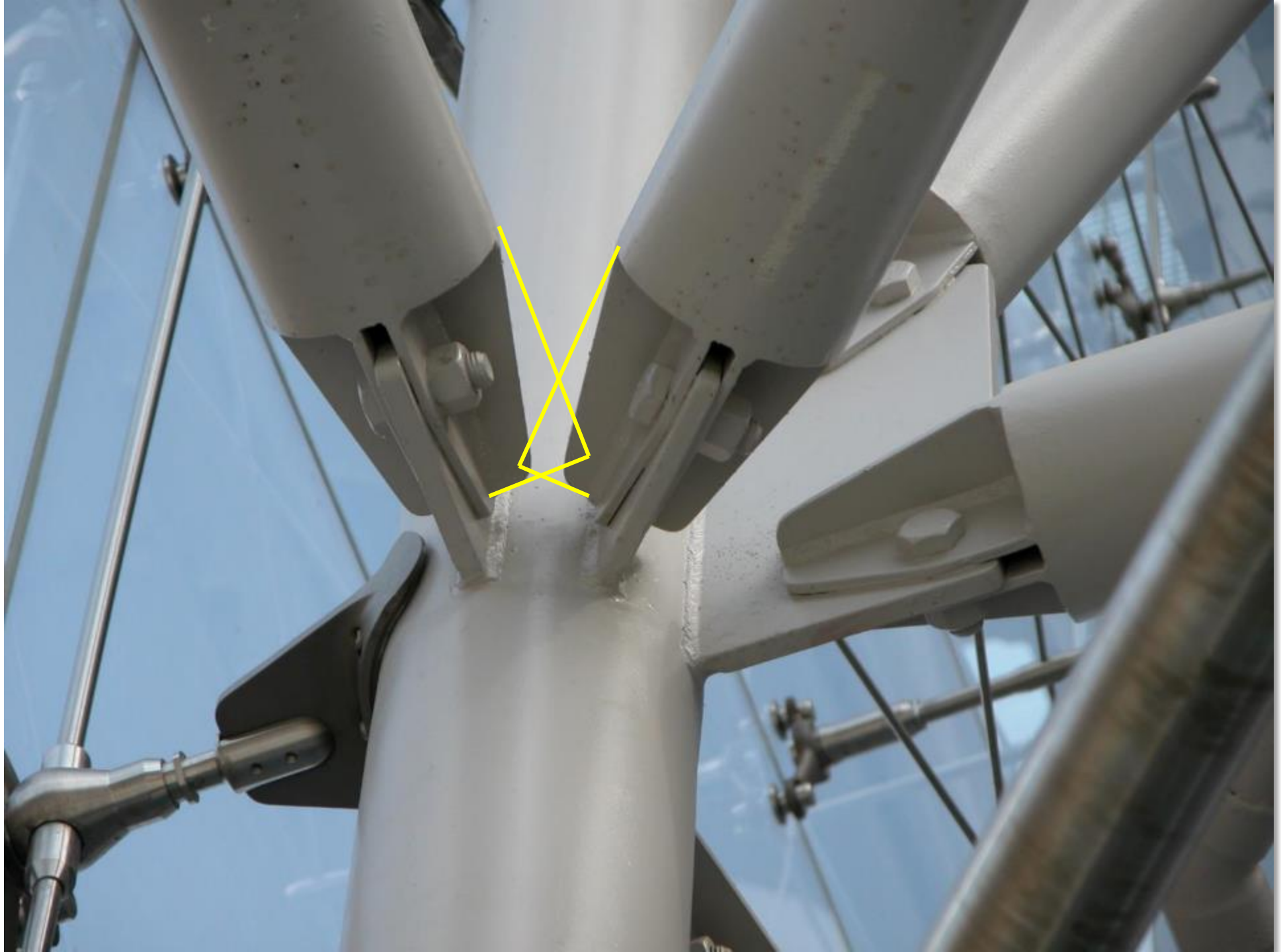
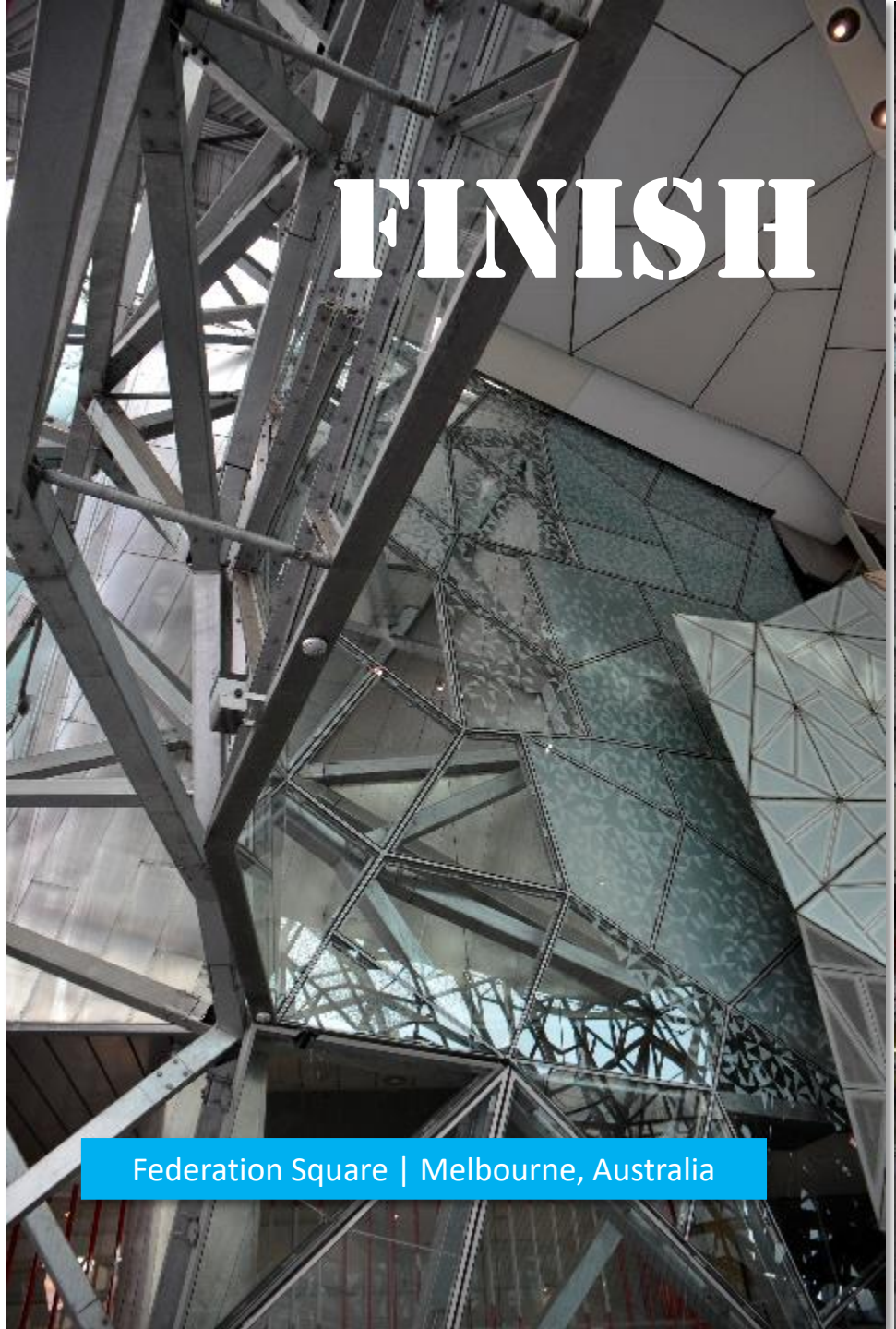


FINISH FACTOR



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
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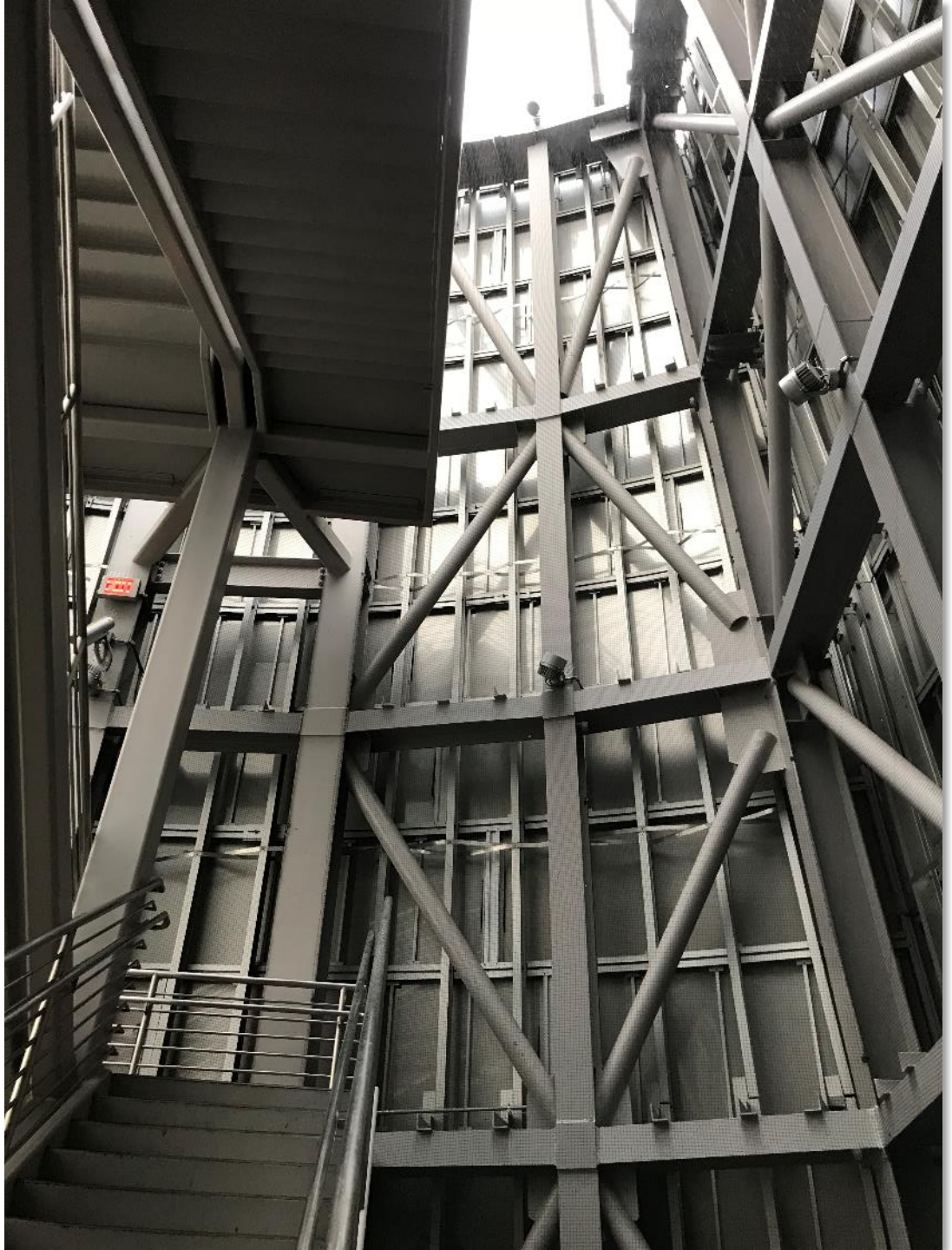
San Francisco Courthouse | Morphosis

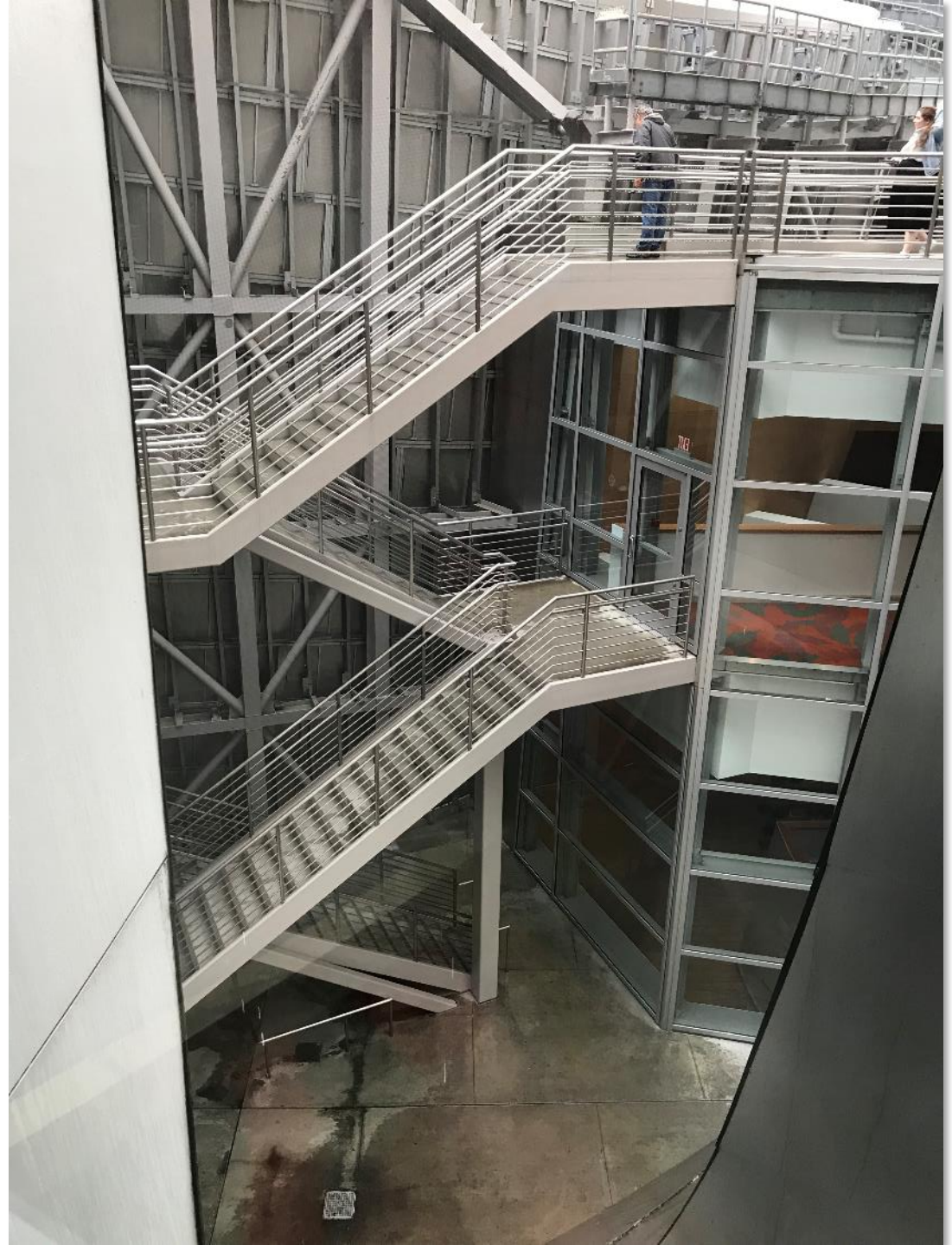

Percolate
333-3333

CalTrans Los Angeles | Morphosis


ONE WAY
STAFF ONLY

Disney Concert Hall, Los Angles | 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

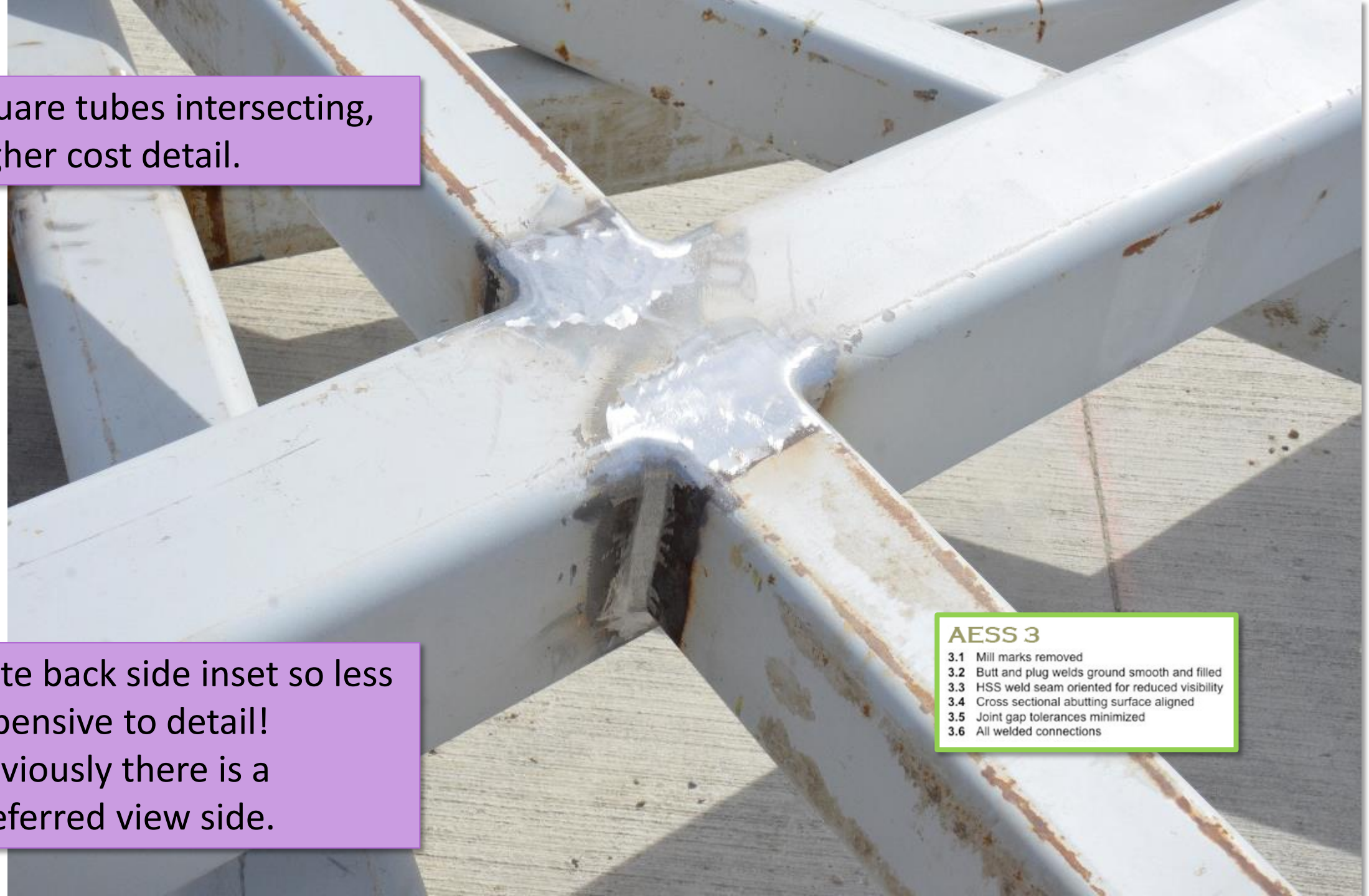

Weld seam oriented?

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

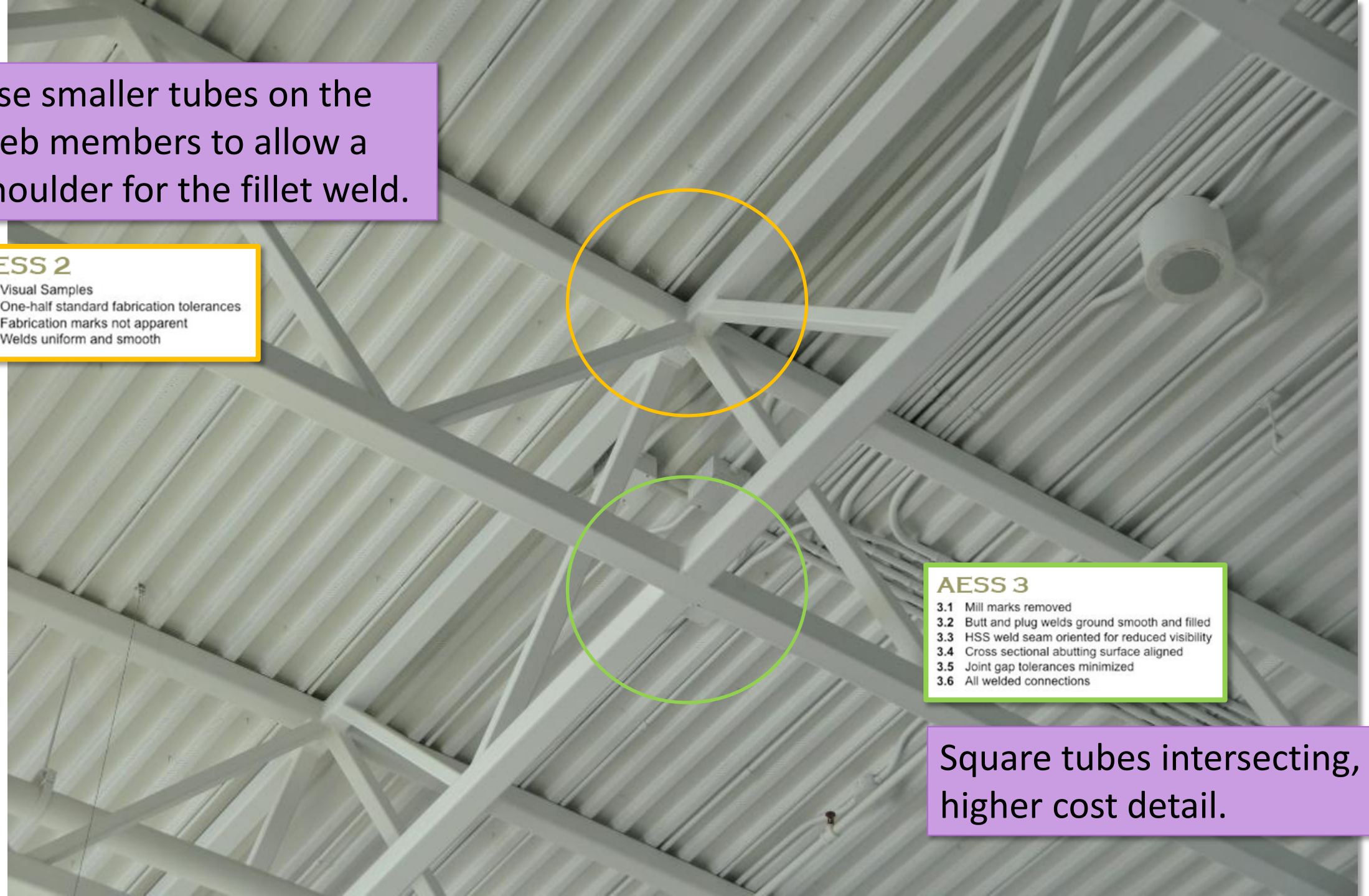
viewing distance

Pedestrian Bridge | Auckland, NZ



Square tubes intersecting, higher cost detail.

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



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

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3.2 Butt and plug welds ground smooth and filled
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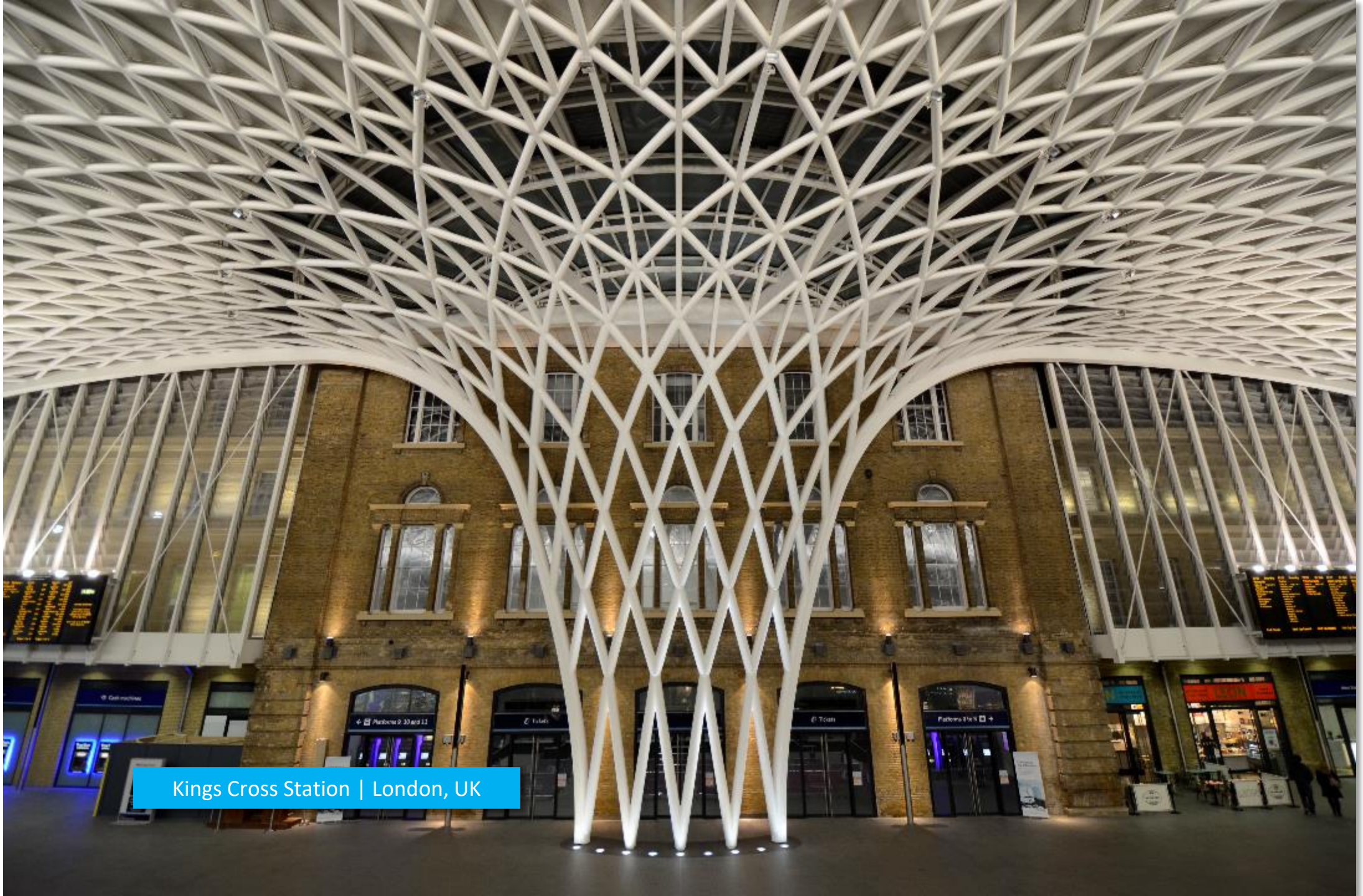
Square tubes intersecting, higher cost detail.

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

viewing distance



This is NOT up too high to see…

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

This is up too high to see.

AESS 2

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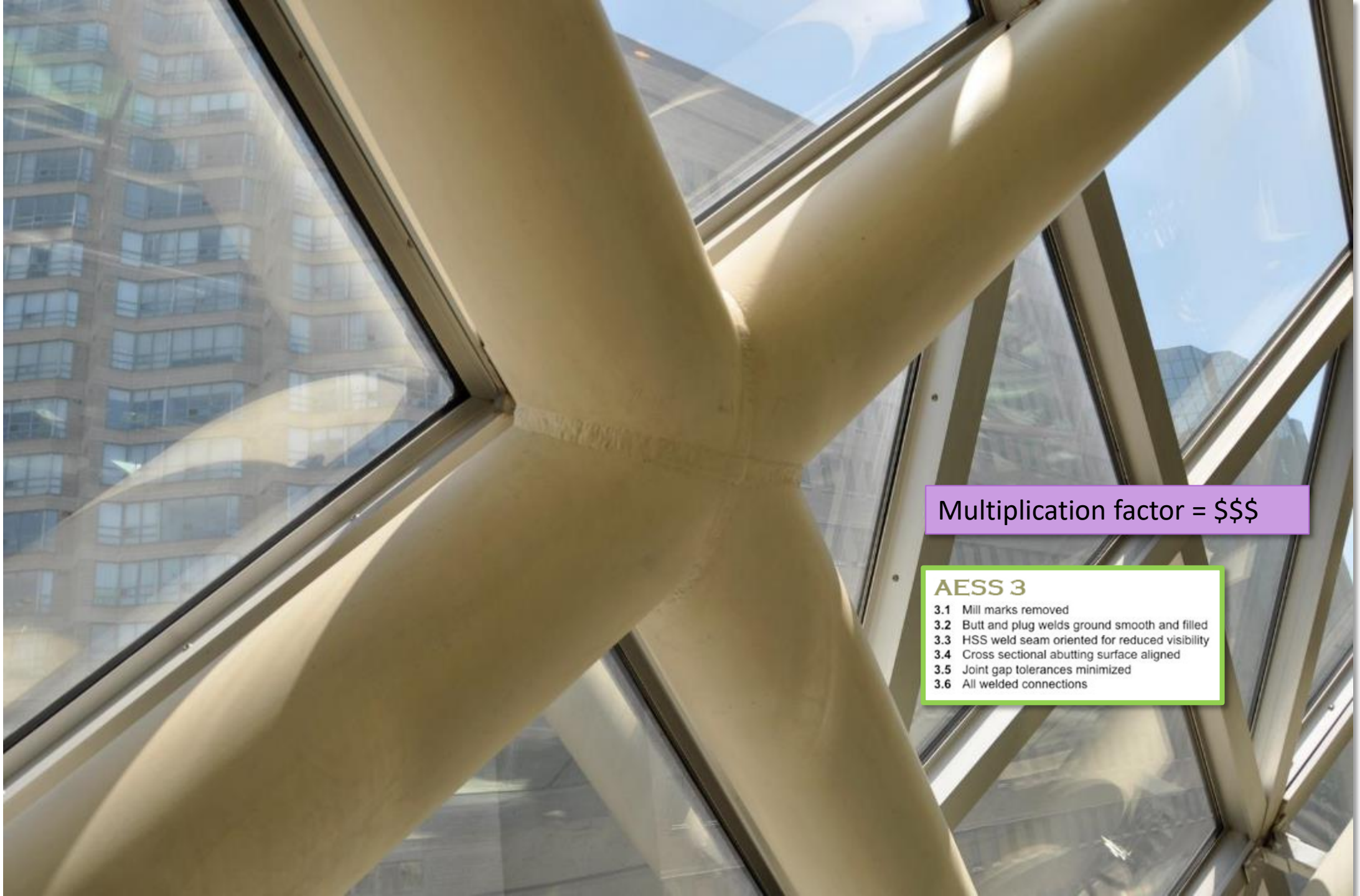
- **2.4** Welds uniform and smooth


Cash machines


Roy Thomson Hall | Toronto, Canada


Multiplication factor = $$$
AESS 3
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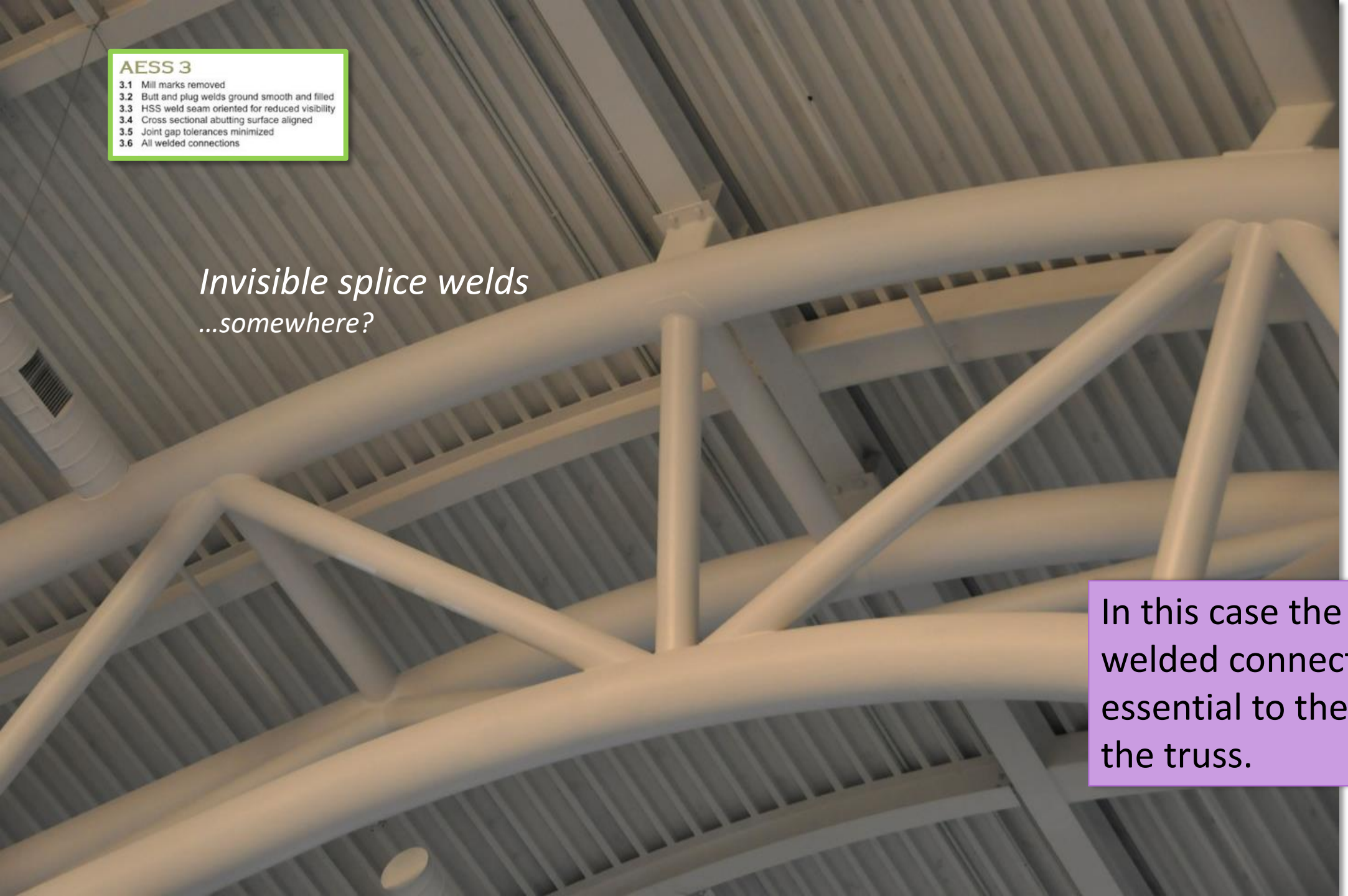
Multiplication factor = $$$

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

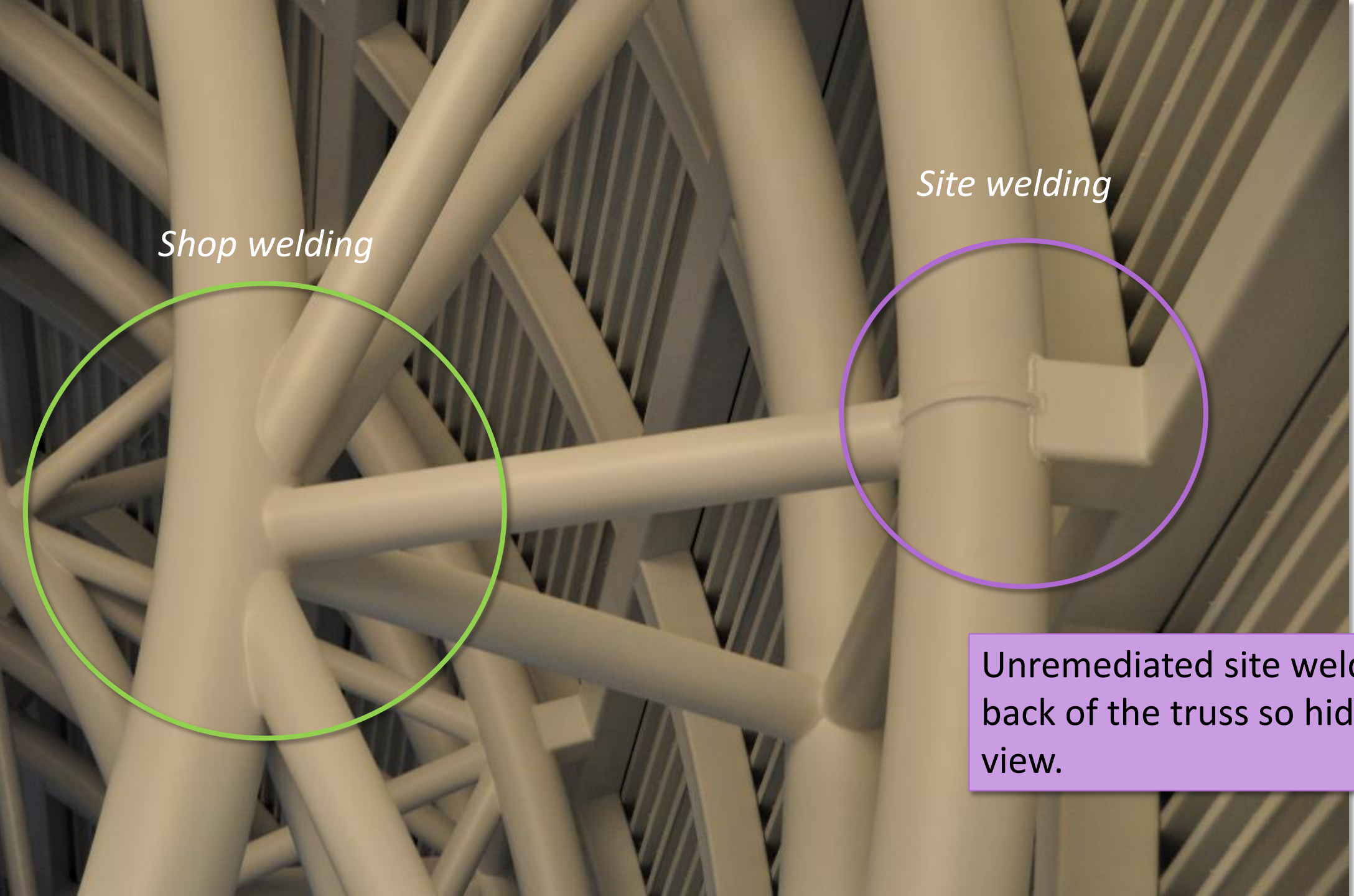
Abilities Center | Toronto, Canada



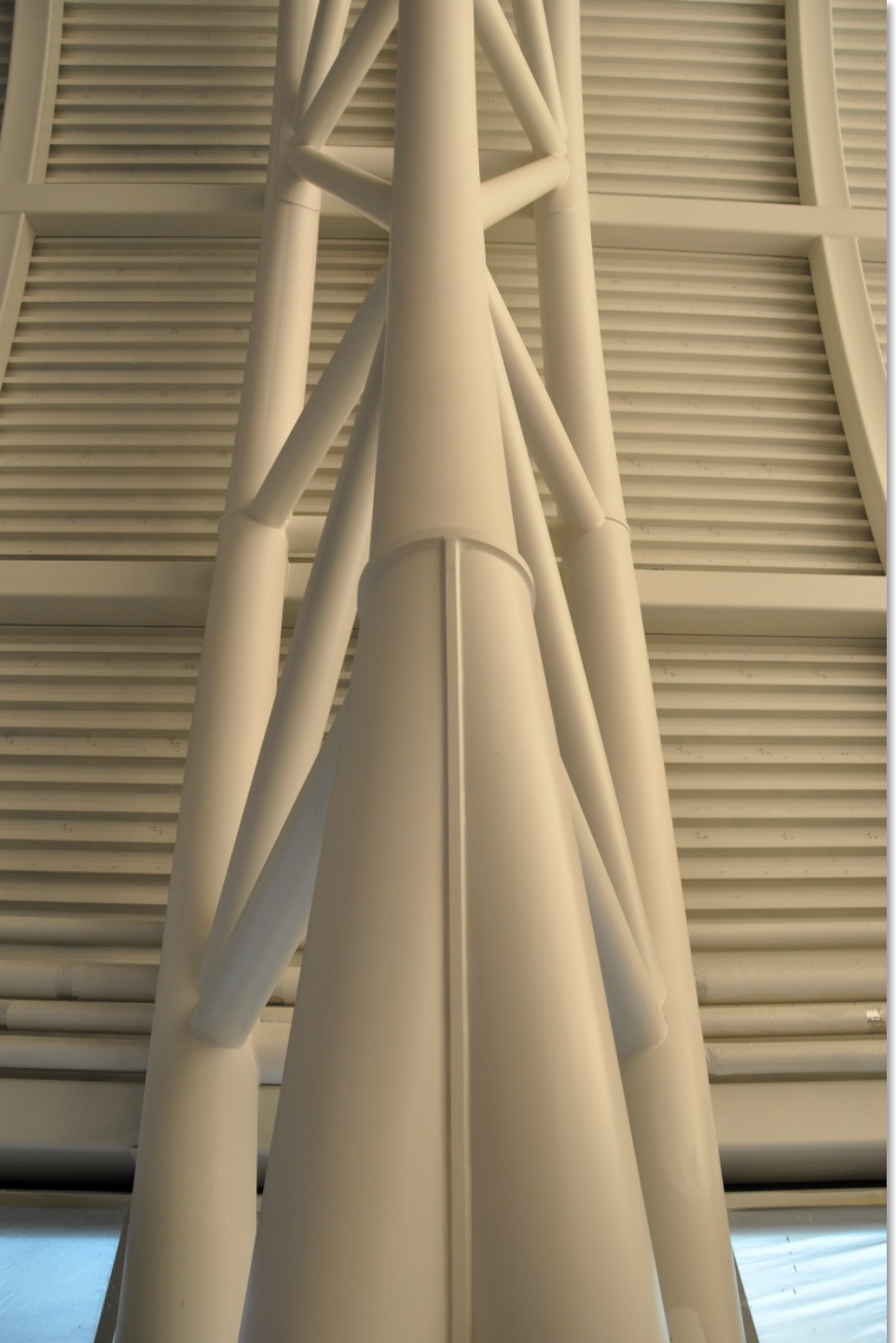
Invisible splice welds

…somewhere?

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



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

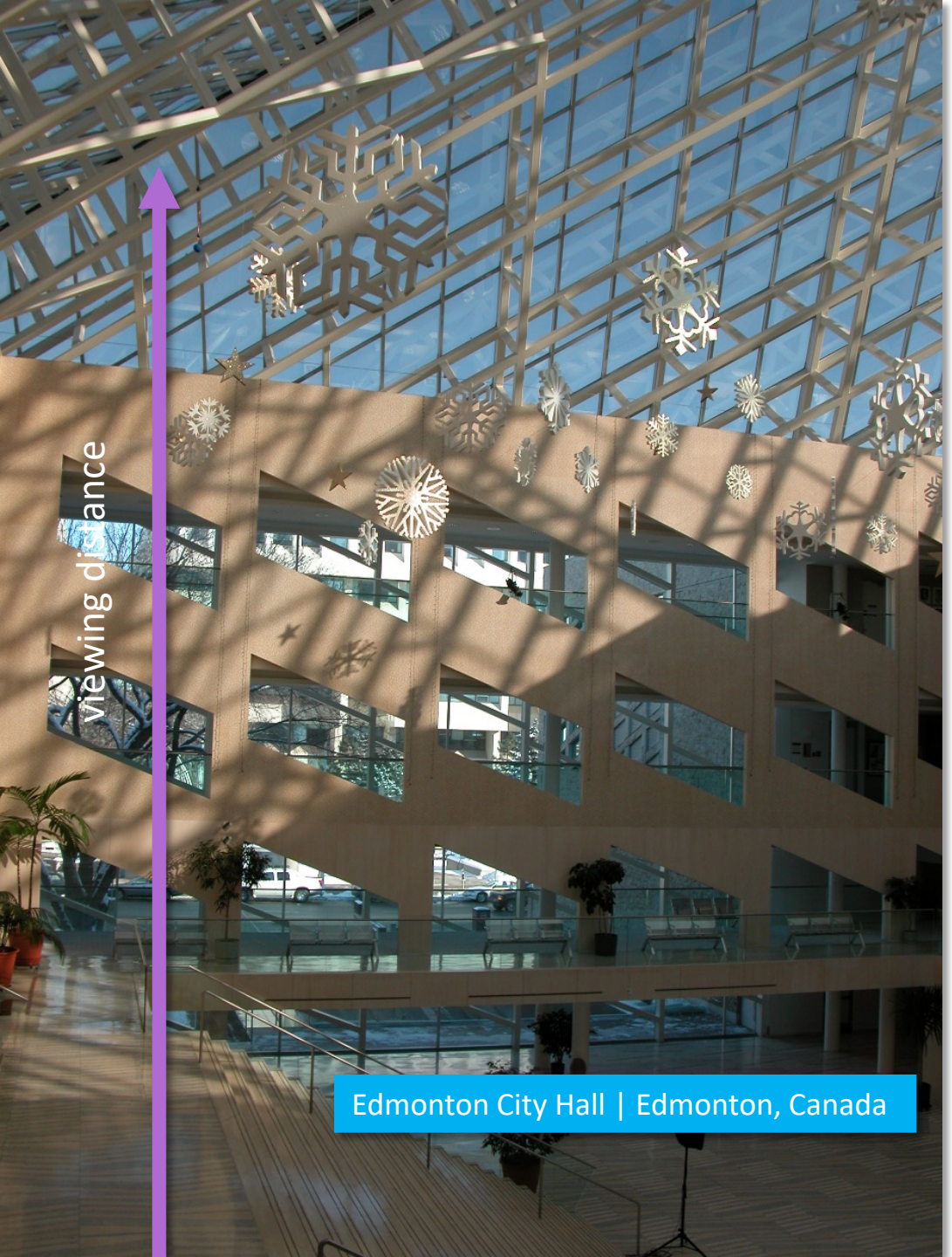


The level of detailing was important as the trusses were readily viewed at human eye level.

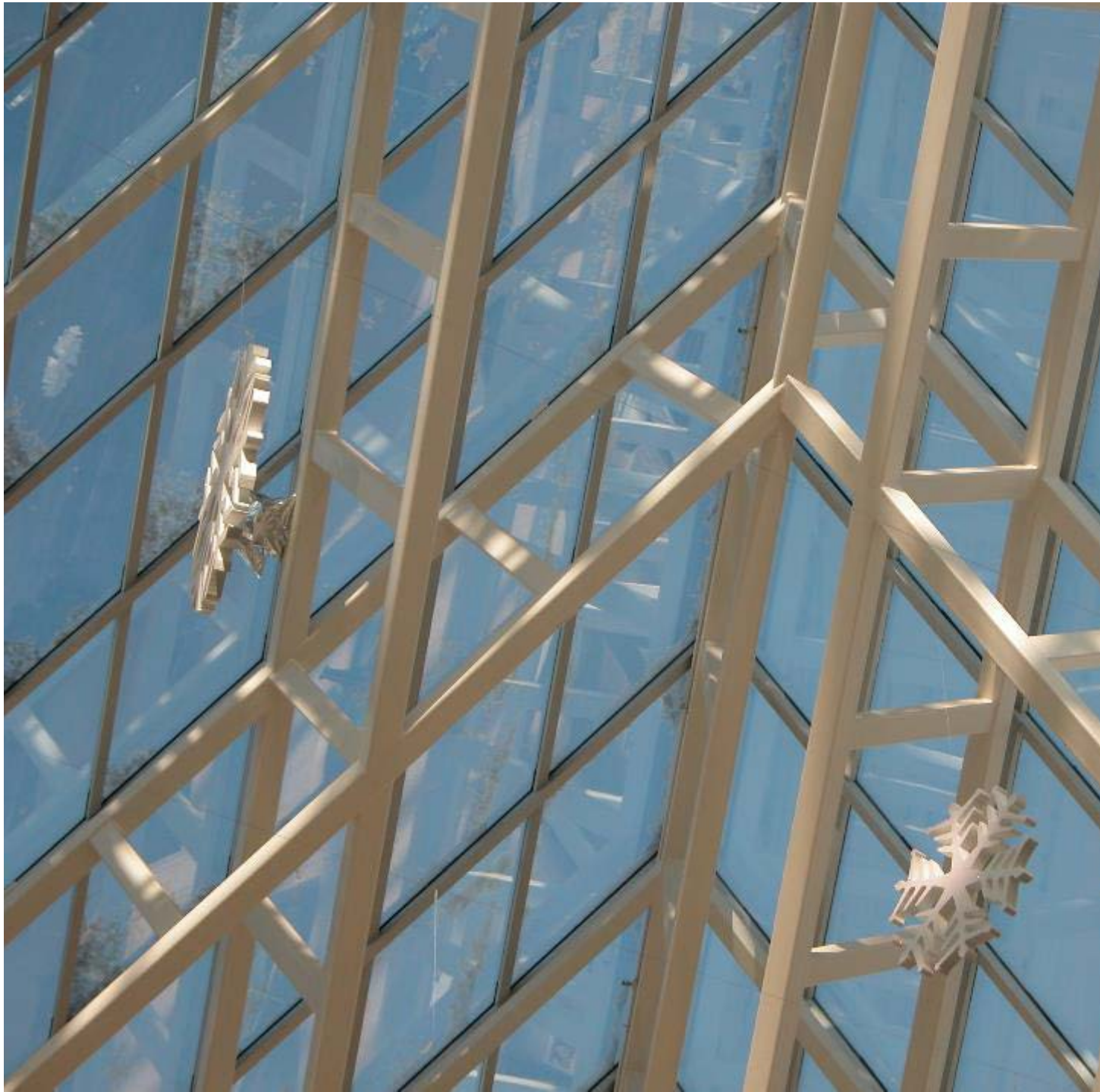
They were also within touching distance.

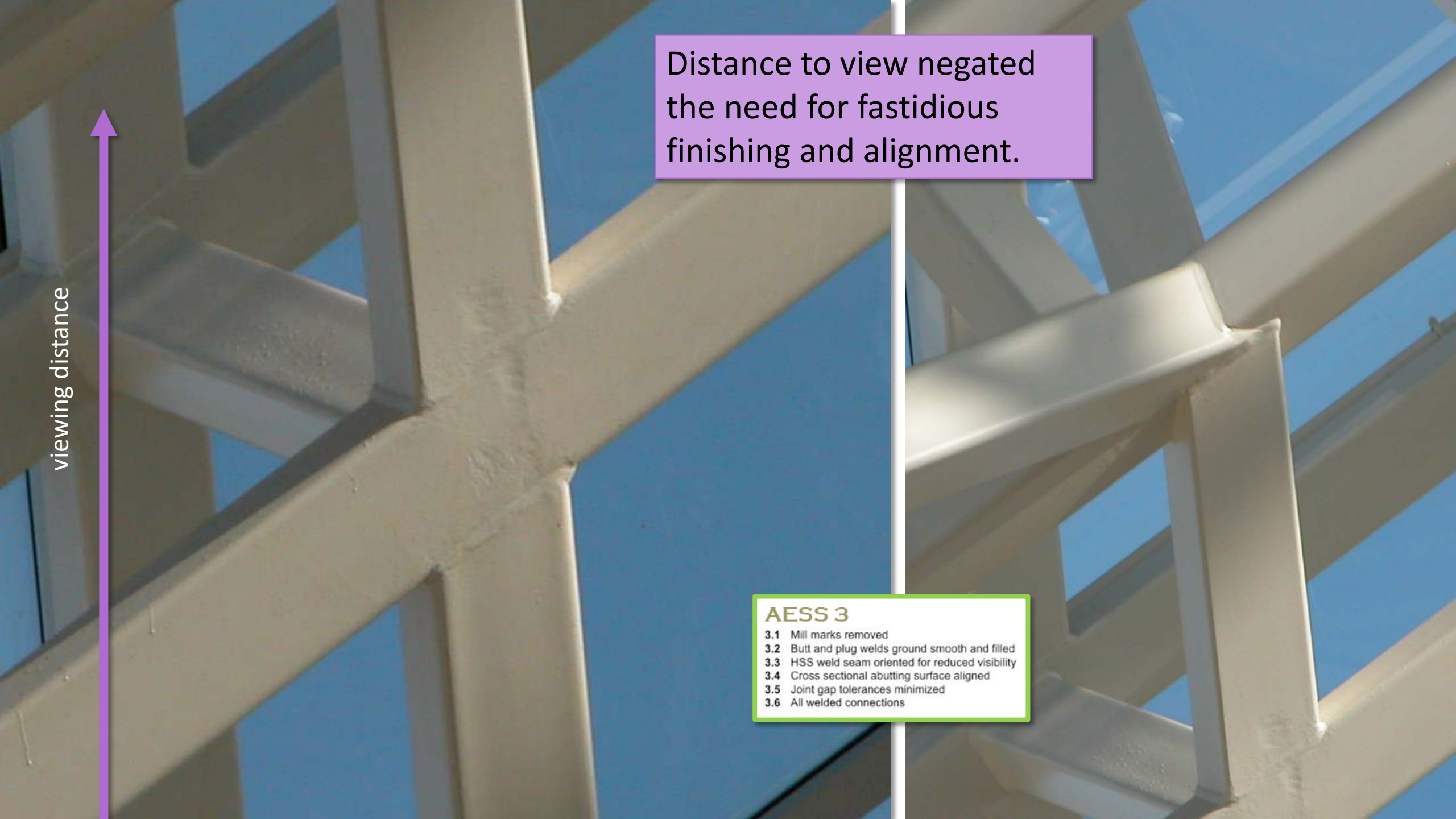
Given the sheer quantity, costs were a factor.

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



Edmonton City Hall | Edmonton, Canada




Distance to view negated the need for fastidious finishing and alignment.
viewing distance
AESS 3
3.1 Mill marks removed
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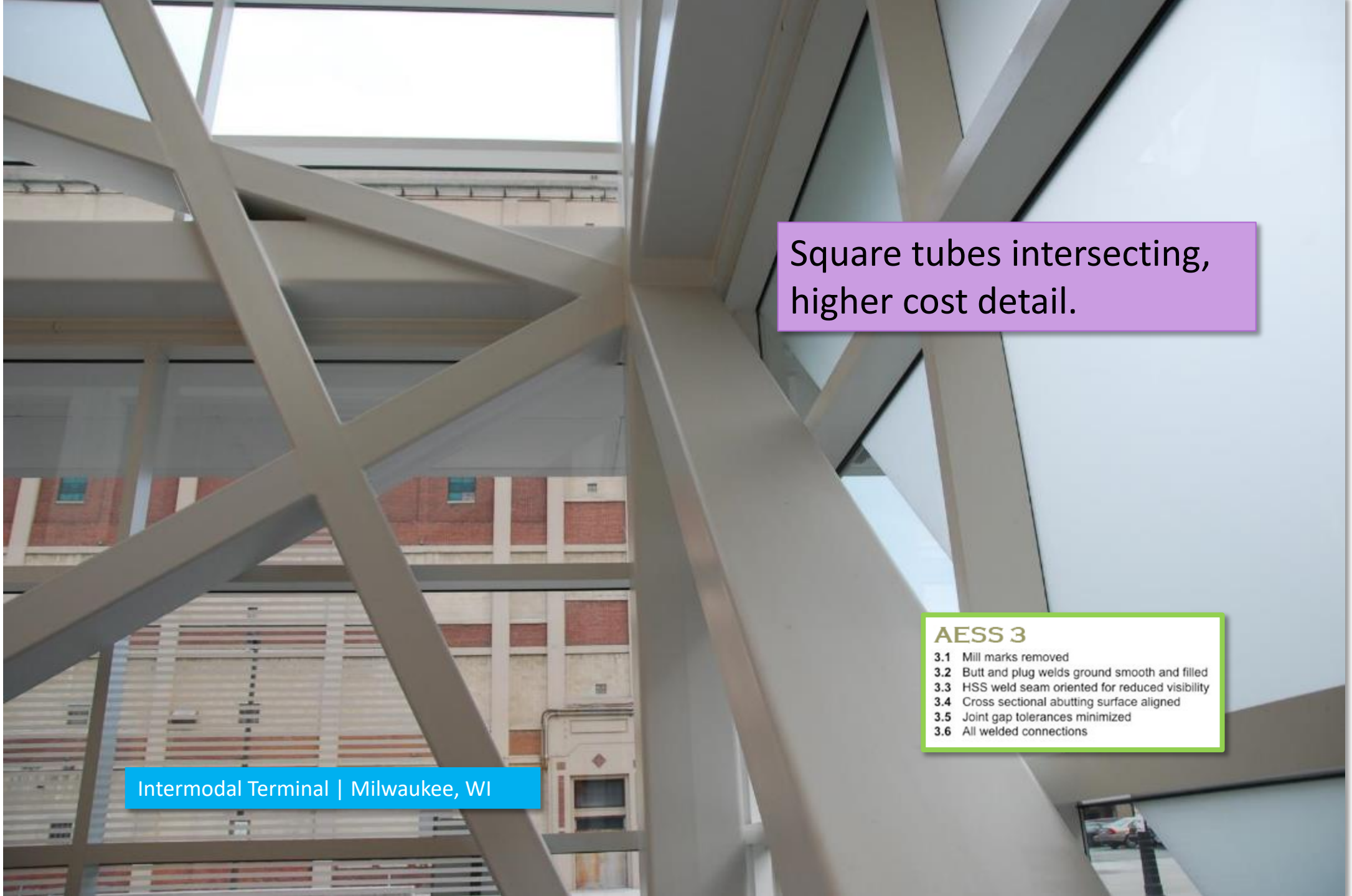
3.3 HSS weld seam oriented for reduced visibility
3.4 Cross sectional abutting surface aligned
3.5 Joint gap tolerances minimized
3.6 All welded connections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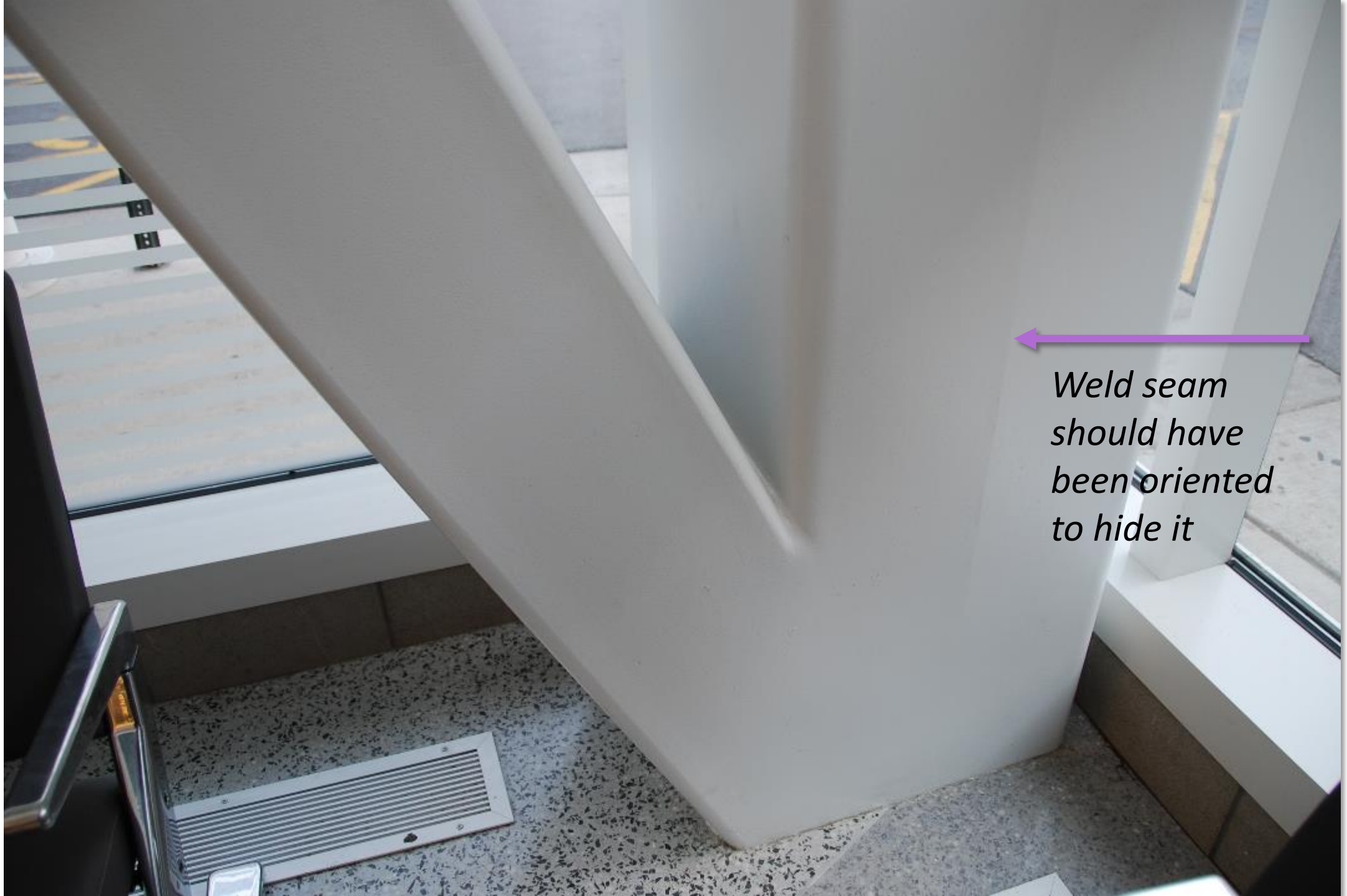
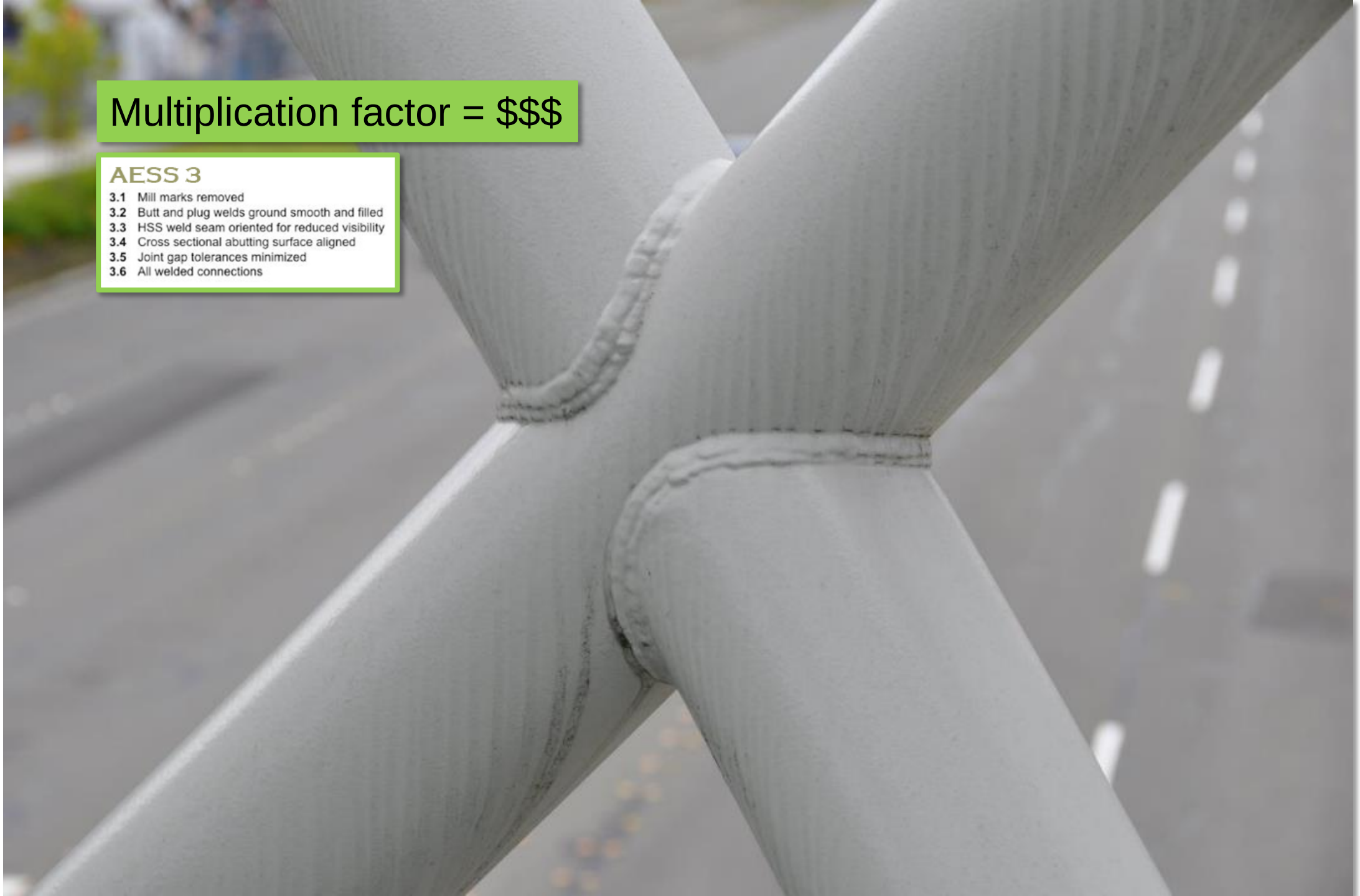
Intermodal Terminal | Milwaukee, WI


Weld seam
should have
been oriented
to hide it

Seattle Museum of Flight | Seattle, WA



Multiplication factor = $$$

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International Airport | Beijing, China


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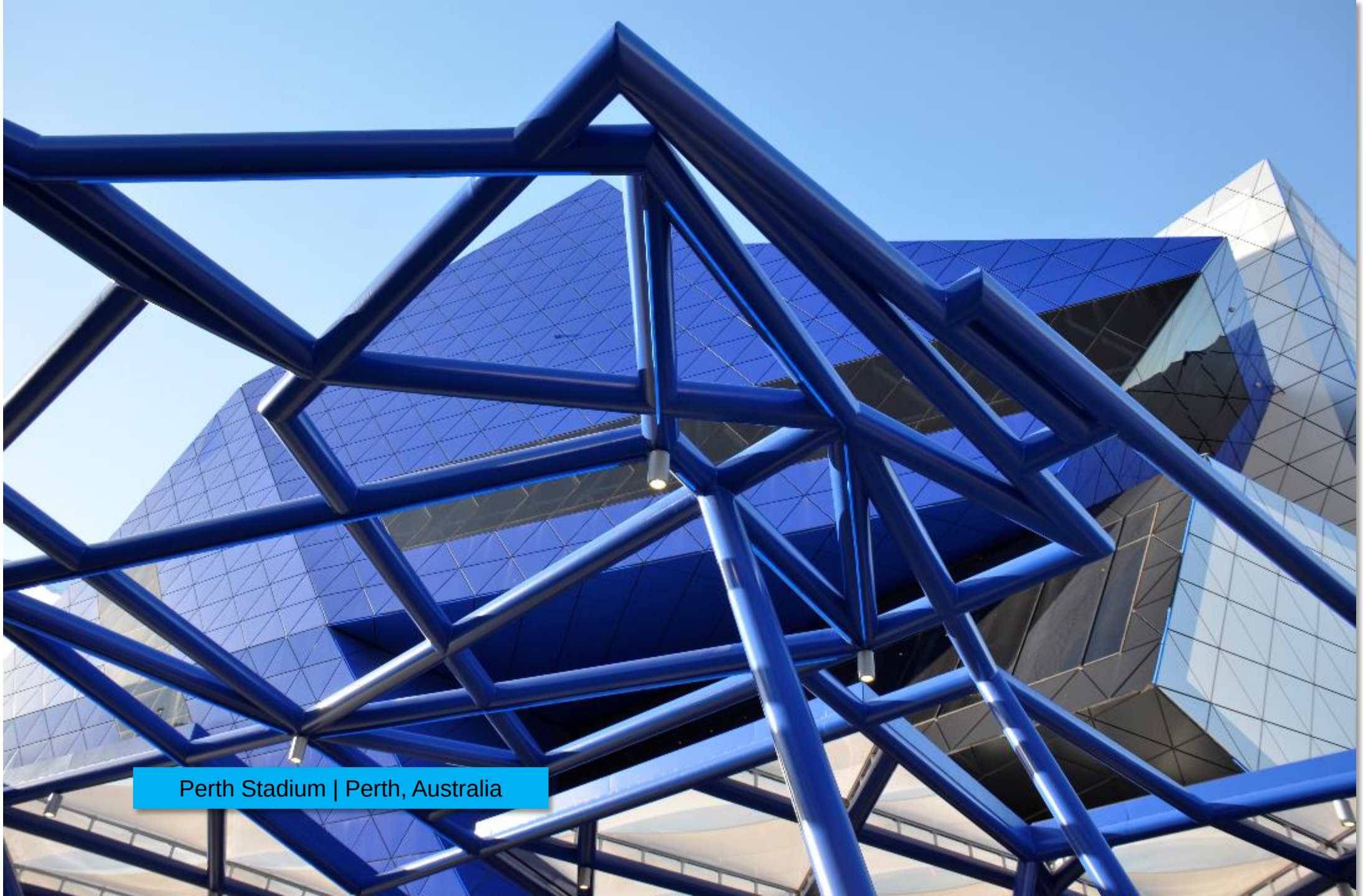
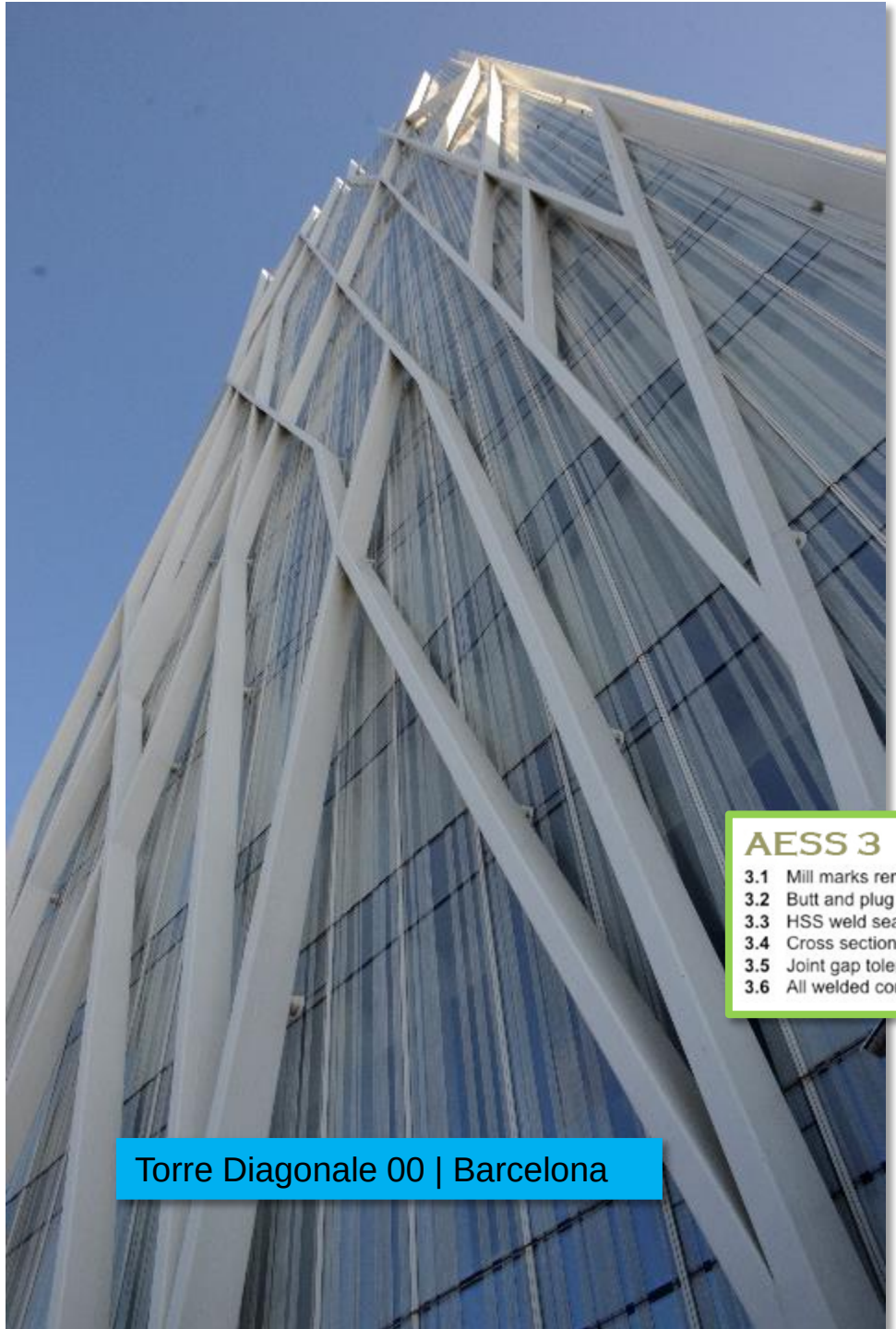
An alternate to the crotch detail requiring weld remediation.


Perth Stadium | Perth, Australia


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



Torre Diagonale 00 | Barcelona

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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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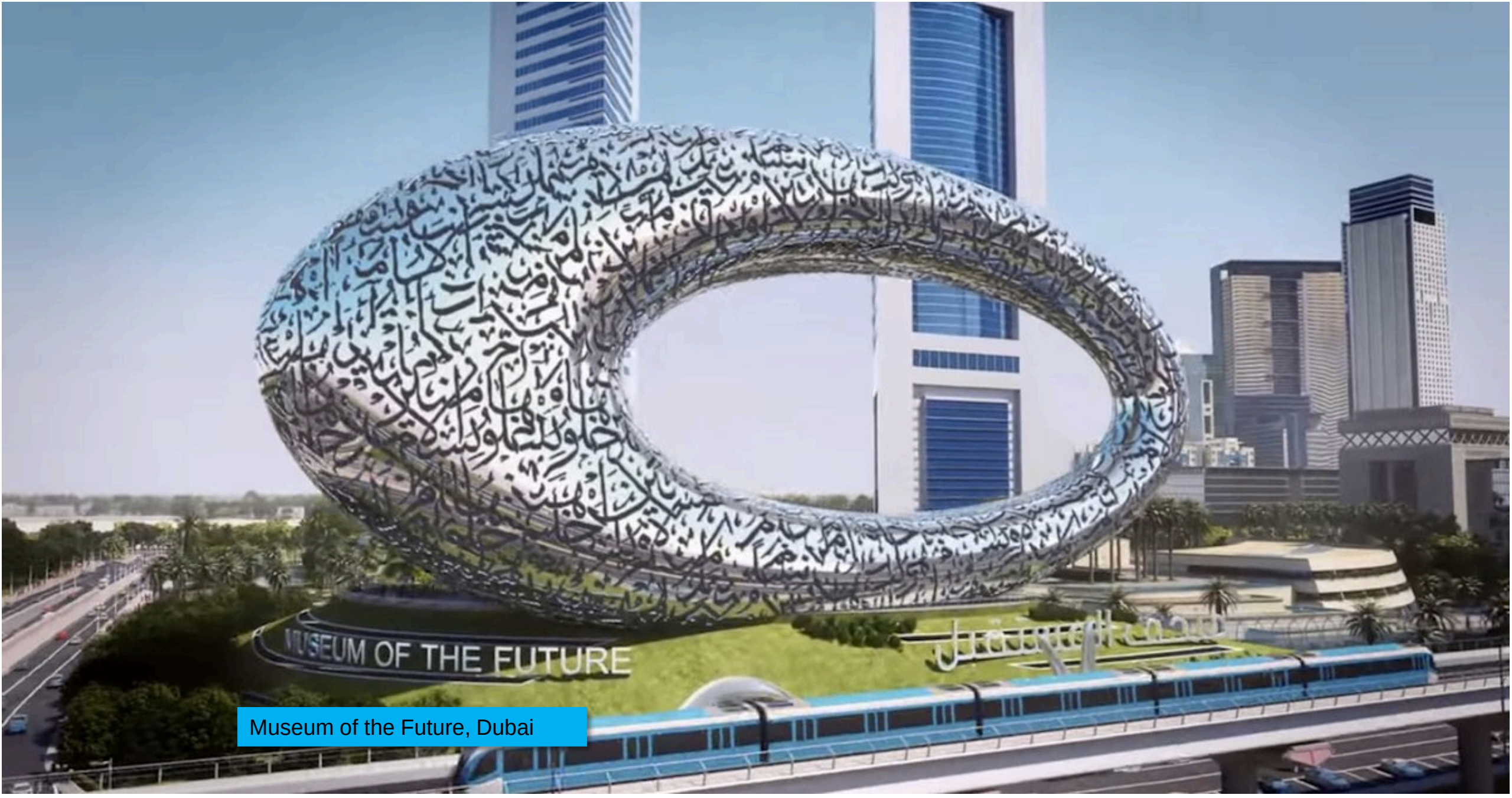
Much more difficult to grind a round surface well

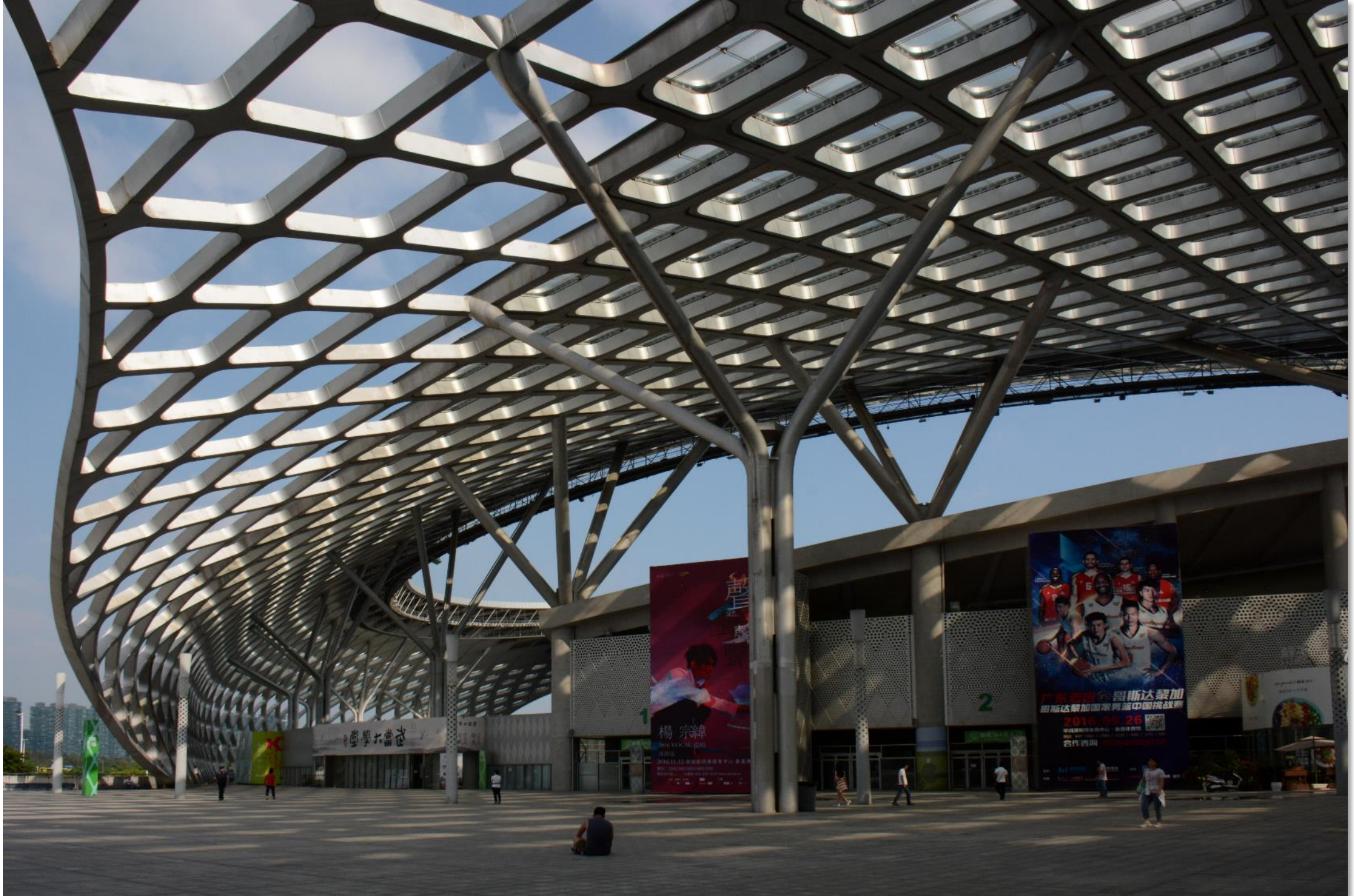
Economically driven connection design is looking for ways to avoid doing this for site splices.

- 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.

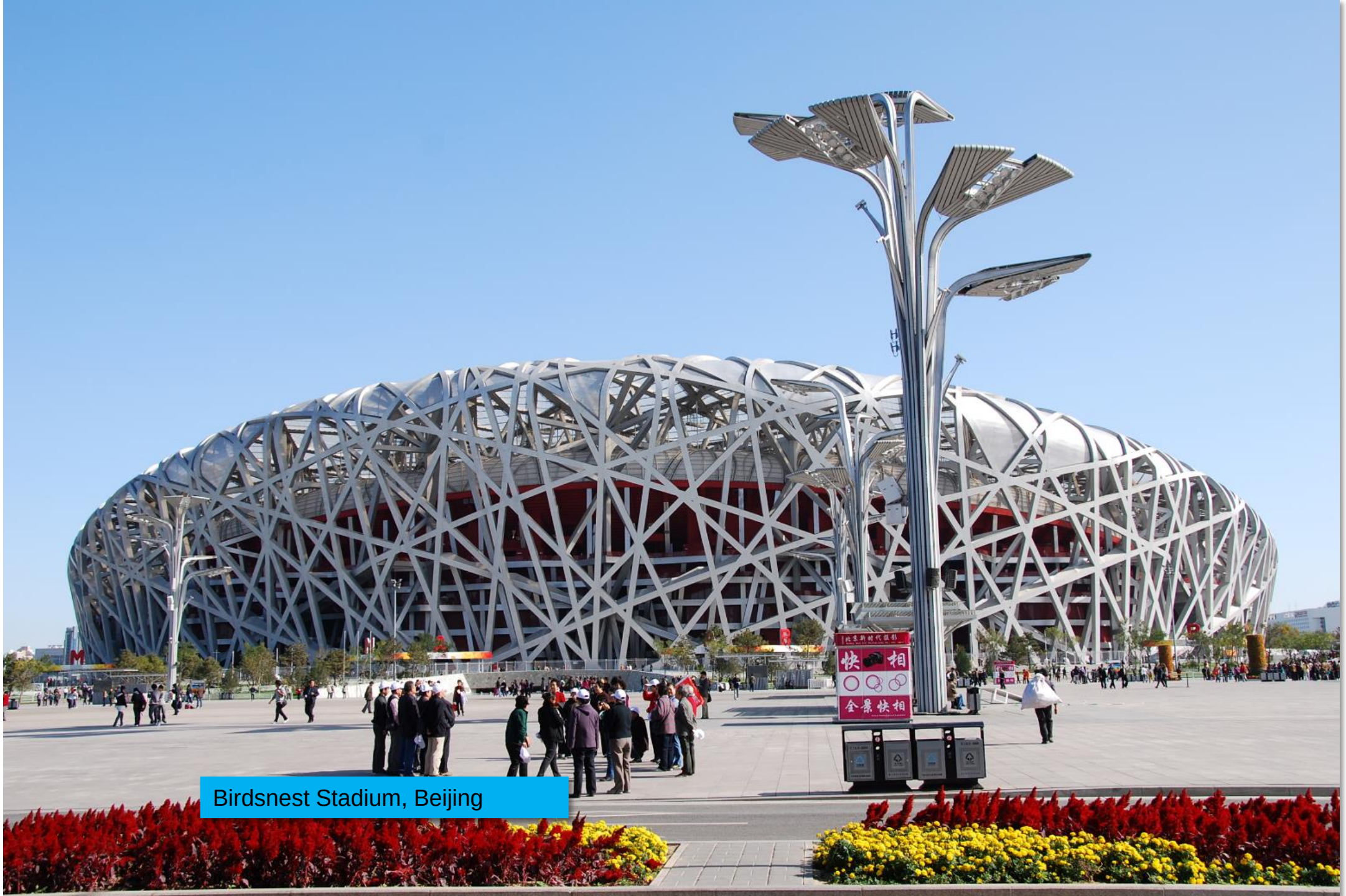


Museum of the Future, Dubai

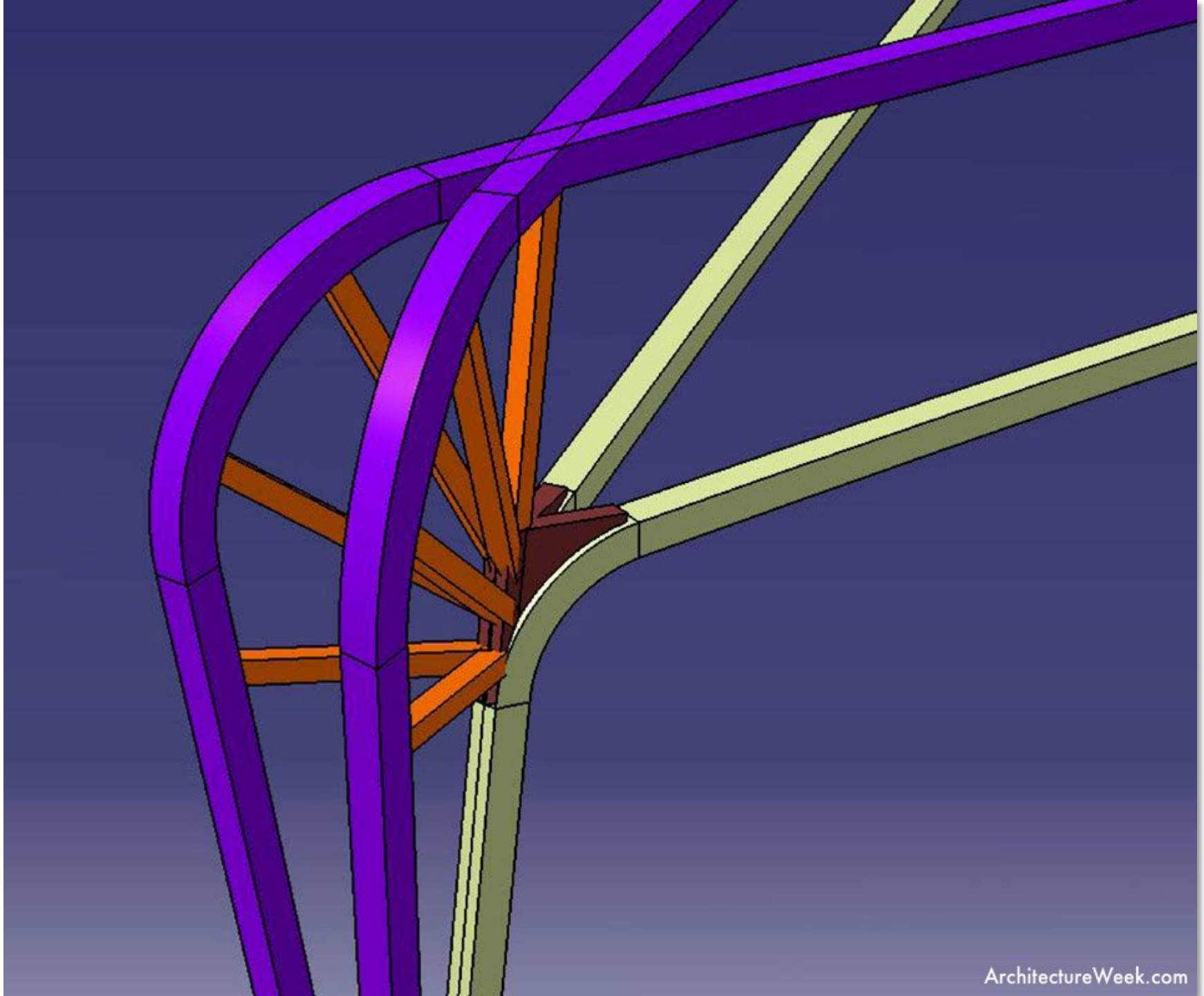
Shenzhen Bay Sports Complex


楊 宗緯
哥斯达黎加
哥斯达黎加国家男篮中国挑战赛
2016.08.26


开盘

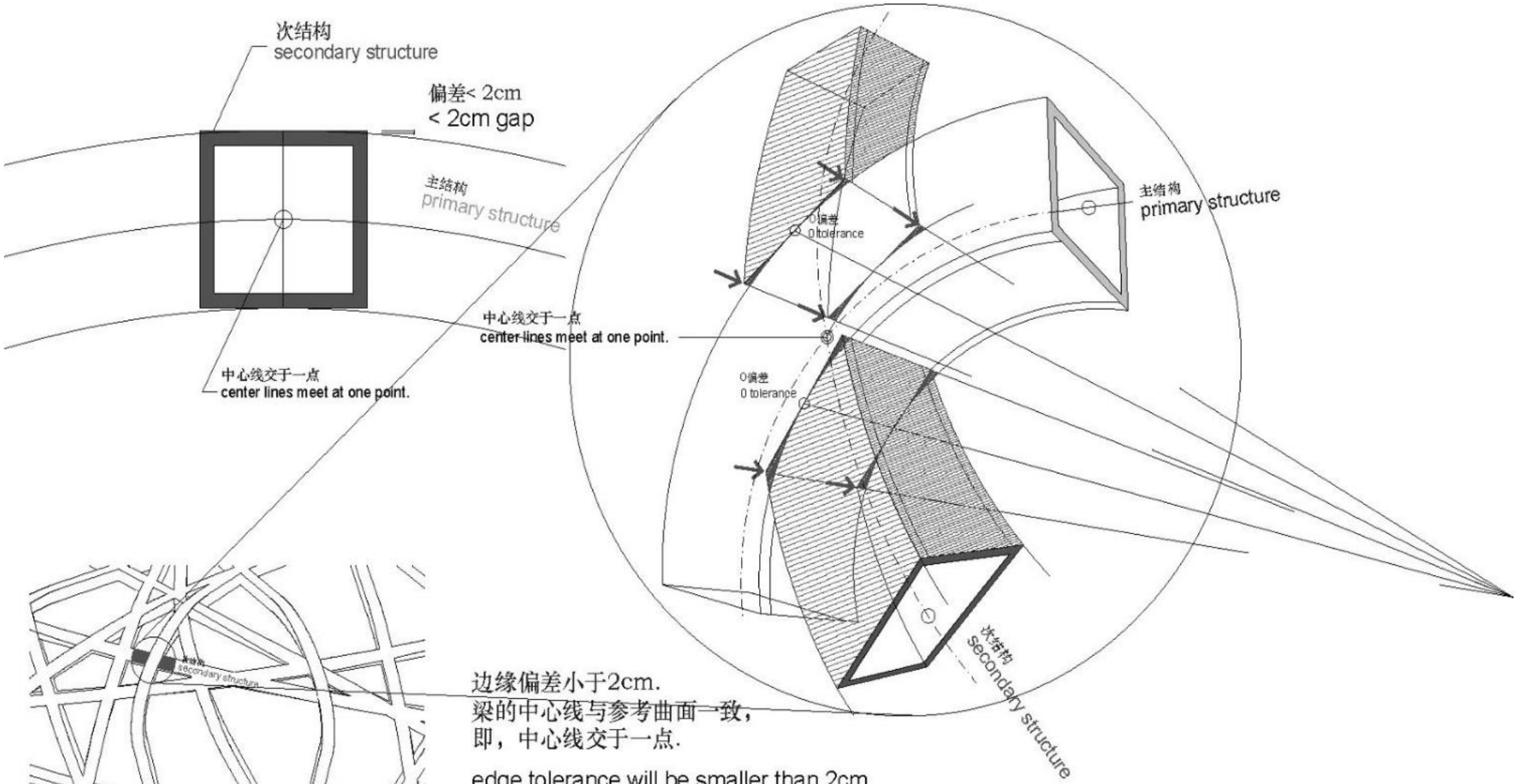


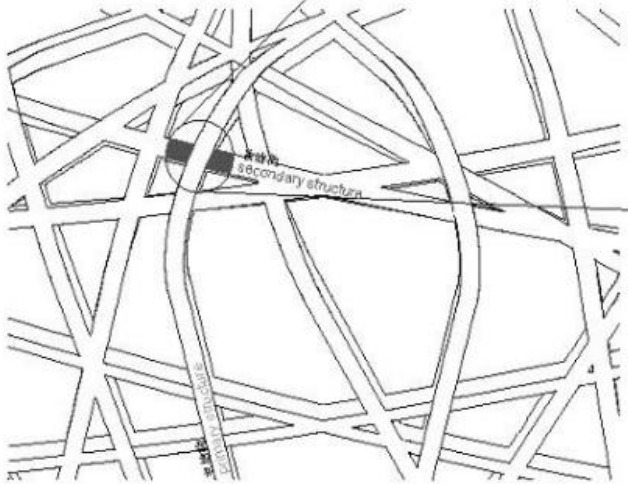
Birdsnest Stadium, Beijing


ArchitectureWeek.com


ArchitectureWeek.com


ArchitectureWeek.com



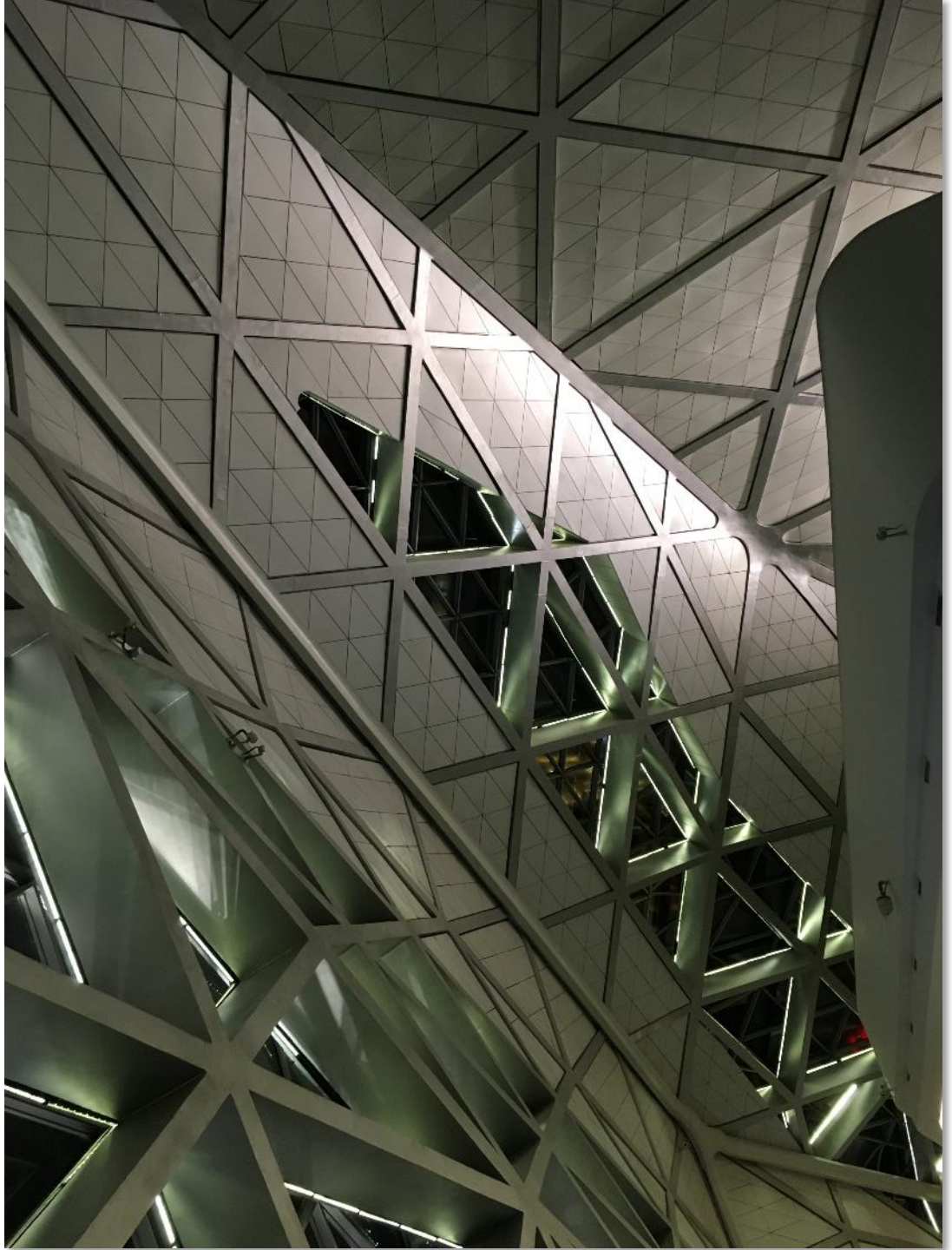


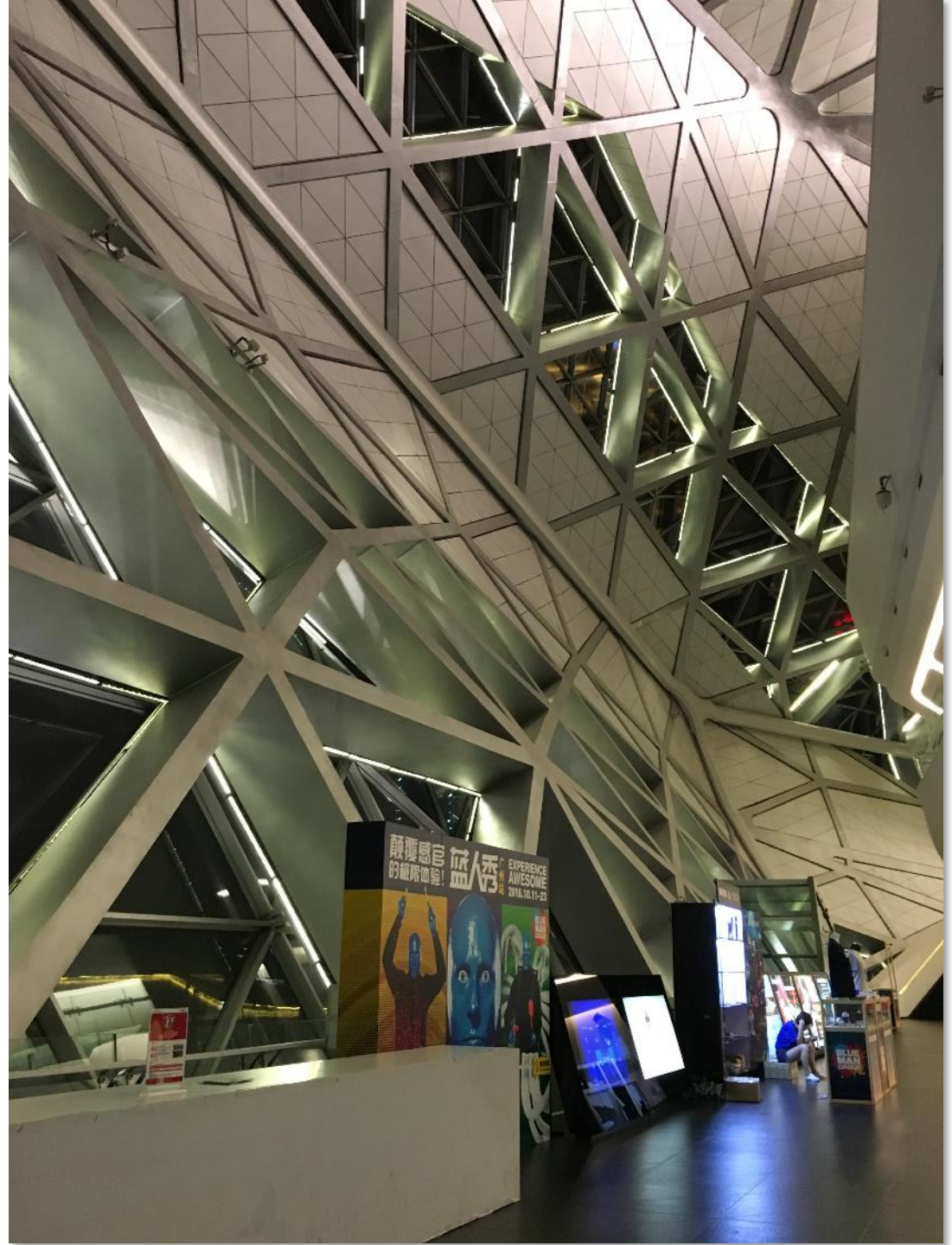
边缘偏差小于2cm.
梁的中心线与参考曲面一致，
即，中心线交于一点.

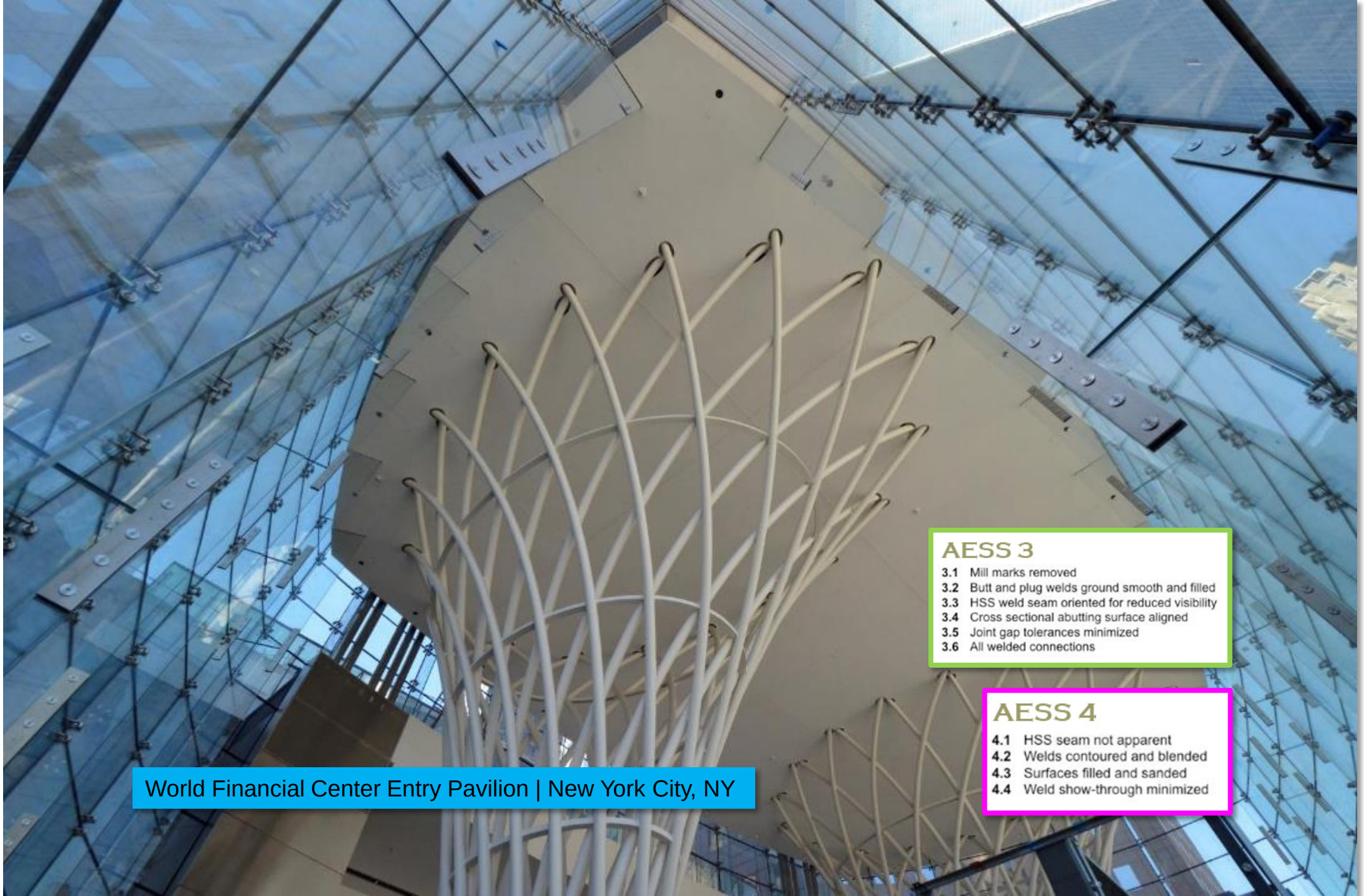
edge tolerance will be smaller than 2cm.
the center line of the beams have to follow the reference curved surface.
ie. center lines cross at one point.

Guangzhou Opera House | Zaha Hadid


安全通道




顛覆感官
的極限體驗!
藍人秀
EXPERIENCE
AWESOME



World Financial Center Entry Pavilion | New York City, NY

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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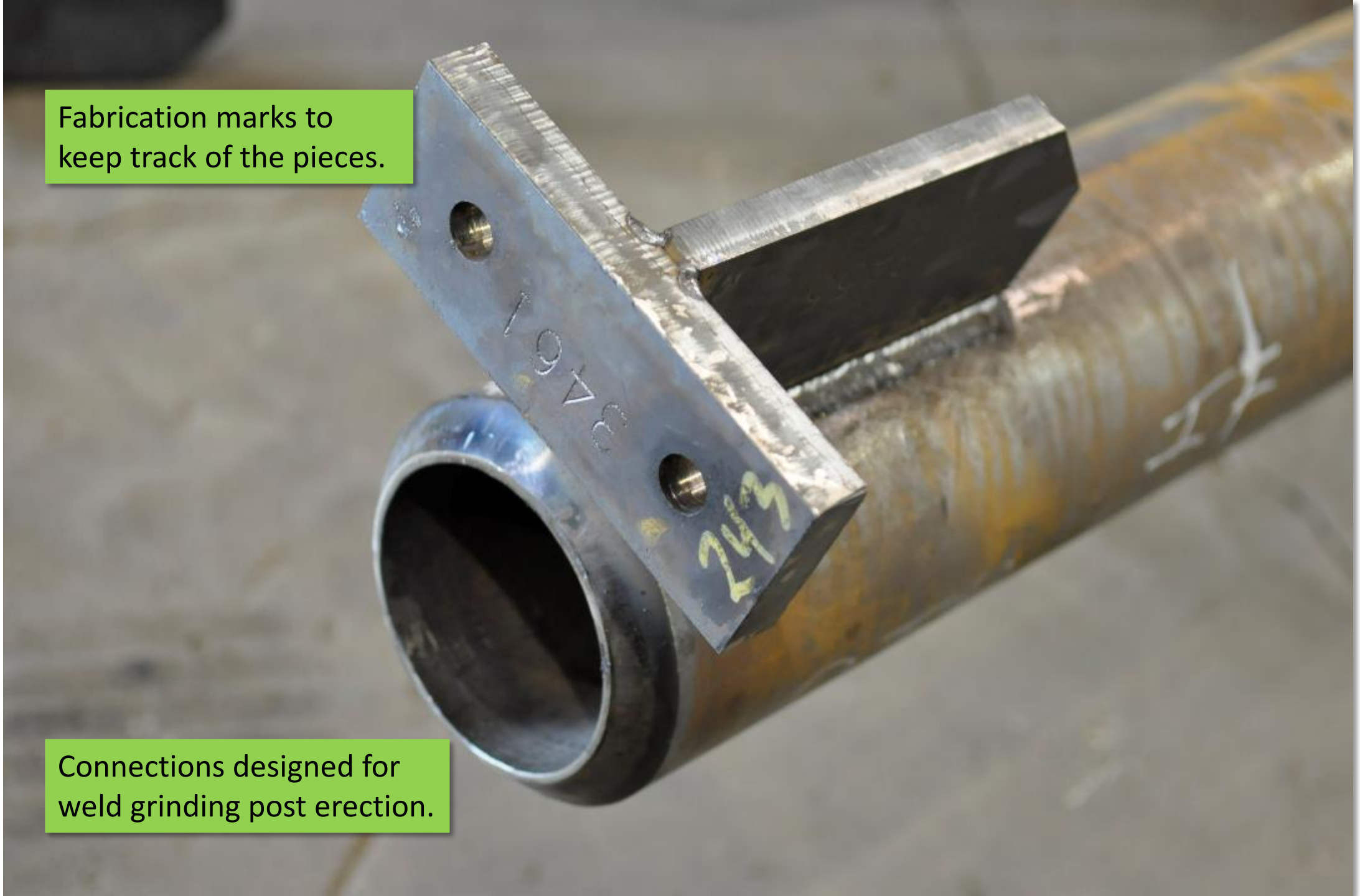
- **3.5** Joint gap tolerances minimized
- **3.6** All welded connections

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


Maximum shop fabrication!

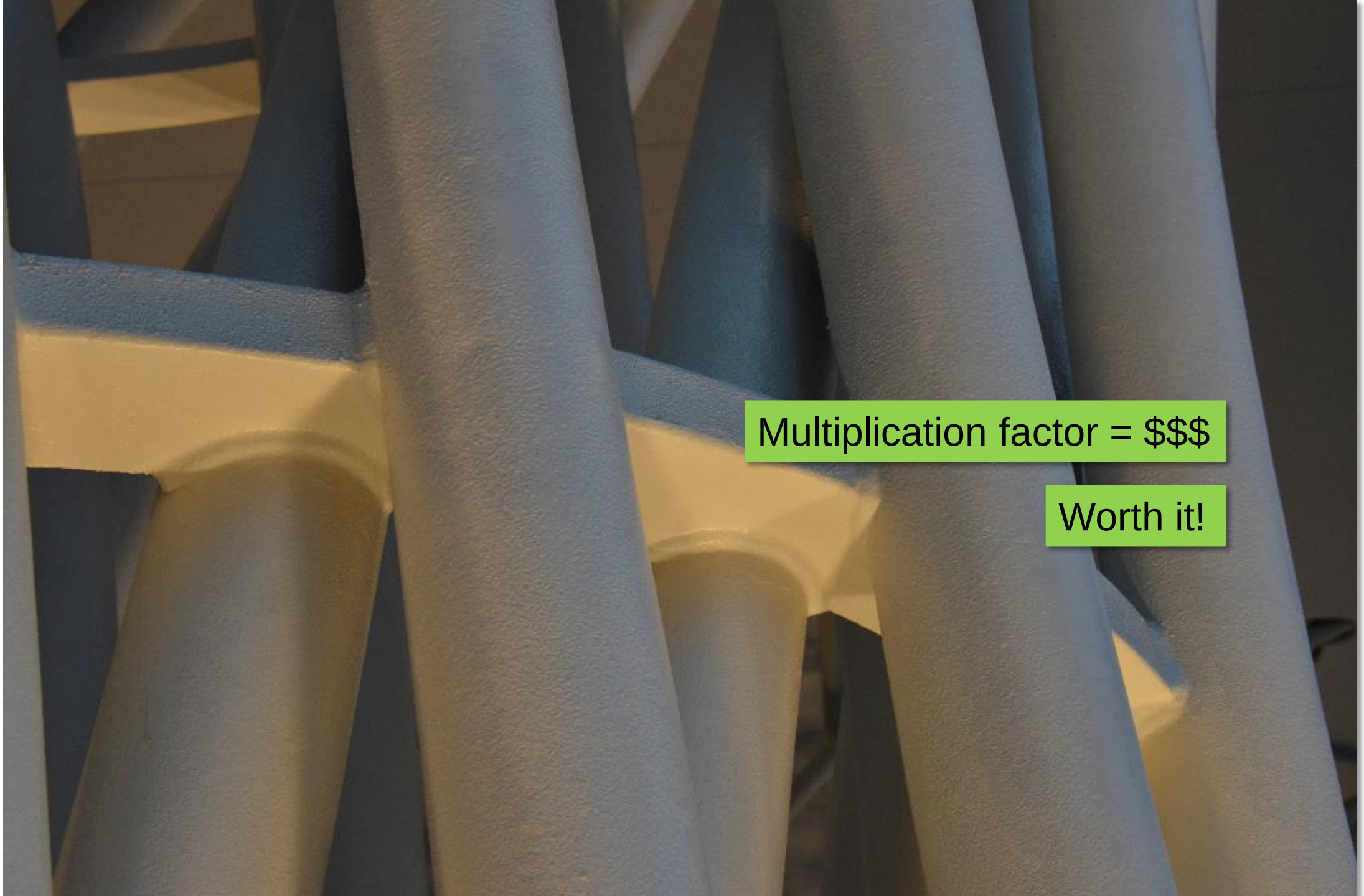

Access for welding between the tubes was very tight, but doable.
Temporary connectors will need to be removed and remediated.

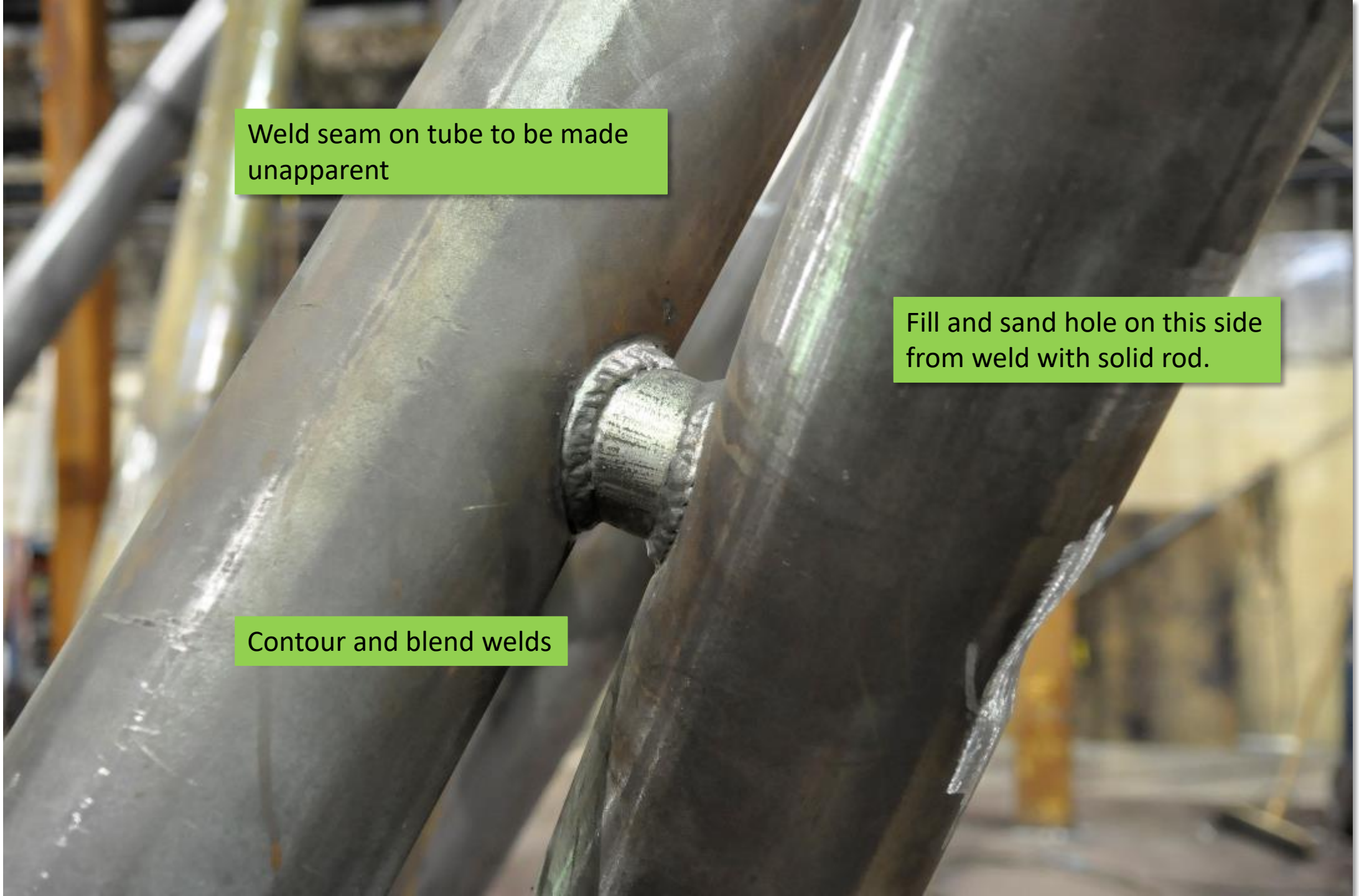

Fabrication marks to keep track of the pieces.
Connections designed for weld grinding post erection.

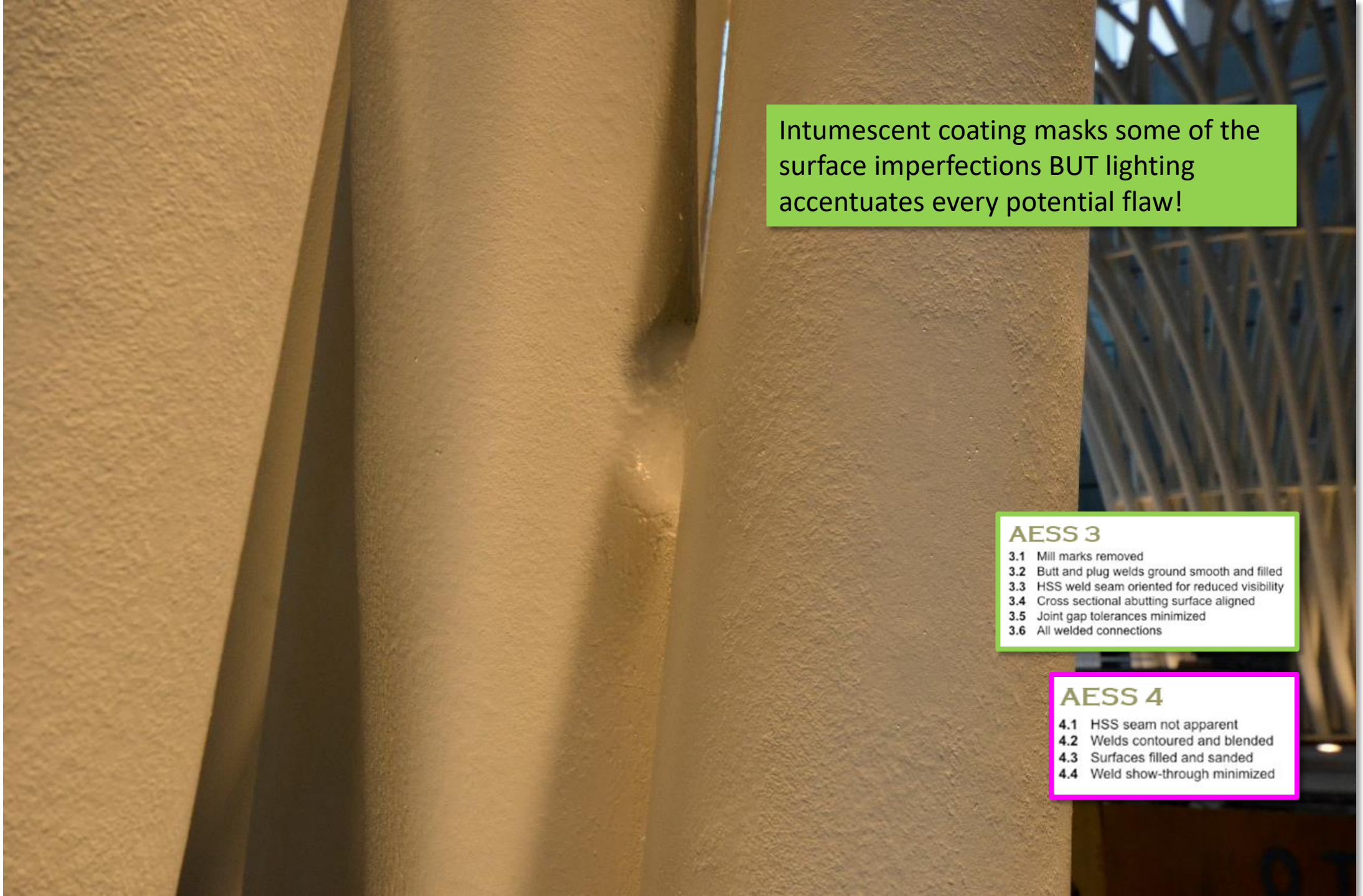

Alignment is super critical in order to have 100% smooth connections post weld grinding.


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


EK
EJ
EI
IF
IG
UT ok
Multiplication factor = $$$


Multiplication factor = $$$
Worth it!


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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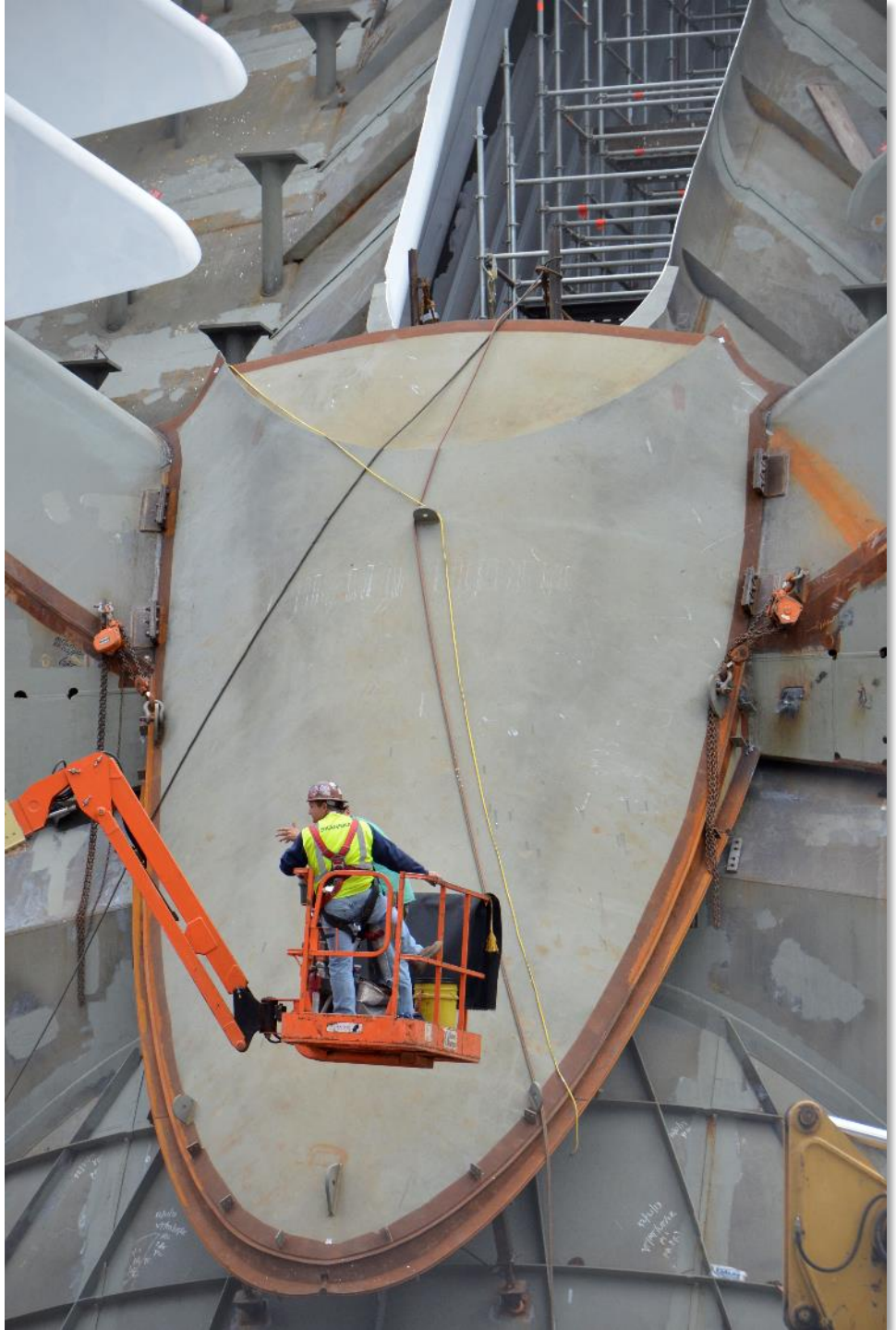
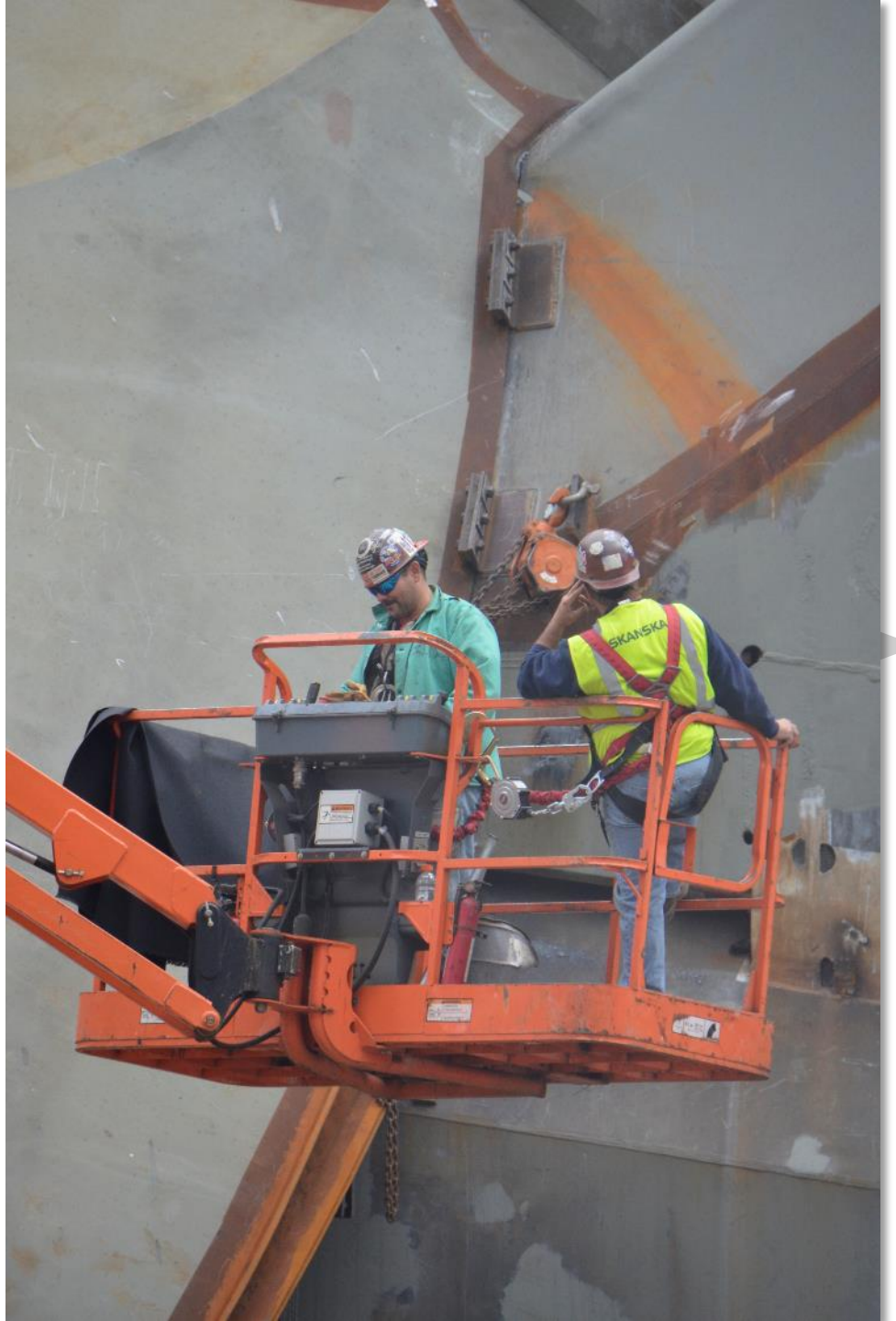
Santiago Calatrava
PATH Station | New York City


SKANSKA

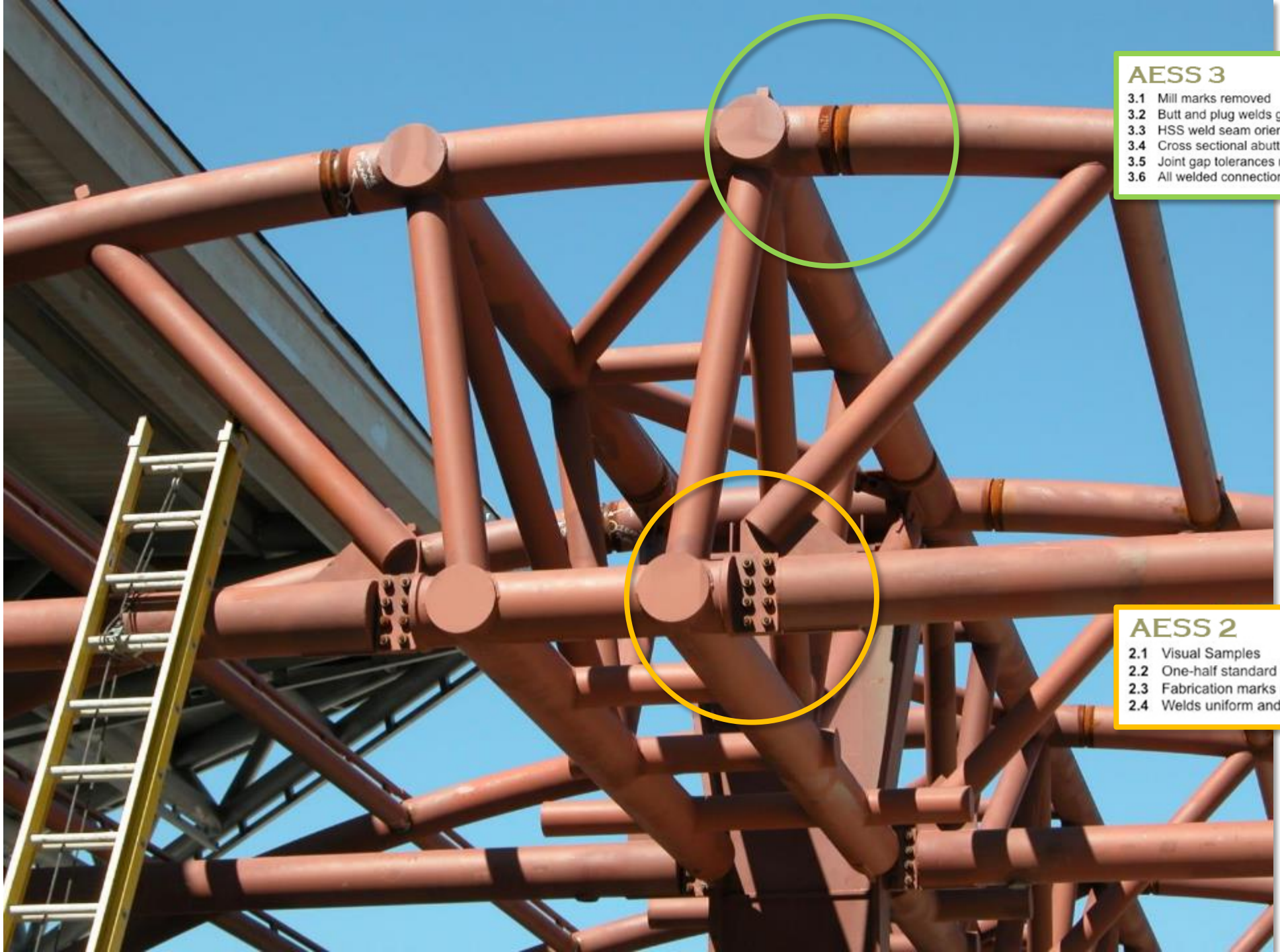



SKANSKA


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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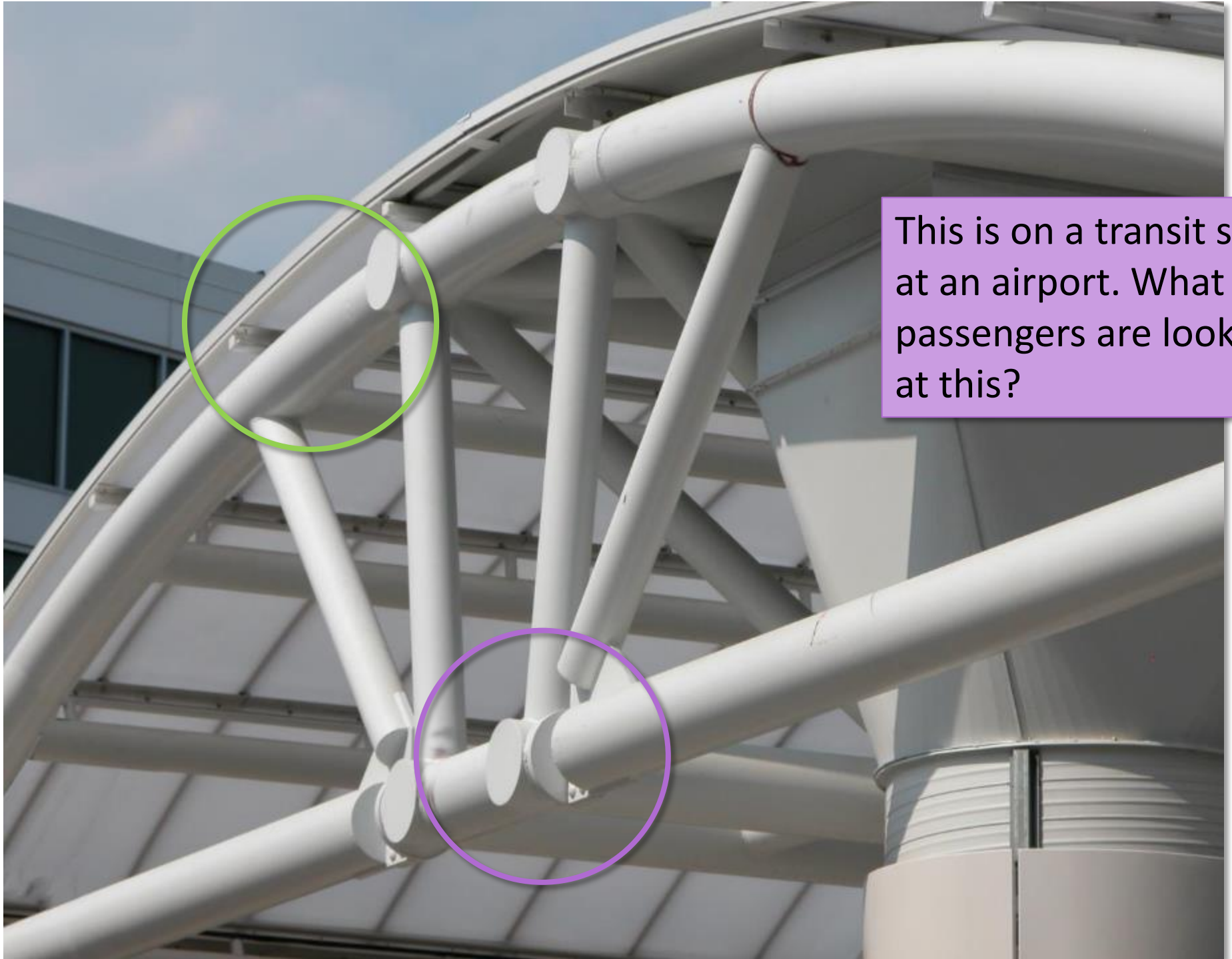
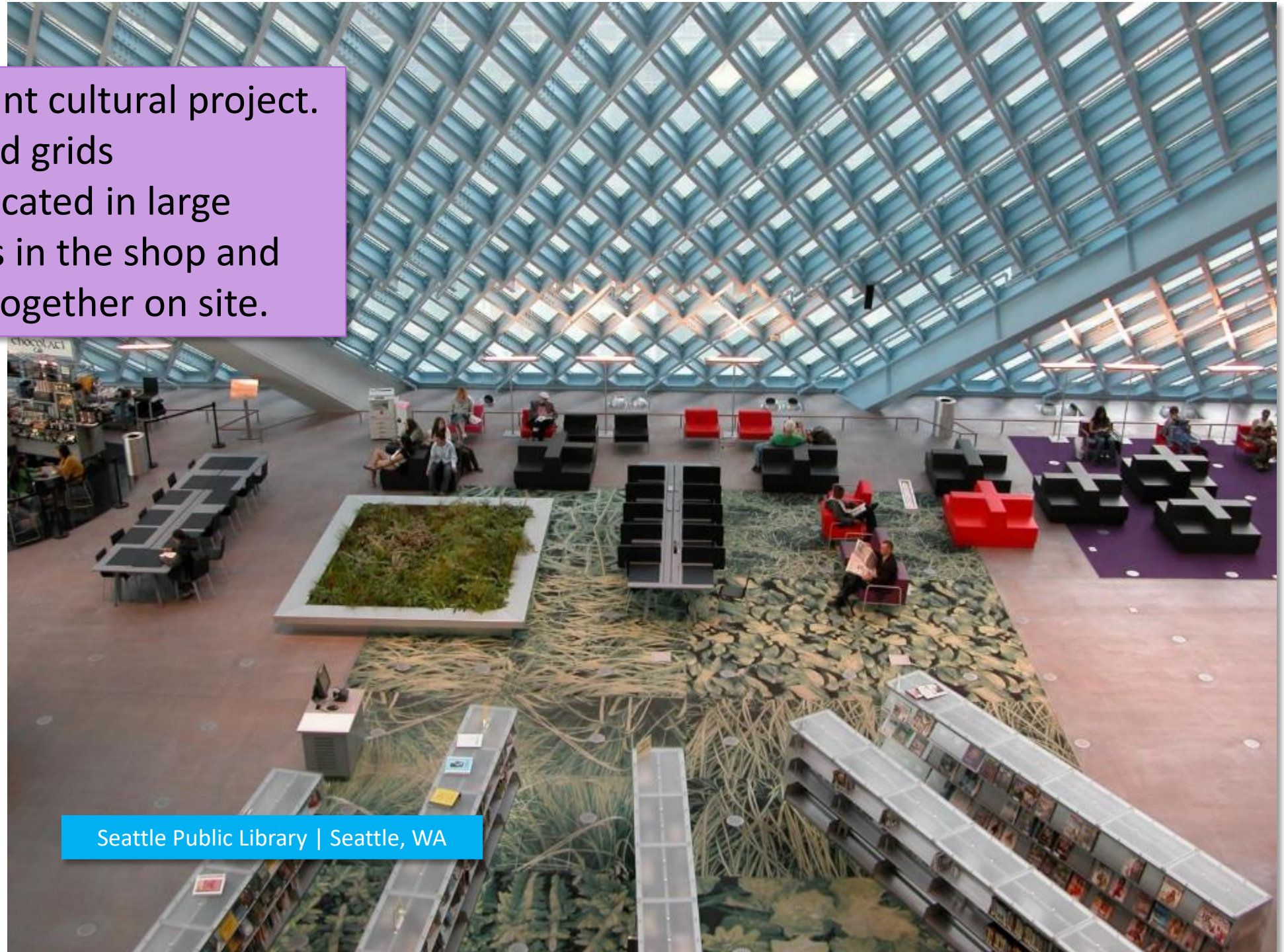


This is on a transit shelter at an airport. What passengers are looking up at this?

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



Seattle Public Library | Seattle, WA

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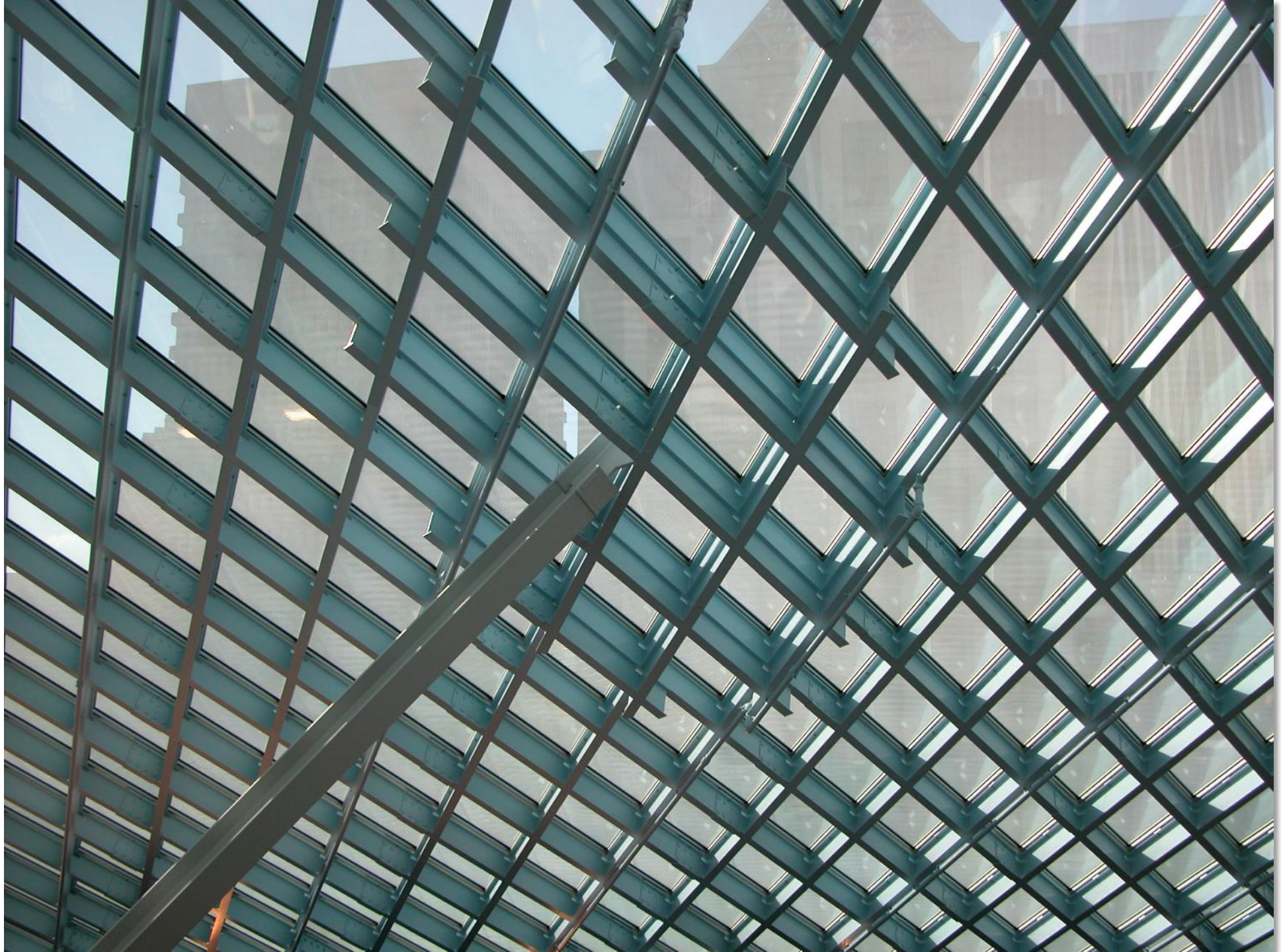
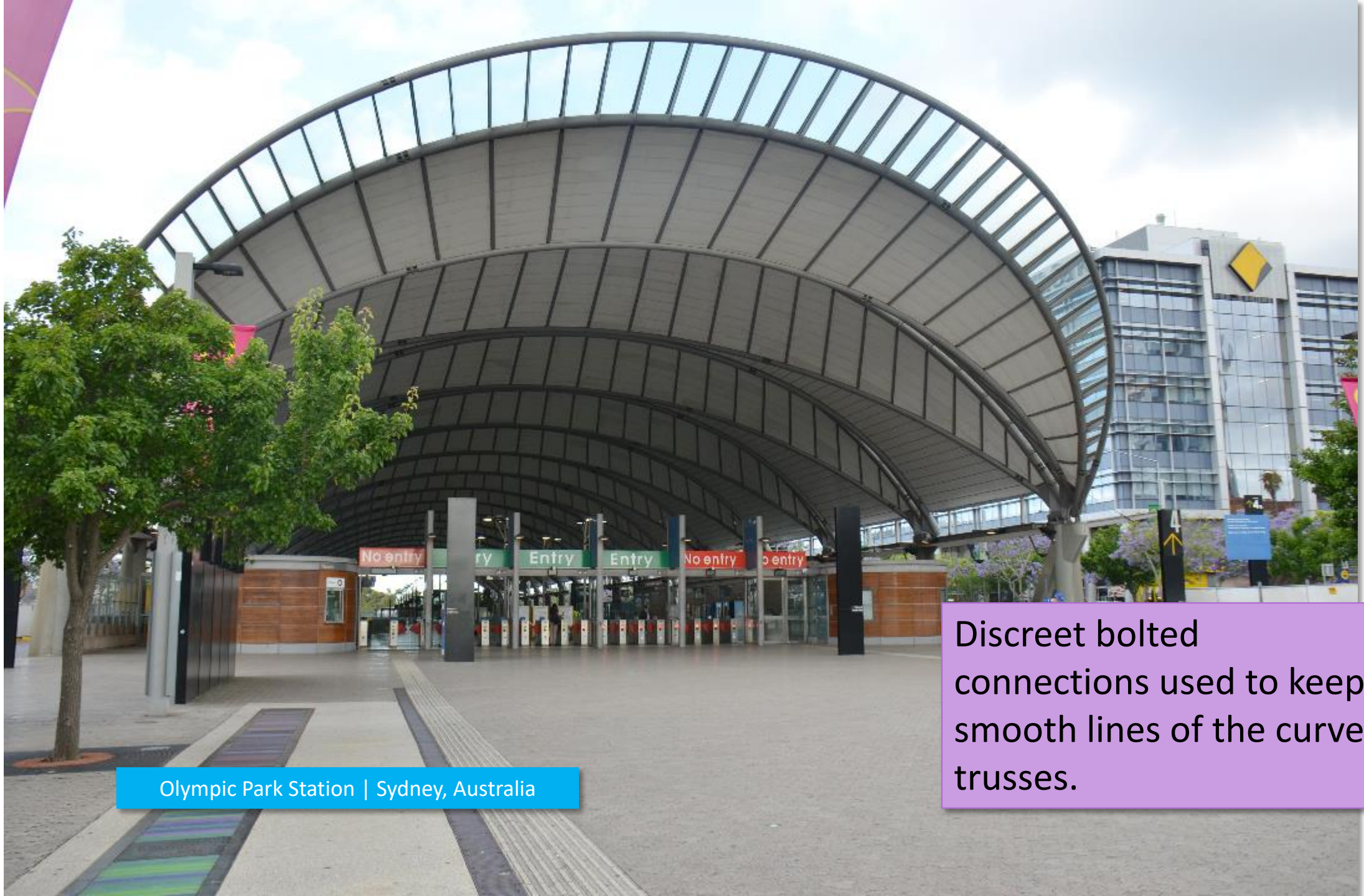
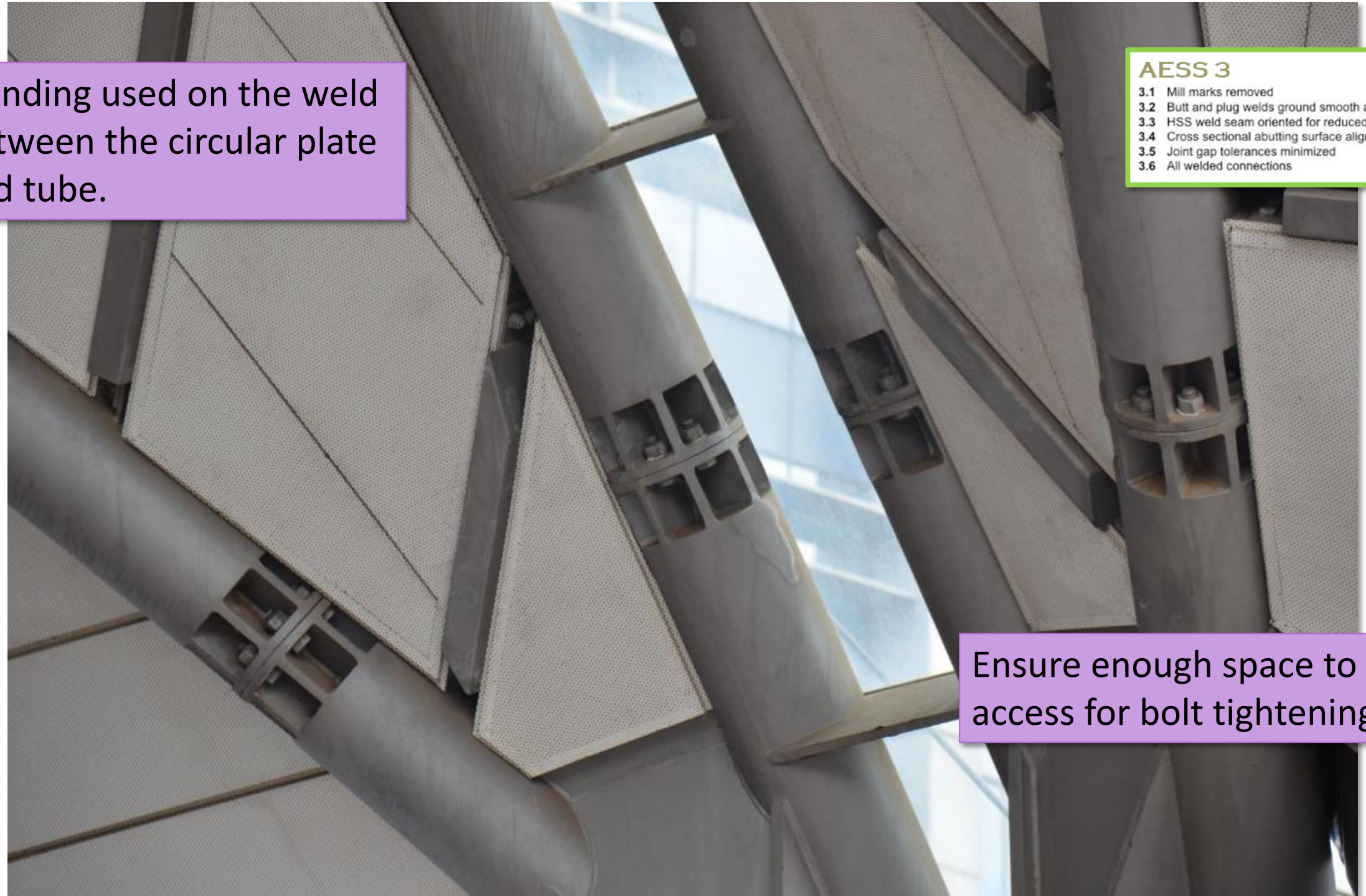




Olympic Park Station | Sydney, Australia

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



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

Ensure enough space to access for bolt tightening.

Office Building at Potsdamer Platz | Berlin, Germany

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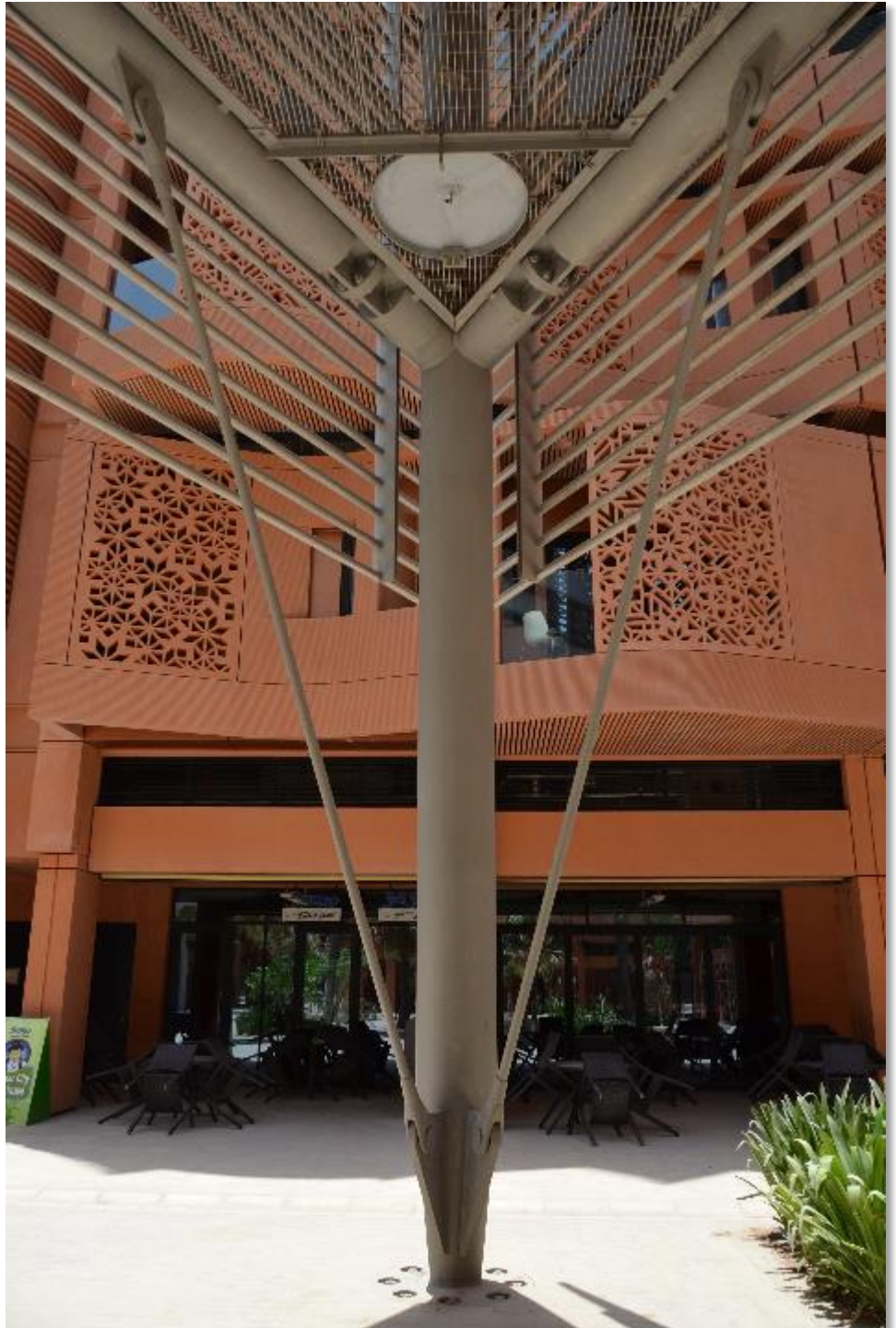
Renzo Piano
Art Institute of Chicago

Masdar City | Abu Dhabi, UAE



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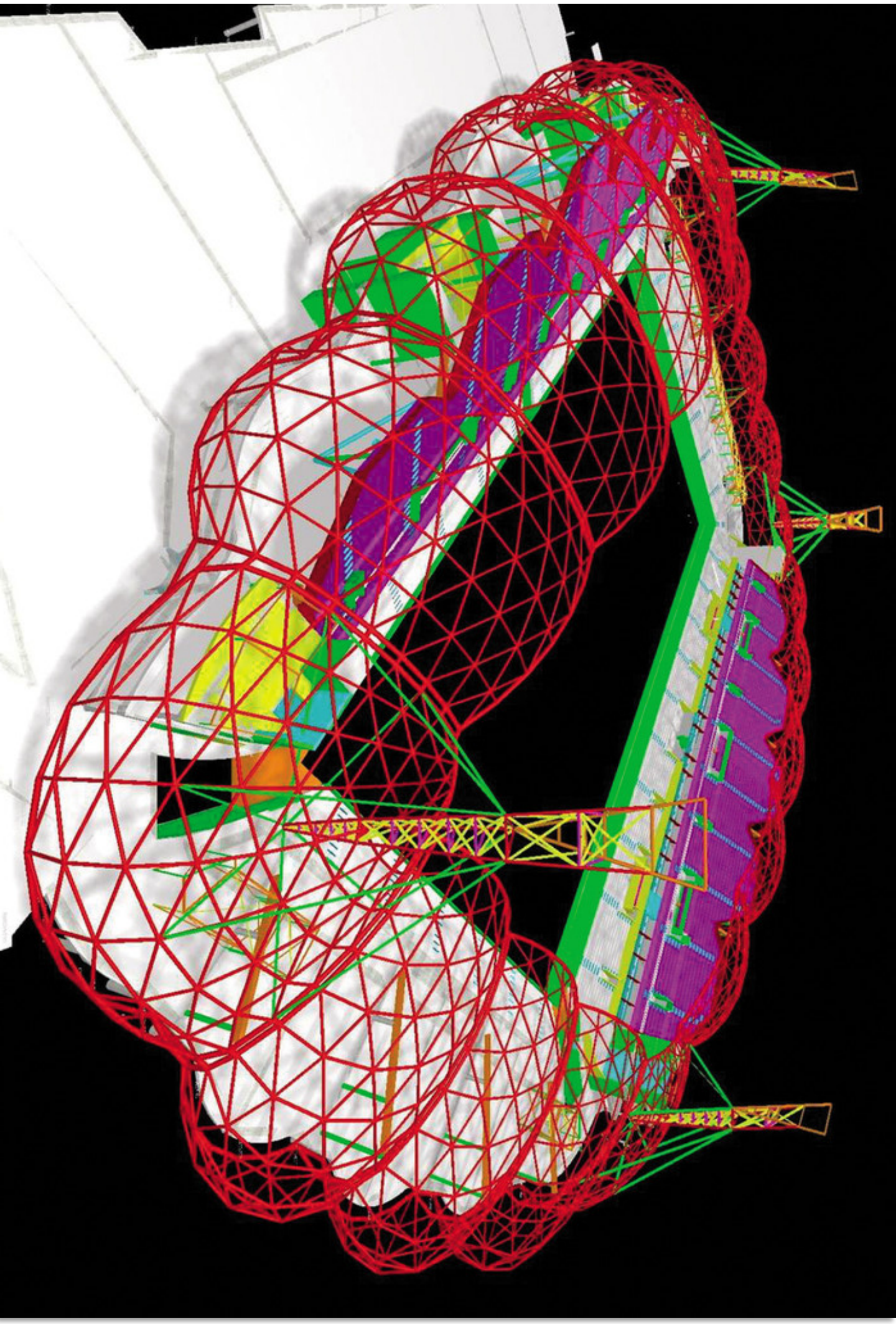
Melbourne Stadium
Gate
Gate

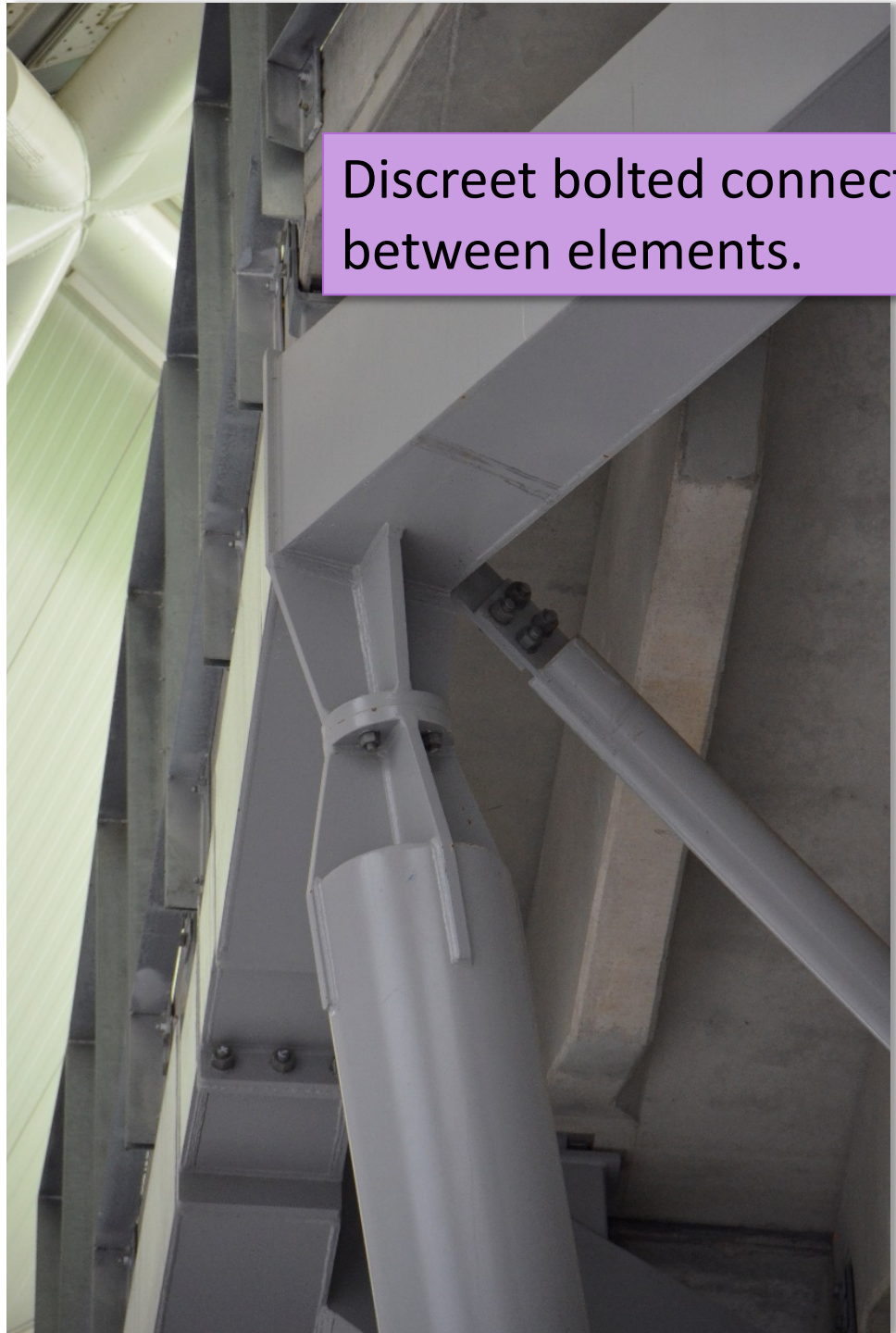
Image: Arup



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


FREE

viewing distance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BEST
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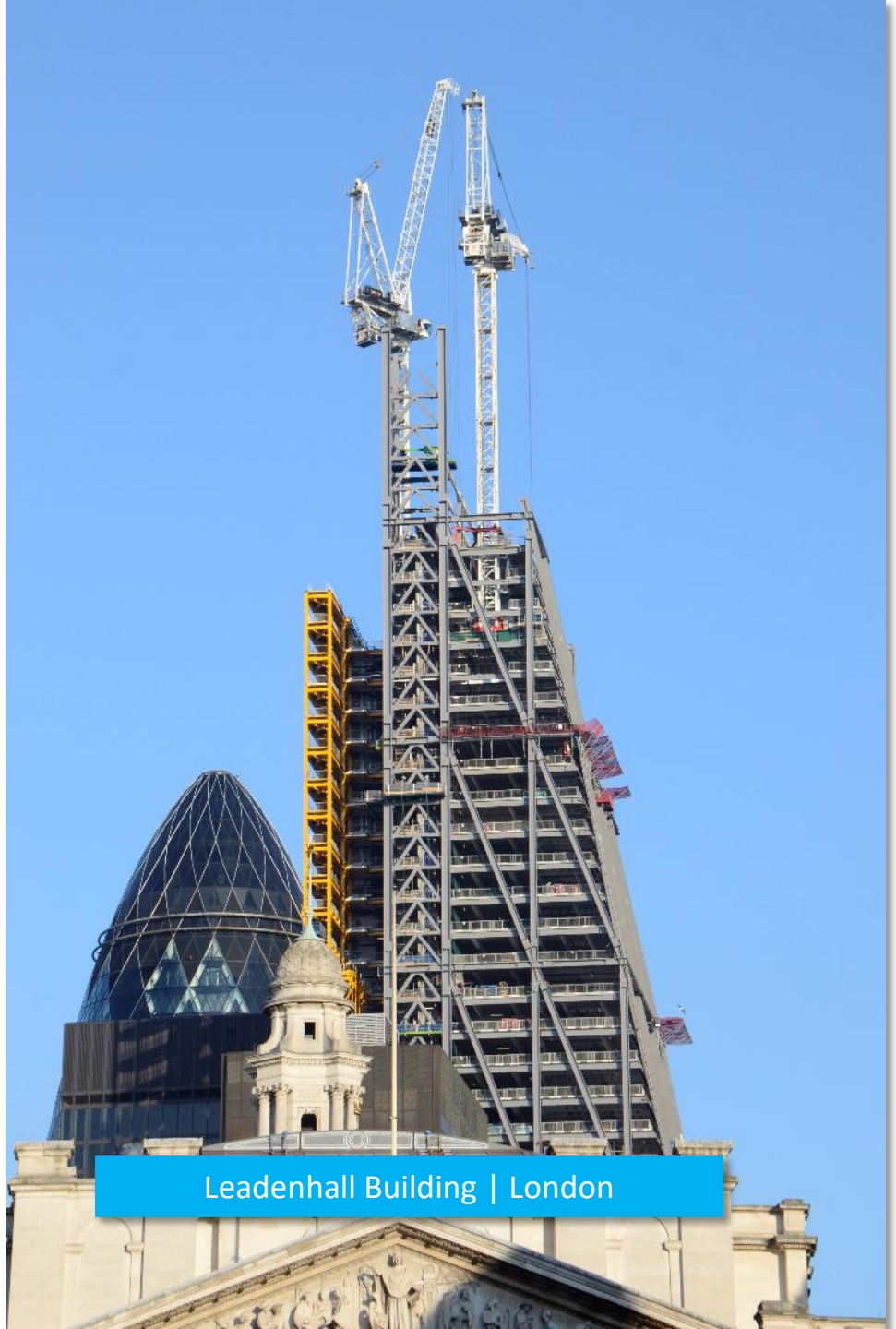
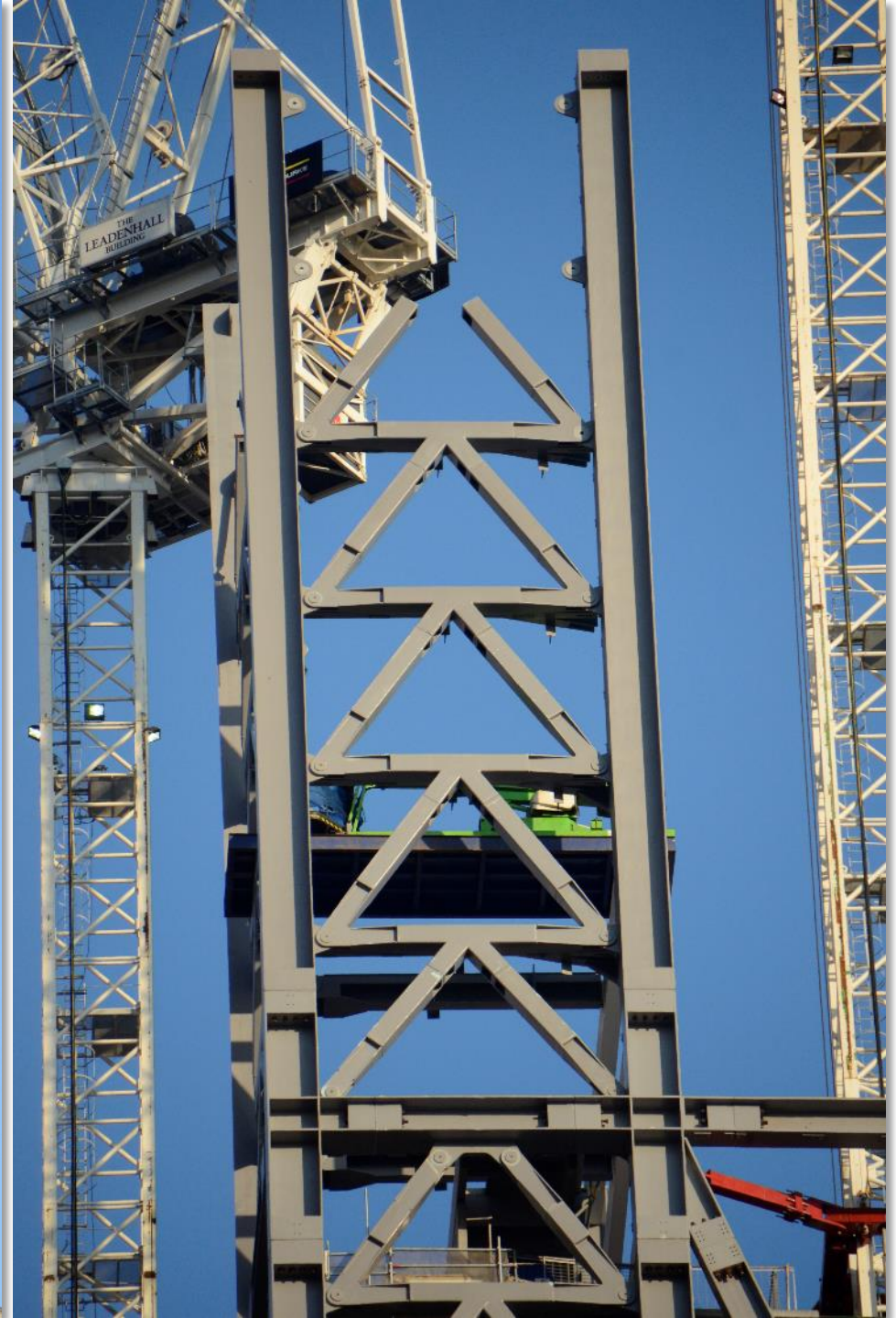
PRICE ON ALL
YOUR SPRING
CARNIVAL BETS
viewing distance


Discreet bolted connections
between elements.
Unremediated welds.

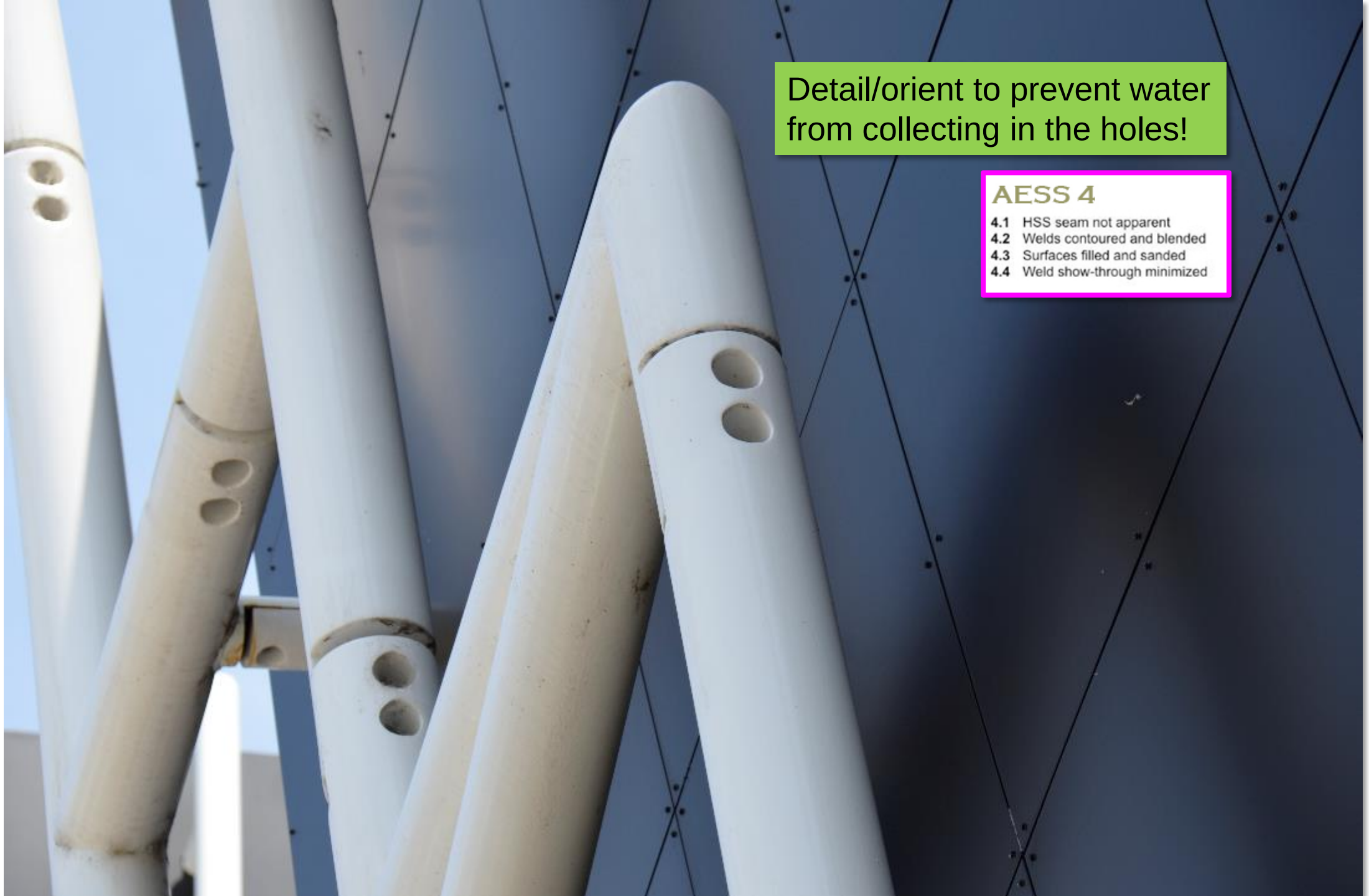


Leadenhall Building | London




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
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

AESS 4
4.1 HSS seam not apparent
4.2 Welds contoured and blended
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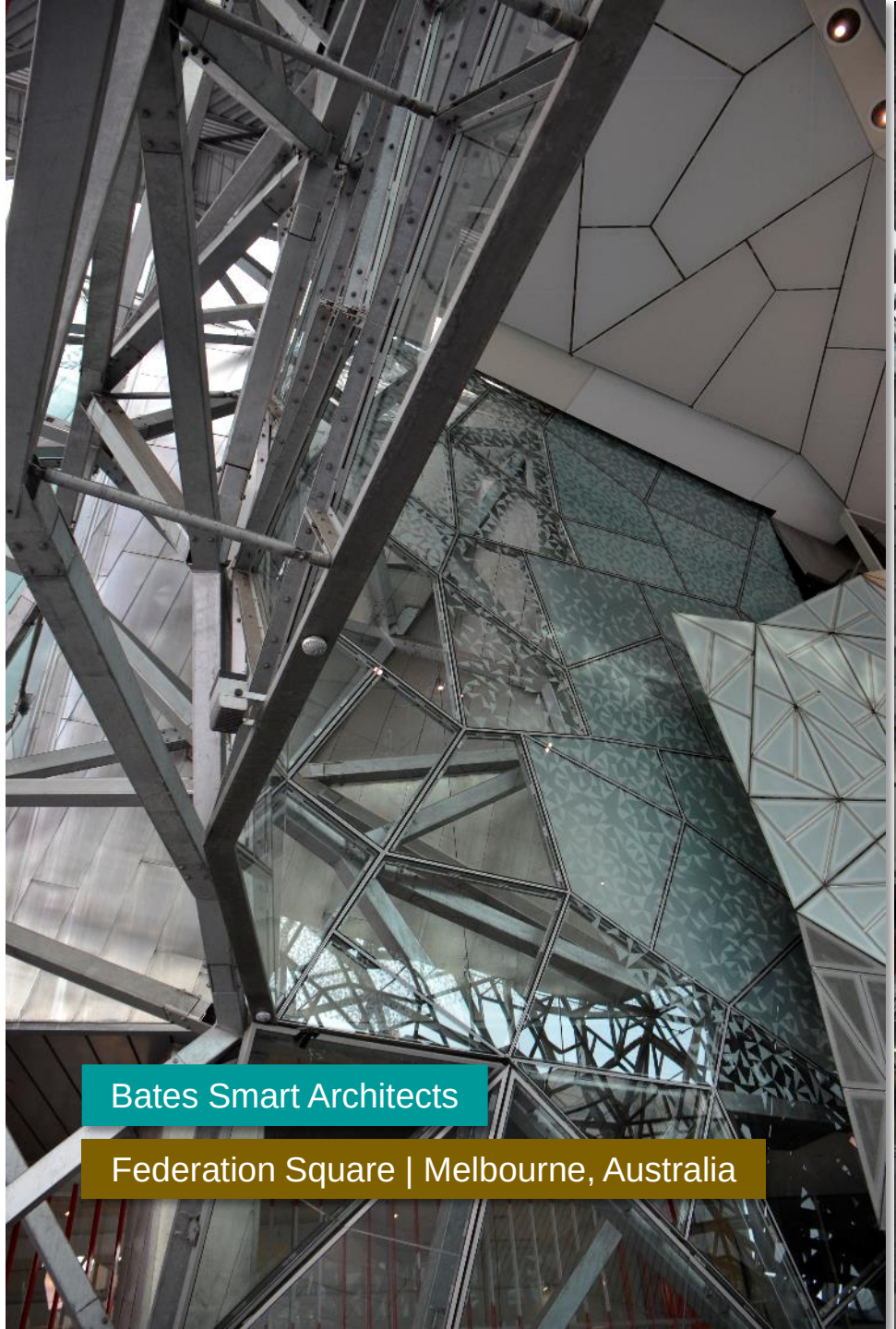
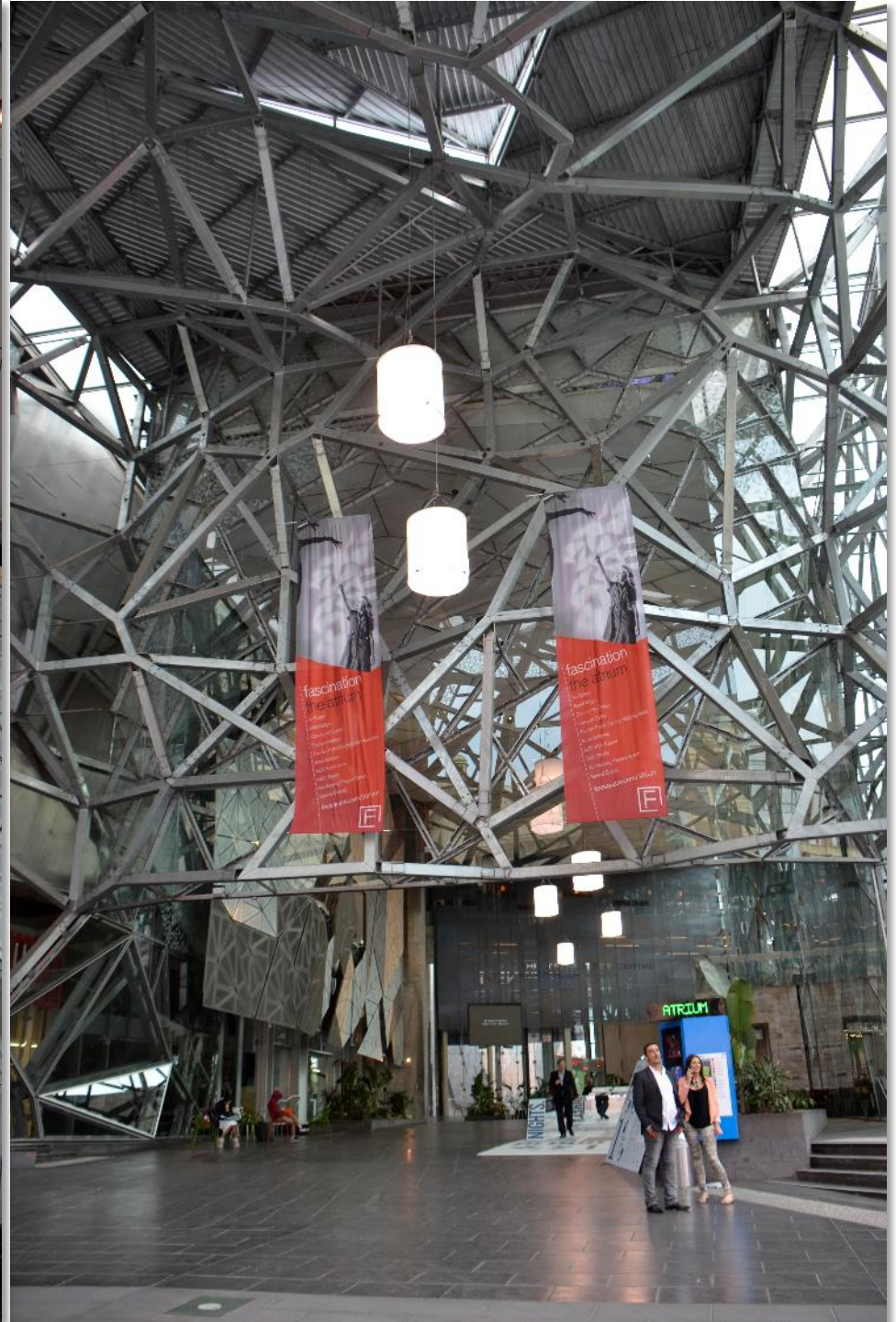
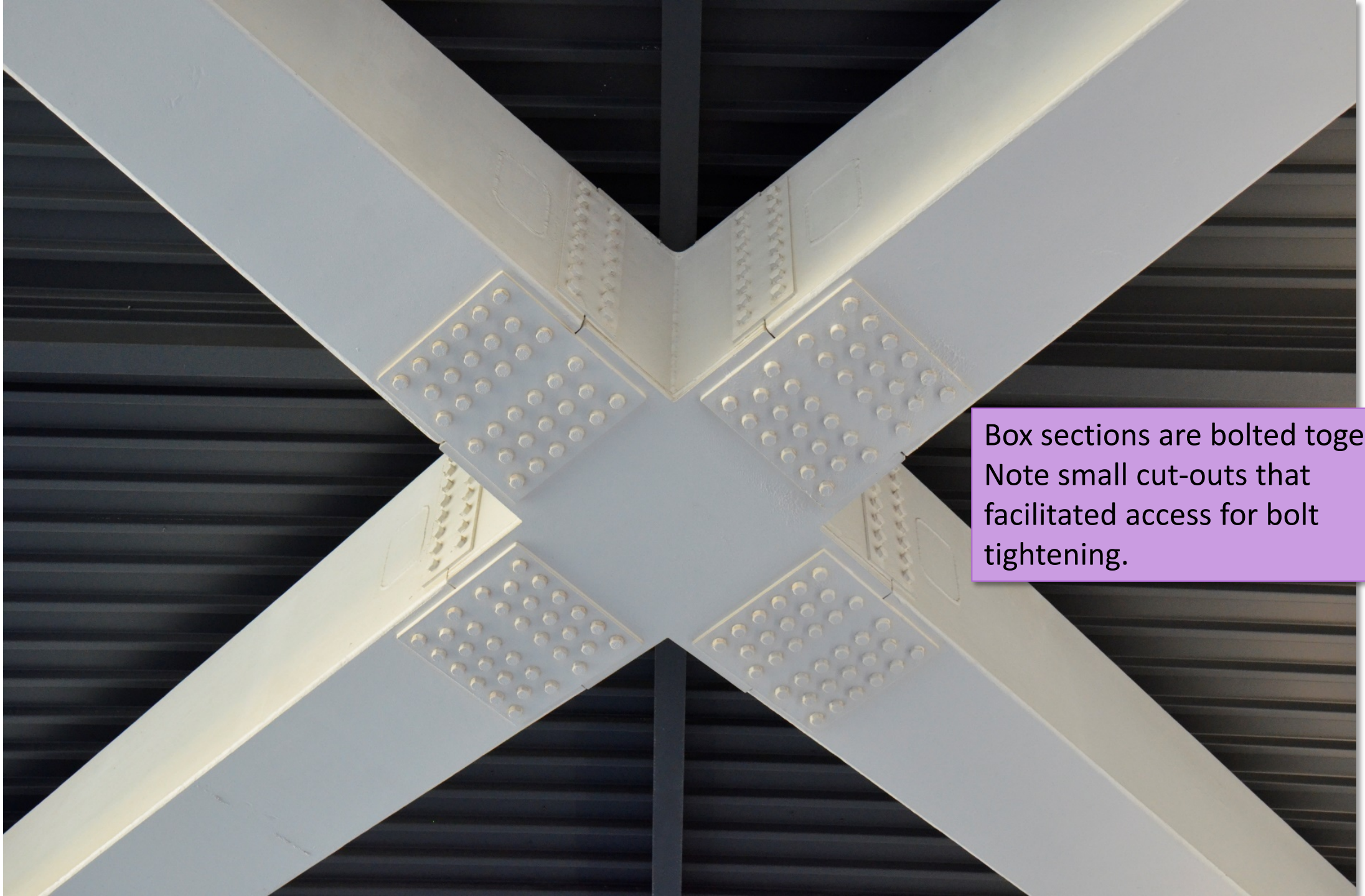


Bates Smart Architects

Federation Square | Melbourne, Australia




viewing distance
Train Station - Valencia, Spain



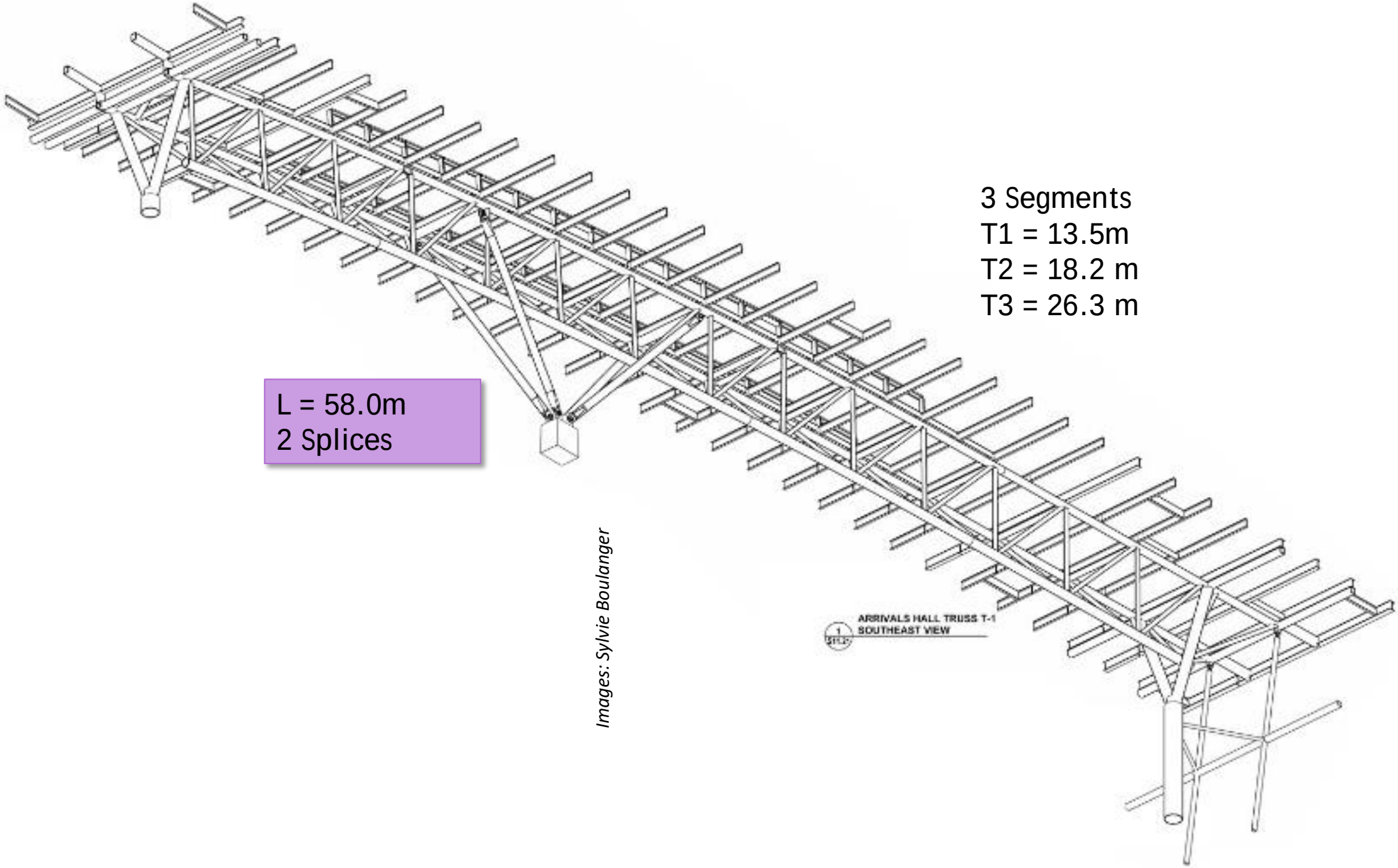
Box sections are bolted together. Note small cut-outs that facilitated access for bolt tightening.

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



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

L = 58.0m
2 Splices

Images: Sylvie Boulanger

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

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

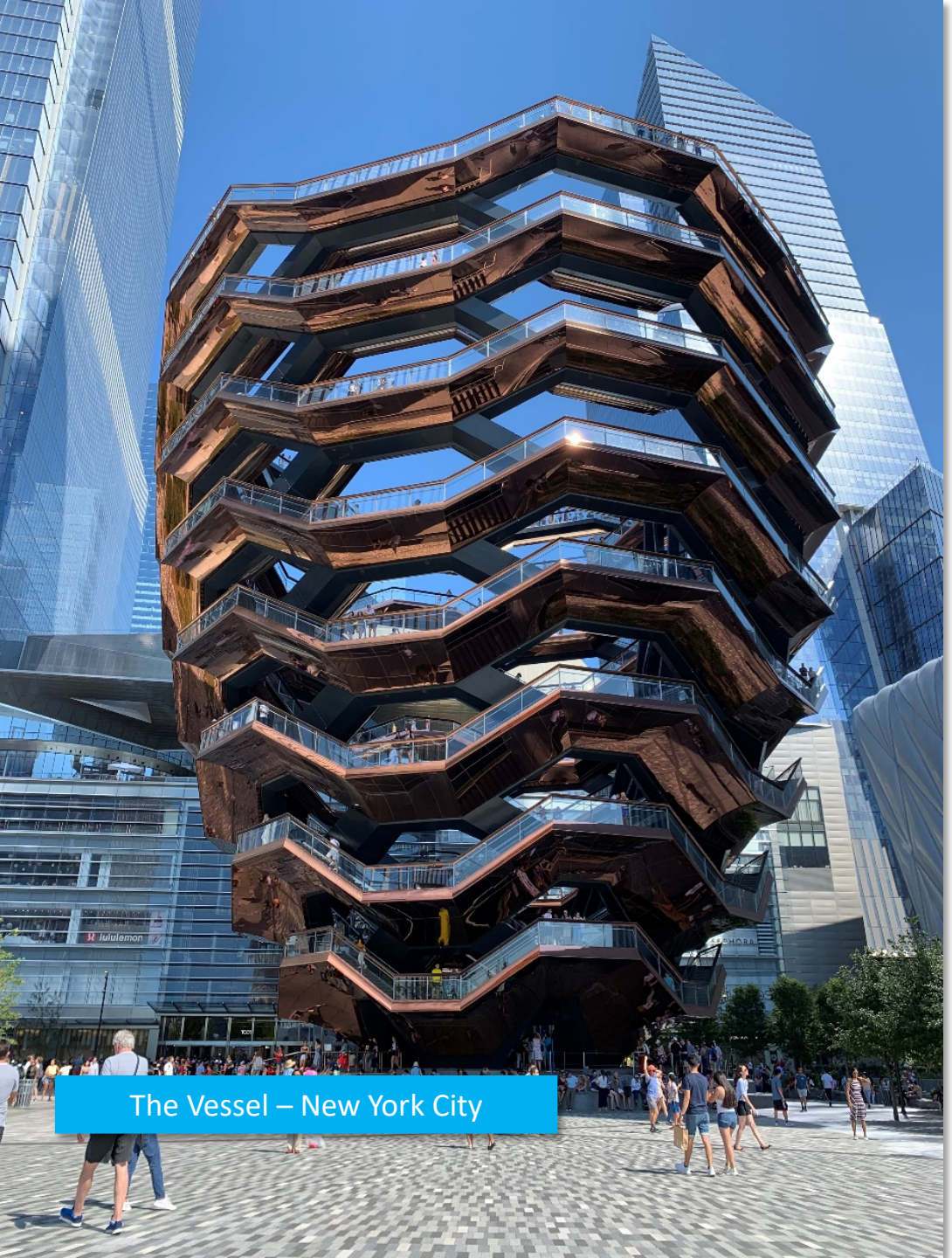
The Shed – New York City

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.


KAESER

Image: Heatherwick Stucios

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

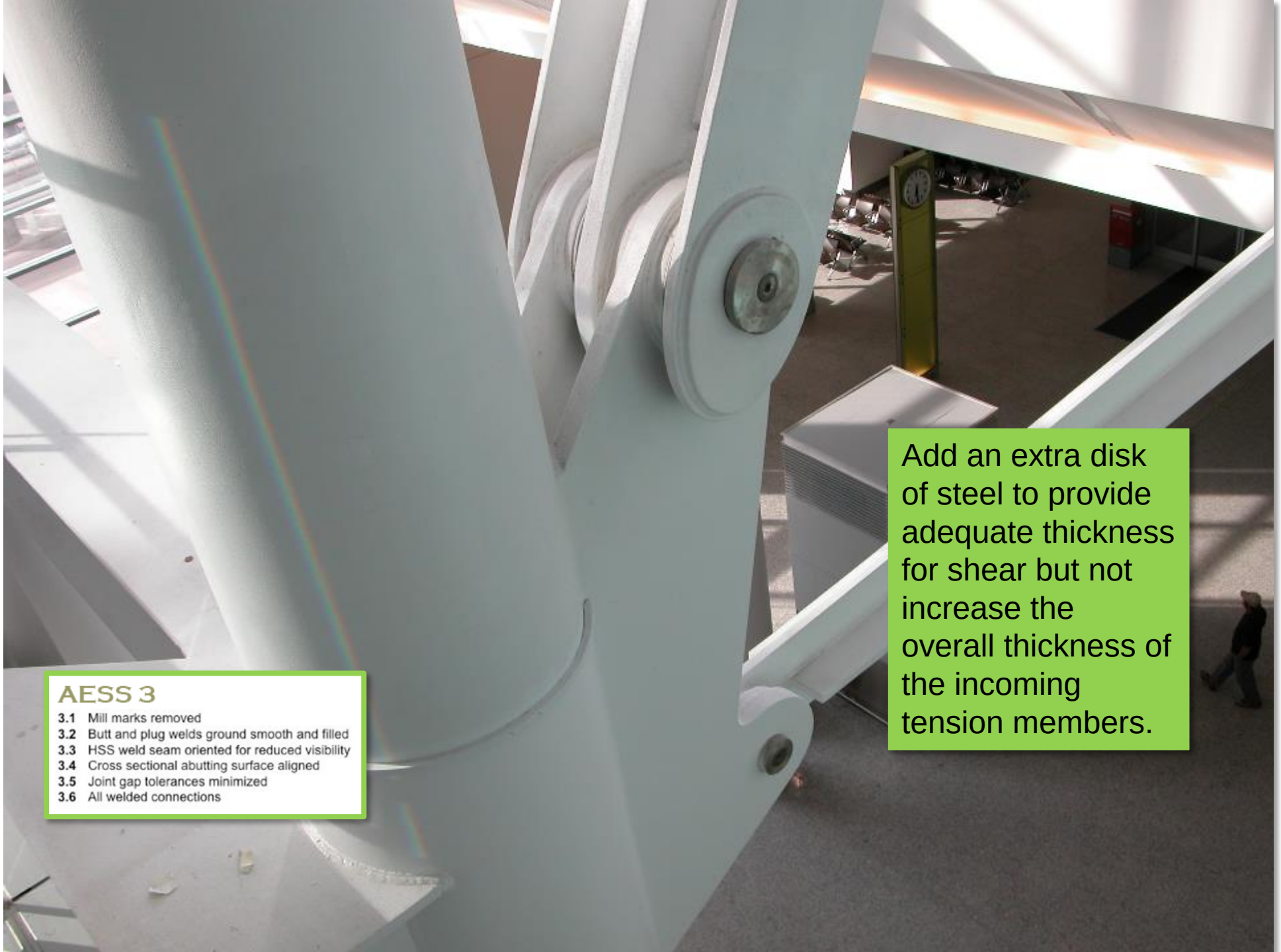
Bullring Shopping Center | Barcelona, Spain


Heathrow Airport | London


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
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
Multiplication factor = $$$
Barajas Airport | Madrid, Spain
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


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

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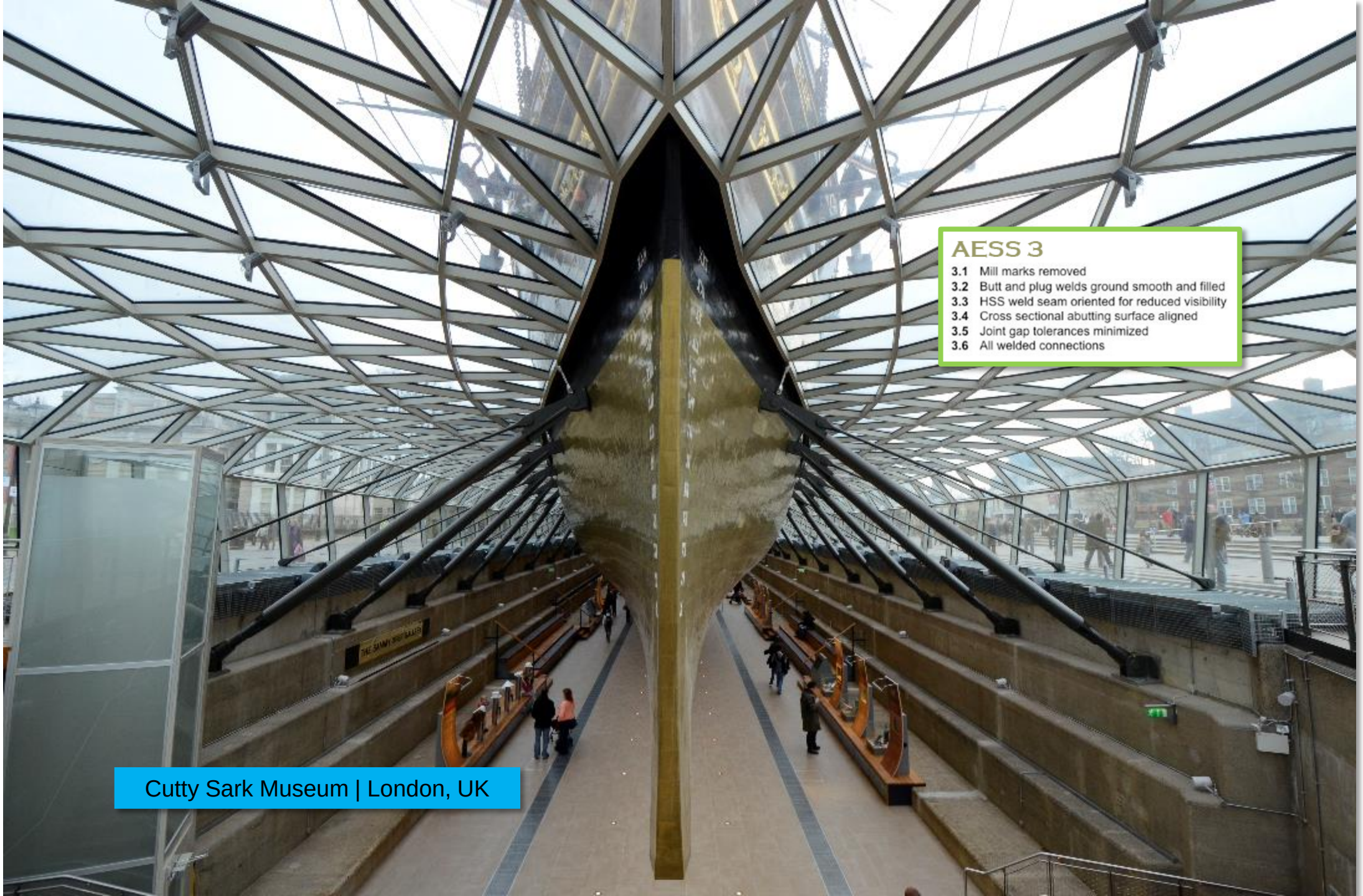
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Cutty Sark Museum | London, UK

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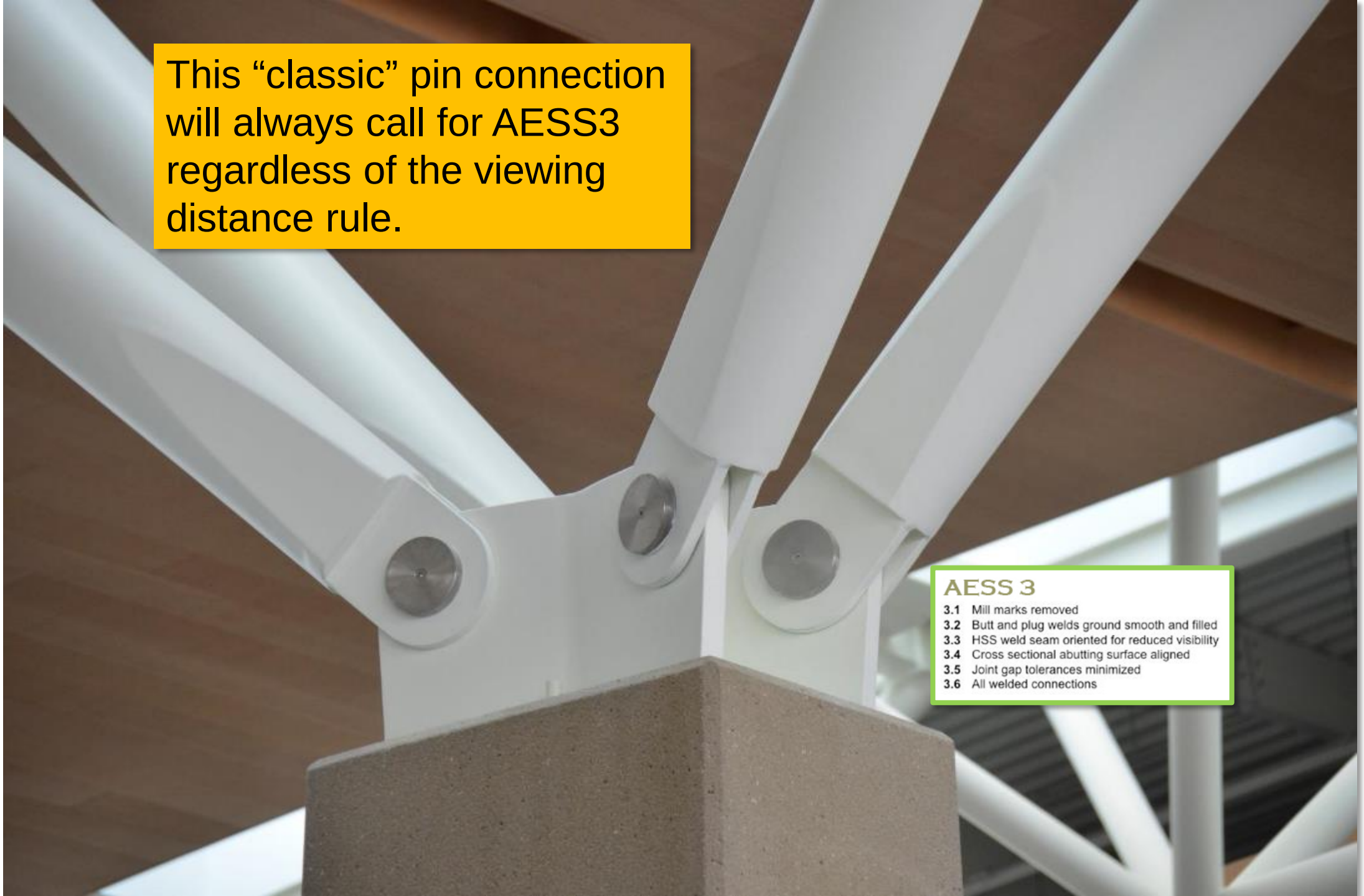
Neo Bankside Housing | London

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

viewing distance

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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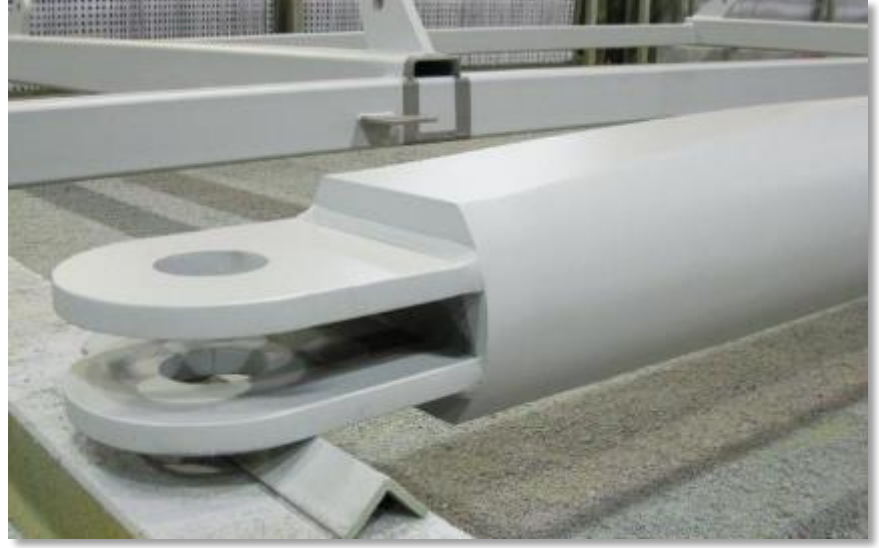


Southern Rail Station, Melbourne | Grimshaw


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

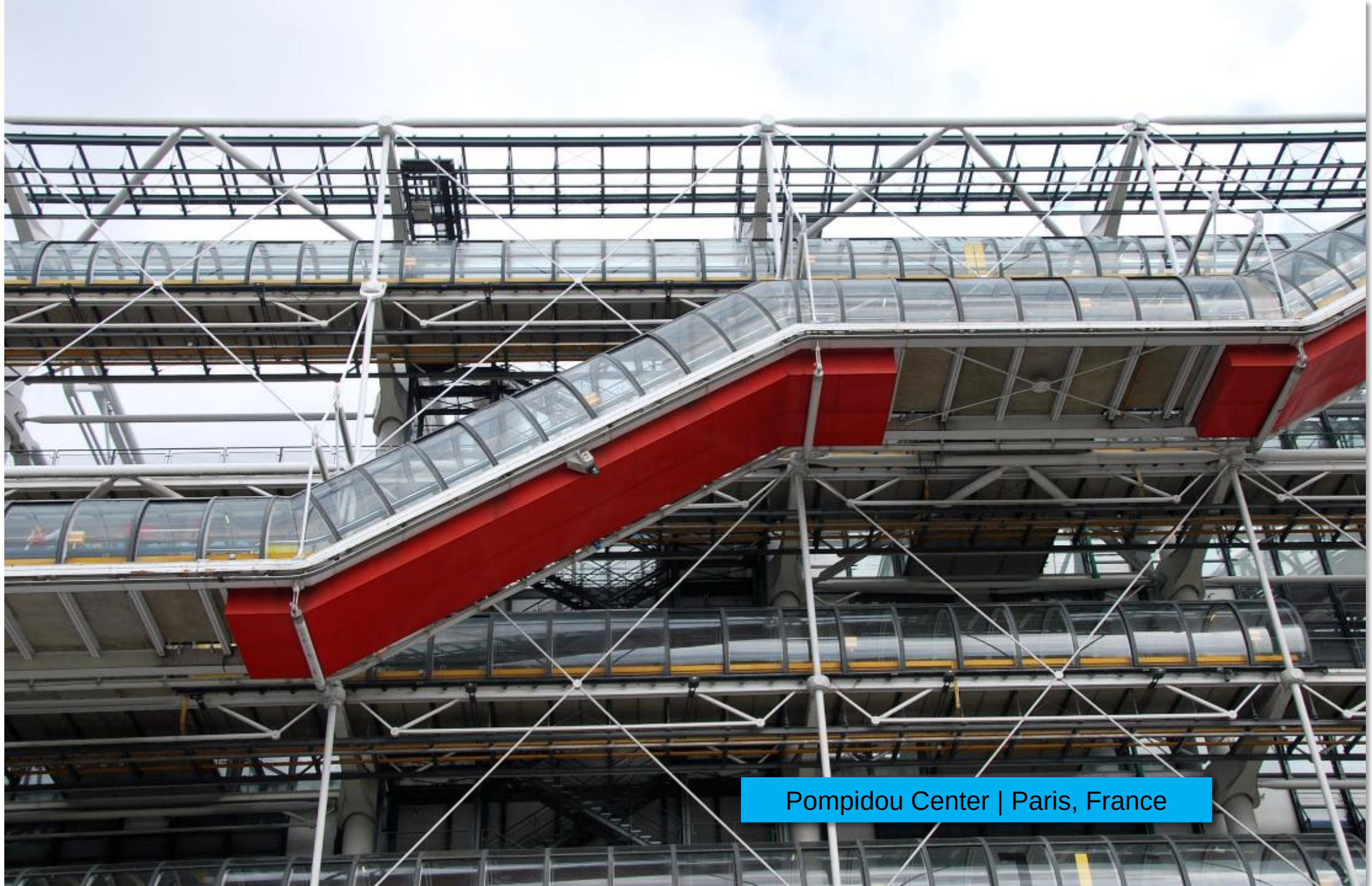
End Condition: usually a clevis

Tightening mechanisms

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

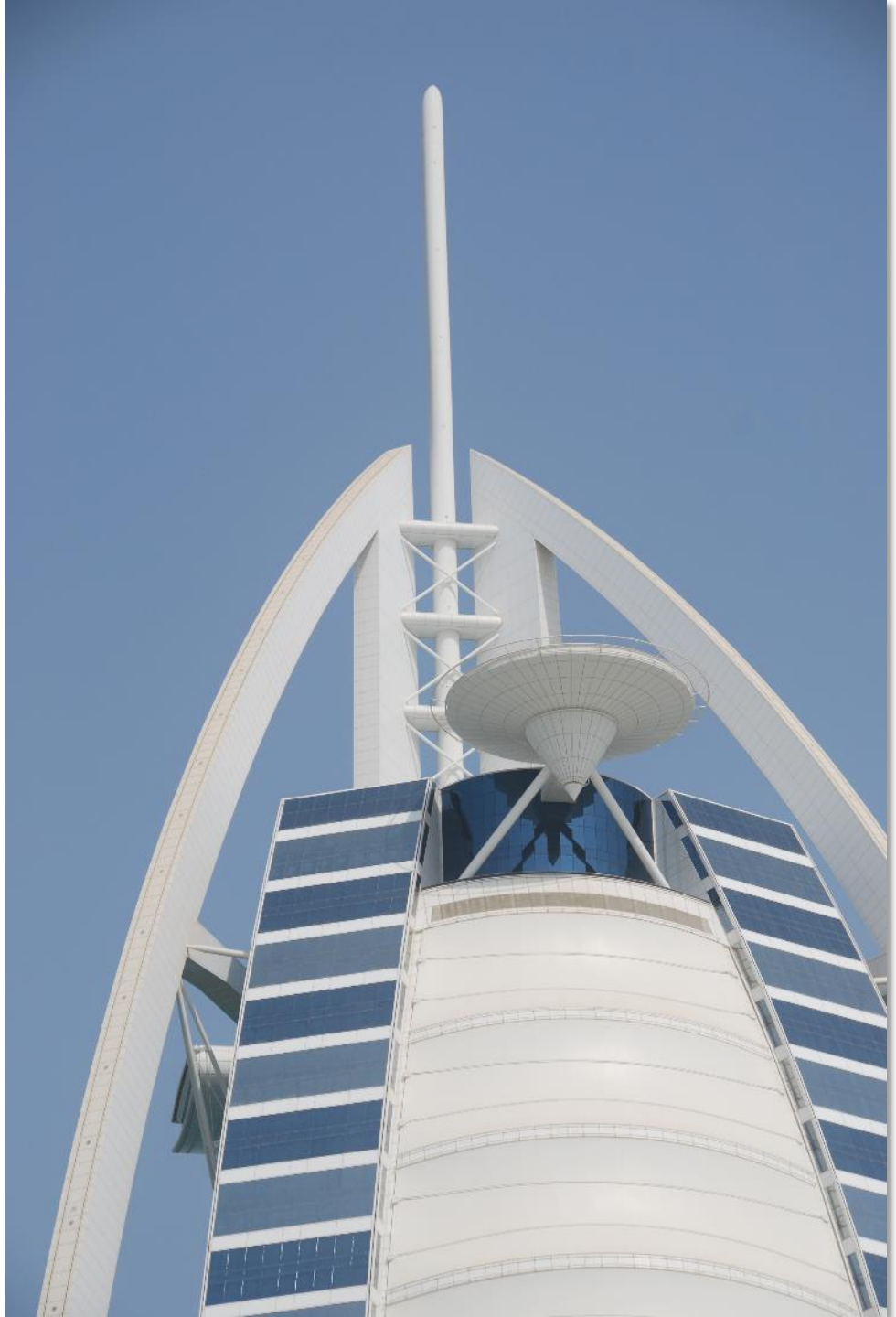
Member

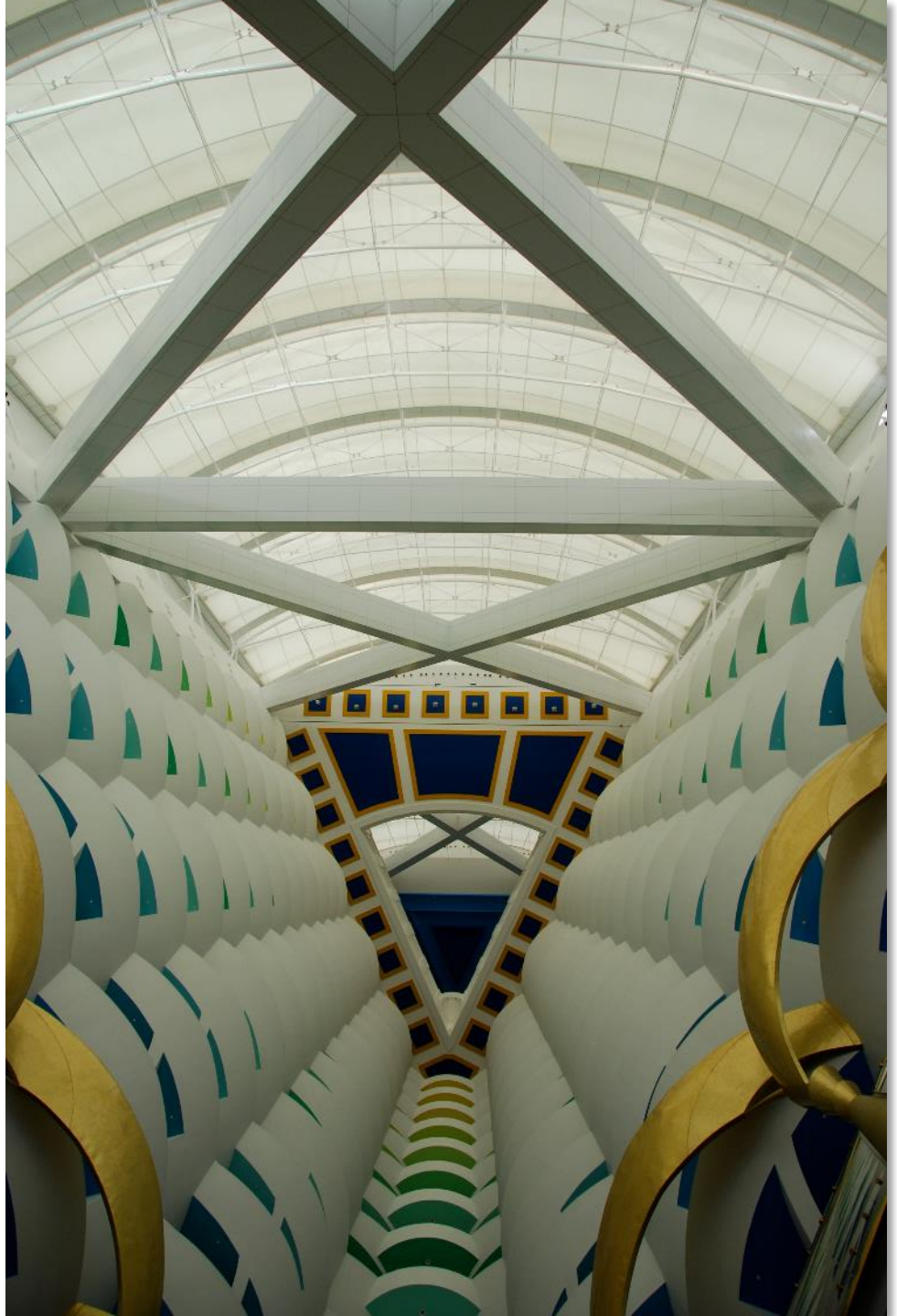
- Cable: can be galvanized or stainless steel as a function of aesthetic requirements or corrosion resistance for exterior; can be encased in a sheathing for weather protection; these can be extremely long
- Rods: solid steel; will need corrosion protection if exterior; limited in length


Pompidou Center | Paris, France

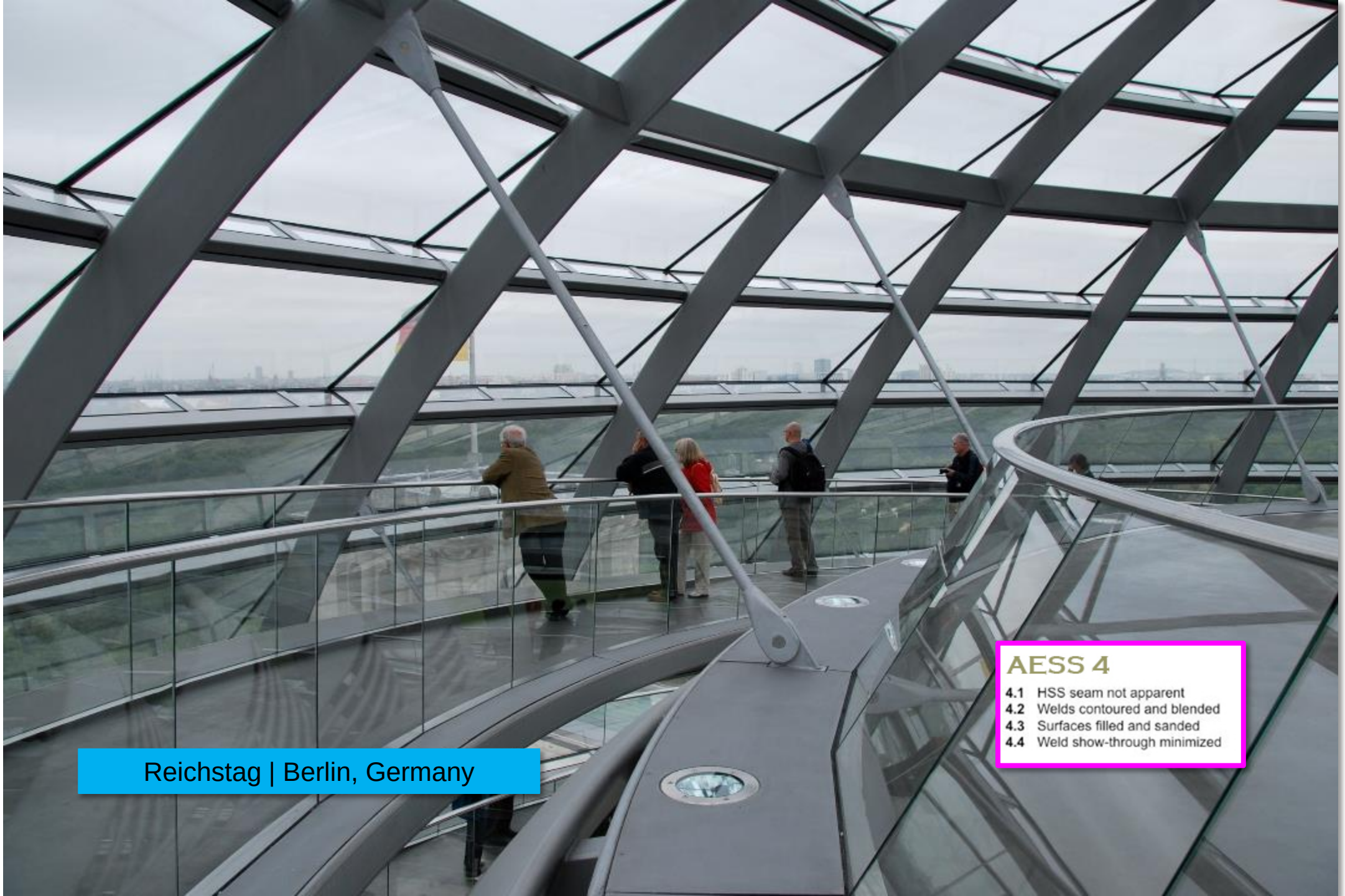
Munich International Airport


Burj Al Arab, Dubai





University Building at Laval



Reichstag | Berlin, Germany


Kurilpa Bridge | Brisbane, Australia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Jubilee Bridge | London

AESS 3

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3.6 All welded connections

viewing distance

Sony Center | Berlin, Germany

AESS 3

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International Airport | Porto, Portugal


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How to Create a Corner

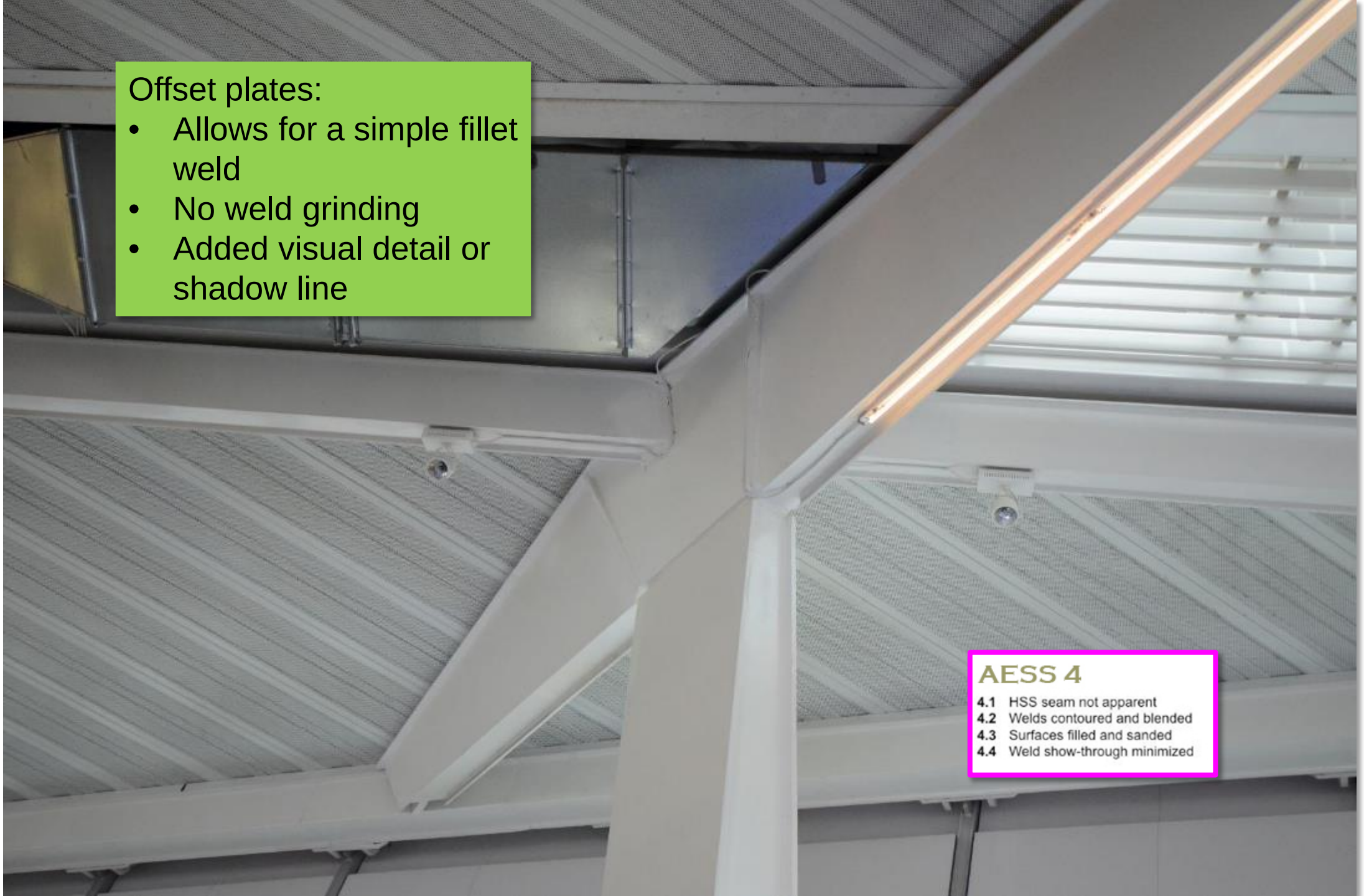
When the “corners” on an HSS tube are too rounded for the desired aesthetic, and crispness is desired

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
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AESS 4
4.1 HSS seam not apparent
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PIVOTAL POINTS
ORIGINS
Plate allows for very crisp corners.

Puente de Luz | Toronto

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

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.

AESS 3

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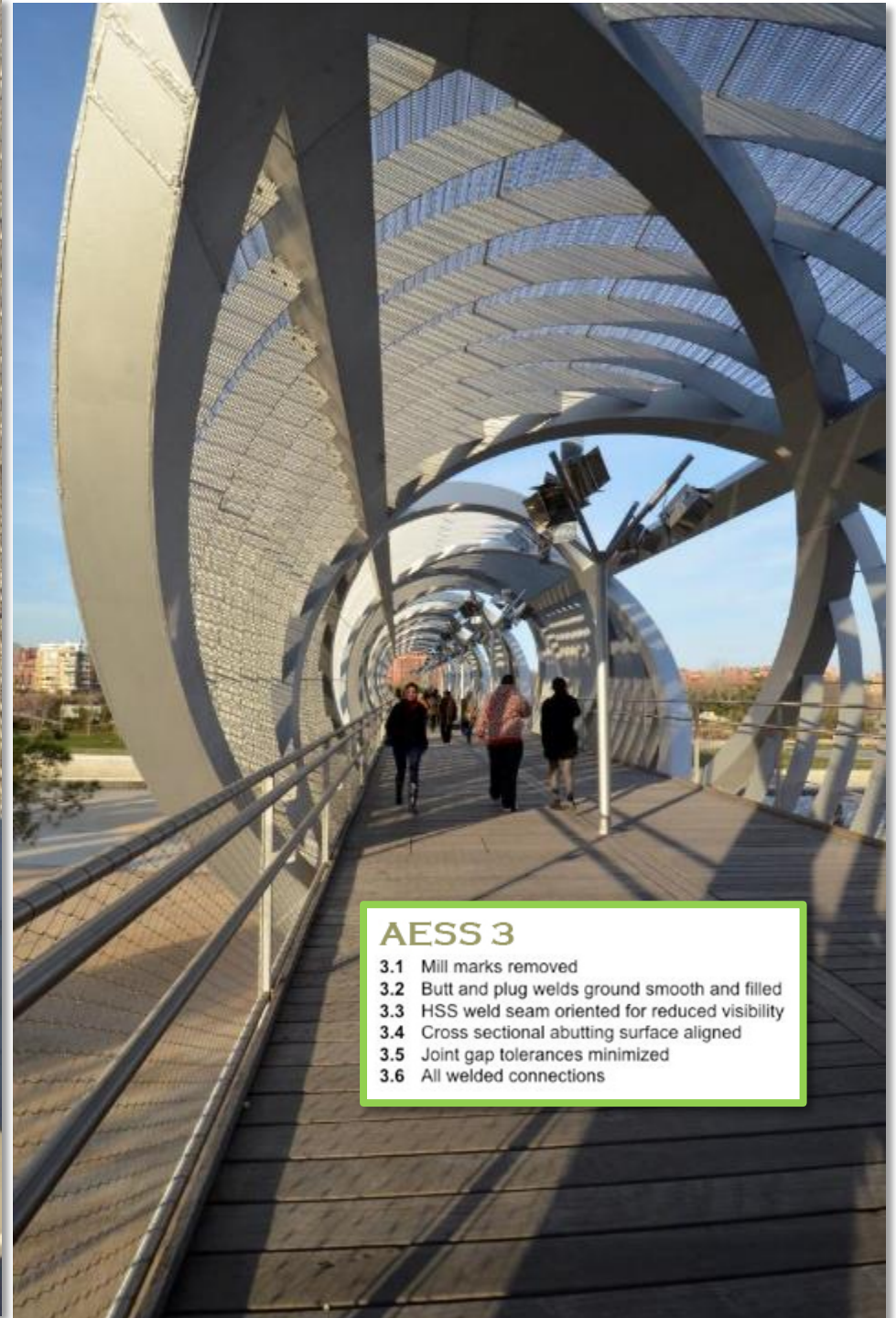
3.6 All welded connections

Arganzuela Bridge | Madrid, Spain



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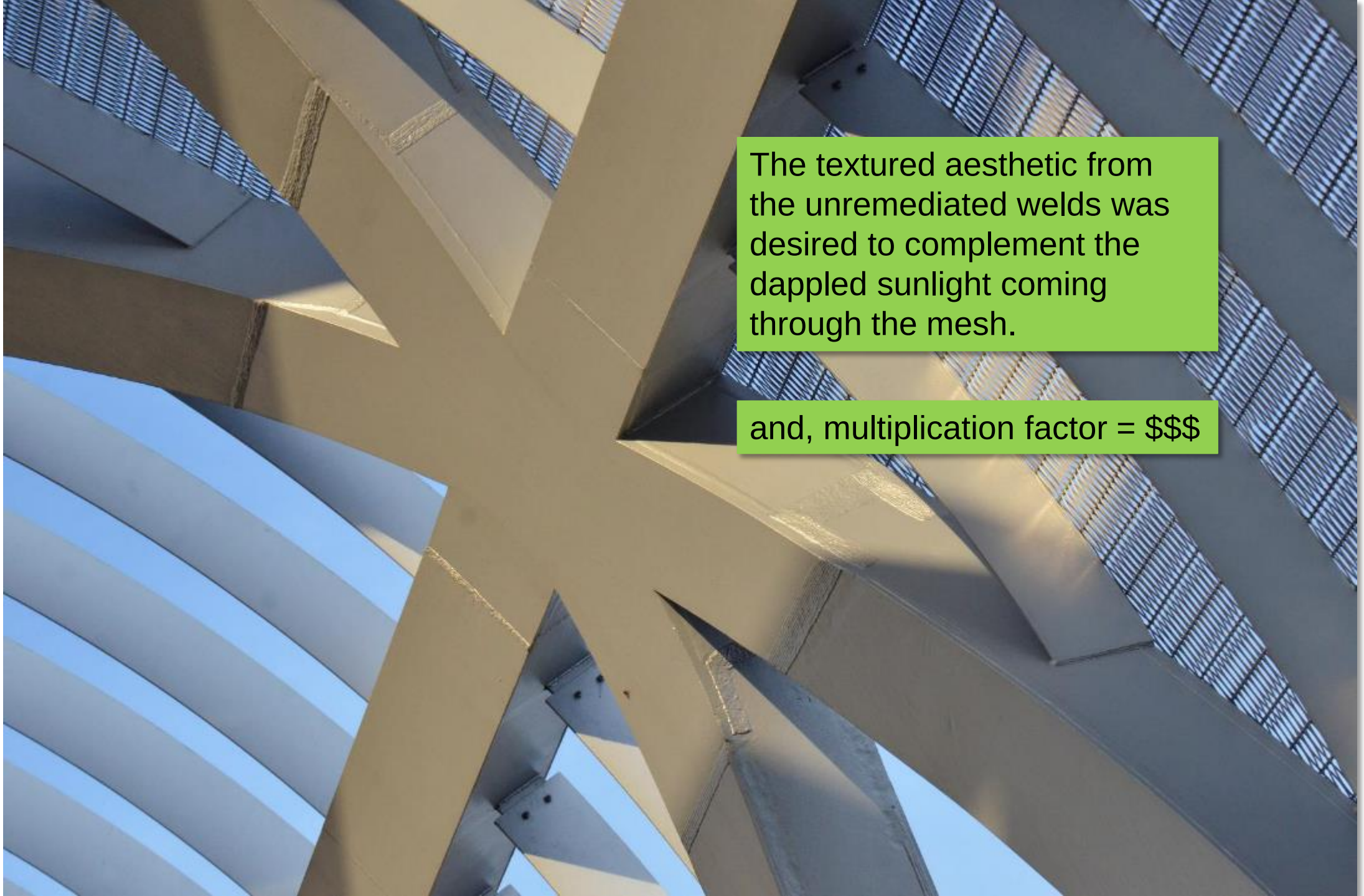
The textured aesthetic from the unremediated welds was desired to complement the dappled sunlight coming through the mesh.
and, multiplication factor = $$$

viewing distance

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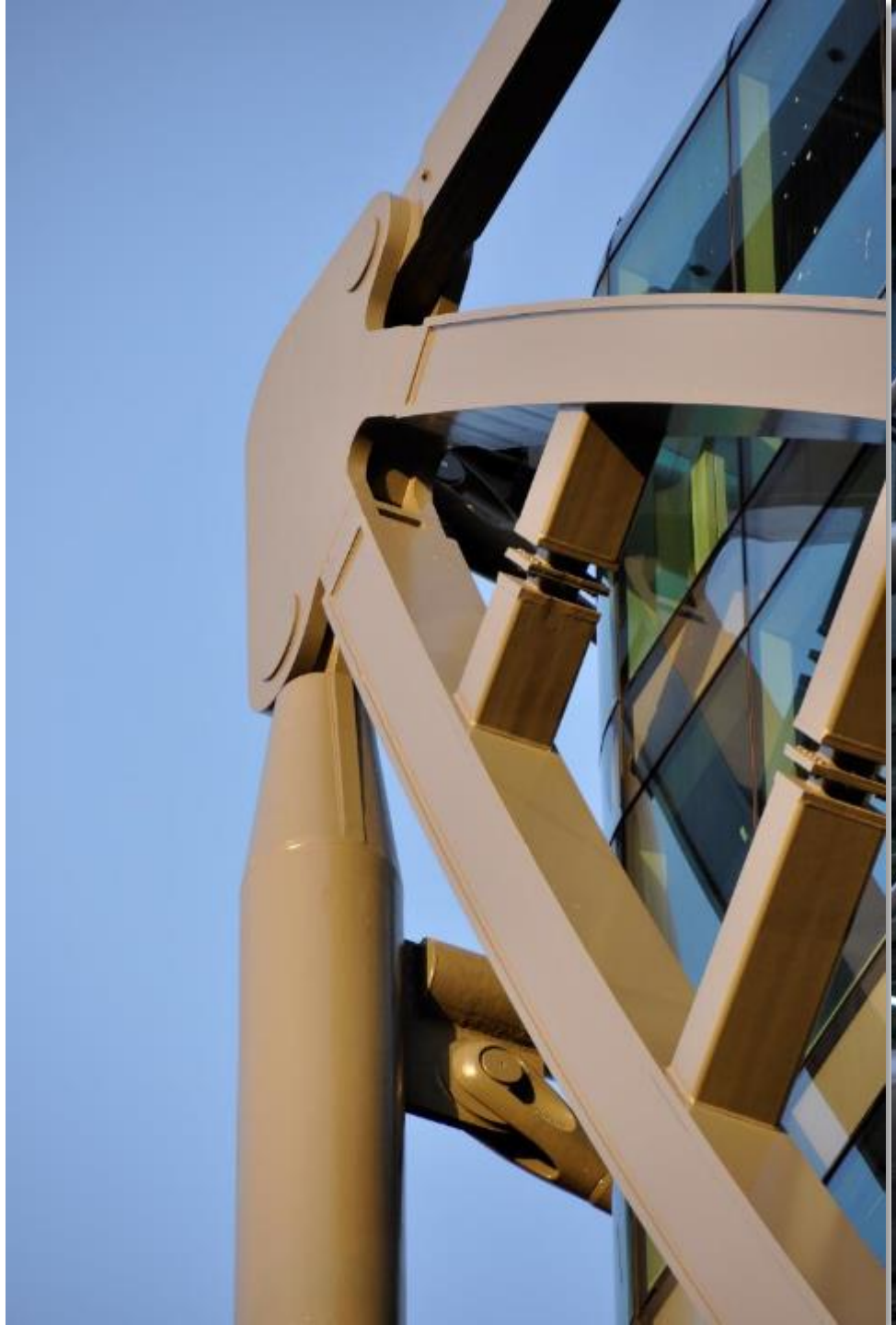



Renzo Piano
The Shard | London, UK


Fire exit


Renzo Piano
New York Times | New York, USA

Rogers Stirk Harbour + Partners

Leadenhall Building | London, UK


CANTI
DECK

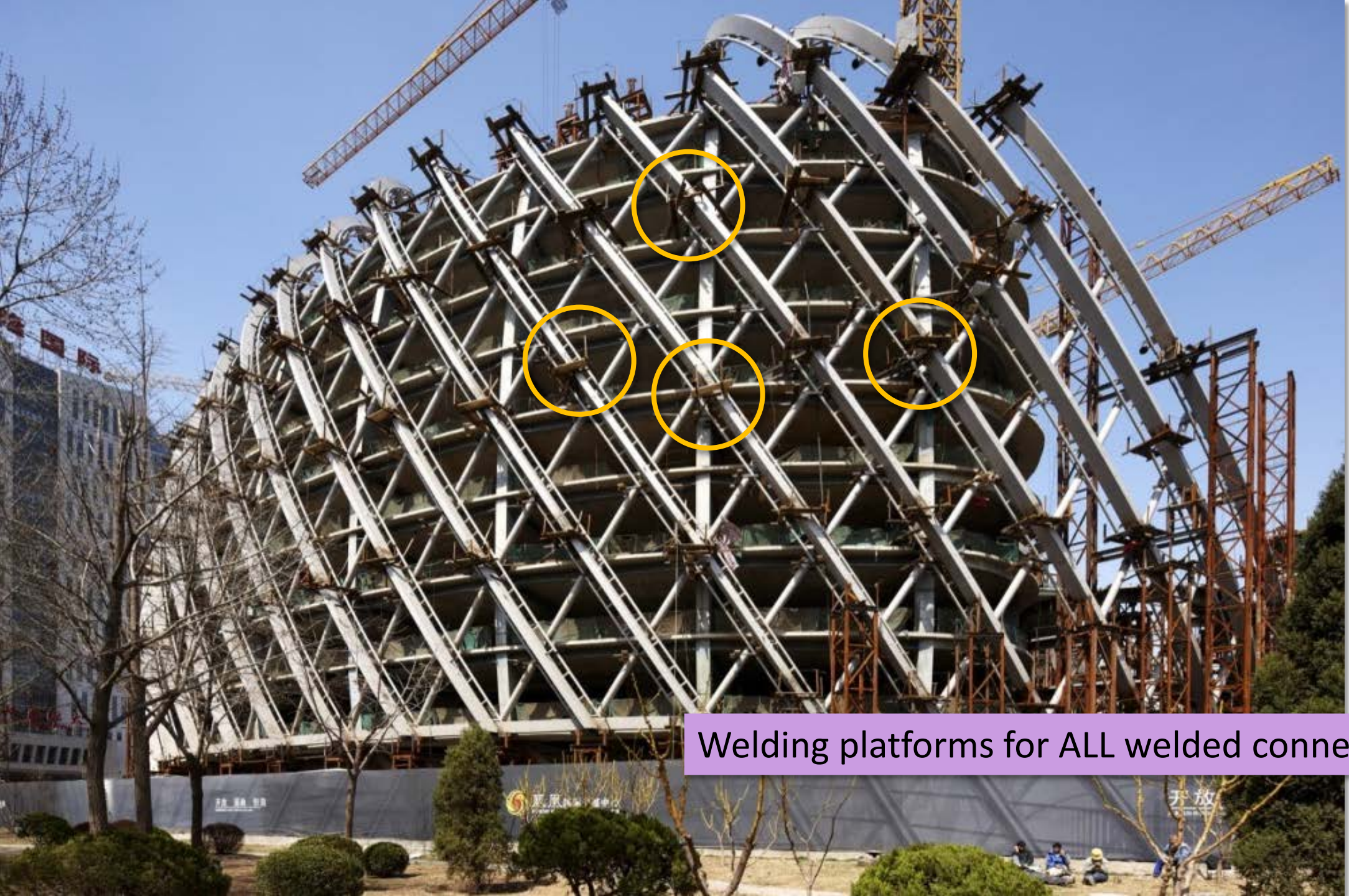
Aranguren + Gallegos Arquitectos

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

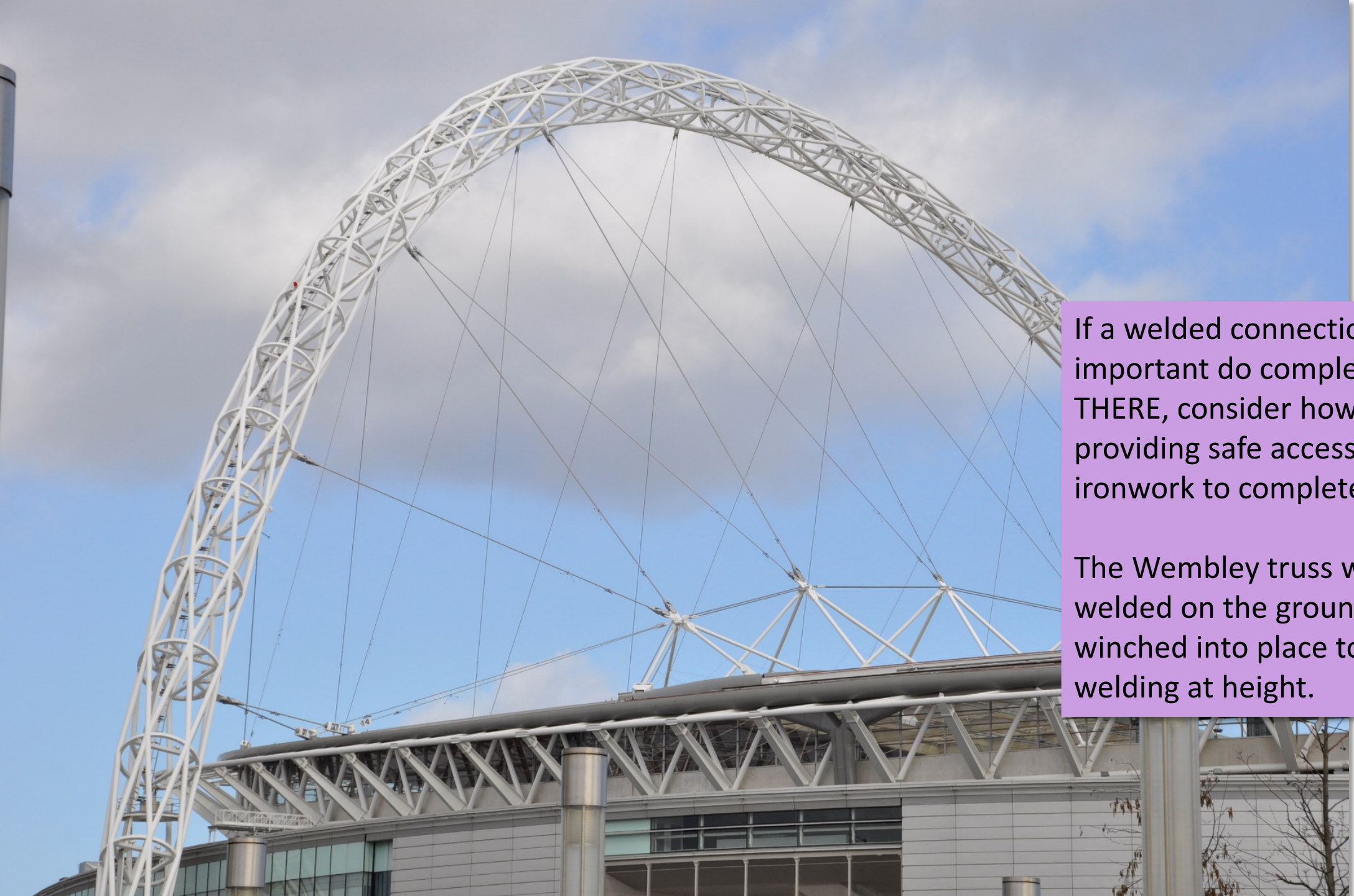


Welding platforms for ALL welded connections

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.



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.