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## Session Description

### Session 5: Façade Fundamentals July 16, 2018

Attaching modern facades to buildings requires an understanding of how facade systems perform—from moisture and thermal performance to structural performance. Developing successful facade attachments requires consensus among a number of different parties about the objectives for the facade system. The project team needs to establish who is responsible for various portions of the design and also establish the criteria against which the system's performance will be compared. In this session, we will explore these issues in depth to set projects up for success.



## Learning Objectives

- Identify issues to consider when creating design criteria for the loading and serviceability of façade systems.
- Describe the roles and responsibilities of project team members for the design and construction of façade attachments.
- Define thermal bridges and thermal breaks, and describe their importance to a building system.
- List the various accumulated tolerances that can affect the installation and performance of façade systems.



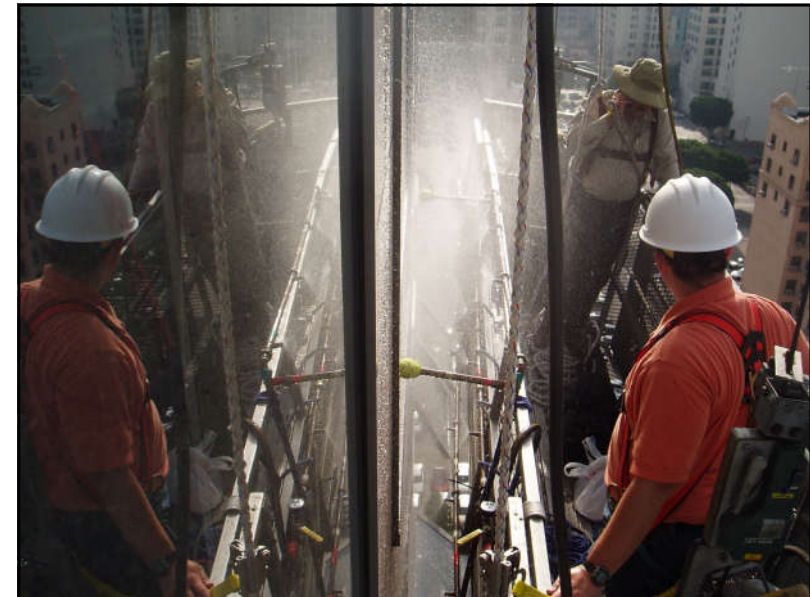
There's always a solution in steel.

## AISC Night School Behind the Façade: Guidance for Supporting Facades on Steel-Framed Buildings



Alec Zimmer, P.E.  
Senior Project Manager  
Simpson Gumpertz & Heger Inc.  
Waltham, MA





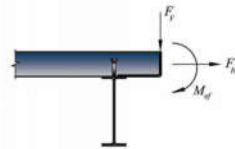


### Attachments: What's the Problem?

- Design Coordination
- RFIs
- Delays in the shop drawing process
- Delays in erection
- Out-of-tolerance erection
- Failures
  - Envelope Performance
  - Structural



## AISC Design Guide 22



17

## Design Guide Objective

- To assist the practicing structural engineer in achieving slab edge and spandrel beam details for steel frames that are:
  - Structurally sound
  - Durable
  - Economical
  - Accommodating of facade requirements



18

## Design Guide Scope

- Focus on attachment strategies and their effect on the design, fabrication, and erection of steel frames.
- Guidance for the structural engineer of record responsible for the design of the steel frame.
- Attachment concepts and performance characteristics – not “preferred” details.
- Not design of the facade systems, just attachments to the steel frame.



19

## Syllabus for Night School Sessions

- Session 1
  - Fundamentals of Facades
  - Design Criteria
- Session 2
  - Design and Execution Responsibilities
- Session 3
  - Thermal Bridging
- Session 4
  - Planning for Clearances
  - Accommodating Tolerances



20

## Syllabus for Night School Sessions

- Session 1
- **Session 2**
  - Traditional Masonry Cavity Walls
  - Panelized Façade Systems
- Session 3
  - Aluminum-Glass Curtain Walls
- Session 4
  - Sizing Joints for Vertical Movement



21

## Syllabus for Night School Sessions

- Session 1
- Session 2
- **Session 3**
  - Slab Edges
  - Spandrel Beams
  - Cladding Supports Away from Floors
- Session 4



22

## Syllabus for Night School Sessions

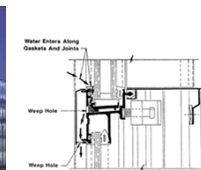
- Session 1
- Session 2
- Session 3
- **Session 4**
  - Accommodating Lateral Drifts
  - In-Plane Movements
  - Out-of-Plane Movements
  - Building Corners



23

### Fundamentals of Façade Performance

## Fundamentals of Façade Performance



The building envelope encloses the building, controlling the transmission of air, water, heat, sound, and light both into and out of the building.



24

*Fundamentals of Façade Performance*

## The Façade and the Building Envelope

25

*Fundamentals of Façade Performance*

## Time Line

26

*Fundamentals of Façade Performance*

## Load Bearing Masonry

27

*Fundamentals of Façade Performance*

## Load Bearing Masonry

- Walls are thick
- Walls support all loads
- Floor “rides” with walls


28

*Fundamentals of Façade Performance*

## Load Bearing Masonry

- Walls manage moisture as a reservoir


The diagram shows a cross-section of a masonry wall with three horizontal floor slabs. Arrows on the right indicate moisture entering the wall from the exterior. On the left side, wavy arrows point outwards from the wall, representing moisture being released. The wall is shown resting on a foundation.


29

*Fundamentals of Façade Performance*

## Time Line


The timeline shows a horizontal axis with markers for 2000, 1000 B.C., 0, 1000 A.D., and 2000. A light blue bar spans from 2000 B.C. to 2000 A.D. A callout box labeled 'Transitional Masonry' points to a small dark grey segment at the end of the bar, between 1000 A.D. and 2000 A.D.


30

*Fundamentals of Façade Performance*

### Transitional Masonry Buildings

The diagram shows a horizontal axis with markers for 1890, 1900, 1910, 1920, 1930, 1940, and 1950. A grey bar spans from approximately 1890 to 1950.



31

*Fundamentals of Façade Performance*

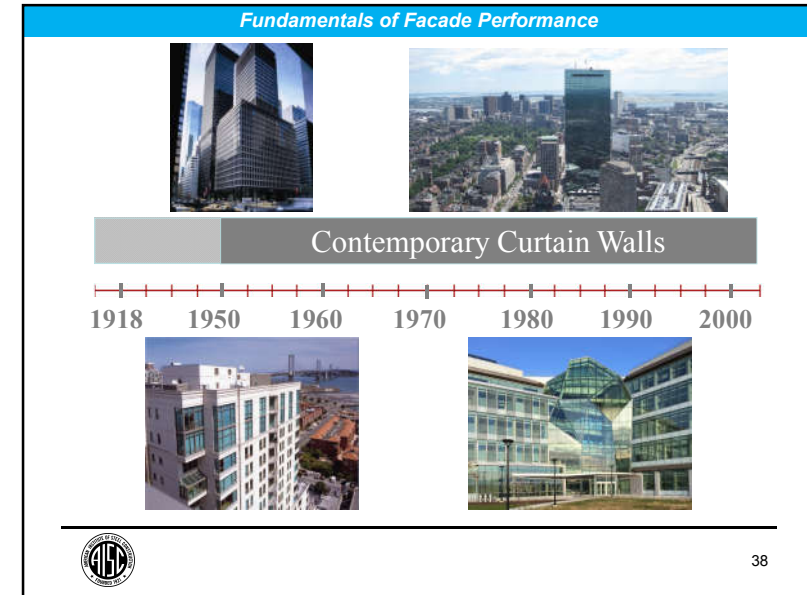
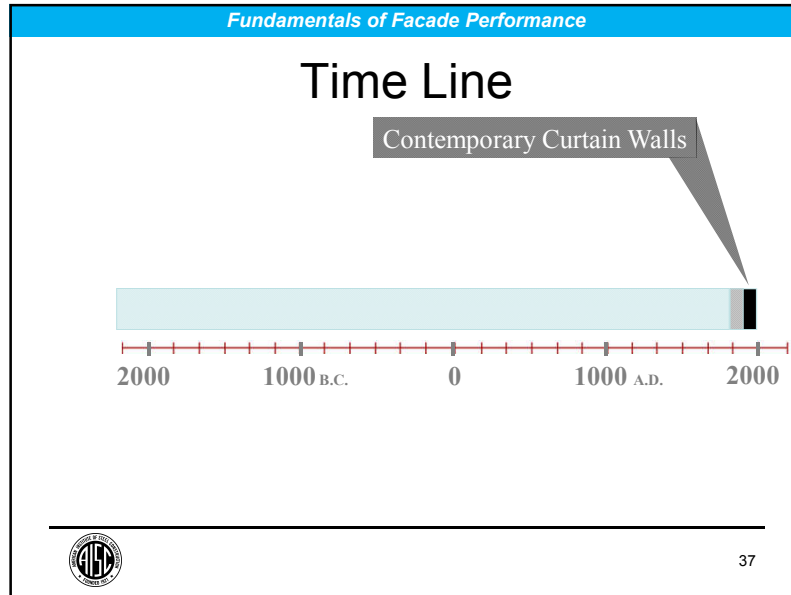
## Transitional Masonry Buildings

- Masonry walls still thick
- Floor & wall loads supported by steel or iron frame
- Wall still functions as a reservoir
- Masonry is tight against frame

The diagram shows a cross-section of a building with a steel frame. Three horizontal steel beams are shown supporting the floor slabs. The masonry walls are shown as thick and are tightly attached to the steel frame. Arrows on the right indicate moisture entering the wall, and wavy arrows on the left indicate moisture being released.


32





*Fundamentals of Façade Performance*

## Contemporary Curtain Walls

- Floor loads carried by frame
- “Skin” transfers wind loads to the frame
- “Skin” typically employs a drainage plane and back-up waterproofing

39

*Exterior Wall System*

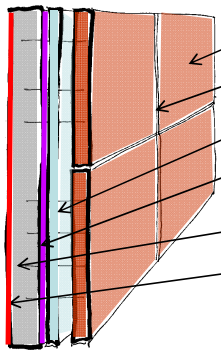
## Performance Requirements of the Exterior Wall System

- Accommodates loads and deformations
- Minimizes water and air flow (vapor movement)
- Controls heat gain and/or loss


40

Exterior Wall System

### Functional Components of the Exterior Wall System



- Cladding
- Joints
- Insulation
- Water barriers and air barriers
- Back-up structure
- Interior finishes





41

Exterior Wall System

### Insulation and Thermal Performance


- Building codes demanding better performance
- Structural attachments can create thermal bridges
- Thermal and moisture modeling can assess consequences of bridges




42

Exterior Wall System

### Facade Design Criteria



- Structural Integrity
- Provisions for Movement
- Envelope Performance





43

Attachment Criteria

### Criteria for Façade Attachment

- Structural Integrity
- Accommodating Movement
- Durability
- Accounting for Tolerances and Clearances
- Constructability
- Economy



44

**Attachment Criteria**

## Structural Integrity

Redundancy      Strength      Ductility

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45

**Attachment Criteria**

## Conflicting Ideas

TWO SUPPORT POINTS      REDUNDANCY

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46

**Attachment Criteria**

## Loads on Attachments

The role of the facade attachment is to provide a reliable **LOAD PATH** from the building enclosure to the building frame for each of the load types acting on the facade.

DEAD WEIGHT SUPPORT + WIND

WIND ONLY

---

47

**Attachment Criteria**

## Loads on Attachments

- Dead Loads**  
Weight of the wall system
- Seismic Loads**  
Perpendicular OR parallel to the wall
- Wind Loads**  
Perpendicular OR parallel to the wall
- Thermal Loads**  
Facade expansion/contraction

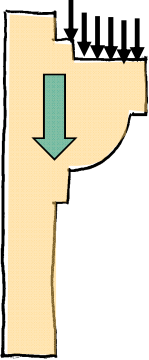
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48

**Attachment Criteria**

## Gravity Loads

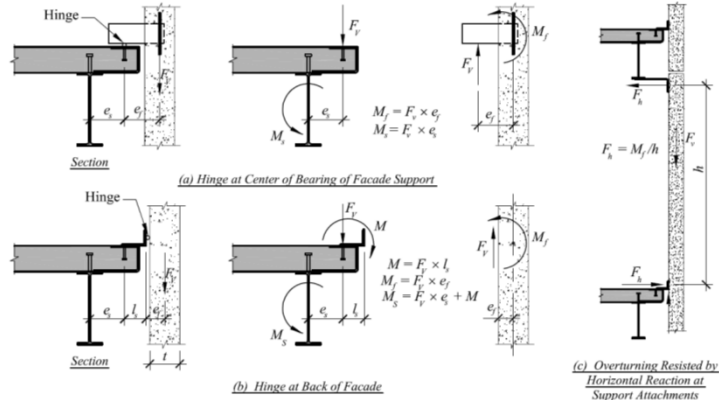
- Facade dead load
  - Need to understand materials and system
- Facade live loads
  - Horizontal projections
- SER usually needs to estimate before wall is designed
- Window washing activities





49

**Attachment Criteria**

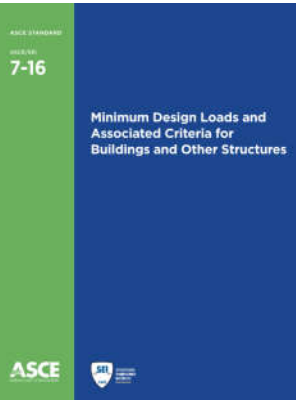
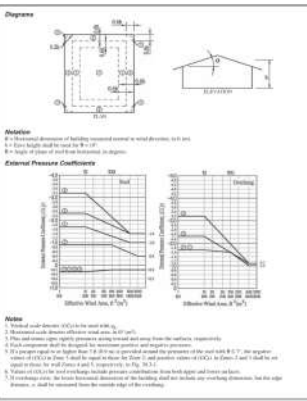
## Gravity Load Eccentricities





50

**Attachment Criteria**

## Wind Loads


51

**Attachment Criteria**

## Wind Tunnel Testing




52

**Attachment Criteria**

## Wind Loads

- Negative pressures combined with gravity eccentricities often control.
- For the base building components, the SER can often be simple and conservative when planning for attachments without undue cost.

53

**Attachment Criteria**

## Seismic Requirements

- Seismic Forces
- Relative Displacements
- Ductility

Christchurch, New Zealand, February 2011  
 Photo: Ronald Mayes / SGH

54

**Attachment Criteria**

## Seismic Design Category

- ASCE 7-16: "A classification assigned to a structure based on its *Risk Category* and the severity of the design earthquake ground motion at the site..."

A	Least restrictive design category, not common
B	Common in low seismic areas
C	Common for higher risk buildings in eastern US and lower risk building in CA
D	Common design category for California and other high seismic areas; highly restrictive design
E	Special category for mapped spectral response acceleration parameters ( $S_1$ ) greater than 0.75
F	Special category for Risk Category IV structures in Seismic Design Category E

55

**Attachment Criteria**

## Seismic Design Applicability

Seismic Design Category	Seismic Design Applicability per ASCE 7-16, Section 13.1.4
A and B	All architectural components with $I_p = 1.0$ are exempt except: <ul style="list-style-type: none"> <li>• Parapets</li> <li>• Storage cabinets</li> </ul>
C, D, E, F	Architectural components are <b>not</b> exempt
ALL	Temporary or moveable equipment

56


**Attachment Criteria**

## Seismic Loads

$$F_p = \frac{0.4a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right)$$

**Table 13.5-1 Coefficients for Architectural Components**

Architectural Component	$a_p^a$	$R_p$	$I_p^b$
Exterior nonstructural wall elements and connections <sup>b</sup>			
Wall element	1	2½	NA
Body of wall panel connections	1	2½	NA
Fasteners of the connecting system	1¼	1	1
Veneer			
Limited deformability elements and attachments	1	2½	2
Low-deformability elements and attachments	1	1½	2



57

**Attachment Criteria**

## Seismic Loads

**13.3.2 Seismic Relative Displacements.** The effects of seismic relative displacements shall be considered in combination with displacements caused by other loads as appropriate. Seismic relative displacements,  $D_{pl}$ , shall be determined in accordance with Eq. (13.3-6):

$$D_{pl} = D_p I_e \quad (13.3-6)$$


58

**Attachment Criteria**

## Limit States for Design

- Attachments must safely accommodate forces.
- Joints must prevent hazardous damage; falling hazards.





59

**Attachment Criteria**

## Limit States for Design

- Serviceability checks may allow lower forces and drifts; for example joint sealant movements.
- ASCE 7-16 Commentary suggests:

$$D + 0.5L + W_a$$


60

**Attachment Criteria**

## Wind Deflections (IBC 2015)

CONSTRUCTION	L	$\delta$ or $W$	$D = L^{1/2}$
Roof members:			
Supporting plaster or stucco ceiling	l/360	l/360	l/240
Supporting nonplaster ceiling	l/240	l/240	l/180
Not supporting ceiling	l/180	l/180	l/120
Floor members:			
---	---	---	l/240
Exterior walls:			
With plaster or stucco finishes	---	l/360	---
With other brittle finishes	---	l/240	---
With flexible finishes	---	l/120	---
Interior partitions: <sup>g</sup>			
With plaster or stucco finishes	l/360	---	---
With other brittle finishes	l/240	---	---
With flexible finishes	l/120	---	---
Farm buildings	---	---	l/180
Greenhouses	---	---	l/120

Footnote f: *The wind load is permitted to be taken as 0.42 times the "component and cladding" loads for the purpose of determining deflection limits herein. Where members support glass in accordance with Section 2403 using the deflection limit therein, the wind load shall be no less than 0.6 times the "component and cladding" loads for the purpose of determining deflection.*

61

**Attachment Criteria**

## Accommodating Relative Movement

- Spandrel deflections, rotations, column shortening, bracket deflections.

62

**Attachment Criteria**

## Accommodating Relative Movement

Fewer panels mean larger joint movements for a given span and support stiffness.

63

**Attachment Criteria**

## Accommodating Relative Movement

- Rules of thumb and code provisions for flexural stiffness to limit facade material cracking.
  - L/360?
  - L/600?
  - L/720?
  - 0.31 in.?
  - 3/4 in.?

64

**Attachment Criteria**

### Accommodating Relative Movement

- Joint sealant compression or extension may control the design of spandrel beams
- Example:** Limiting compression of a sealant joint to 1/4 in. for a 30 ft long beam is  $L/1440$

$\Delta_{TL} + K_e L$

$\delta_{SIL} \leq \frac{1}{8}''$

$\frac{3}{4}''$

$\frac{1}{2}''$

$\frac{1}{4}''$

$\frac{1}{8}''$

65

**Attachment Criteria**

### Accommodating Relative Movement

#### Inter-Story Drift from Lateral Loads

- Common drift limits:
  - Wind
    - $H/400$  (0.0025H) to  $H/500$  (0.002H)
  - Inelastic Seismic Drift
    - $0.025 H$  (10 times wind!)
- For a 12 ft story height:
  - Wind – 0.36 inches
  - Seismic – 3.6 inches

ASCE 7-16 13.5.3.1 Requires that panel connections and joints accommodate at least 1/2 in. interstory movement.

66

**Attachment Criteria**

### Accommodating Relative Movement

(a) Rotation at Attachments    (b) Flexure of Façade Element    (c) Increased Rotations at Façade Sub-Element Such as a Window

67

**Attachment Criteria**

### Forces from Restraint


- Best to avoid restraint altogether
- Predicting restraint forces inexact
  - Cracking
  - Creep
  - Attachment stiffness
- Watch out for inadvertent restraint

68

**Attachment Criteria**

## Durability of the Attachment

- Attachments are usually hard to inspect.
- Consider what happens if the wall leaks.
- Consider how likely the wall is to leak over time.
- Special attention to thin steel parts or steel fasteners.



69

**Attachment Criteria**

## Galvanized or Stainless?

- HDG Advantages:
  - Less expensive
  - More readily available
  - Field welding uses more common procedures
- HDG Disadvantages:
  - Zinc coating defects may allow rust product to stain facade
  - Zinc coating is sacrificial and has a defined life
  - Field-welds require touch-up after welding

70

**Attachment Criteria**

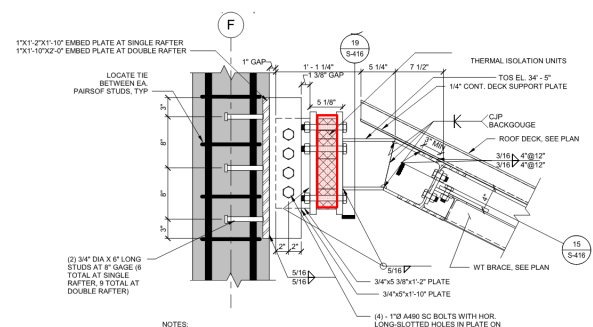
## Problems Associated with Support and Anchorage

- Anchors contributing to poor drainage
- Anchors not stiff enough to prevent differential movement that tears barriers
- Damage to barriers during erection and installation
- Constructability
- Coordination of trades

71

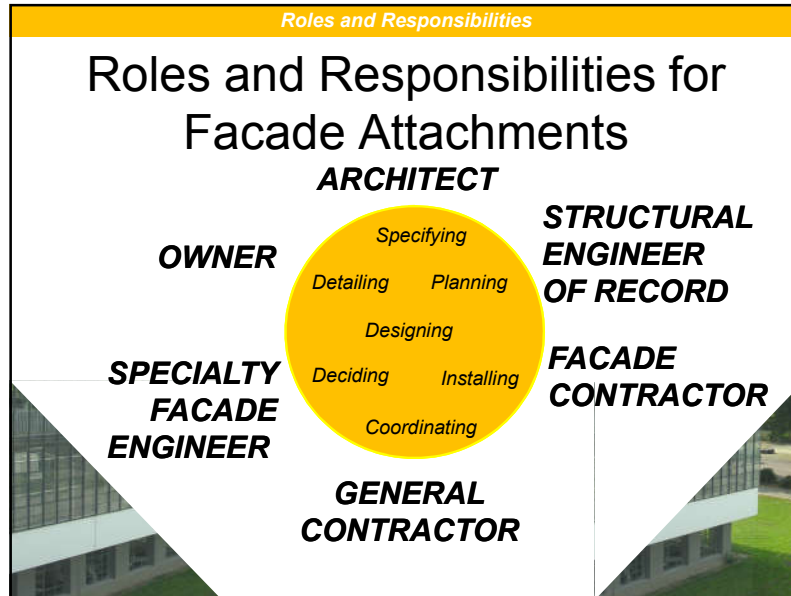
**Attachment Criteria**

## Constructability and Economy



SECTION: RAFTER TO CONC COLUMN CONNECTION  
1 1/2" = 1'-0"


72



Roles and Responsibilities

## Owner

- Contributes to facade requirements
  - Performance, aesthetics, budget
- Controls contractual relationships
- Maintenance
- Periodic inspections per local regulations




74

Roles and Responsibilities

## Architect (or PDP)

- Selects the system that can meet the project's requirements
- Fundamental building design decisions that effect facade attachments (materials, jointing patterns, thermal performance, etc.)
- Selects and defines attachment strategy in consultation with others
  - Structural engineer of record, facade engineer(s) and facade consultants, manufacturers, facade specialty contractors.




75

Roles and Responsibilities

## Structural Engineer of Record

- Must understand the facade system and the **strategy** for attachment to design the primary structure
- Provides anticipated structural movements
- Designs frame and slab edge consistent with attachment strategy



76

*Roles and Responsibilities*

## Structural Engineer of Record

- Delineates the structural steel elements from the attachment items by the SSE
- Indicates the assumptions/limitations of the facade attachments
- Indicates the tolerances of the steel frame
- Provides sufficient adjustability in structural frame details



77

*Roles and Responsibilities*

## Contractors

- General Contractor/Construction Manager
  - Coordinates trades and submittals
  - Reviews for conformance with project specifications
- Facade Contractor
  - Coordinates with the manufacturer of facade elements
  - Usually hires Specialty Structural Engineer
  - Responsible for fabrication and erection



78

*Roles and Responsibilities*

## Specialty Structural Engineer

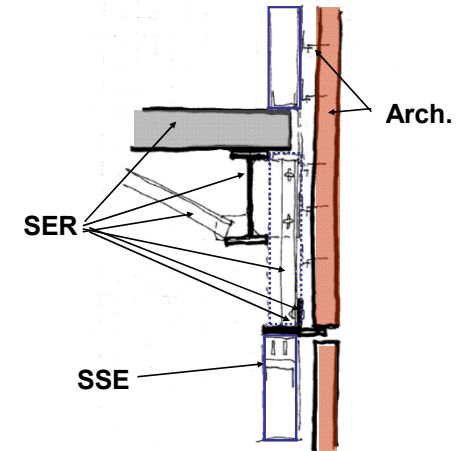
- Design professional responsible for the design of the facade and its attachments
  - Usually under contract to the contractor
- There may be one SSE for the facade elements itself and another SSE for the attachments.
- May be responsible for inspection during construction as delegated by the PDP or SER



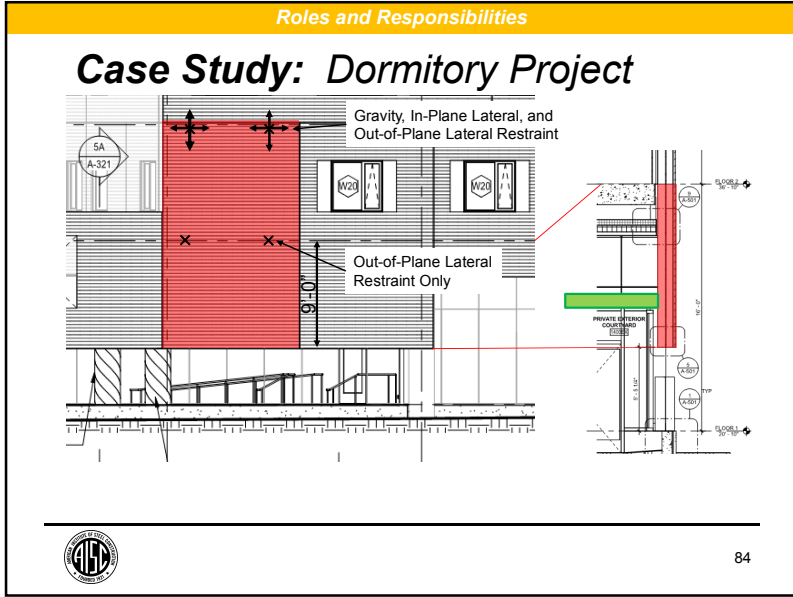
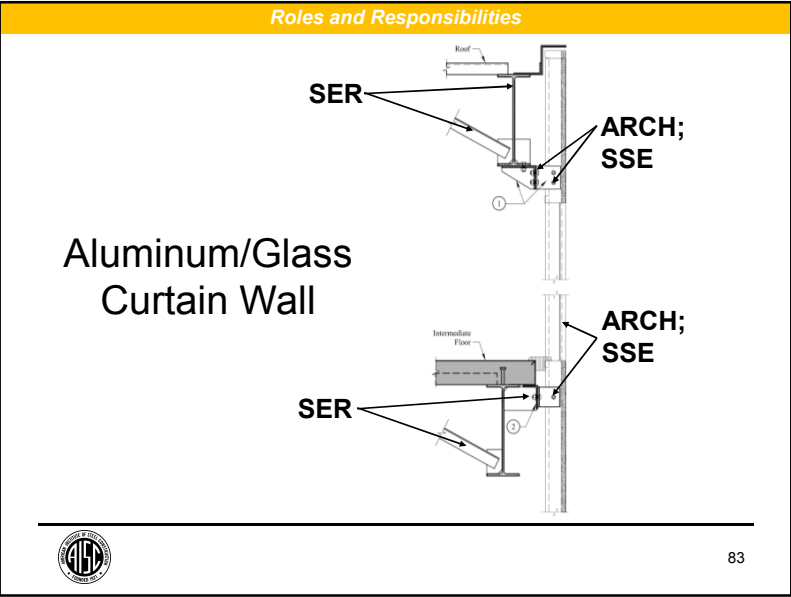
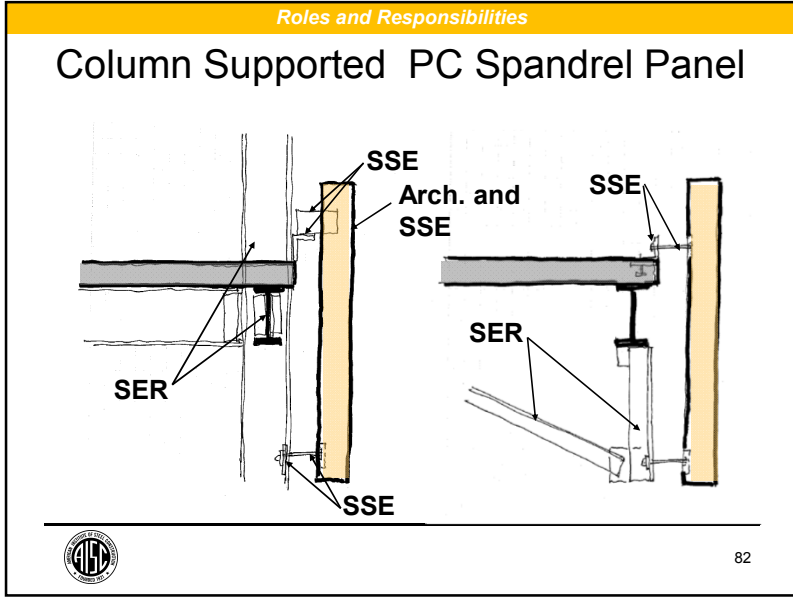
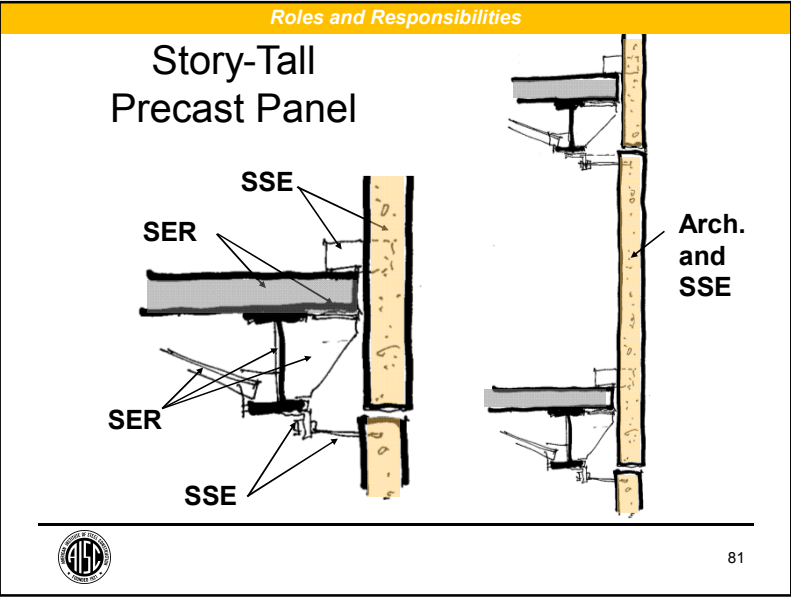
79

*Roles and Responsibilities*

## Masonry Veneer



80



**Roles and Responsibilities**

## Summary

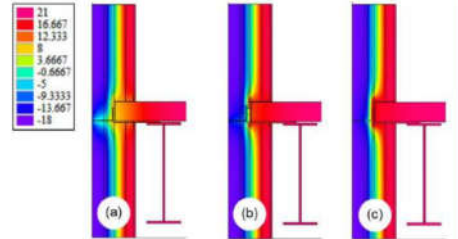
- Communicate!
- Façade attachments are difficult because every member of the design team has a significant role in the planning, designing and coordination.




85


**Thermal Bridges and Breaks**

## Thermal Bridges and Breaks



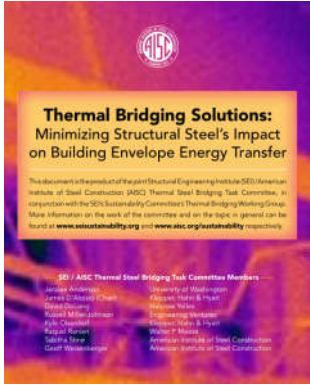
Peterman et al, "Thermal Break Strategies for Cladding Systems in Building Structures" (2017)

As the state of building design evolves to improve thermal efficiency, the need to accommodate thermal breaks in façade attachments continues to develop.

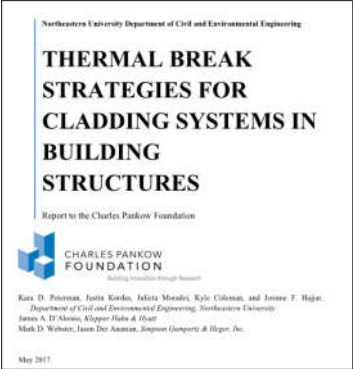

86

**Thermal Bridges and Breaks**


## Two Good Resources



[https://www.aisc.org/globalassets/modern-steel/archives/2012/03/2012v03\\_thermal\\_bridging.pdf](https://www.aisc.org/globalassets/modern-steel/archives/2012/03/2012v03_thermal_bridging.pdf)



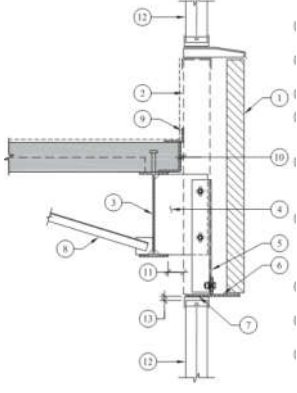
<http://www1.coe.neu.edu/~jhajjar/home/Peterman,%20Webster,%20Aloisio,%20Hajjar%20et%20al,%20-%20Thermal%20Break%20Strategies%20-%20CPF%20Final%20Report%20-%20May%202017.pdf>



87

**Thermal Bridges and Breaks**

## Risks of Thermal Bridges

- Energy loss
- Occupant comfort
- Condensation
  - Corrosion
  - Mold growth




88

*Thermal Bridges and Breaks*

## Alignment of Thermal Break

TRIM POUR STOP FLUSH WITH TOP OF SLAB AT WINDOW OPENINGS  
 3/4" x 6" LONG HEADED STUDS @ 1'-6" OC TYP., @ 1'-0" OC LEVEL 4 EXCEPT LINES J AND 10.  
 HORIZONTAL LONG-SLOTTED HOLE IN PLATE  
 #4x3'-6" @ 6" AT BRICK PIERS; @ 12" ELSEWHERE  
 3'-0"  
 DECK ORIENTATION VARIES  
 3/4" A325 ERECTION BOLT  
 SPANDREL BEAM  
 GRID  
 SHEATHING  
 AIR BARRIER/WATER BARRIER  
 INSULATION  
 CAVITY  
 L7x4 (GALV.) WITH LONG VERTICAL SLOTTED HOLE IN VERTICAL LEG. MASK AREAS TO BE WELDED. SEE NOTE 1. SEE TABLE FOR THICKNESS.  
 (2) 3/4" A325 ERECTION BOLTS MIN. PER RELIEVING ANGLE SEGMENT  
 BENT PLATE 3/8" x 7/8" x 0'-8 1/4" CONT. POUR STOP. MITER AT CORNERS.  
 1/4" 4" @ 12"  
 1/4" 2" @ 16"  
 1/4" 2" @ 16"

89

*Thermal Bridges and Breaks*

## Prefabricated Assemblies

90

*Thermal Bridges and Breaks*

## Built-Up Assemblies

- Thermal Isolation Pads
- Thermal Isolation Bushings
- Thermal Isolation Washers or Stainless Washers
- Stainless Steel Bolts

91

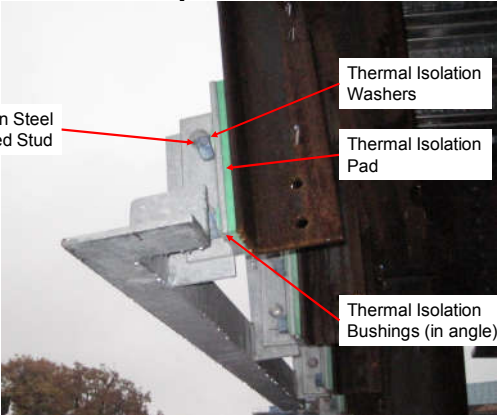
*Thermal Bridges and Breaks*

## Built-Up Assemblies

92

*Thermal Bridges and Breaks*

## Built-Up Assemblies




Carbon Steel Welded Stud

Thermal Isolation Washers

Thermal Isolation Pad

Thermal Isolation Bushings (in angle)



93

*Thermal Bridges and Breaks*

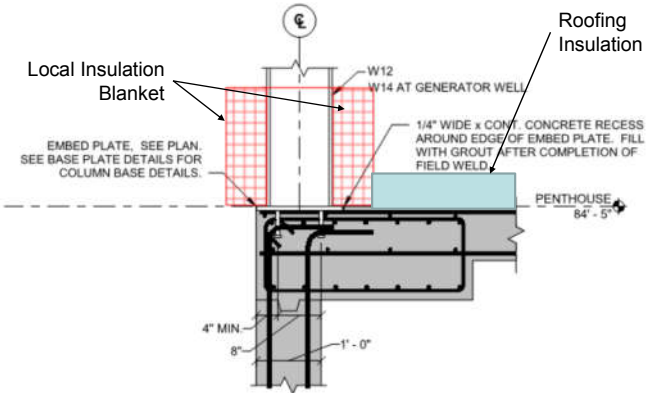
## Thermal Insulating Coatings




94

*Thermal Bridges and Breaks*

## Local Insulation Blankets



Local Insulation Blanket

Roofing Insulation


W12  
W14 AT GENERATOR WELL

1/4" WIDE x COM. CONCRETE RECESS AROUND EDGE OF EMBED PLATE. FILL WITH GROUT AFTER COMPLETION OF FIELD WELD.

EMBED PLATE. SEE PLAN. SEE BASE PLATE DETAILS FOR COLUMN BASE DETAILS.

PENTHOUSE  
84' - 5"

4" MIN.  
8"  
1' - 0"

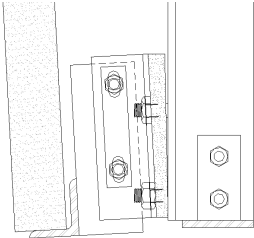



95

*Thermal Bridges and Breaks*

## Additional Deflection and Rotation in the Connection

- Unlike a conventional steel-to-steel connection, a thermally-broken connection will include additional deflection and rotation due to:
  - Oversize in the bolt holes
  - Bending and compression in the thermal break material
  - Bolt flexural deformation
  - Bolt shear deformation

96

**Thermal Bridges and Breaks**

## Bending in Bolts / Studs

- Borrowing approach from AISC Design Guide 1, Second Edition, Example 4.11:

$$\phi F'_{nt} = \phi \left[ 1.3F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_{rv} \right] \leq \phi F_{nt} \quad \text{AISC 360-16 (J-3.3a)}$$

$$f_t = f_{ta} + f_{tb}$$

$$f_{ta} = \frac{2M_u}{d \times n \times A} + \frac{T_u}{n \times A}$$

$$f_{tb} = \frac{V_u \times l}{n \times Z}$$

$$Z = \frac{d^3}{6}$$

97

**Thermal Bridges and Breaks**

## Northeastern University Study Conclusions

- Using non-conductive shims is a thermally effective means of mitigating thermal bridges. This strategy is especially effective for continuous thermal bridges...
- FRP structural members are very effective at thermal bridge mitigation, in continuous and discrete cladding details.
- Stainless steel bolts offer significant improvement in thermal transmittance...
- Recommendation to cap compressive stress in FRP isolation pads to 0.3 to 0.35 of ultimate stress

98

**Thermal Bridges and Breaks**

## Future Studies: Stainless Steel Thermal Performance

99

**Thermal Bridges and Breaks**

## Future Studies: Fire Ratings and Thermal Breaks



- Influence of temperature on polymers used as thermal separators has not been studied thoroughly
- Strength and stiffness of polymers is compromised at elevated temperatures

100

*Thermal Bridges and Breaks*

## Cost-Benefit Analysis


- Do the benefits to the owner justify the potential detailing challenges and construction costs?



101


*Accommodating Tolerances and Clearances*

## Accommodating Construction Tolerances and Clearances



University of Southern Indiana

Adjustability must be provided between the structural details and facade attachment details to achieve a facade erected within acceptable tolerances relative to the theoretical plane.





102

*Accommodating Tolerances and Clearances*

## Tolerances and Clearances

- Tolerances:
  - Permissible amount of deviation from a specified criterion: dimension, shape, location.
- Clearances:
  - Space purposely provided between two parts to allow for movement, accommodate tolerances and provide access.


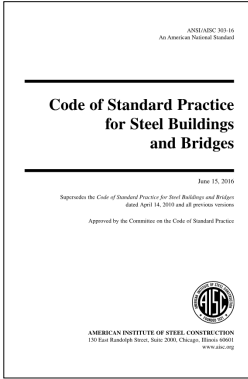


103

*Accommodating Tolerances and Clearances*

## Specifying Frame Tolerances

- Unreasonable for designers to disregard the realities of construction practice
- Note adjustable items on construction documents





104

Accommodating Tolerances and Clearances

## Types of Tolerances

- Material Production Tolerances
- Fabrication and Assembly Tolerances
- Erection and Installation Tolerances
- Accumulated Tolerances

*Design Guide 22 includes summaries of major facade materials and components.*





105

Accommodating Tolerances and Clearances

## Accumulated Tolerances

- Unlikely that all tolerances will vary to the maximum allowed and all occur in the same direction.
- However, no statistical data is usually available to the designer about the distribution of variation.


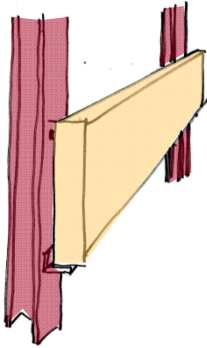


106

Accommodating Tolerances and Clearances

## Accumulated Tolerances


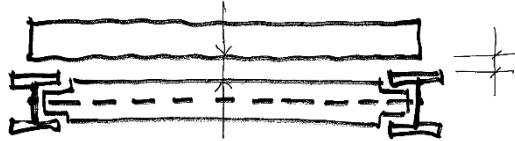
- Example:
  - PC panel supported on columns at 10<sup>th</sup> story
  - 40 ft span
  - Column plumbness:
    - -2 in. inward; +1 in. outward
  - Steel beam sweep:
    - +/- 1/2 in.
  - PC plan location at each end:
    - +/- 1/2 in.
  - PC bow:  $L/360 = +/- 1.33$  in.



107

Accommodating Tolerances and Clearances

## Accumulated Tolerances




108

**Accommodating Tolerances and Clearances**

## Accumulated Tolerances

- Maximum change in planned gaps if using all tolerance maximums:
  - At columns:
    - Open:  $2 + .5 = 2.5$  in.
    - Close:  $1 + .5 = 1.5$  in.
  - At mid span:
    - Open:  $2 + .5 + .5 + 1.33 = 4.33$  in.
    - Close:  $1 + .5 + .5 + 1.33 = 3.33$  in.





109

**Accommodating Tolerances and Clearances**

## Accumulated Tolerances

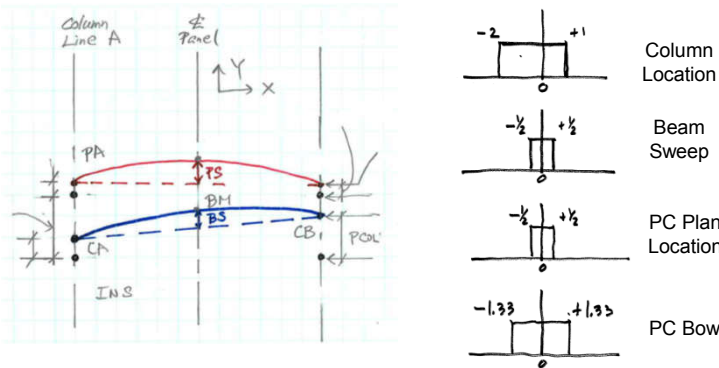
- If you started with a theoretical 2 in. gap at the columns:
  - Largest gap =  $2 + 2.5 = 4.5$  in.
  - Smallest gap =  $2 - 1.5 = 0.5$  in.
- If you started with a theoretical 4 in. gap at the midspan:
  - Largest gap =  $4 + 4.33 = 8.33$  in.
  - Smallest gap =  $4 - 3.33 = 0.67$  in.

110

**Accommodating Tolerances and Clearances**

## Accumulated Tolerances




Column Location:  $-2$  to  $+1$

Beam Sweep:  $-\frac{1}{2}$  to  $+\frac{1}{2}$

PC Plan Location:  $-\frac{1}{2}$  to  $+\frac{1}{2}$

PC Bow:  $-1.33$  to  $+1.33$




111

**Accommodating Tolerances and Clearances**

## SRSS Values

- Change in gap at column line
  - $-\sqrt{(1^2+0.5^2)}$  to  $+\sqrt{(2^2+0.5^2)} = -1.1$  in. to  $+2.1$  in.
- Change in gap at middle of panel
  - $-\sqrt{(1^2+0.5^2+0.5^2+1.33^2)}$  to  $+\sqrt{(2^2+0.5^2+0.5^2+1.33^2)}$
  - =  $-1.8$  in. to  $+2.5$  in.

For change in gap at middle of panel:  
 For uncorrelated case, 3% is below  $-1.8$  in. and 6% is above  $+2.5$  in. (total of about 9%)  
 For correlated case, 5% is below  $-1.8$  in. and 9% is above  $+2.5$  in. (total of about 14%)




112

**Accommodating Tolerances and Clearances**

## Recommendations for Accumulated Tolerances

- Understand the sources of variability
  - Steel frame sources, facade sources
- Understand the consequence of exceeding the tolerance provisions in the details
- Understand the costs associated with providing means to accommodate the variability

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113

**Accommodating Tolerances and Clearances**

## Recommendations for Accumulated Tolerances


- For each project, the team should develop a design criteria for addressing facade accumulated tolerances. For example:
  - Decide the target amount of adjustability
    - SRSS
    - AISC steel frame erection tolerances
    - Qualitative/quantitative probability analysis
    - Experience and judgment
  - Decide what elements will be adjustable and by how much.

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114

**Accommodating Tolerances and Clearances**

## Sizing Joints




Designation: C1472 - 16

**Standard Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width<sup>1</sup>**

This standard is issued under the fixed designation C1472; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

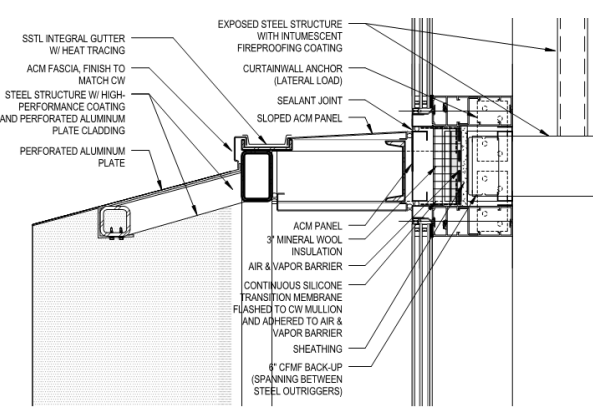
*7.7.2 Negative Tolerance—A negative tolerance is one that has a tendency to cause a joint opening to become smaller. This has serious technical concerns in that, if not considered, a joint becomes too small to accommodate anticipated movements within the movement capacity of the sealant. The sealant in these circumstances can become stressed beyond its manufacturer's rating and subject to failure.*

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115

**Accommodating Tolerances and Clearances**


## Case Study: Sunshade



The diagram shows a detailed cross-section of a sunshade joint assembly. Key components labeled include:

- SSTL INTEGRAL GUTTER W/ HEAT TRACING
- ACM FASCIA, FINISH TO MATCH CW
- STEEL STRUCTURE W/ HIGH-PERFORMANCE COATING AND PERFORATED ALUMINUM PLATE CLADDING
- PERFORATED ALUMINUM PLATE
- EXPOSED STEEL STRUCTURE WITH INTUMESCENT FIREPROOFING COATING
- CURTAINWALL ANCHOR (LATERAL LOAD)
- SEALANT JOINT
- SLOPED ACM PANEL
- ACM PANEL
- 3" MINERAL WOOL INSULATION
- AIR & VAPOR BARRIER
- CONTINUOUS SILICONE TRANSITION MEMBRANE FLASHED TO CW MULLION AND ADHERED TO AIR & VAPOR BARRIER
- SHEATHING
- 4" CFME BACK-UP (SPANNING BETWEEN STEEL OUTRIGGERS)

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116


**Accommodating Tolerances and Clearances**

## Case Study: Sunshade

**Accommodating Tolerances and Clearances**

## Case Study: Sunshade


## Key “Take-Aways”



1. The design team needs to develop a **strategy**, or strategies, for supporting the facade elements from the primary frame.
2. Given this **strategy**, the team needs to communicate responsibilities and scope.
  - Architect, SER, SSE, Contractor(s)
3. The SER needs to know the facade attachment **strategy** and needs enough information from the facade designer to anticipate the impact on the primary frame.
4. The SER needs to communicate the relevant frame performance characteristics (principally deformations).

119

## Key “Take-Aways”



5. The SER should strive to develop slab edge and spandrel beam designs that are consistent with the facade attachment **strategy**.
6. Tolerances, facade movements and frame movements need to be considered in total. Strategy and responsibility need to be clearly communicated and accepted.
7. The SER’s documents for the primary structure should indicate pertinent assumptions about facade attachment loads.
8. The Project Documents should indicate who is responsible for facade design and attachment and all performance requirements.

120

## Key “Take-Aways”



9. Consider that the steel frame will often be fabricated ahead of final facade attachment design, and detail the primary frame accordingly.
10. The steel frame detailers and fabricators are NOT the coordinators of the facade attachment details. The design team needs to develop and coordinate the strategy for the facade and its attachments so that shop drawings for the frame can be completed, sometimes ahead of deferred facade engineering by others.



121

There's always a solution in steel.

## Question time



## Individual Webinar Registrants

### CEU/PDH Certificates

Within 2 business days...

- You will receive an email on how to report attendance from: [registration@aisc.org](mailto:registration@aisc.org).
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



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Within 2 business days...

- New reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.



## 8-Session Registrants

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### CEU/PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.



## 8-Session Registrants

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Access to the quiz: Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG

Quiz and Attendance records: Posted Tuesday mornings.  
[www.aisc.org/nightschool](http://www.aisc.org/nightschool) - click on Current Course Details.

Reasons for quiz:

- EEU – must take all quizzes and final to receive EEU
- CEUs/PDHS – If you watch a recorded session you must take quiz for CEUs/PDHS.
- REINFORCEMENT – Reinforce what you learned tonight. Get more out of the course.

NOTE: If you attend the live presentation, you do not have to take the quizzes to receive CEUs/PDHS.



## 8-Session Registrants

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**Access to the recording:** Information for accessing the recording will be emailed to you by this Wednesday. The recording will be available for three weeks. For 8-session registrants only. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

**CEUs/PDHS** – If you watch a recorded session you must take AND PASS the quiz for CEUs/PDHS.



## Night School Resources for 8-session package Registrants

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Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!



## Night School Resources for 8-session package Registrants

Go to [www.aisc.org](http://www.aisc.org) and sign in.

The screenshot shows the AISC website homepage. At the top, there are navigation links: EDUCATION, PUBLICATIONS, NASCC: THE STEEL CONFERENCE, SAFETY, STEEL SOLUTIONS CENTER, AWARDS AND COMPETITIONS, and RESEARCH LIBRARY. Below these is a large banner with the AISC logo and the text "AISC". Underneath the banner is a "Login" section with the text "If you're an existing customer, please enter your username and password." There are two input fields: "USERNAME" and "PASSWORD". To the right of the login form is a "DON'T HAVE AN ACCOUNT?" section with the text "My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore." and a "REGISTER NOW" button.

## Night School Resources for 8-session package Registrants

Go to [www.aisc.org](http://www.aisc.org) and sign in.

The screenshot shows the MyAISC user profile page. On the left, there is a sidebar with links: IN THIS SECTION, Edit Profile, My Downloads, My Pending Quizzes, My Events, Order History, Course History, and Course Resources (circled in red). The main content area has a "MyAISC" header and sections for "MY PROFILE" (with an "EDIT PROFILE" button), "MY PURCHASED DOWNLOADS" (with a "VIEW DOWNLOADS" button), and "MY COURSE RESOURCES" (with a "VIEW RESOURCES" button, also circled in red). The "MY COURSE RESOURCES" section includes the text "View online resources for Night School and Live Webinar package registrations."

## Night School Resources for 8-session package Registrants

The screenshot shows the AISC website with the "Course Resources" section. The breadcrumb trail is "AISC > MyAISC > COURSE RESOURCES". Below the breadcrumb is a table with the following data:

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM

## Night School Resources for 8-session package Registrants

The screenshot shows the AISC website with the "8-SESSION PACKAGE RESOURCES" section. The breadcrumb trail is "AISC > MyAISC > NIGHT SCHOOL RESOURCES > NS13 8-SESSION PACKAGE RESOURCES". Below the breadcrumb is the title "Night School 13: Design of Industrial Buildings" and a table with the following data:

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	<a href="#">Handouts</a>	<a href="#">Video</a>	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Brag Bracing Dm	3/27/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending
NS13 - Final Exam	4/10/2017 7:00:00 PM			Available 04/12/2017 5pm EST	



### Night School Resources for 8-session package Registrants

- Weekly “quiz and recording” email.
- Weekly updates of the master Quiz and Attendance record found at [www.aisc.org/nightschool](http://www.aisc.org/nightschool). Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.



### Night School Resources for 8-session package Registrants

- Webinar connection information:
  - Found in your registration confirmation/receipt.
  - Reminder email sent out Monday mornings.
- Link to handouts also found here.



# Thank You

Please give us your feedback!  
*Survey at conclusion of webinar.*

There's always a solution in steel.

