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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.



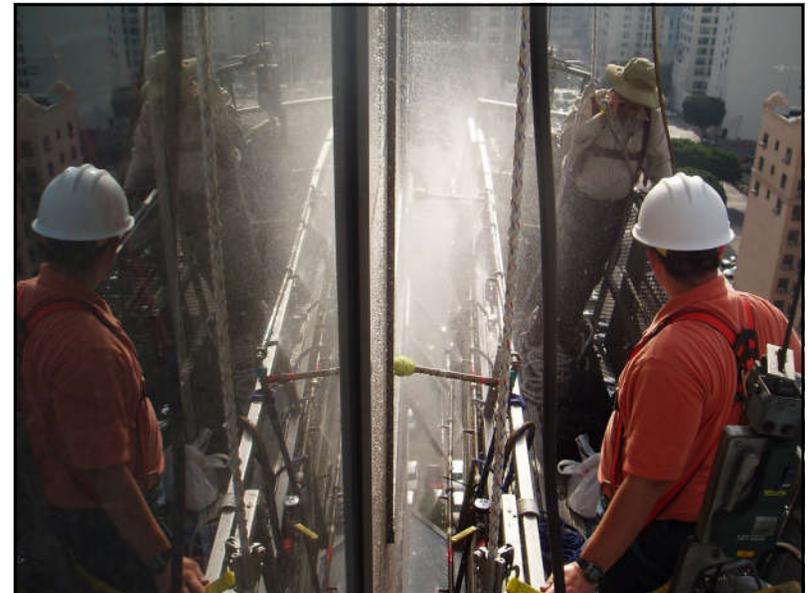
There's always a solution in steel.

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





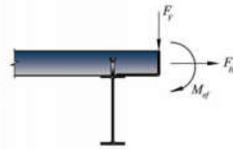


Attachments: What's the Problem?

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



AISC Design Guide 22



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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



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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.



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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



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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



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Syllabus for Night School Sessions

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



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Syllabus for Night School Sessions

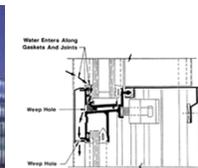
- Session 1
- Session 2
- Session 3
- **Session 4**
 - Accommodating Lateral Drifts
 - In-Plane Movements
 - Out-of-Plane Movements
 - Building Corners



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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.



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Fundamentals of Façade Performance

The Façade and the Building Envelope

Diagram illustrating the building envelope components and energy flow. Components shown include roofing, walls, windows, all interfaces, doors, and foundations. Arrows indicate energy flow: blue arrows for air/heat entering and red arrows for heat escaping.

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Fundamentals of Façade Performance

Time Line

Timeline showing the evolution of building types. The timeline spans from 2000 B.C. to 2000 A.D. Key building types are identified: Load Bearing Masonry (from 2000 B.C. to 2000 A.D.), Transitional Masonry (from approximately 1900 to 2000 A.D.), and Contemporary Curtain Walls (from approximately 1900 to 2000 A.D.).

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Fundamentals of Façade Performance

1250 B.C. 430 B.C. A.D. 530

Timeline illustrating the evolution of Load Bearing Masonry. Key historical examples are shown: 1250 B.C. (Ruins of a classical temple), 430 B.C. (The Parthenon), A.D. 530 (Hagia Sophia), A.D. 1220 to 1472 (Gothic cathedral), and 1713 (A brick building).

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Fundamentals of Façade Performance

Load Bearing Masonry

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

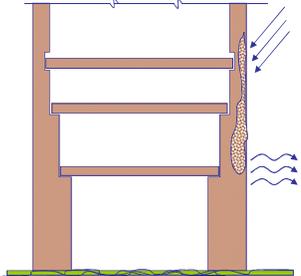
Diagram illustrating the structure of Load Bearing Masonry. The left side shows a brick wall with a window. The right side shows a cross-section of a wall with horizontal floor joists resting on the wall, demonstrating how the floor “rides” with the walls. Red arrows indicate vertical load transfer.

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Fundamentals of Façade Performance

Load Bearing Masonry

- Walls manage moisture as a reservoir



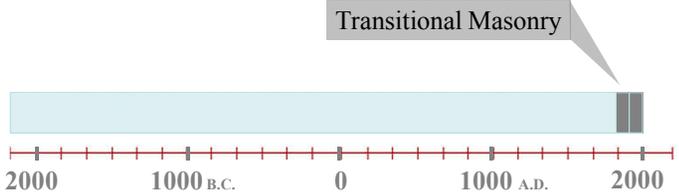
The diagram shows a cross-section of a masonry wall with three horizontal floor slabs. Arrows on the right indicate moisture entering the wall from the exterior and being stored within the masonry. Wavy arrows on the right indicate moisture leaving the wall towards the exterior. The wall sits on a foundation.



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Fundamentals of Façade Performance

Time Line



The diagram shows a horizontal timeline from 2000 B.C. to 2000 A.D. A light blue bar represents the duration of masonry use. A callout box labeled 'Transitional Masonry' points to a small dark grey segment at the end of the timeline, between 0 and 2000 A.D.

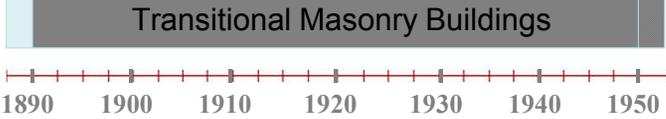


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Fundamentals of Façade Performance



Transitional Masonry Buildings



The diagram shows a horizontal timeline from 1890 to 1950. A grey bar above the timeline indicates the period of transitional masonry buildings.

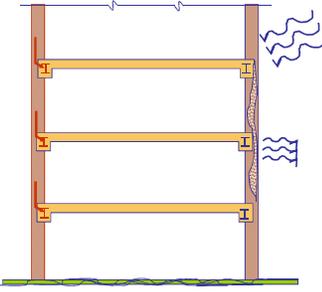


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Fundamentals of Façade Performance

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. The masonry walls are thick and are shown in contact with the steel frame. Arrows on the right indicate moisture entering and leaving the wall, showing its function as a reservoir.



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Fundamentals of Façade Performance

Transitional Masonry Buildings

(From Good Practices in Construction, by Philip G. Knobloch, The Porcel Paint Press, 1923)

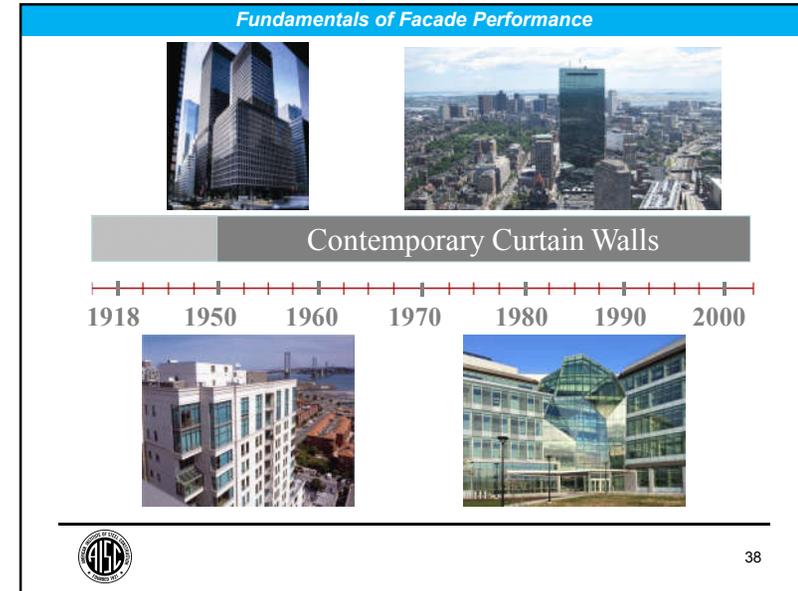
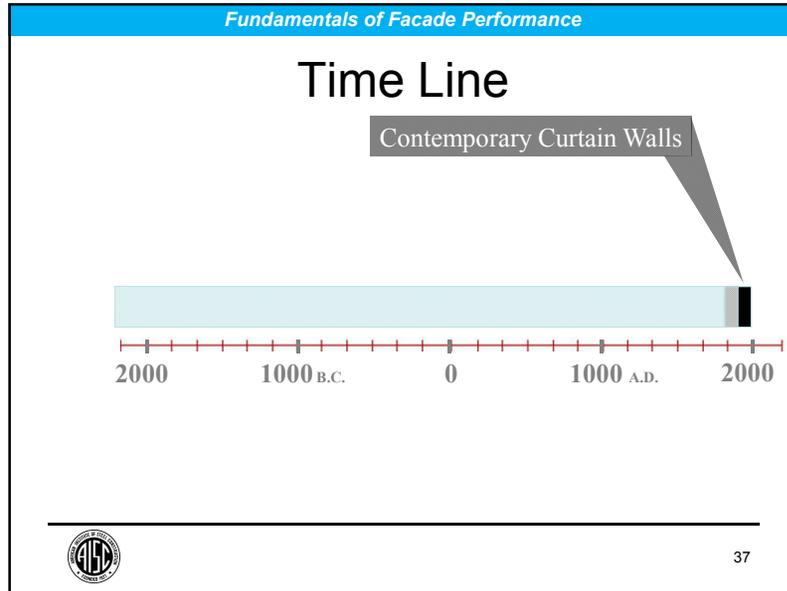

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Fundamentals of Façade Performance

Transitional Masonry Buildings


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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

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Exterior Wall System

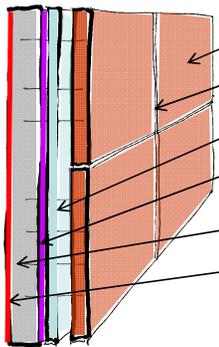
Performance Requirements of the Exterior Wall System

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

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Exterior Wall System

Functional Components of the Exterior Wall System



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



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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



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Exterior Wall System

Facade Design Criteria



- Structural Integrity
- Provisions for Movement
- Envelope Performance



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Attachment Criteria

Criteria for Façade Attachment

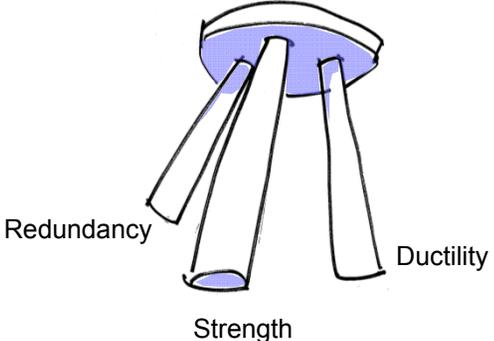
- Structural Integrity
- Accommodating Movement
- Durability
- Accounting for Tolerances and Clearances
- Constructability
- Economy



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Attachment Criteria

Structural Integrity



Redundancy

Strength

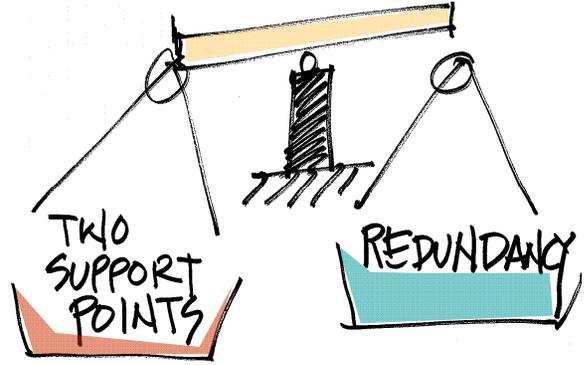
Ductility



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Attachment Criteria

Conflicting Ideas



TWO SUPPORT POINTS

REDUNDANCY

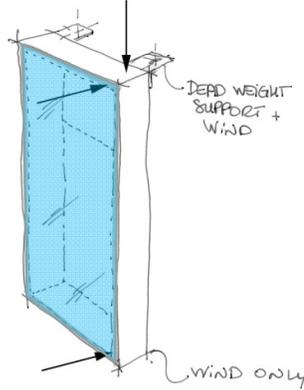


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Attachment Criteria

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



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Attachment Criteria

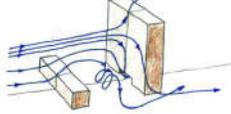
Loads on Attachments



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

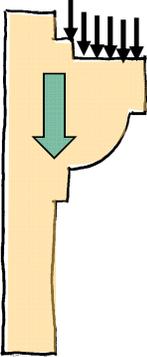


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Attachment Criteria

Gravity Loads

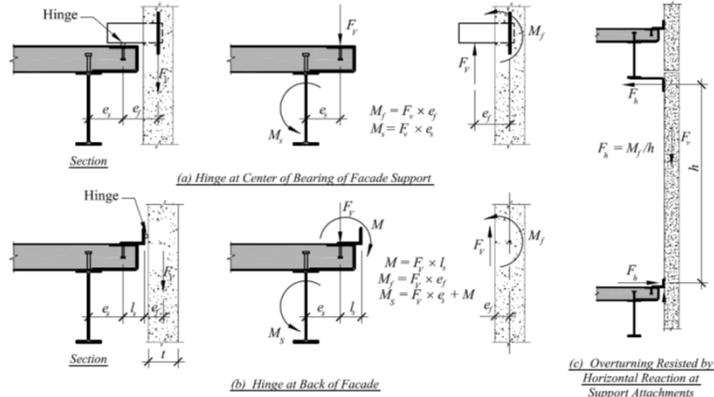
- Façade dead load
 - Need to understand materials and system
- Façade live loads
 - Horizontal projections
- SER usually needs to estimate before wall is designed
- Window washing activities




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Attachment Criteria

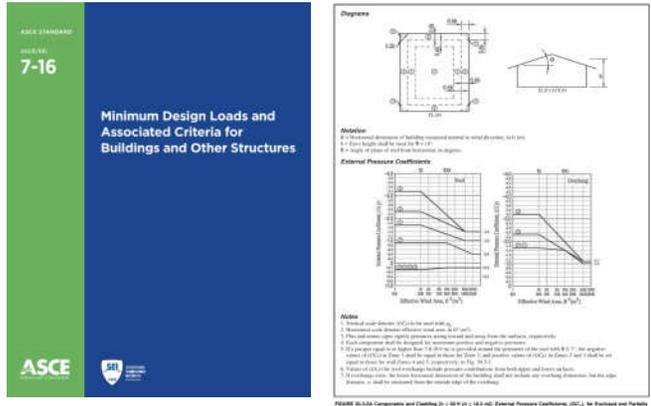
Gravity Load Eccentricities




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Attachment Criteria

Wind Loads




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Attachment Criteria

Wind Tunnel Testing

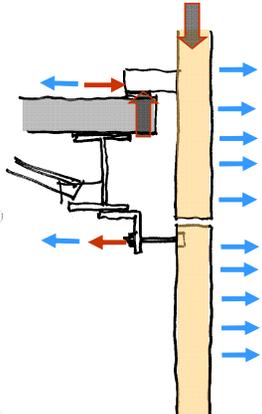



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Attachment Criteria

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.




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Attachment Criteria

Seismic Requirements

- Seismic Forces
- Relative Displacements
- Ductility



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


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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


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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"> • Parapets • Storage cabinets
C, D, E, F	Architectural components are not exempt
ALL	Temporary or moveable equipment


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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 ^b			
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

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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):

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

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Attachment Criteria

Limit States for Design

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



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Attachment Criteria

Limit States for Design

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

$$D + 0.5L + W_a$$

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Attachment Criteria

Wind Deflections (IBC 2015)

CONSTRUCTION	L	δ or W	$D = L^{3/4}$
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/360	---	l/240
Exterior walls:			
With plaster or stucco finishes	---	l/360	---
With other brittle finishes	---	l/240	---
With flexible finishes	---	l/120	---
Interior partitions: ^g			
With plaster or stucco finishes	l/360	---	---
With other brittle finishes	l/240	---	---
With flexible finishes	l/120	---	---
Farm buildings:			
Greenhouses	---	---	l/180
---	---	---	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.

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Attachment Criteria

Accommodating Relative Movement

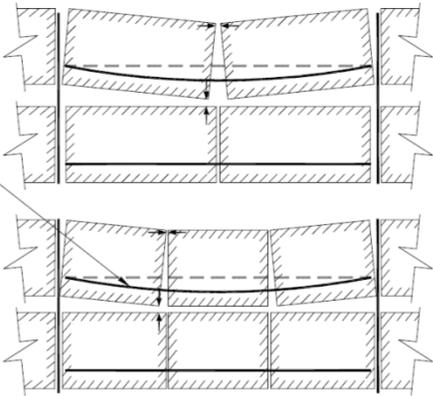
- Spandrel deflections, rotations, column shortening, bracket deflections.




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Attachment Criteria

Accommodating Relative Movement



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

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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.?



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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 $L/1440$

$\Delta_{SIL} \leq \frac{1}{8}''$
 $\Delta_{TL} + K_e L$

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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.

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Attachment Criteria

Accommodating Relative Movement

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

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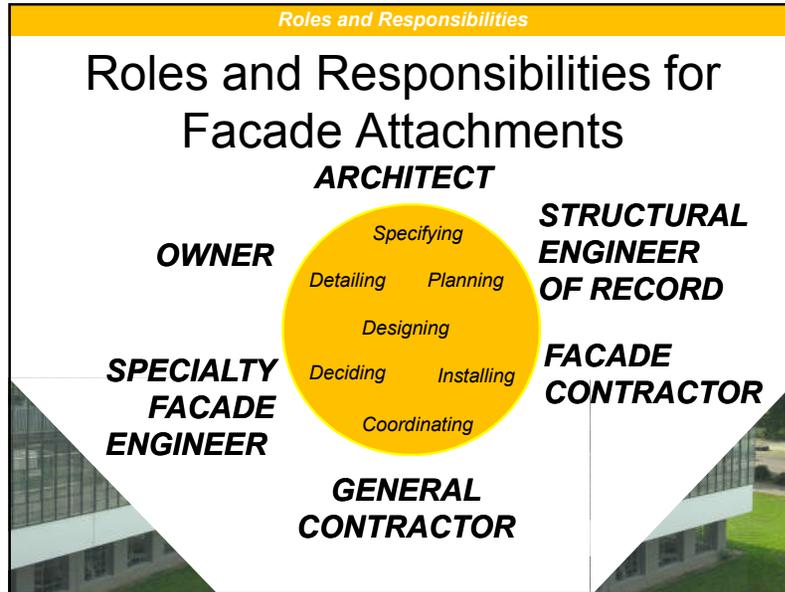
Attachment Criteria

Forces from Restraint

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

This bolt fractured and panel fell.
 Bldg. Exp. Joint
 Slotted Insert
 Panel Joint

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Roles and Responsibilities

Owner

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



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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.



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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



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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



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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



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Roles and Responsibilities

Specialty Structural Engineer

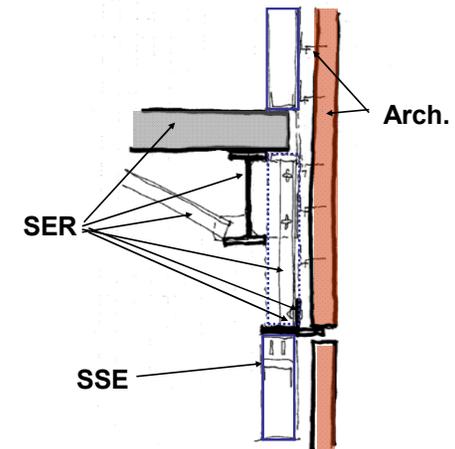
- Design professional responsible for the design of the facade and its attachments
 - Usually under contract to the contractor
- There may be one SSE for the facade elements itself and another SSE for the attachments.
- May be responsible for inspection during construction as delegated by the PDP or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



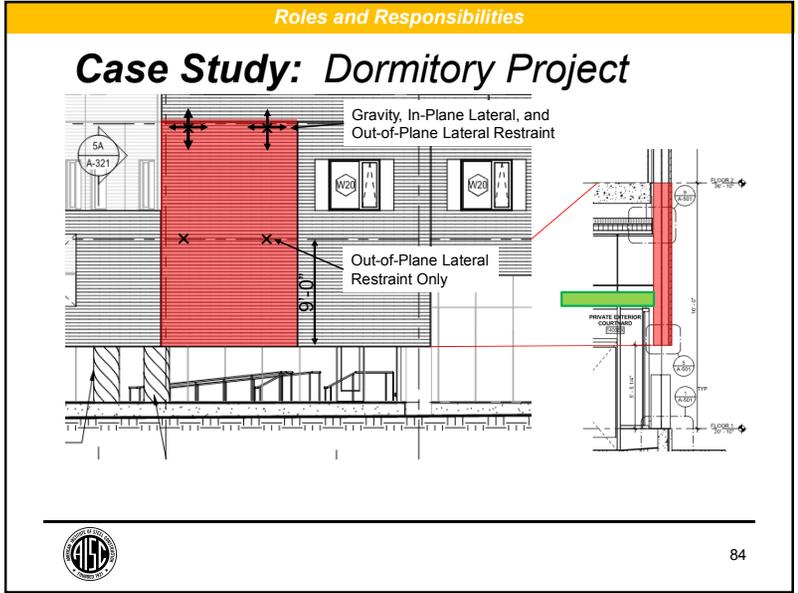
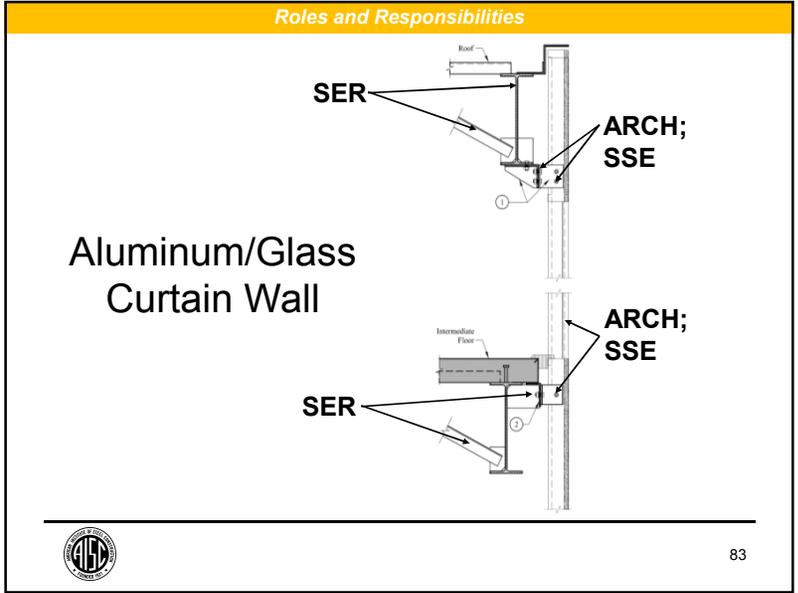
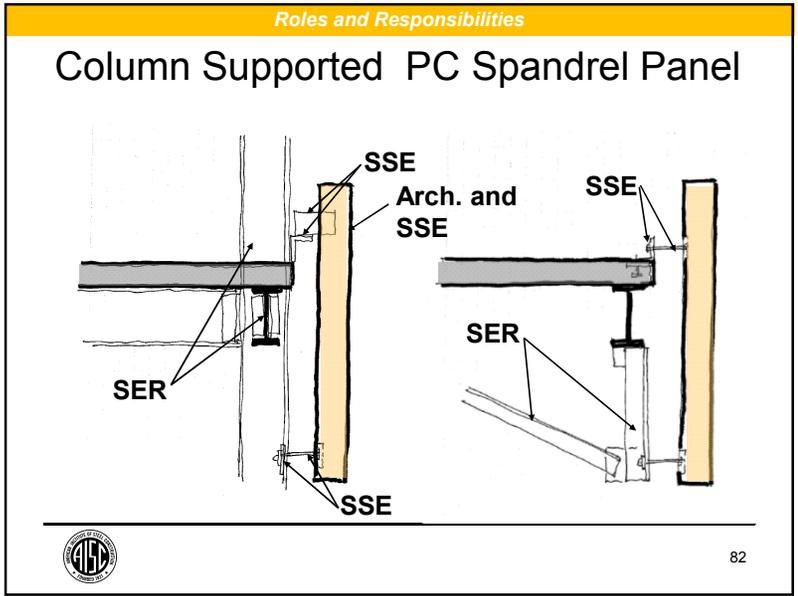
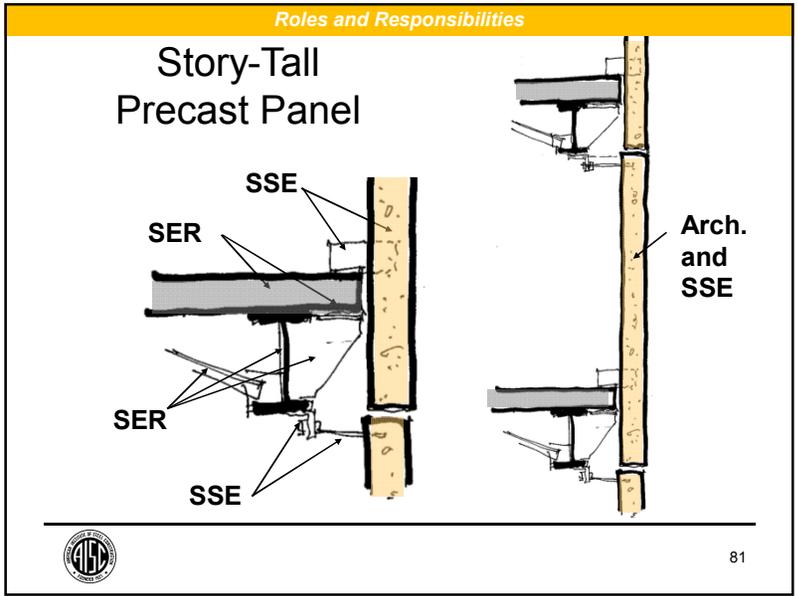
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Roles and Responsibilities

Masonry Veneer



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Roles and Responsibilities

Summary

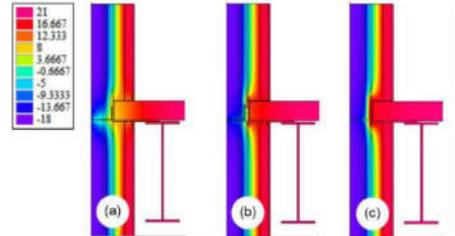
- Communicate!
- Façade attachments are difficult because every member of the design team has a significant role in the planning, designing and coordination.




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Thermal Bridges and Breaks

Thermal Bridges and Breaks



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

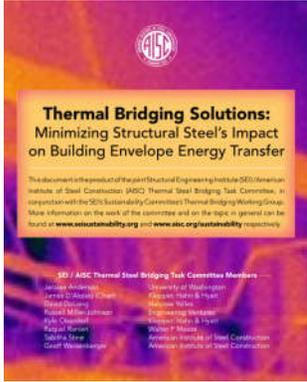
As the state of building design evolves to improve thermal efficiency, the need to accommodate thermal breaks in façade attachments continues to develop.



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Thermal Bridges and Breaks

Two Good Resources

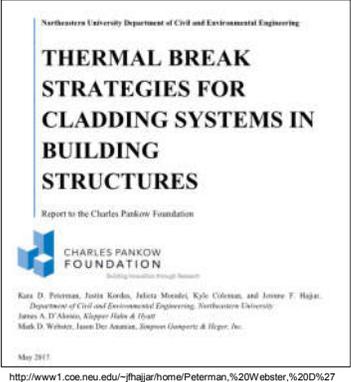


**Thermal Bridging Solutions:
Minimizing Structural Steel's Impact
on Building Envelope Energy Transfer**

This document is the product of the joint Structural Engineering Institute (SEI) American Institute of Steel Construction (AISC) Thermal Steel Bridging Task Committee, in cooperation with the SEI's Sustainability Committee Thermal Bridging Working Group. More information on the work of the committee and on the topic in general can be found at www.aisc.org/sustainability.

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Gail W. Webster, AISC

https://www.aisc.org/globalassets/modern-steel/archives/2012/03/2012v03_thermal_bridging.pdf



THERMAL BREAK STRATEGIES FOR CLADDING SYSTEMS IN BUILDING STRUCTURES

Report to the Charles Pankow Foundation

CHARLES PANKOW FOUNDATION
Building Innovation Through Research

Kurt D. Peterman, Justin Kordek, Melissa Morandi, Kyle Coleman, and Jerome F. Hajjar,
Department of Civil and Environmental Engineering, Northeastern University
James A. D'Alonzo, Klappert Hulse & O'Neil
Mark D. Webster, Insum Der Anstalt, Ingenieurbüro Gumpertz & Hoyer, Inc.

May 2017

<http://www1.coe.neu.edu/~jhajjar/home/Peterman,%20Webster,%20D%27Alonzo,%20Hajjar%20et%20al.%20-%20Thermal%20Break%20Strategies%20-%20CPFF%20Final%20Report%20-%20May%202017.pdf>

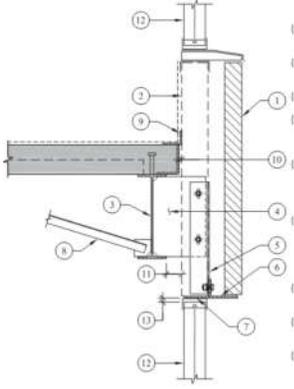


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Thermal Bridges and Breaks

Risks of Thermal Bridges

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




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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" 2" @ 16"
 1/4" 2" @ 16"

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Thermal Bridges and Breaks

Prefabricated Assemblies

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Thermal Bridges and Breaks

Built-Up Assemblies

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

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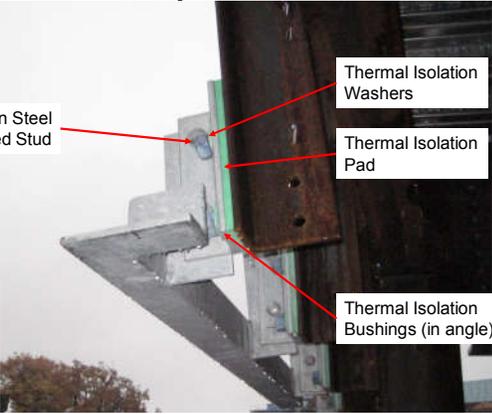
Thermal Bridges and Breaks

Built-Up Assemblies

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Thermal Bridges and Breaks

Built-Up Assemblies



Carbon Steel Welded Stud

Thermal Isolation Washers

Thermal Isolation Pad

Thermal Isolation Bushings (in angle)



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Thermal Bridges and Breaks

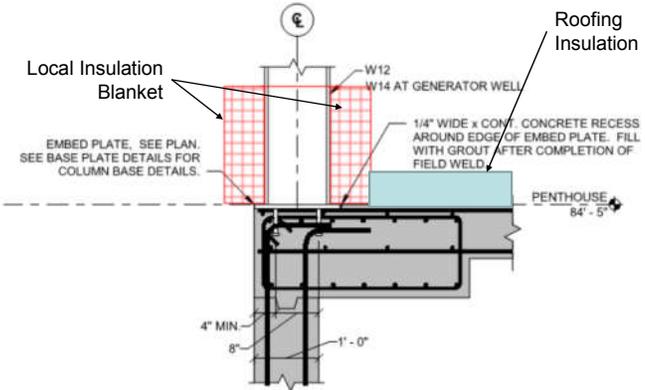
Thermal Insulating Coatings




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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"

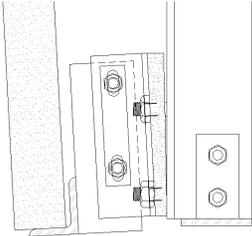


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Thermal Bridges and Breaks

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




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Thermal Bridges and Breaks

Bending in Bolts / Studs

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

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

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

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

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

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

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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

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Thermal Bridges and Breaks

Future Studies: Stainless Steel Thermal Performance

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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

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Thermal Bridges and Breaks

Cost-Benefit Analysis

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



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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.



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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.

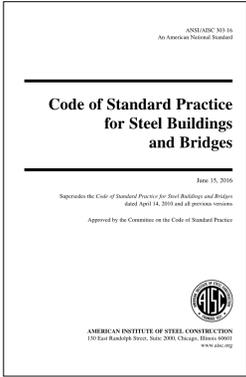


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Accommodating Tolerances and Clearances

Specifying Frame Tolerances

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



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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.



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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.

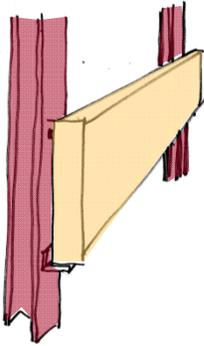


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Accommodating Tolerances and Clearances

Accumulated Tolerances

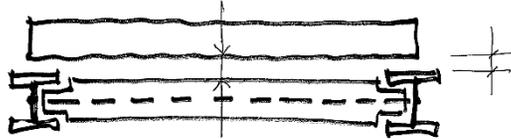
- Example:
 - PC panel supported on columns at 10th story
 - 40 ft span
 - Column plumbness:
 - -2 in. inward; +1 in. outward
 - Steel beam sweep:
 - +/- 1/2 in.
 - PC plan location at each end:
 - +/- 1/2 in.
 - PC bow: $L/360 = +/- 1.33$ in.



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Accommodating Tolerances and Clearances

Accumulated Tolerances



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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.



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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.

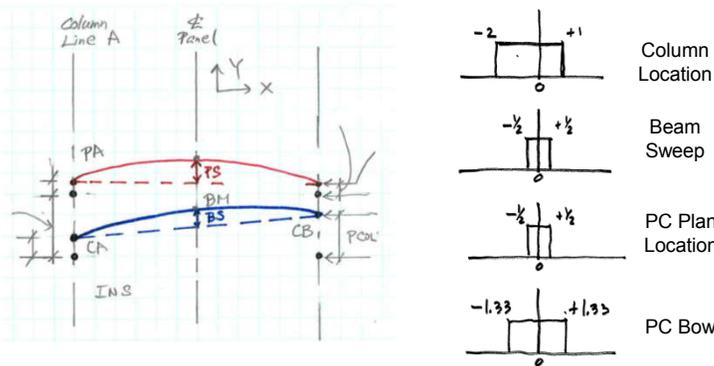




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Accommodating Tolerances and Clearances

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 $+1.33$



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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%)



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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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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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Accommodating Tolerances and Clearances

Sizing Joints



Designation: C1472 - 16

Standard Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width¹

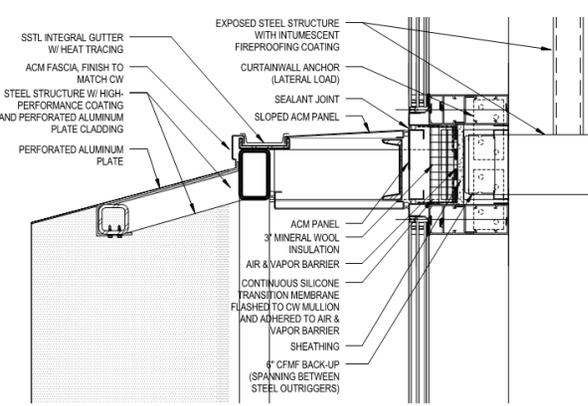
This standard is issued under the fixed designation C1472; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates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

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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Accommodating Tolerances and Clearances

Case Study: Sunshade



The diagram shows a cross-section of a sunshade joint assembly. On the left, an SSSL integral gutter with heat tracing is shown. The sunshade panel is supported by a steel structure with high-performance coating and perforated aluminum plate cladding. The joint assembly includes an ACM fascia finish to match the CW, a sealant joint, and a sloped ACM panel. The sunshade panel is supported by a steel structure with high-performance coating and perforated aluminum plate cladding. The joint assembly includes an ACM fascia finish to match the CW, a sealant joint, and a sloped ACM panel. The sunshade panel is supported by a steel structure with high-performance coating and perforated aluminum plate cladding. The joint assembly includes an ACM fascia finish to match the CW, a sealant joint, and a sloped ACM panel.


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Accommodating Tolerances and Clearances

Case Study: Sunshade

The drawing shows a cross-section of a sunshade attachment. Key components include:
 - HSS5x3x3/8 channel section.
 - 1"x7"x8" plate with standard holes.
 - WT7x34x0'-7" long wide flange section.
 - HSS6X4 channel section.
 - 1/4"xCONT. BENT PLATE.
 - BENT PLATE TO HSS.
 - HSS5x3 channel section.
 - L5x5x5/16x0'-3" section.
 - Dimensions: 3 SIDES, TOP; 1/4"; 1"-6"; 1"; 1/4"; 2"; 3/16"; 2"; 2"; 1/4"; 1/4"; 2"; 2"; T&B.
 - Notes: ALL STEEL TO EXTERIOR OF THERMAL ISOLATION PAD IS GALV.; TC-D4A BOT. TYP.; C6 SEE PLAN FOR EXTENTS; R=1/4" α=45°.

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Accommodating Tolerances and Clearances

Case Study: Sunshade

The photograph shows the physical installation of the sunshade attachment detail, highlighting the clearances and tolerances between the steel components.

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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).

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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.

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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.



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There's always a solution in steel.

Question time



4-Session Package Registrants Course Resources

1. Log on to your AISC account and go to Course Resources.
<https://www.aisc.org/myaisc/course-resources/>
2. Locate your course.
3. Access handouts, videos, quizzes, quiz scores and attendance records.

aisc > MY ACCOUNT > COURSE RESOURCES > DESIGN OF FAÇADE ATTACHMENTS PACKAGE RESOURCES

Design of Façade Attachments

4-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
R1 Façade Fundamentals	N/A	Handouts	Video Façade 42N1173	Quiz Quiz R1	Pending
L1 Façade Attachments Part 1	May 9 2018 3:30PM EDT	Available 05/09/2018 5pm EDT	Available 05/11/2018 9:00PM EDT	Available 05/11/2018 9:00PM EDT	Pending
L2 Façade Attachments Part 2	May 16 2018 3:30PM EDT	Available 05/16/2018 5pm EDT	Available 05/18/2018 9:00PM EDT	Available 05/18/2018 9:00PM EDT	Pending
L3 Façade Attachments - Building Lateral Drifts	May 23 2018 3:30PM EDT	Available 05/23/2018 5pm EDT	Available 05/25/2018 9:00PM EDT	Available 05/25/2018 9:00PM EDT	Pending
Final Exam	N/A			Available 6/27/2018 9:00 PM EDT	



4-Session Package Registrants Videos and Quizzes

Videos

- For Session R1, recording will be available upon registering. Recording access expires on June 17.
- For Sessions L1 – L3, find access to recordings within two days after the live air date. Recording access expires on June 17.

Quizzes

- For Session R1, find access to quiz upon registering. Quiz is due on June 17.
- For Sessions L1 – L3, find access to quizzes within two days after the live air date. All quizzes are due on June 17.
- Quiz scores are displayed in the Course Resources table.



4-Session Package Registrants

Course Credit

Attendance and PDH Certificates

- For Session R1, you must pass the quiz to receive credit for the session.
- For Sessions L1 – L3, you have two options to receive credit for the session.
 - Option 1: Watch the session live. Credit for live attendance will be displayed in the Course Resources table within two days of the session.
 - Option 2: Watch the recording and pass the quiz.

Distribution of Certificates

- All certificates will be issued after the final session. Only the registrant will receive certificates for the course.

