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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.

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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.

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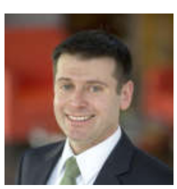
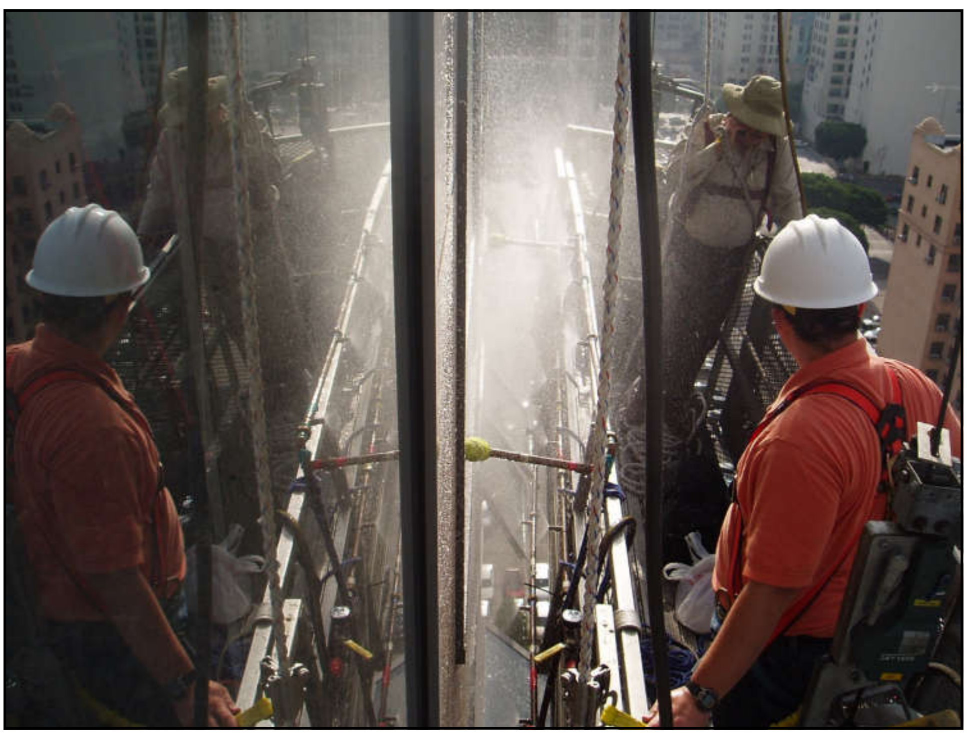
Behind the Facade: Guidance for Supporting Facades on Steel-Framed Buildings



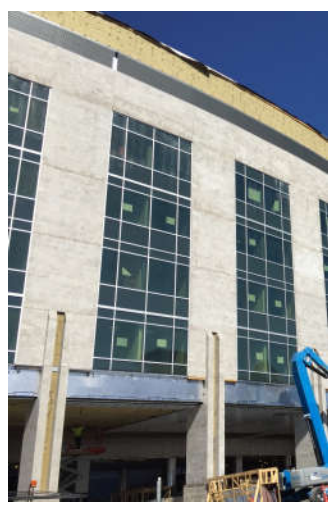
Alec Zimmer, P.E.
Senior Project Manager
Simpson Gumpertz & Heger Inc.
Waltham, MA

structural STEEL



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



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AISC Design Guide 22

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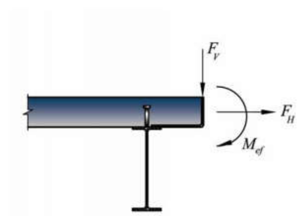
Steel Design Guide

Façade Attachments
to Steel-Framed Buildings



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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
- Session 2
- Session 3
- Session 4

- Fundamentals of Facades
- Design Criteria
- Design and Execution Responsibilities
- Thermal Bridging
- Planning for Clearances
- Accommodating Tolerances

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Syllabus for Night School Sessions

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

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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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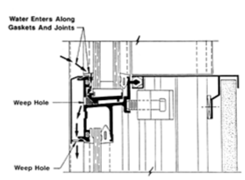
Fundamentals of Facade Performance

Fundamentals of Facade 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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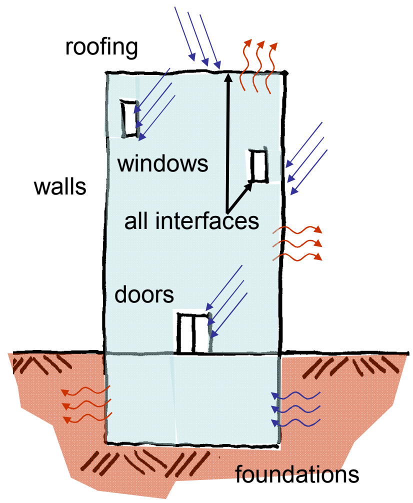
Fundamentals of Facade Performance

The Facade and the Building Envelope



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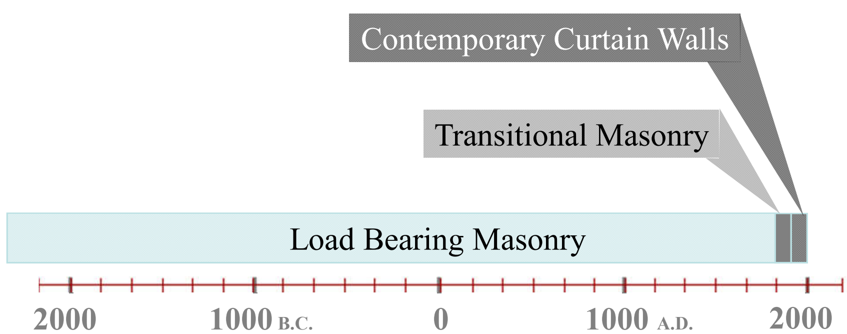
Fundamentals of Facade Performance

Time Line



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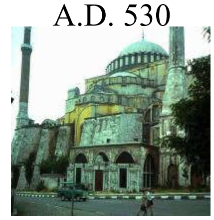
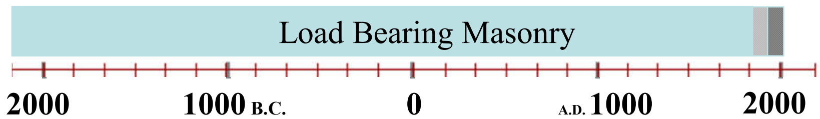
Fundamentals of Facade Performance

1250 B.C.

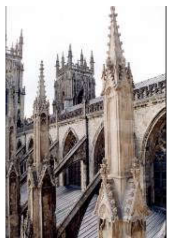
430 B.C.

A.D. 530





A.D.
1220 to
1472



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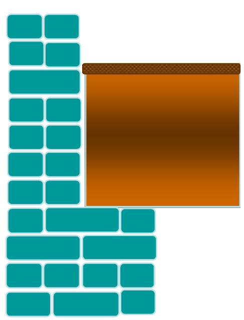
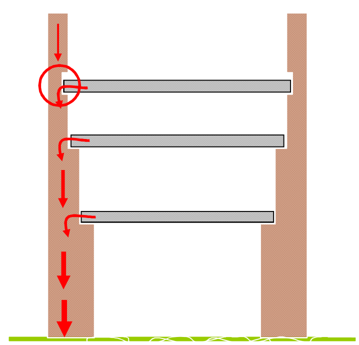
Fundamentals of Facade Performance

Load Bearing Masonry

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





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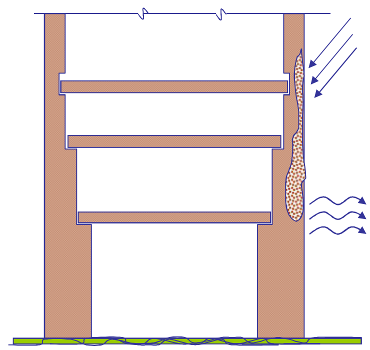
Fundamentals of Facade Performance

Load Bearing Masonry

- Walls manages moisture as a reservoir



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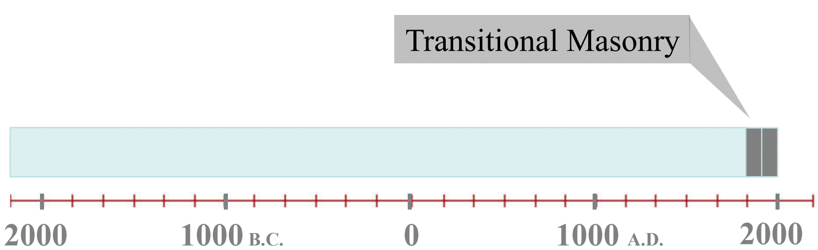
Fundamentals of Facade Performance

Time Line



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Fundamentals of Facade Performance

Transitional Masonry Buildings

1890 1900 1910 1920 1930 1940 1950

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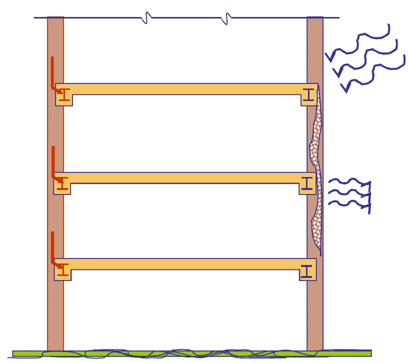
Fundamentals of Facade Performance

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



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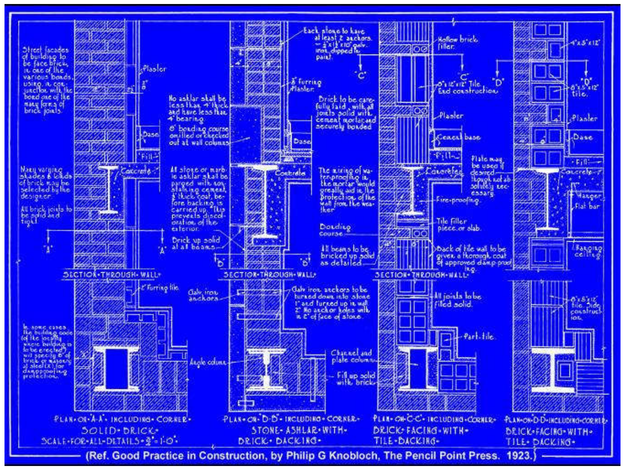
Fundamentals of Facade Performance

Transitional Masonry Buildings



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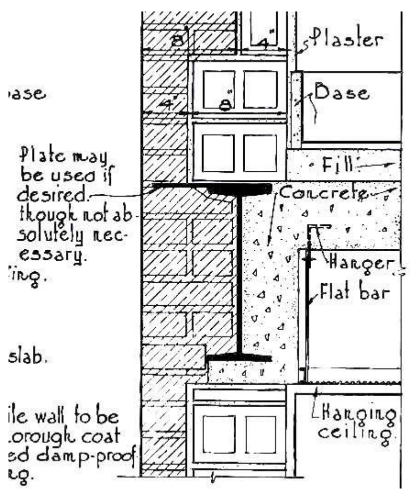
Fundamentals of Facade Performance

Transitional Masonry Buildings



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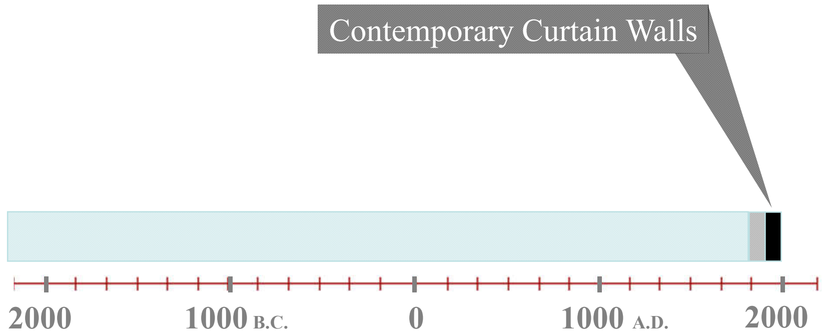
Fundamentals of Facade Performance

Time Line



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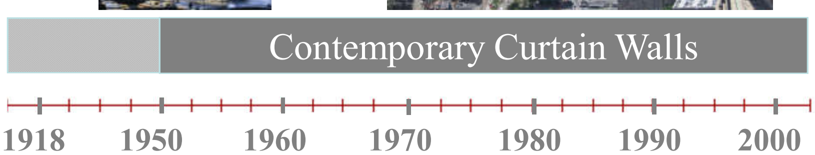
Fundamentals of Facade Performance



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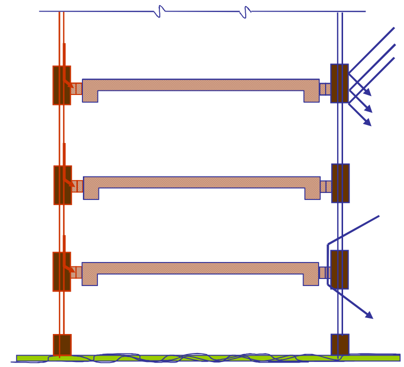
Fundamentals of Facade Performance

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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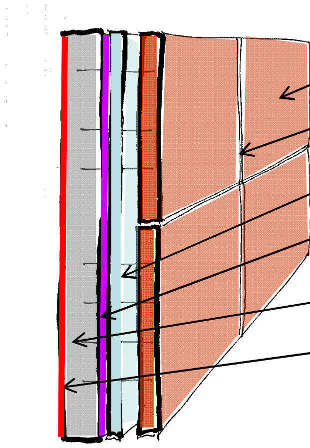
Exterior Wall System

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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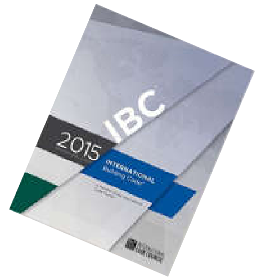
Exterior Wall System

Facade Design Criteria



- Structural Integrity
- Provisions for Movement
- Envelope Performance

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Attachment Criteria

Criteria for Facade Attachment

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

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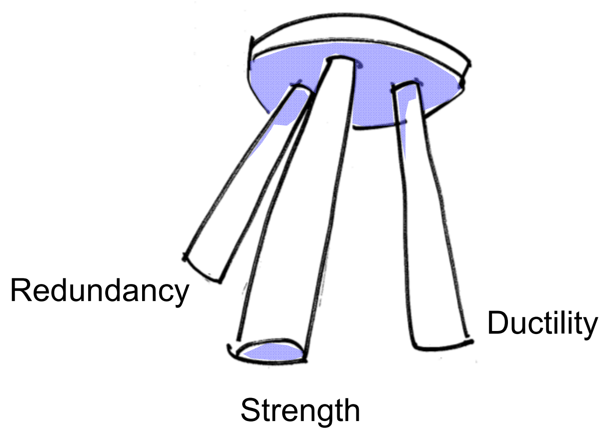
Attachment Criteria

Structural Integrity



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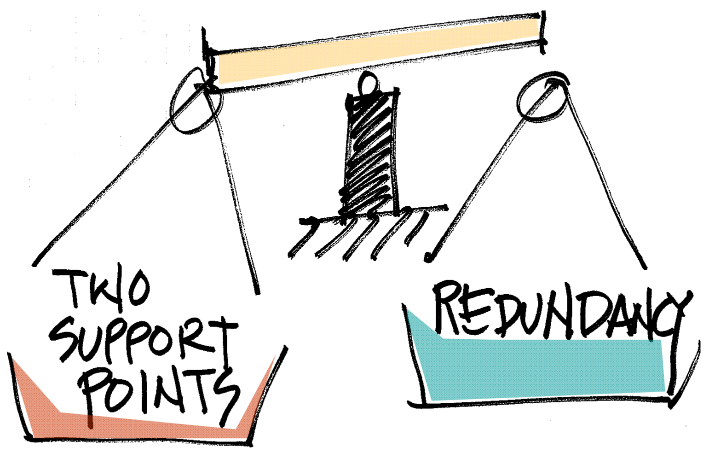
Attachment Criteria

Conflicting Ideas



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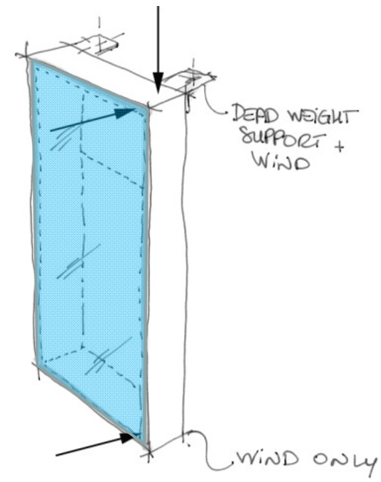
Attachment Criteria

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.

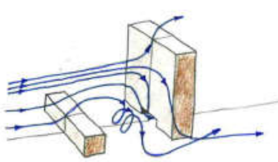


Attachment Criteria

Loads on Attachments

Dead Loads
Weight of the wall system

Seismic Loads
Perpendicular OR parallel to the wall



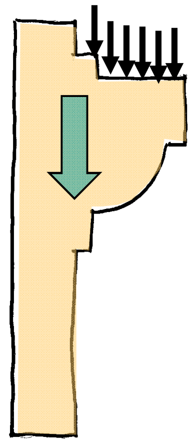
Wind Loads
Perpendicular OR parallel to the wall

Thermal Loads
Facade expansion/contraction

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



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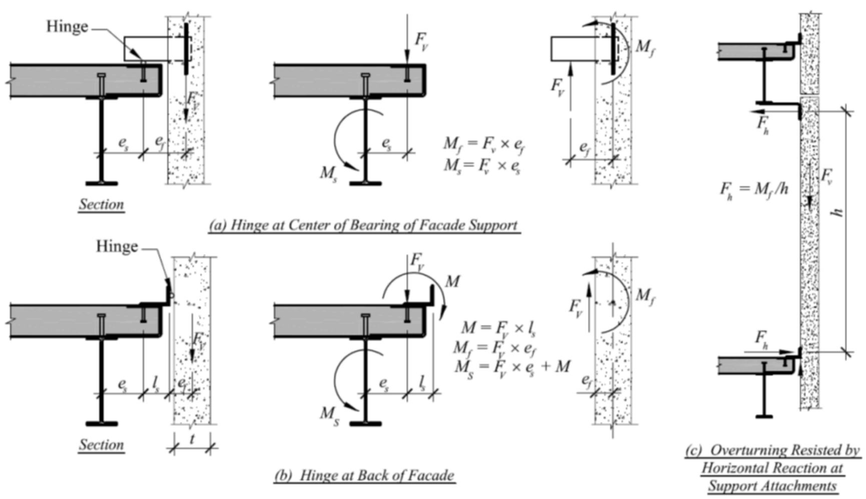
Attachment Criteria

Gravity Load Eccentricities



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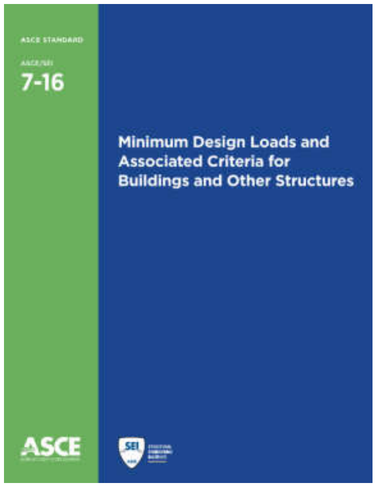
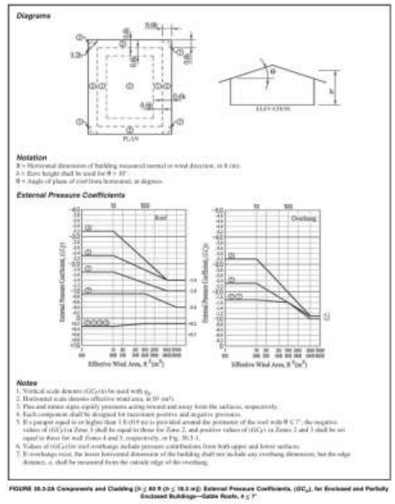
Attachment Criteria

Wind Loads





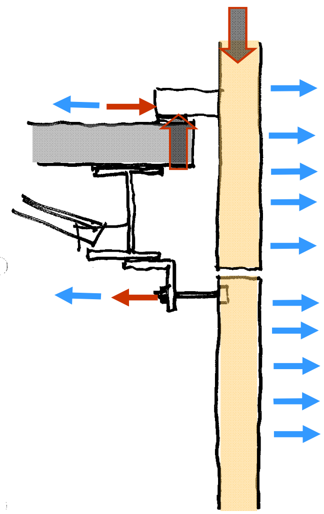
Attachment Criteria

Wind Tunnel Testing

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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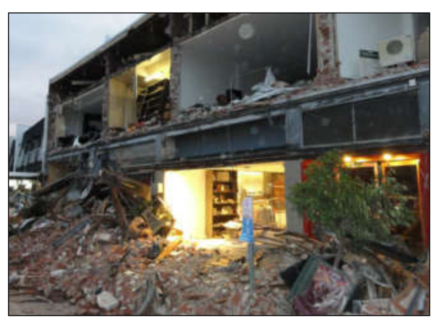
Attachment Criteria

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: • 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

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

Table 13.5-1 Coefficients for Architectural Components

Architectural Component	a_p[a]	R_p	Ω_0[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_{pI}, shall be determined in accordance with Eq. (13.3-6):

$$D_{pI} = D_p I_e \qquad (13.3\text{-}6)$$

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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)

TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

CONSTRUCTION	L	S or W[f]	$D + L$[d, g]
Roof members:[e]			
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:[b]			
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

For SI: 1 foot = 304.8 mm.

a. For structural roofing and siding made of formed metal sheets, the total load deflection shall not exceed l/60. For secondary roof structural members supporting formed metal roofing, the live load deflection shall not exceed l/150. For secondary wall members supporting formed metal siding, the design wind load deflection shall not exceed l/90. For roofs, this exception only applies when the metal sheets have no roof covering.

b. Flexible, folding and portable partitions are not governed by the provisions of this section. The deflection criterion for interior partitions is based on the horizontal load defined in Section 1607.14.

c. See Section 2403 for glass supports.

d. The deflection limit for the $D+L$ load combination only applies to the deflection due to the creep component of long-term dead load deflection plus the short-term live load deflection. For wood structural members that are dry at time of installation and used under dry conditions in accordance with the ANSI/AWC NDS, the creep component of the long-term deflection shall be permitted to be estimated as the immediate dead load deflection resulting from 0.5D. For wood structural members at all other moisture conditions, the creep component of the long-term deflection is permitted to be estimated as the immediate dead load deflection resulting from D. The value of 0.5D shall not be used in combination with ANSI/AWC NDS provisions for long-term loading.

e. The above deflections do not ensure against ponding. Roofs that do not have sufficient slope or camber to ensure adequate drainage shall be investigated for ponding. See Section 1611 for rain and ponding requirements and Section 1503.4 for roof drainage requirements.

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.

g. For steel structural members, the dead load shall be taken as zero.

h. For aluminum structural members or aluminum panels used in skylights and sloped glazing framing, roofs or walls of sunroom additions or patio covers not supporting edge of glass or aluminum sandwich panels, the total load deflection shall not exceed l/60. For continuous aluminum structural members supporting edge of glass, the total load deflection shall not exceed l/175 for each glass lite or l/60 for the entire length of the member, whichever is more stringent. For aluminum sandwich panels used in roofs or walls of sunroom additions or patio covers, the total load deflection shall not exceed l/120.

i. For cantilever members, l shall be taken as twice the length of the cantilever.

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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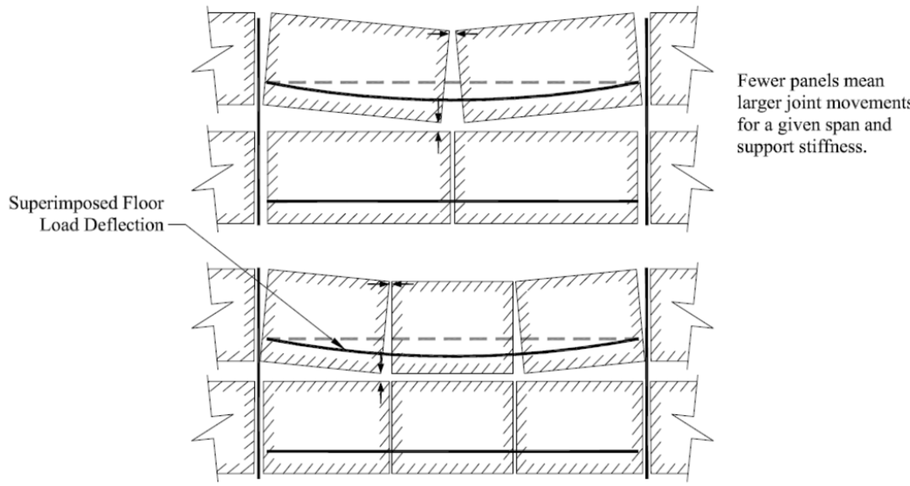
Attachment Criteria

Accommodating Relative Movement



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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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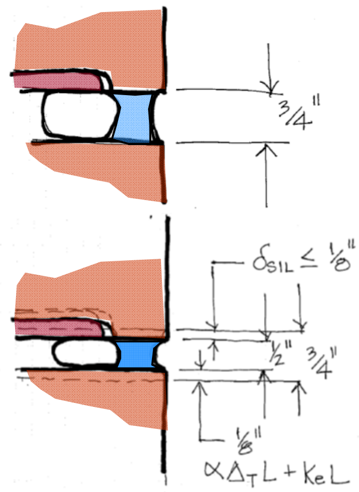
Attachment Criteria

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



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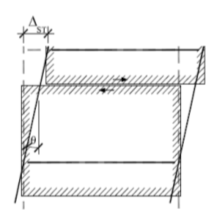
Attachment Criteria

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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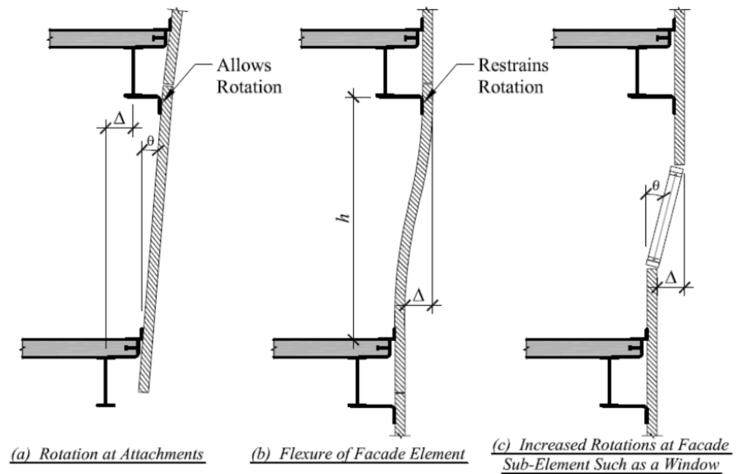
Attachment Criteria

Accommodating Relative Movement



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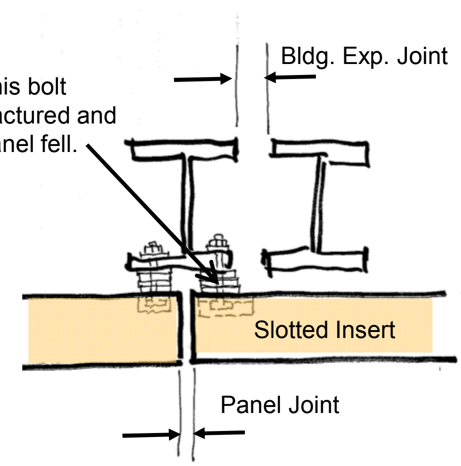
Attachment Criteria

Forces from Restraint

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



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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.

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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

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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

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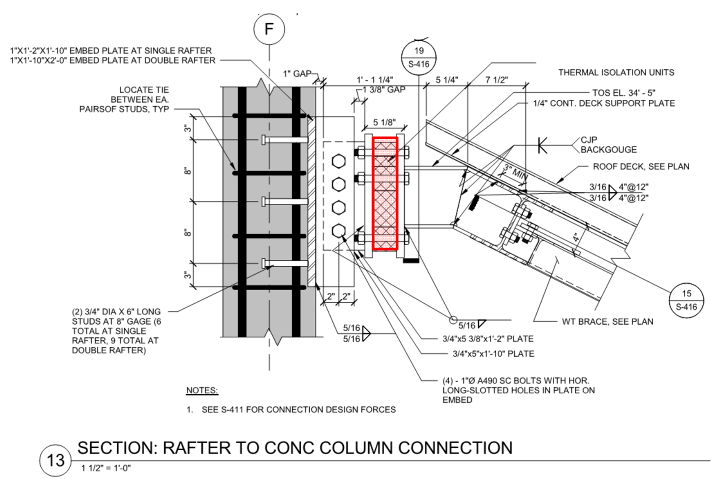
Attachment Criteria

Constructability and Economy



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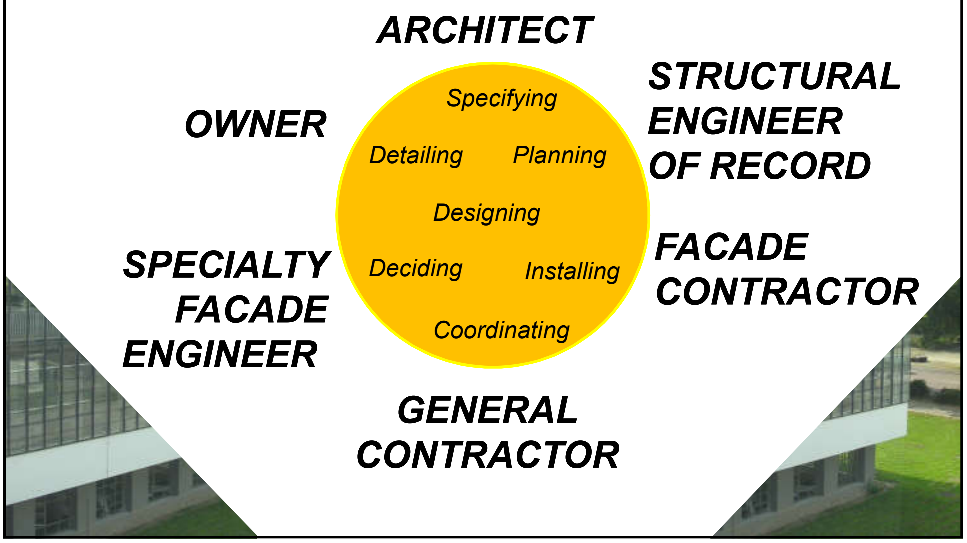
Roles and Responsibilities

Roles and Responsibilities for Facade Attachments



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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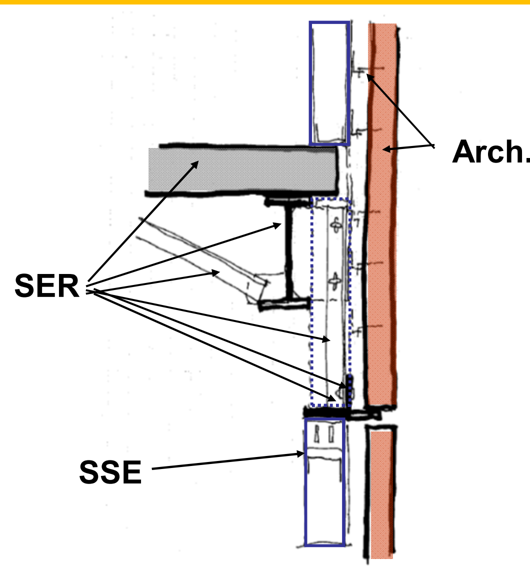
Roles and Responsibilities

Masonry Veneer



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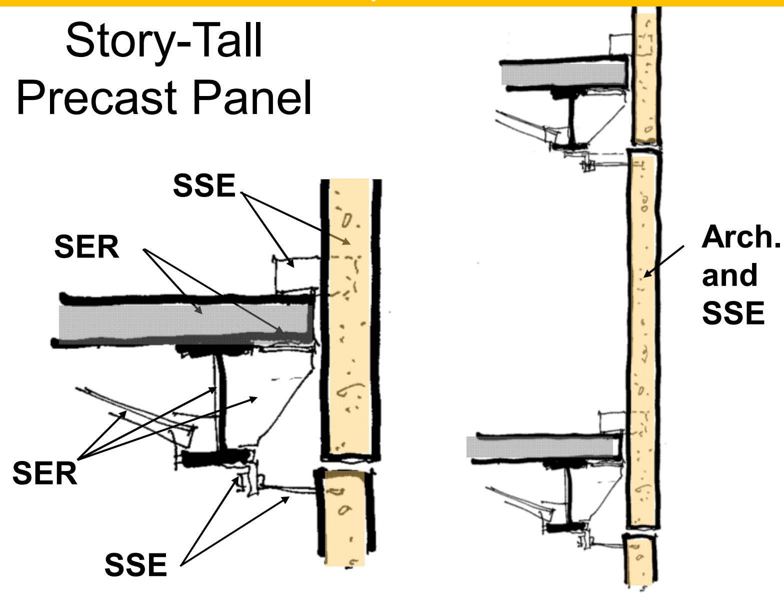
Roles and Responsibilities

Story-Tall Precast Panel



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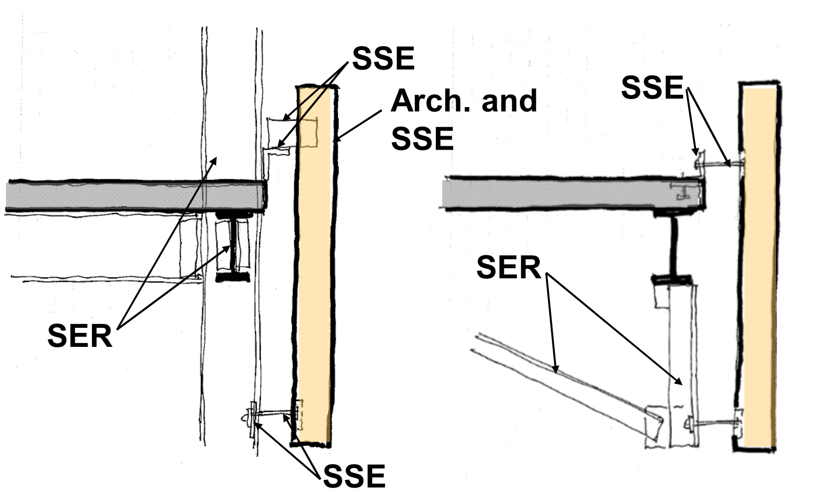
Roles and Responsibilities

Column Supported PC Spandrel Panel



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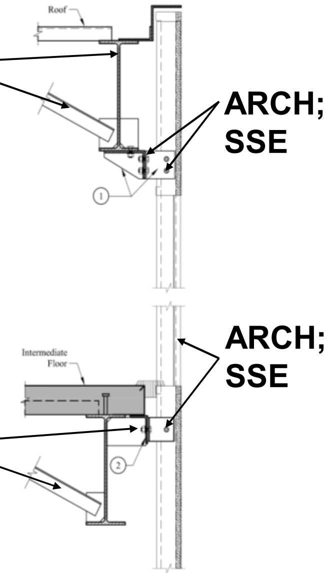
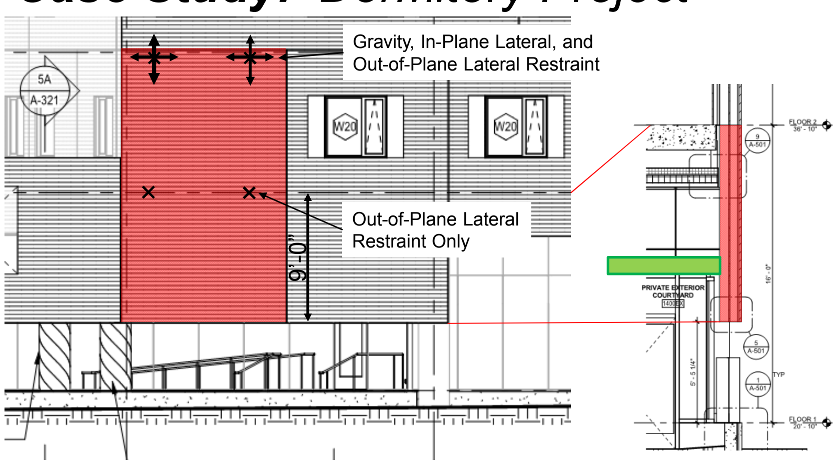
Roles and Responsibilities

Aluminum/Glass Curtain Wall



Roles and Responsibilities

Case Study: *Dormitory Project*



Roles and Responsibilities

Summary

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

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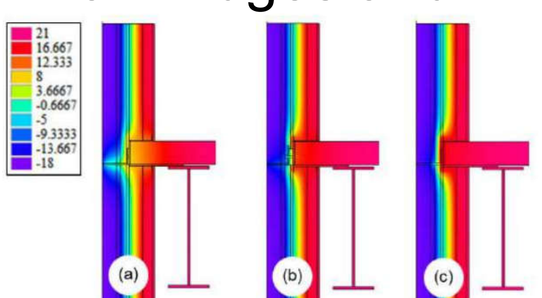
Thermal Bridges and Breaks

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 facade attachments continues to develop.

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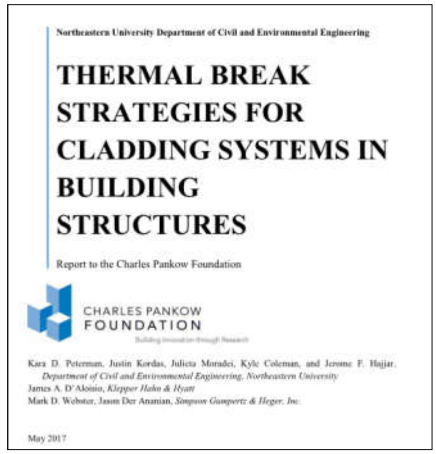
Thermal Bridges and Breaks

Two Good Resources

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

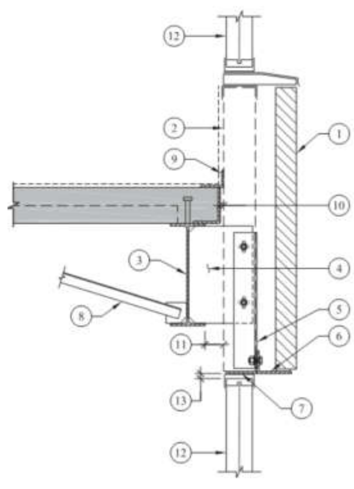


http://www1.coe.neu.edu/~jfhajjar/home/Peterman,%20Webster,%20D%27Aloisio,%20Hajjar%20et%20al.%20-%20Thermal%20Break%20Strategies%20-%20CPF%20Final%20Report%20-%20May%202017.pdf

Thermal Bridges and Breaks

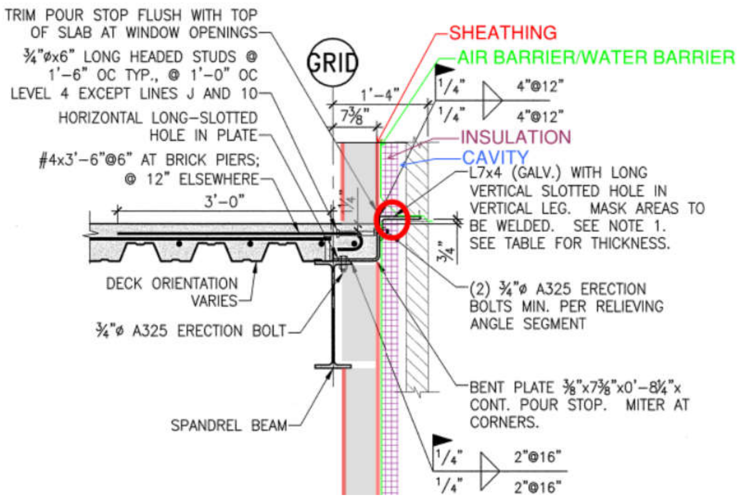
Risks of Thermal Bridges

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



Thermal Bridges and Breaks

Alignment of Thermal Break



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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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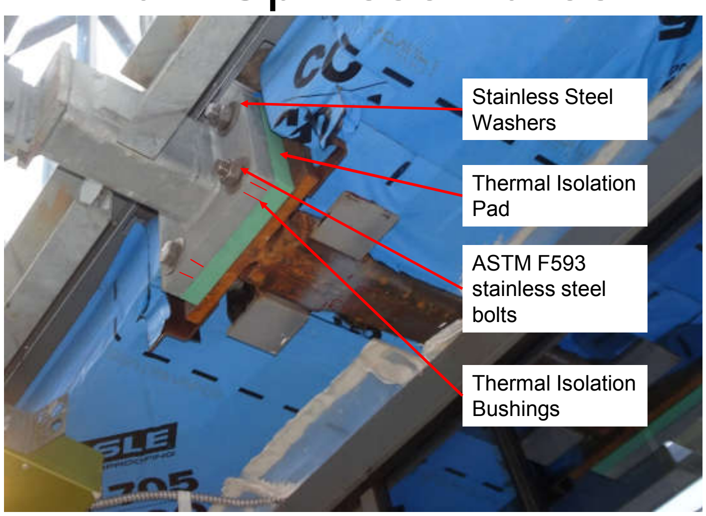
Thermal Bridges and Breaks

Built-Up Assemblies



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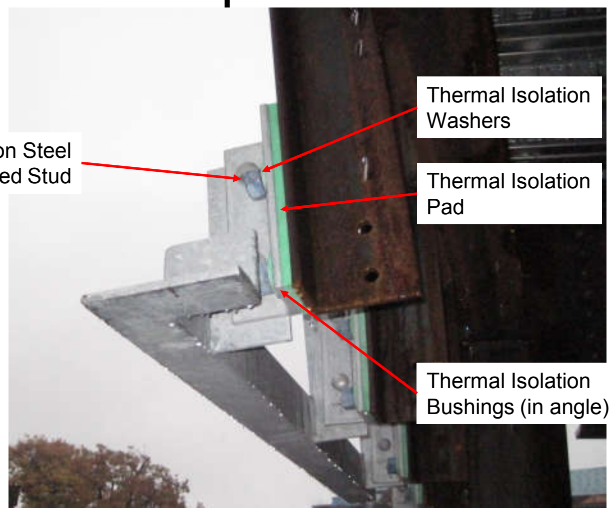
Thermal Bridges and Breaks

Built-Up Assemblies



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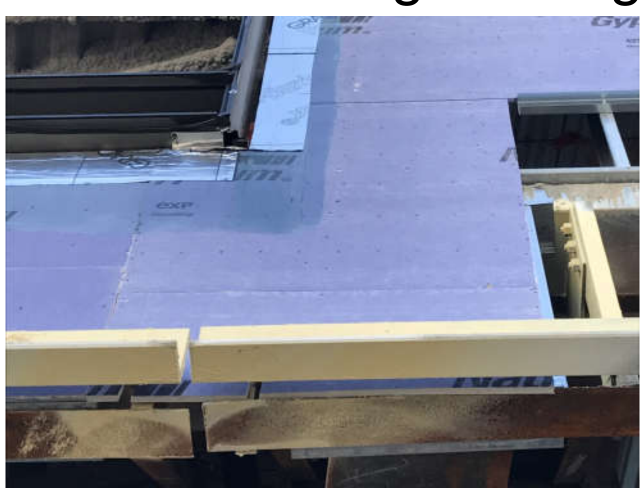
Thermal Bridges and Breaks

Thermal Insulating Coatings



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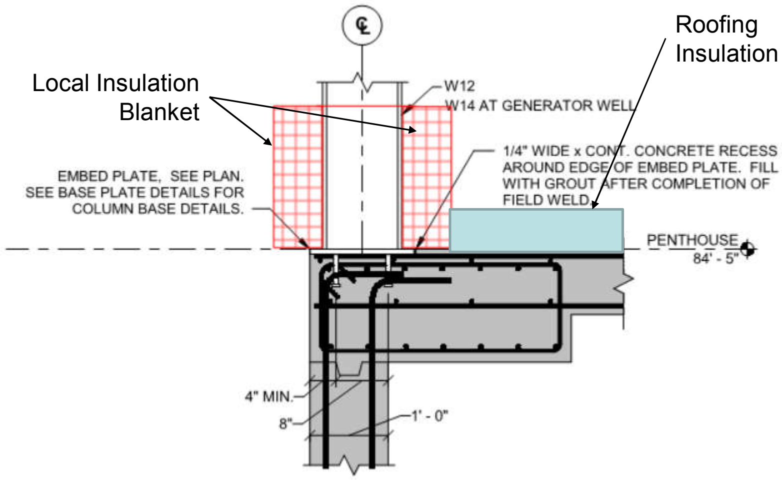
Thermal Bridges and Breaks

Local Insulation Blankets



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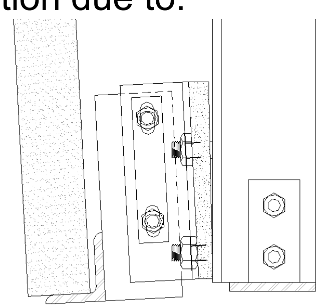
Thermal Bridges and Breaks

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:

$$\emptyset F'_{nt} = \emptyset\left[1.3F_{nt} - \frac{F_{nt}}{\emptyset F_{nv}} f_{rv}\right] \le \emptyset F_{nt}$$

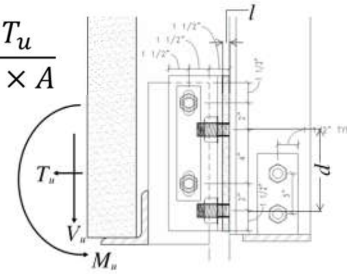
AISC 360-16 (J-3.3a)

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

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

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

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



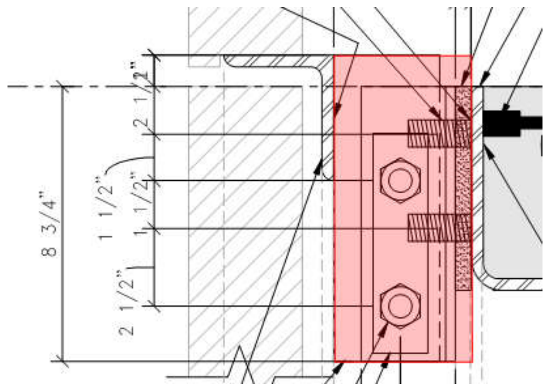
Thermal Bridges and Breaks

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

Thermal Bridges and Breaks

Future Studies: Stainless Steel Thermal Performance



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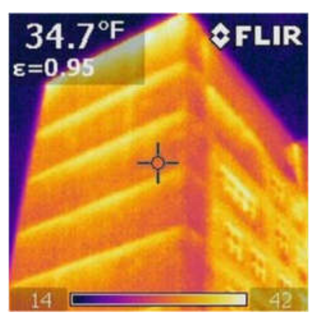
Thermal Bridges and Breaks

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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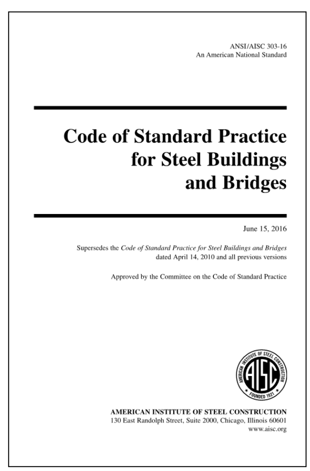
Accommodating Tolerances and Clearances

Specifying Frame Tolerances

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



ANSI/AISC 303-16
An American National Standard

Code of Standard Practice for Steel Buildings and Bridges

June 15, 2016

Supersedes the *Code of Standard Practice for Steel Buildings and Bridges* dated April 14, 2010 and all previous versions

Approved by the Committee on the Code of Standard Practice

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
130 East Randolph Street, Suite 2000, Chicago, Illinois 60601
www.aisc.org

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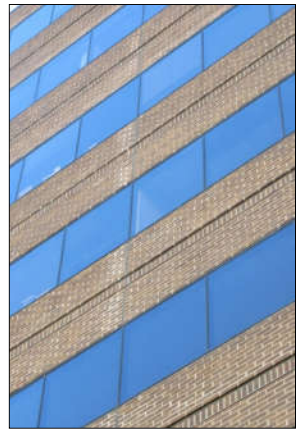
Accommodating Tolerances and Clearances

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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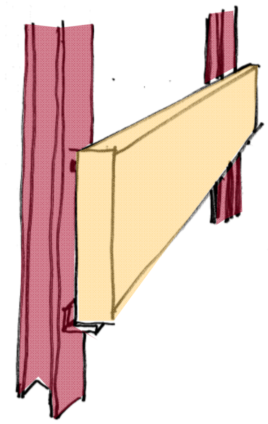
Accommodating Tolerances and Clearances

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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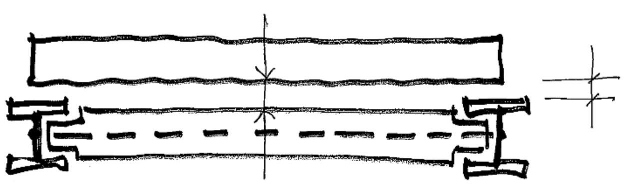
Accommodating Tolerances and Clearances

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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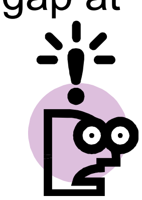
Accommodating Tolerances and Clearances

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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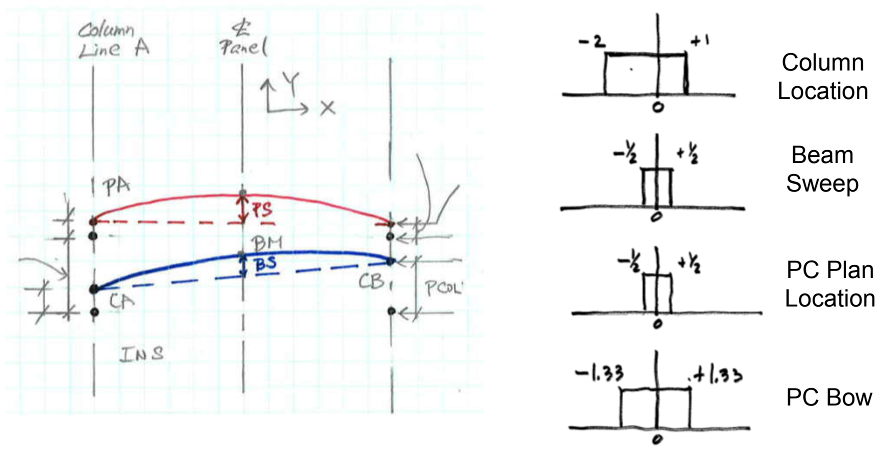
Accommodating Tolerances and Clearances

Accumulated Tolerances



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%)

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 Width[1]

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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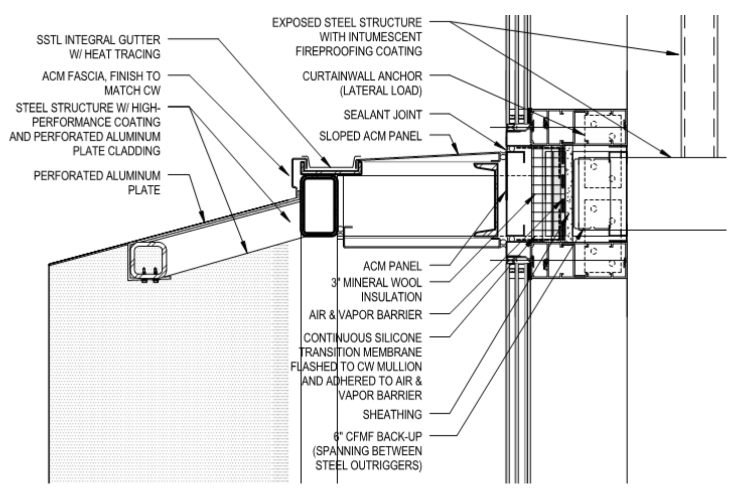
Accommodating Tolerances and Clearances

Case Study: *Sunshade*



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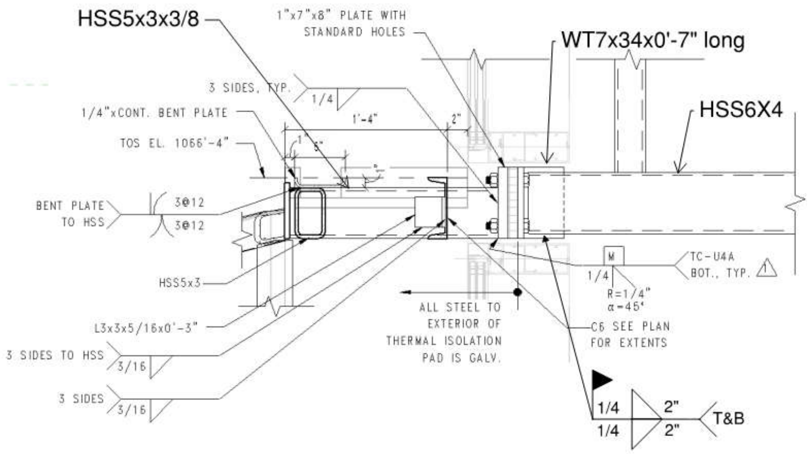
Accommodating Tolerances and Clearances

Case Study: *Sunshade*



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Accommodating Tolerances and Clearances

Case Study: *Sunshade*

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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

structural
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Individual Webinar Registrants

CEU/PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: 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!

Individual Webinar Registrants

CEU/PDH Certificates

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

CEU/PDH Certificates

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

8-Session Registrants

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 - 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

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.

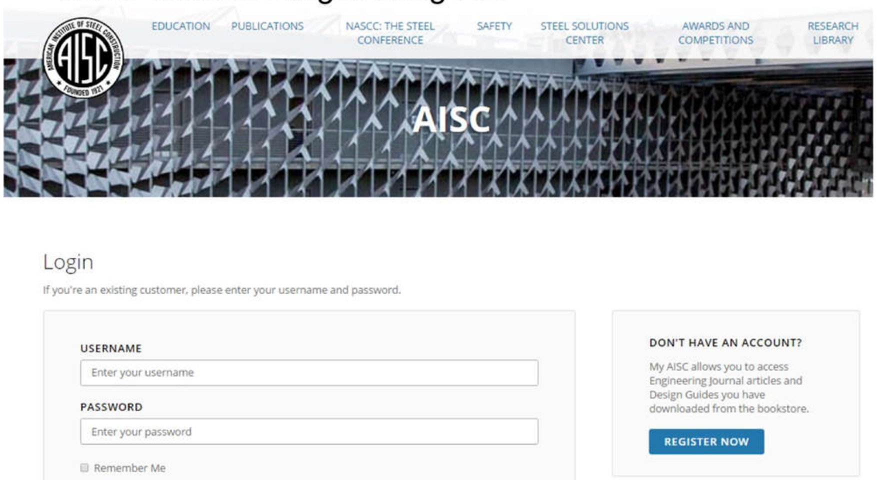
CEUs/PDHS – If you watch a recorded session you must take AND PASS the quiz for CEUs/PDHs.

Night School Resources for 8-session package Registrants

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 and sign in.



Night School Resources for 8-session package Registrants

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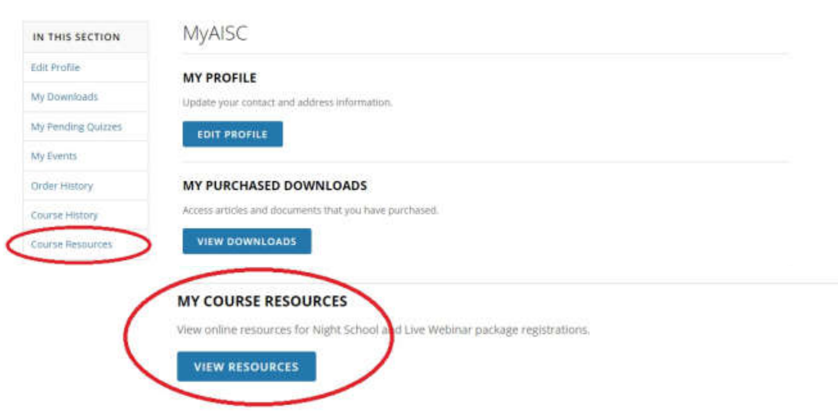

Night School Resources for 8-session package Registrants

AISC › MYAISC › COURSE RESOURCES

Course Resources

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

AISC › MYAISC › NIGHT SCHOOL RESOURCES › NS13 8-SESSION PACKAGE RESOURCES

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	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	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	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	Handouts	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	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	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	Handouts	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	

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- Weekly "quiz and recording" email.
- Weekly updates of the master Quiz and Attendance record found at www.aisc.org/nightschool. Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.

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

There's always a solution in steel.

Thank You

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

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