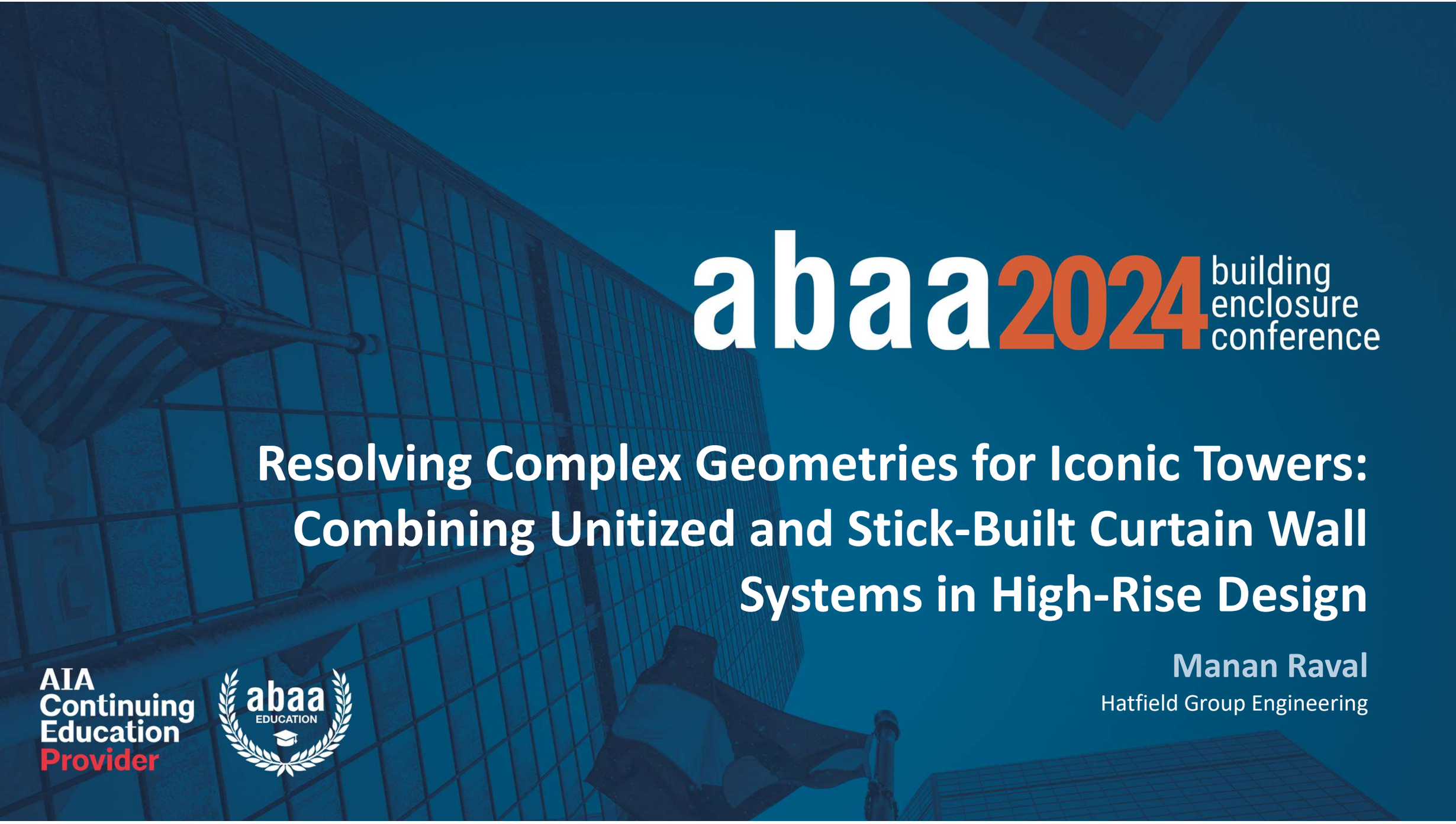

Resolving Complex Geometries for Iconic Towers: Combining Unitized and Stick-Built Curtain Wall Systems in High-Rise Design

Manan Raval
Hatfield Group Engineering

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Resolving Complex Geometries for Iconic Towers

This session will explore curtain wall detailing, fabrication, testing, and installation oversight strategies for resolving complex geometries involved in iconic high-rise tower design that combine stick-built and unitized systems. It will begin with a general overview of the key differences between stick-built and unitized curtain wall systems, covering the pros and cons of both in terms of water and air barrier performance, schedule and cost efficiency, quality control, installation time, construction equipment and labor demands, and inspection requirements.

abaa building enclosure conference

Manan Raval, PE

Manan Raval, PE is Partner for Facades and Envelopes at Hatfield Group. He is widely recognized as an industry expert in facade design and specialty glass systems. He has led facade engineering for complex buildings worldwide, among them high-profile arts institutions, residential developments, and mixed-use hubs.

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Learning Objectives

1. Evaluate the relative pros and cons of stick-built and unitized curtain wall systems and determine when each system is most appropriate for particular projects.
2. Identify design situations where combining stick-built and unitized curtain wall systems serves performance, aesthetic, and other project goals and apply those systems effectively.
3. Recognize opportunities to procure curtain walls more economically without compromising quality through exploring international procurement routes.
4. Identify and overcome common pitfalls in curtain wall design, detailing, and installation for specific design conditions, including complex geometries that involved inclined glass and curved glass panels.

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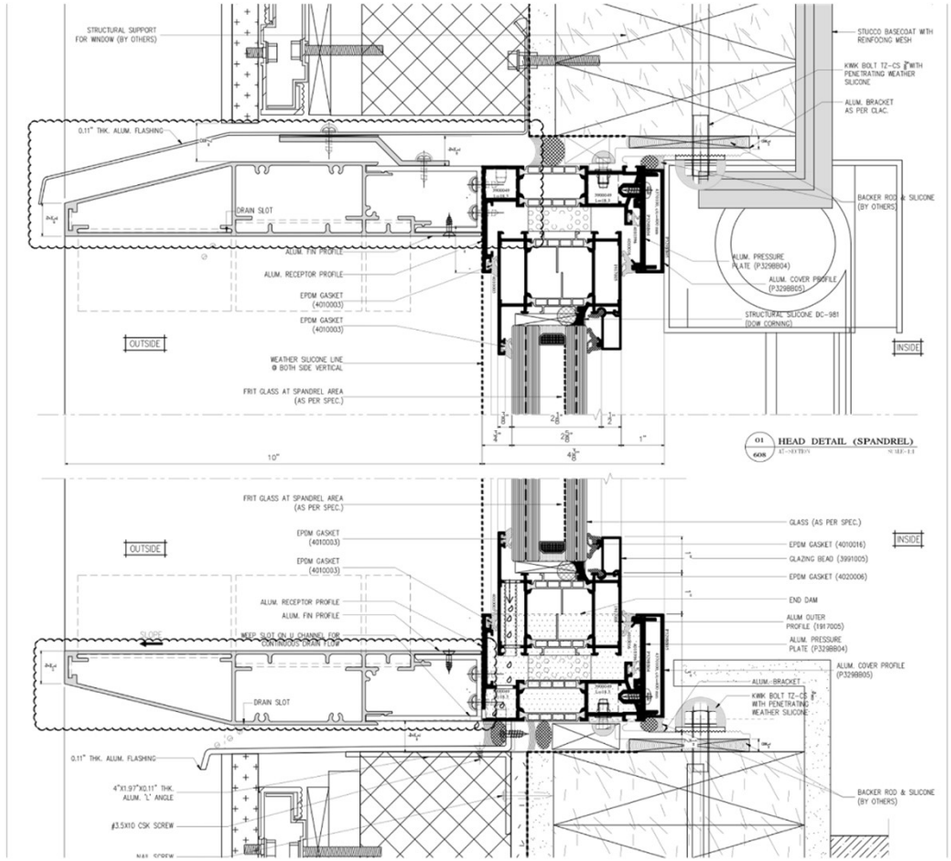
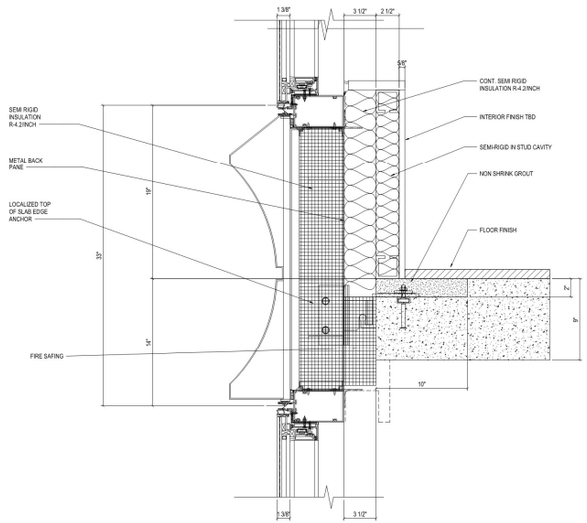
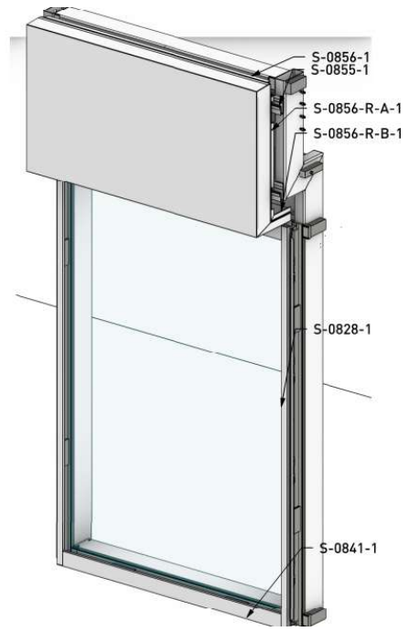
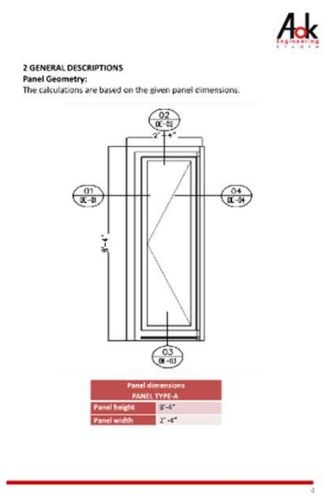
Detailing During Design

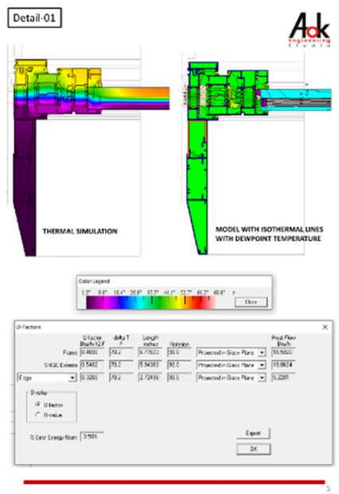


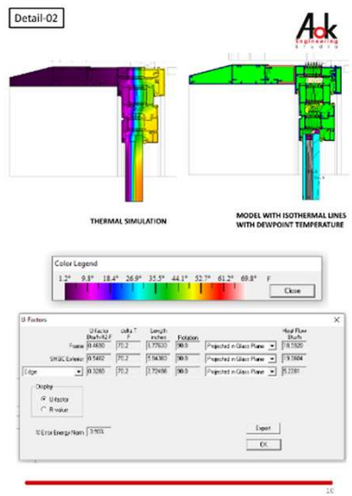


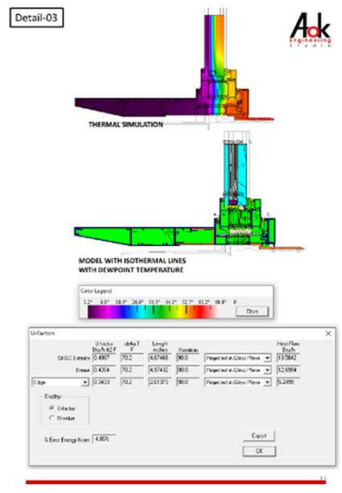


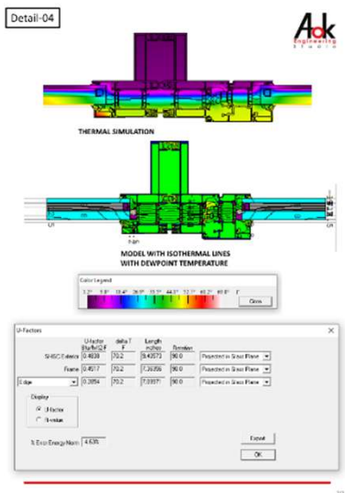
Performance Calculations

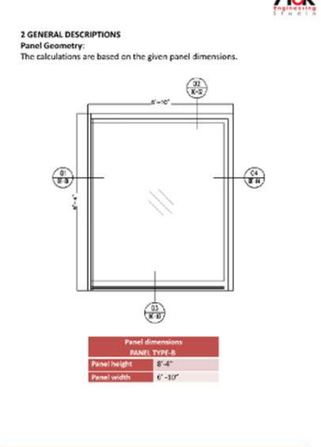


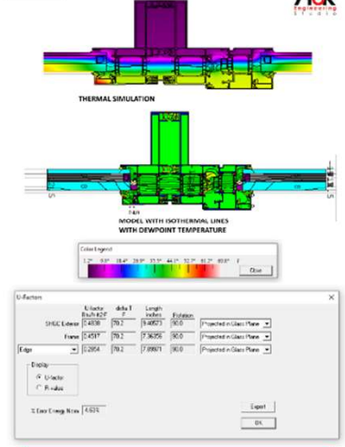


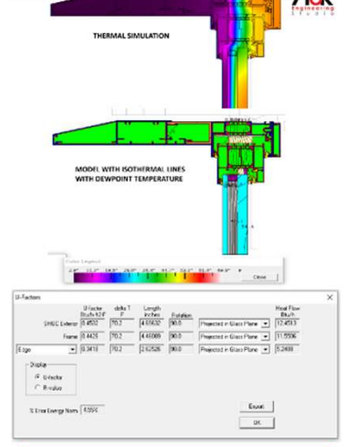


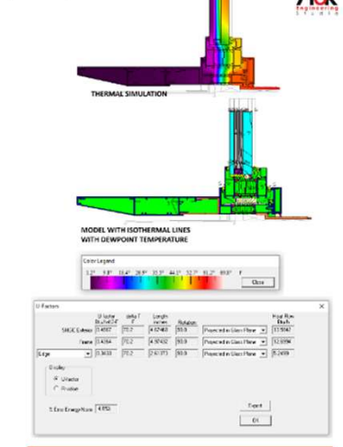




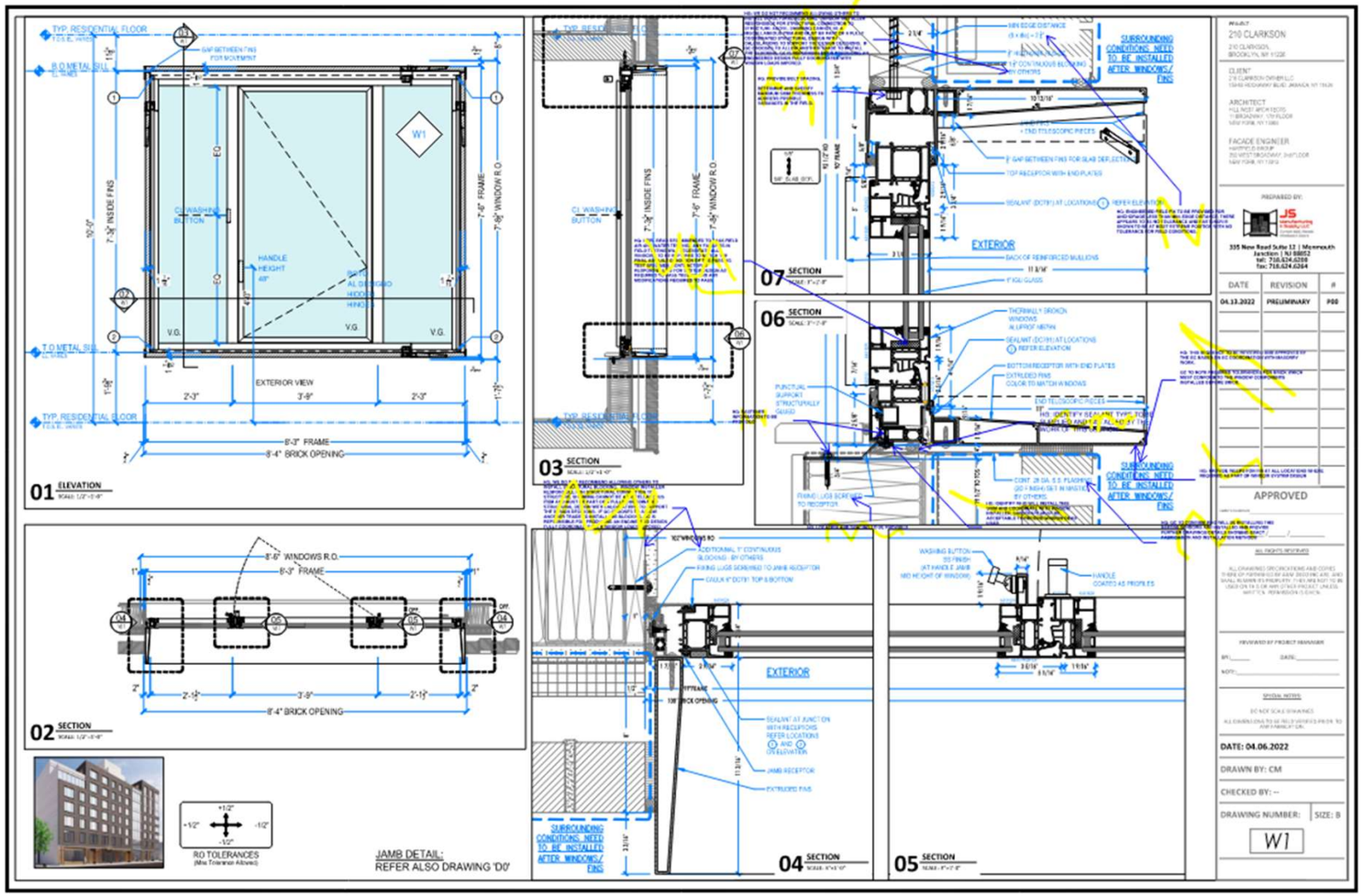








Shop Drawing Technical Markups



Procurement Manufacturing Oversight

PMU and Mock Up Testing

Curtain Wall Systems

Curtain Wall

- A configuration of exterior wall framing members
  - Framing members hang from the structure
  - Located outboard of building structure
- Not “infill” Framing

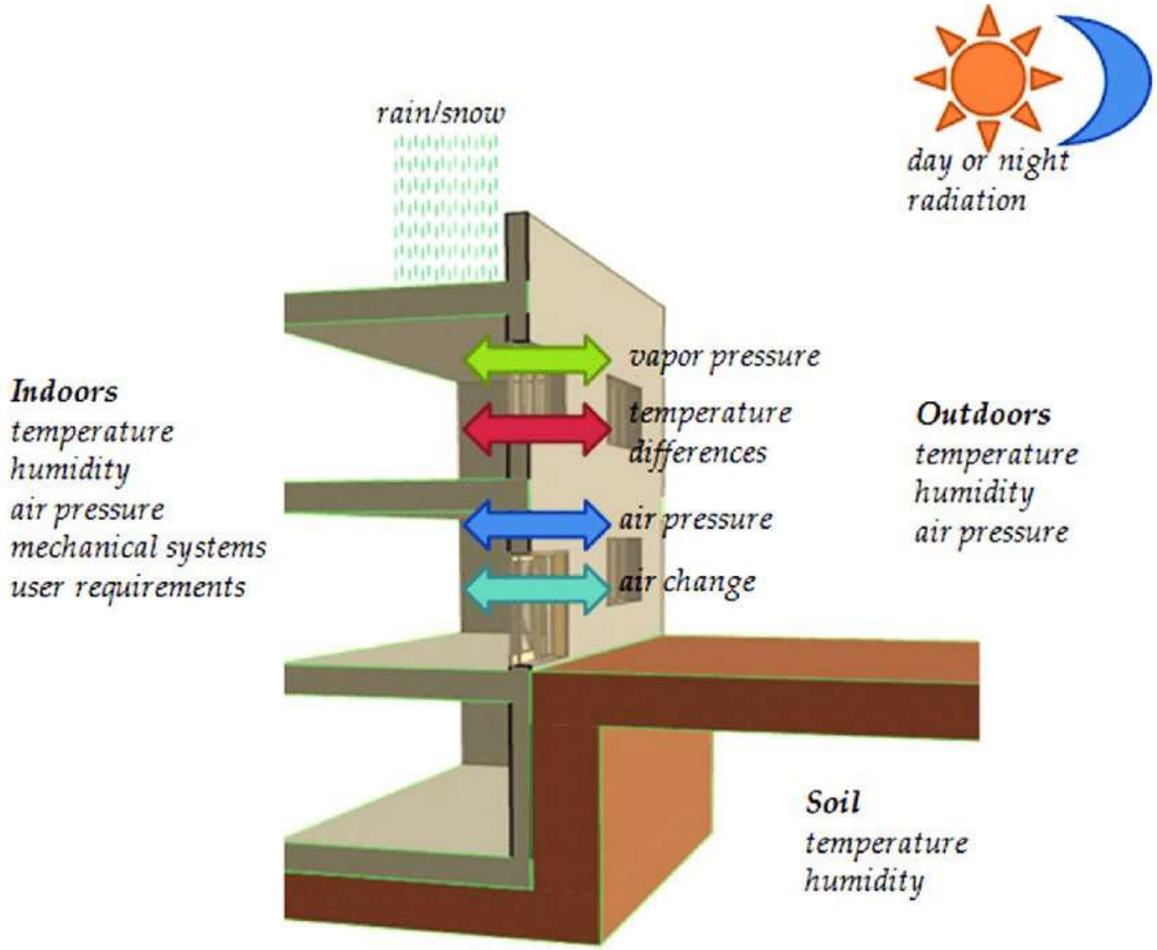
How Curtain Walls Function

Like other building enclosure systems, main functions must be fulfilled:

- System as a separator between indoor and outdoor conditions

- Maintain thermal comfort
  - Control solar heat gain
  - Control heat loss
  - Control air infiltration/exfiltration

- Maintain acoustical comfort
  - Reduce transfer of exterior sound
  - Reduce sound transfer between floors



How Curtain Walls Function

- Shelter from wind/rain/snow
  - Protection from wind borne debris
  - Hurricanes, tornado
  - Air pollution

- Security
  - Low level deterrence
    - Resist entry of unauthorized people
  - Heigh level deterrence
    - Blast and ballistic protection

How Curtain Walls Function

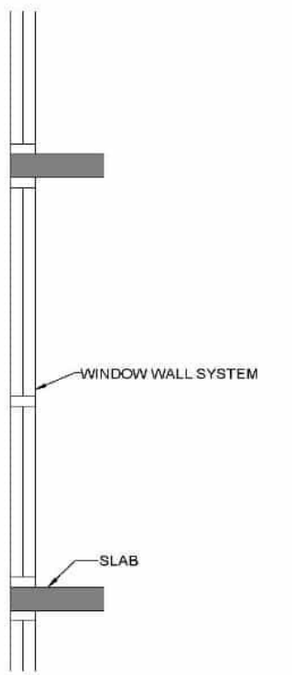
- Acoustics
  - Double glazing and the cavity space can substantially reduce noise pollution from external environment of the building
- Durability
  - Protect the superstructure from environmental decay
- Aesthetic
  - Provide appropriate architectural expression

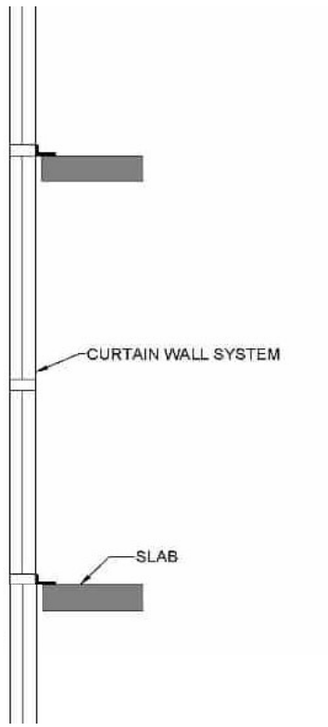
How Curtain Walls Function

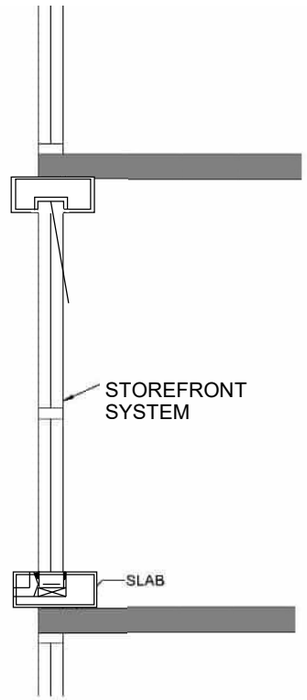
- Window Wall
- Curtain Wall

- Storefront Glazing
  - Not hung from structure
  - Different style of framing, performance and installation

Window
Curtain

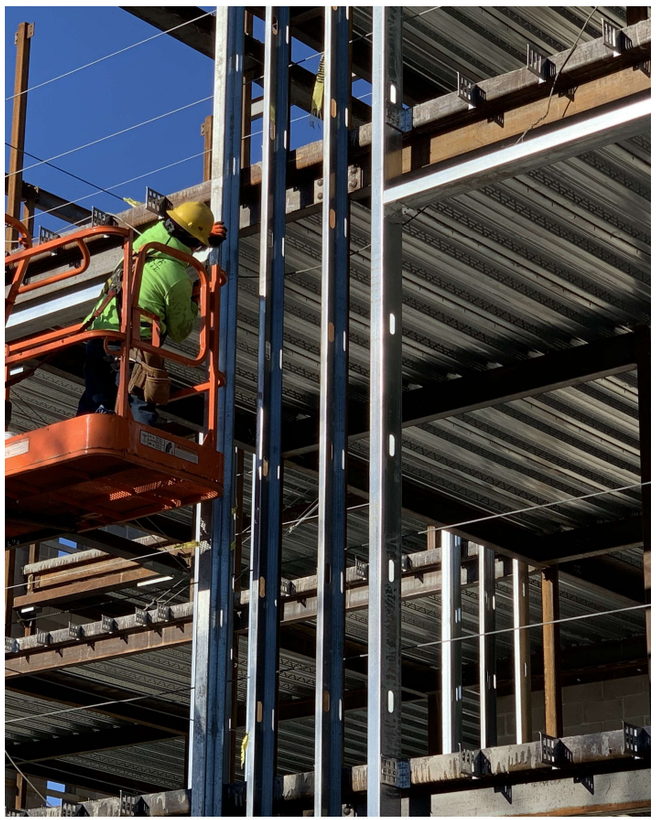






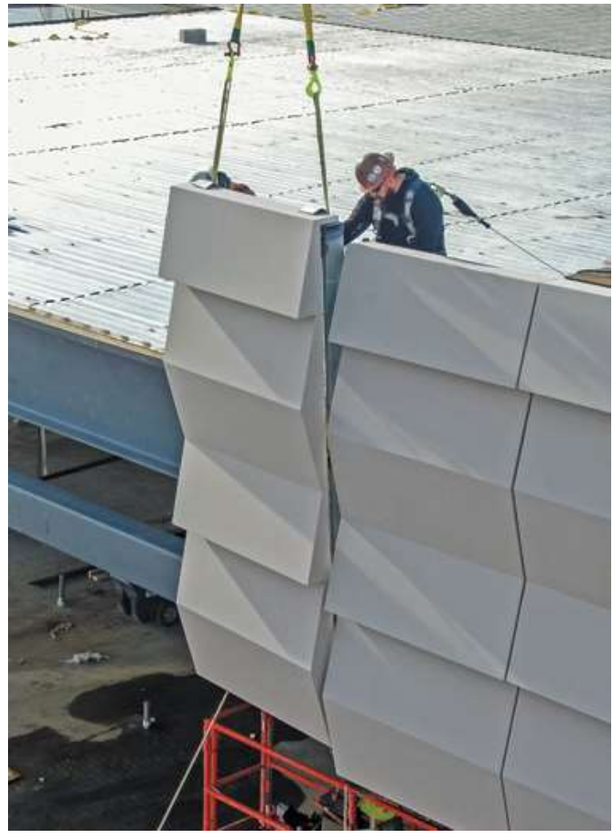
Other Types of Curtain Walls

Stud Wall Framing as Curtain Wall



Terracotta Cladding as Curtain Wall

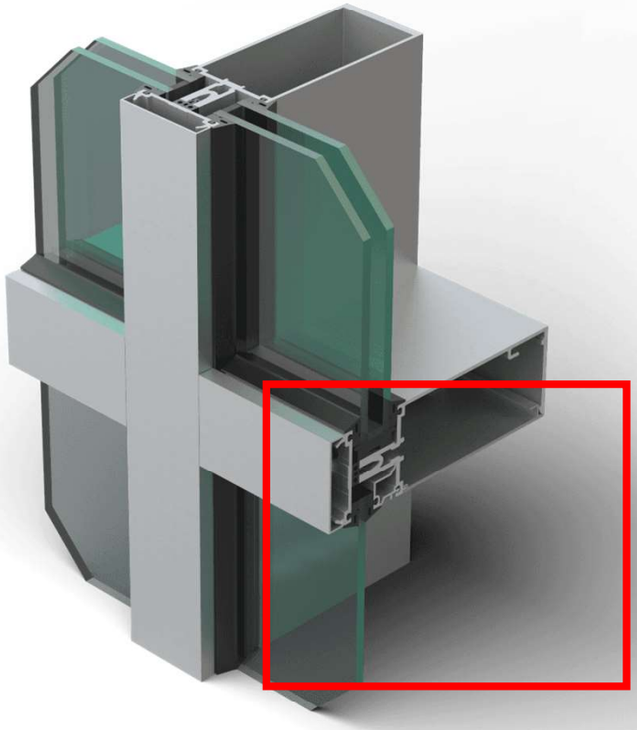
Precast Concrete Cladding as Curtain Wall



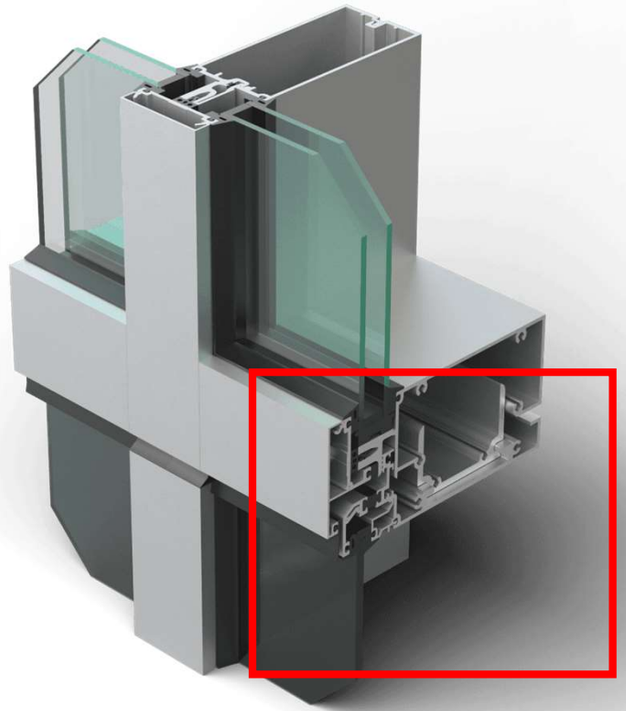
Stick Built v. Unitized Curtain Walls

Stick v. Unitized

- Stick Built
  - The components are installed piece-by-piece on the building structure



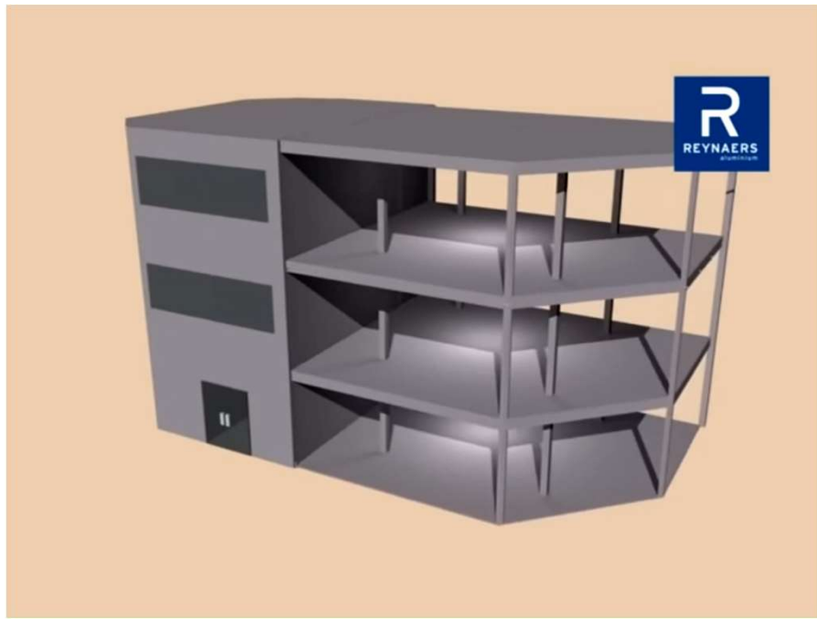
- Unitized
  - The components have been pre-assembled in factory before being shipped to the site



Stick Built Curtain Walls

Stick Built Curtain Wall

- Site Assembled From Individual Components
    - Some shop fabrication done ahead of time before materials delivered to site
- Field Glazed, Not Pre-glazed
- Typically installed with scaffolding from the outside



Stick Built Curtain Walls: Advantages and Disadvantages

Advantages: Stick Built

- Schedule and Cost Efficiency
    - Lower cost to transport the materials to the site
    - Shorter lead time
        - Components are not pre-built
    - Space Saving
        - Not a lot of storage space is needed on site
- Overall cost saving

Disadvantages: Stick Built

- Longer installation Time
    - Each component must be assembled and installed individually
- May require scaffolding or other equipment to reach higher elevations
    - Requires 100% external access to all floors for installation

Disadvantages: Stick Built

- Requires skilled labor
    - Very dependent on-site skills and assembly
    - Not well suited for high-rise due to access requirements

Disadvantages: Stick Built

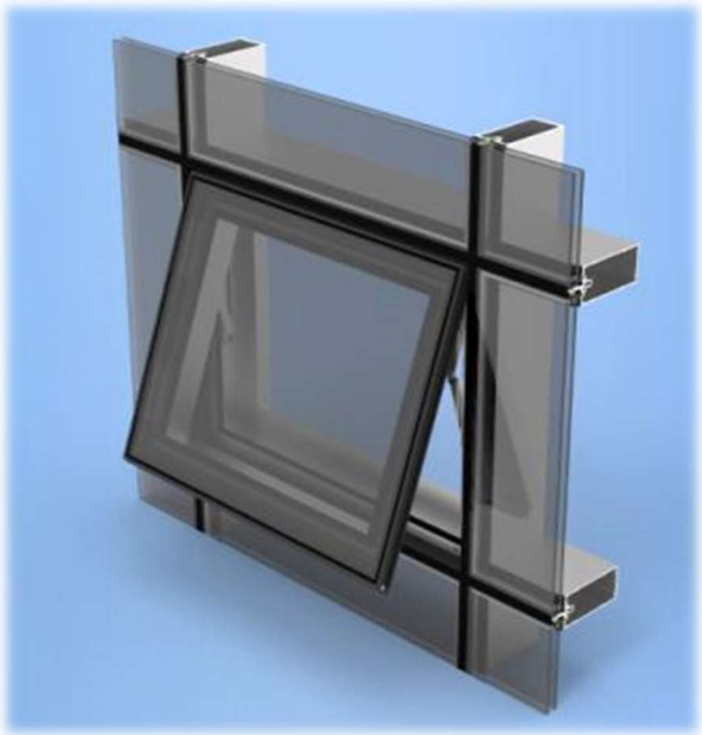
- May be more susceptible to water infiltration and other types of weather damage over time

- Large number of joints increases the possibility of weather tightness failure

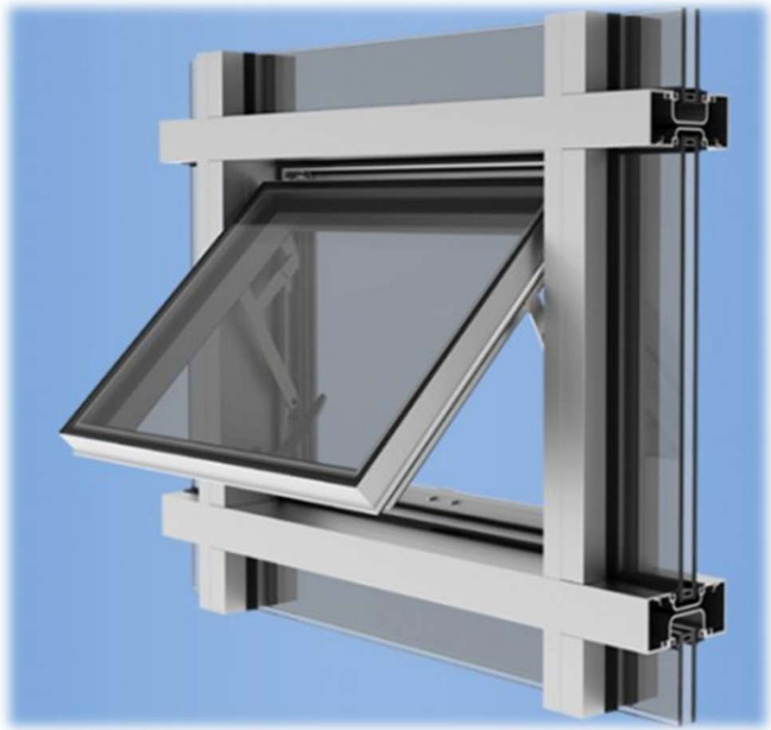
Disadvantages: Stick Built

- May be more difficult to achieve good thermal performance due to the need for careful insulation installation during assembly

Operable Stick-Built Window



Operable Unitized Window



Unitized Curtain Walls

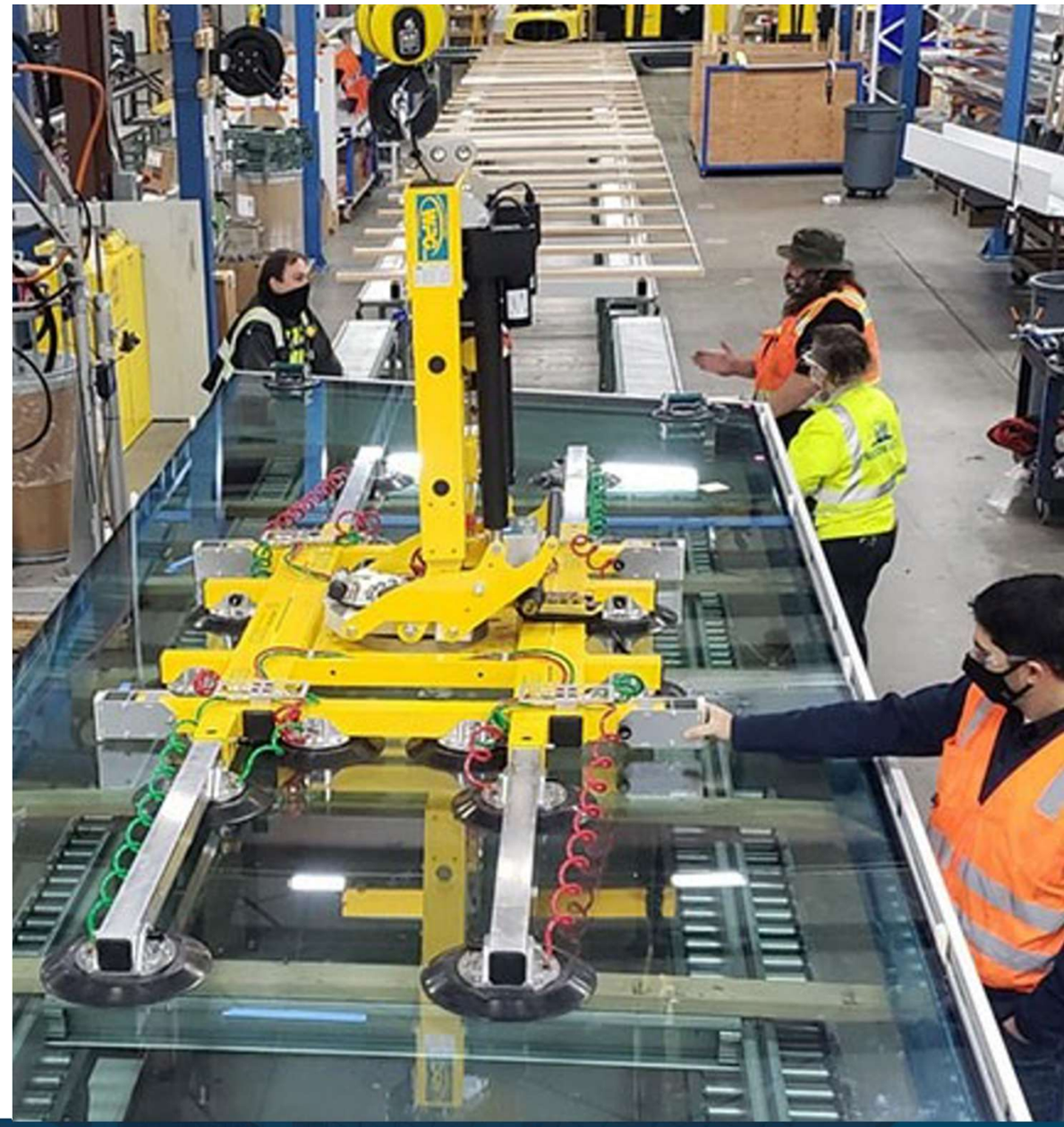
Disadvantages: Stick Built

- Fabricated and assembled in factory into discreet units
    - Field work is limited to:
        - Installing anchors
        - Hoisting panels into position
        - Weather sealing at joints between unitized panels

Unitized Curtain Walls
Advantages and Disadvantages

Advantages: Unitized

- Quality
  - Precise fabrication and assembly in climate-controlled setting
  - Easier Quality Control
    - Free of contamination from construction dust/debris
    - Free of exposure to the elements and temperature variations
    - Better air, water, and thermal performance
  - Ease of access for technicians
    - No need to hang off the side of a building



Advantages: Unitized

- Schedule Efficiency
  - Fabricated ahead of time before the building is ready to receive the system
  - Manufacturing of repeatable components for assembly line
    - Streamlined and efficient process
  - Fast site installation
    - Rapid closure of the building envelope
    - Interior finish work can start sooner

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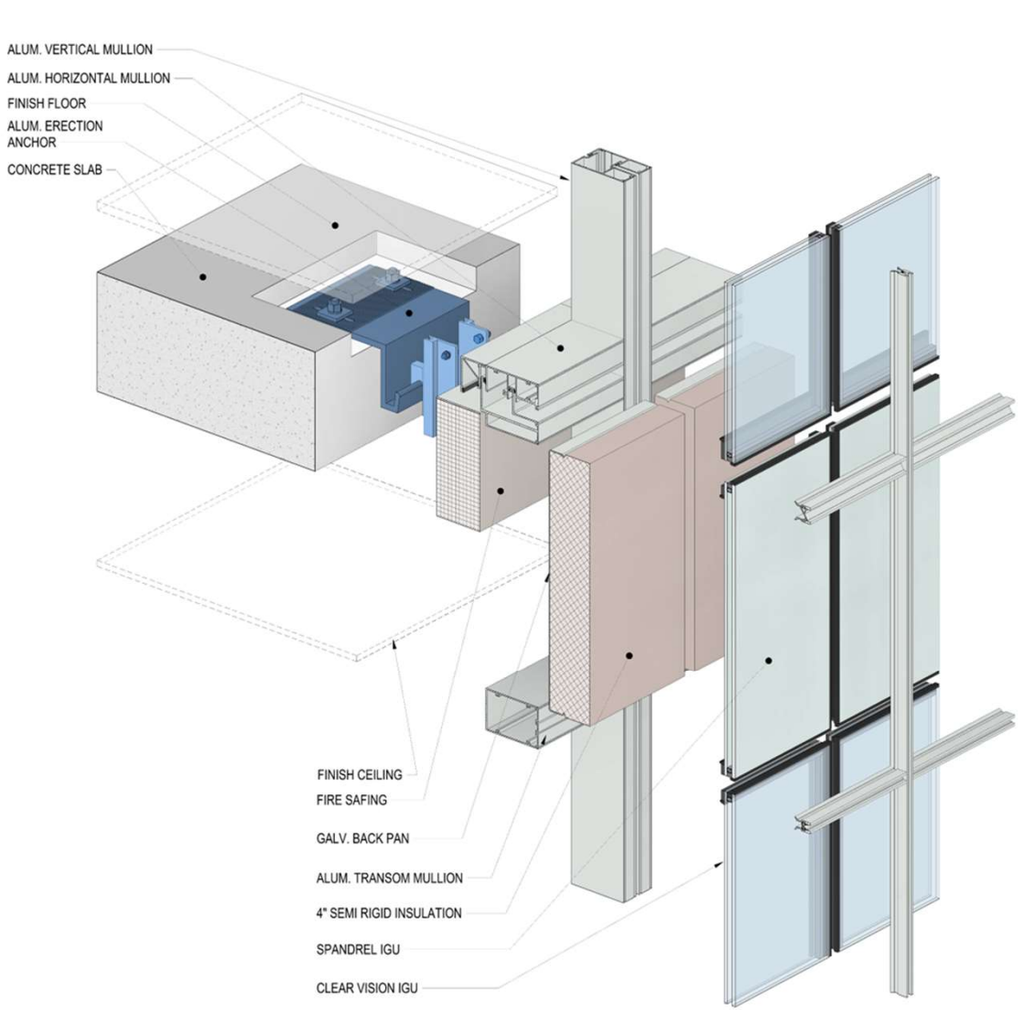
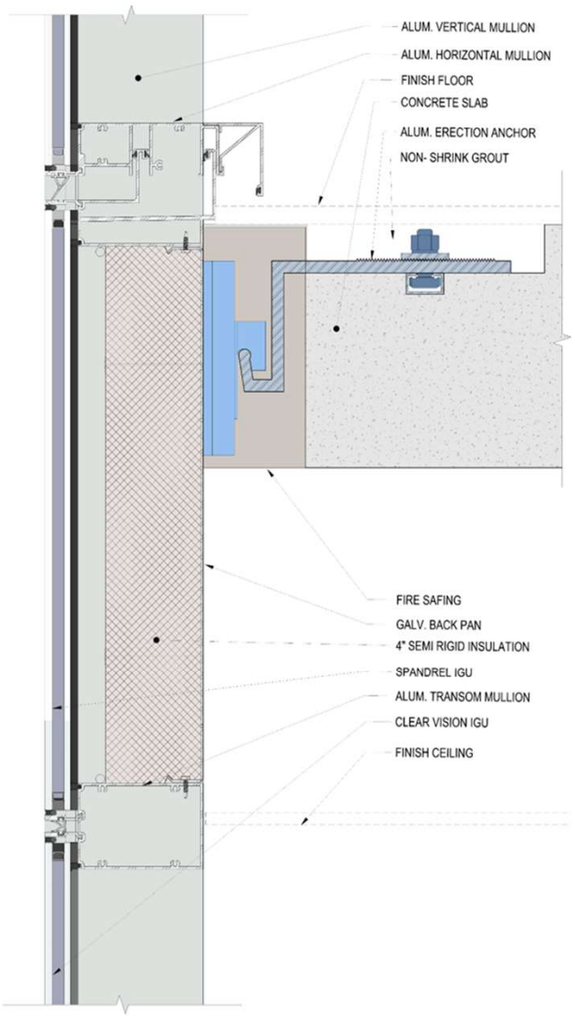
Disadvantages: Unitized

- Not suitable for all building types
  - Best suited to large projects such as high-rise buildings
- More costly as a system on a cost per square foot basis
- Inspections required at both the fabrication plant and at job site
  - The fabrication plant could be out of country

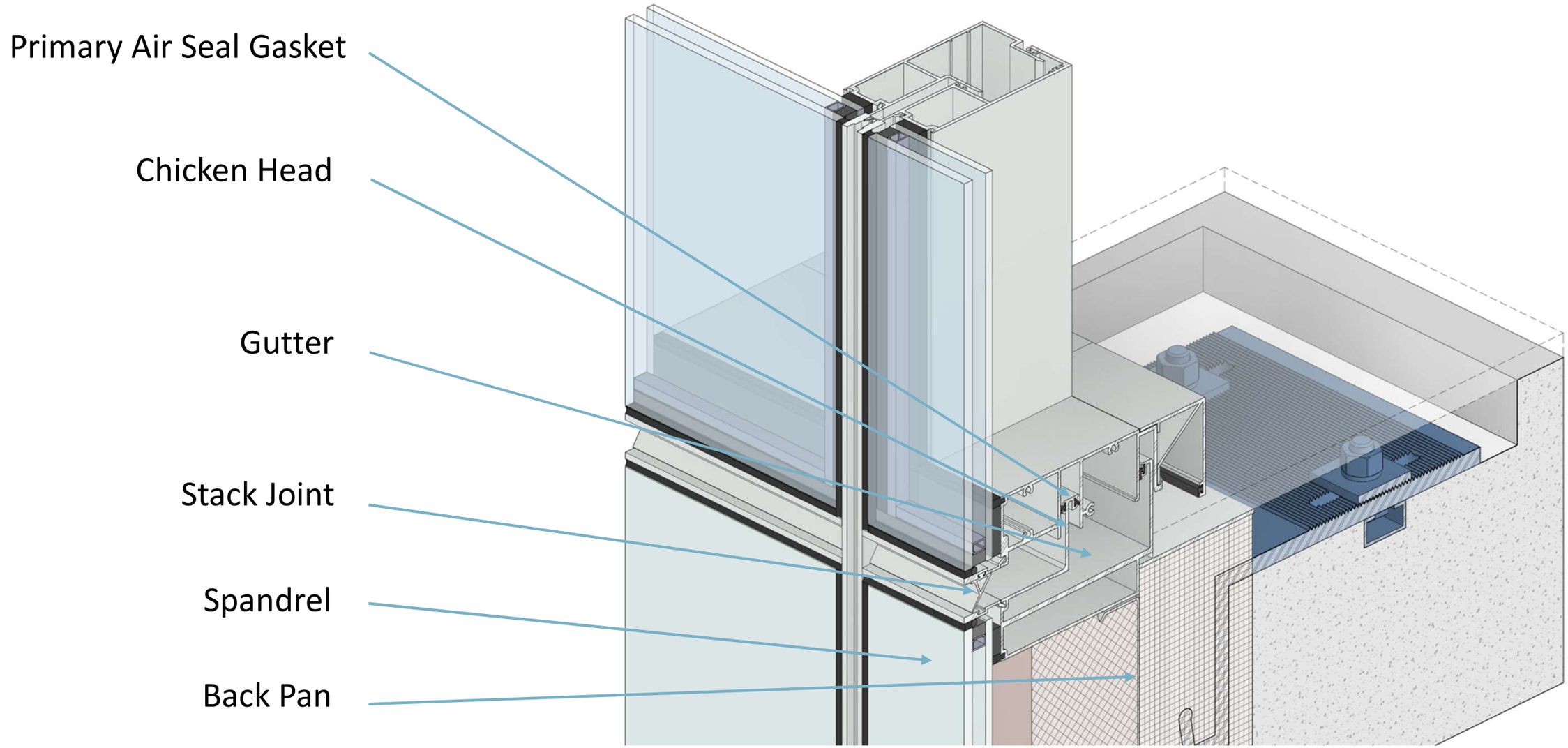
Curtain Wall Components

Section View of Curtain Wall Sub-Systems





Section View of Curtain Wall Sub-Systems



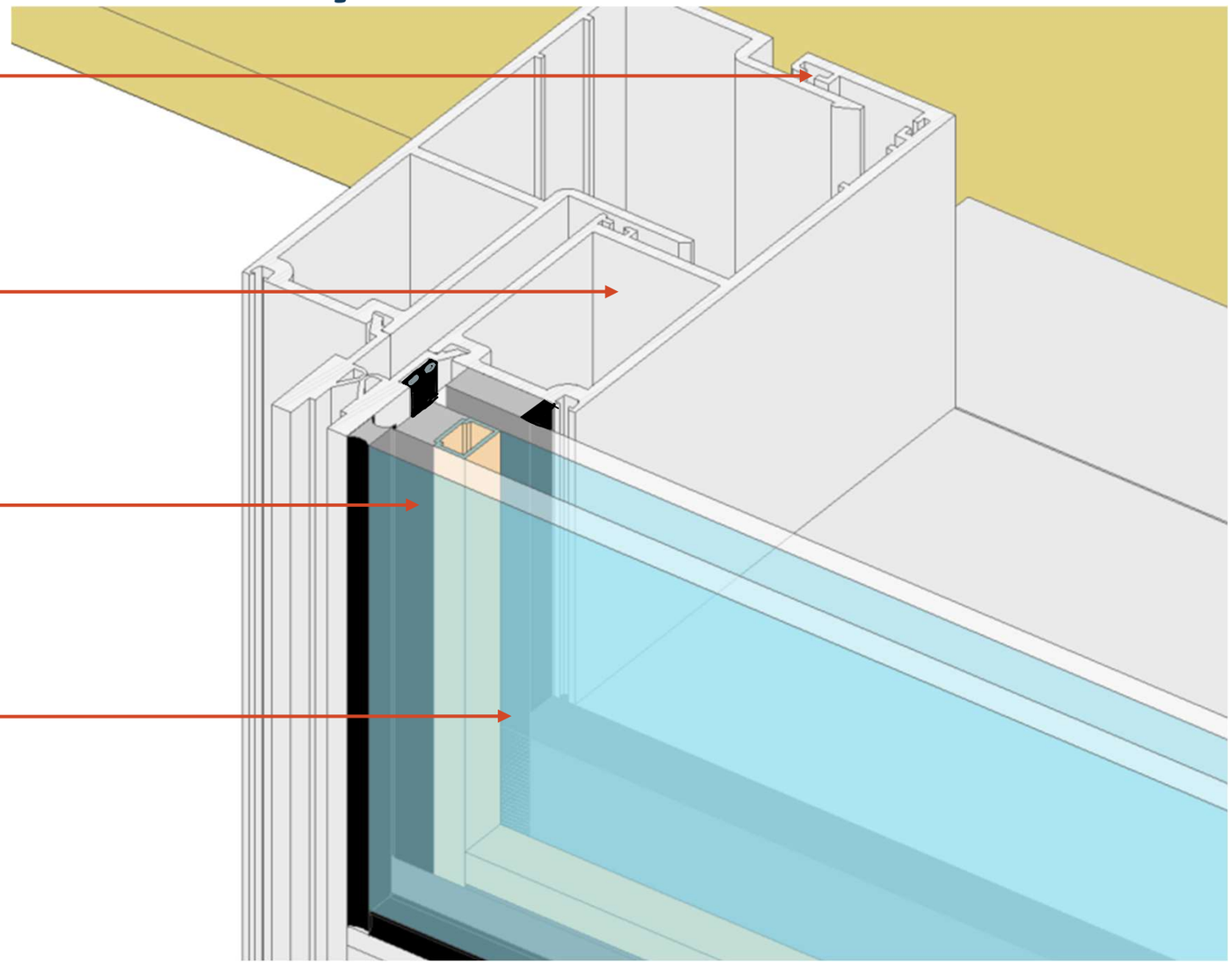
Section View of Curtain Wall Sub-Systems

Secondary Seal

Primary Seal

Thermal Break

Structural Silicone Glazing



Section View of Curtain Wall Sub-Systems

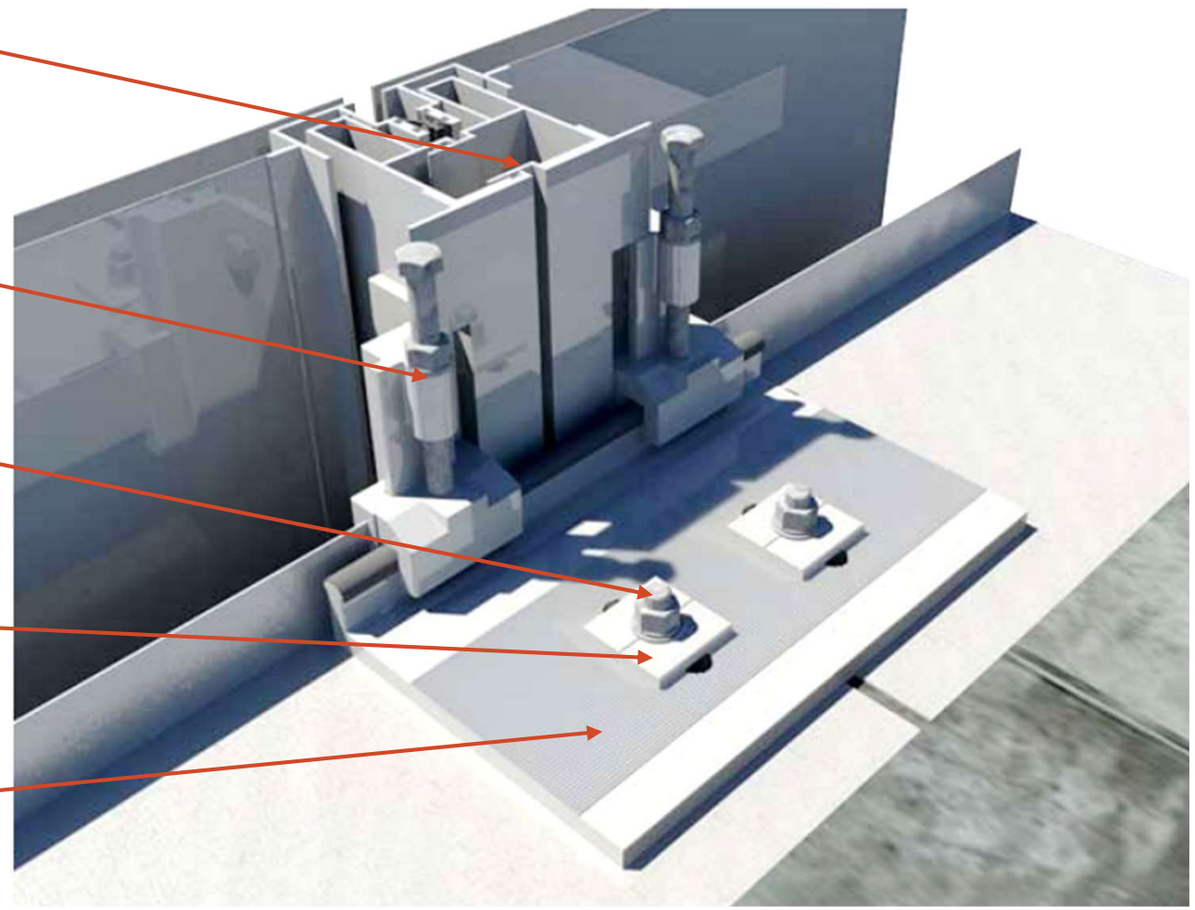
Interlocking Mullion

Fist Anchor w/ Adjustable Bolt

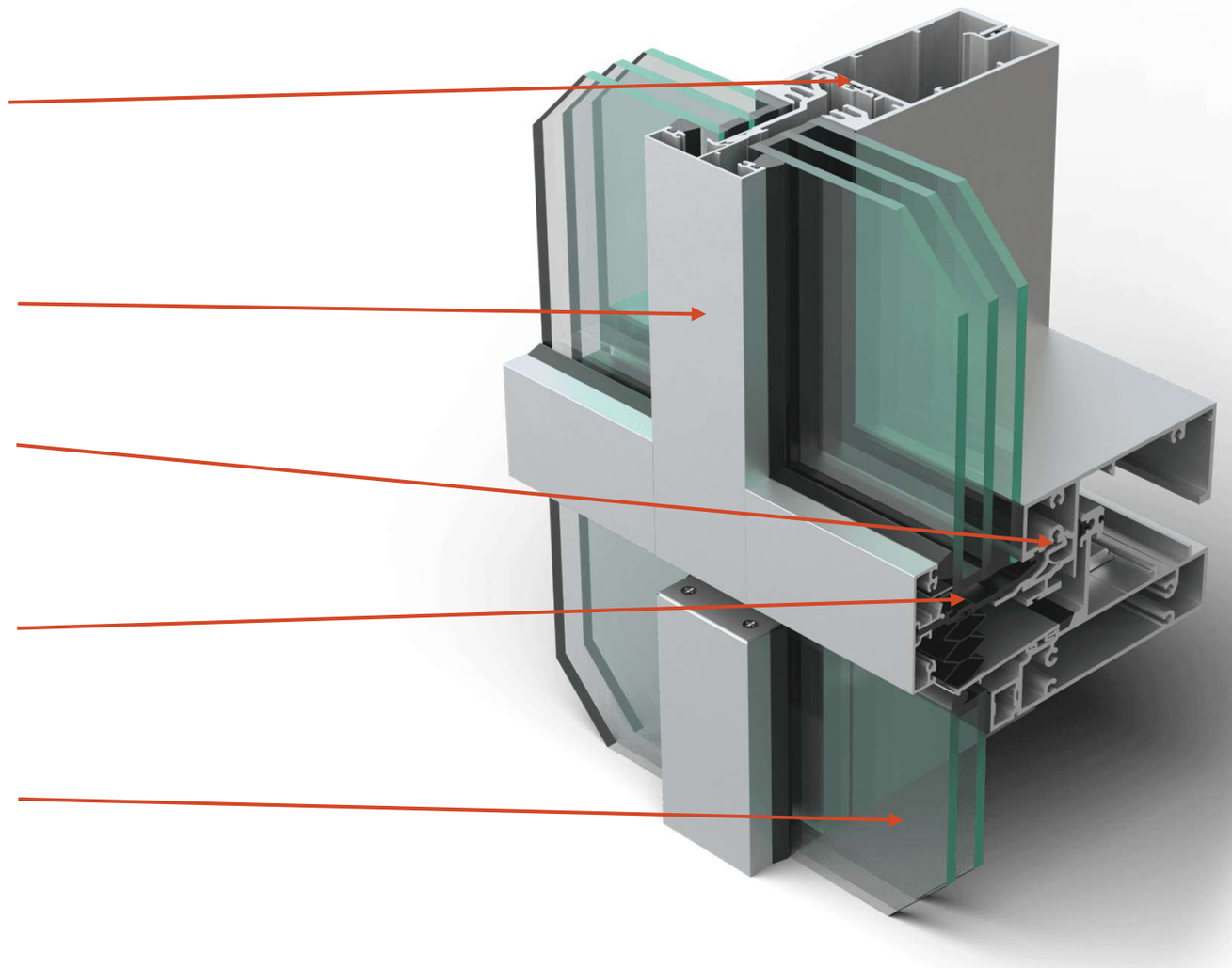
T- Bolts

Serrated Washer Plate

Erection Anchor Plate



Section View of Curtain Wall Sub-Systems

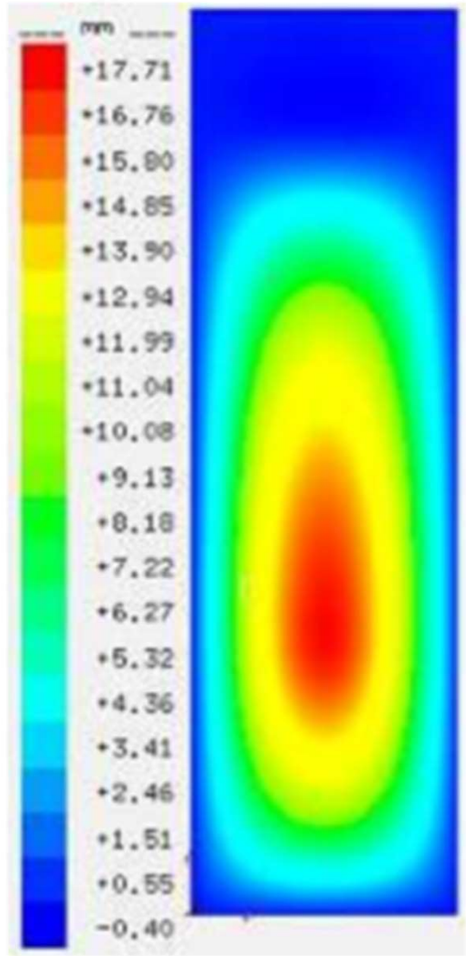


Performance of Curtain Wall Sub-Systems

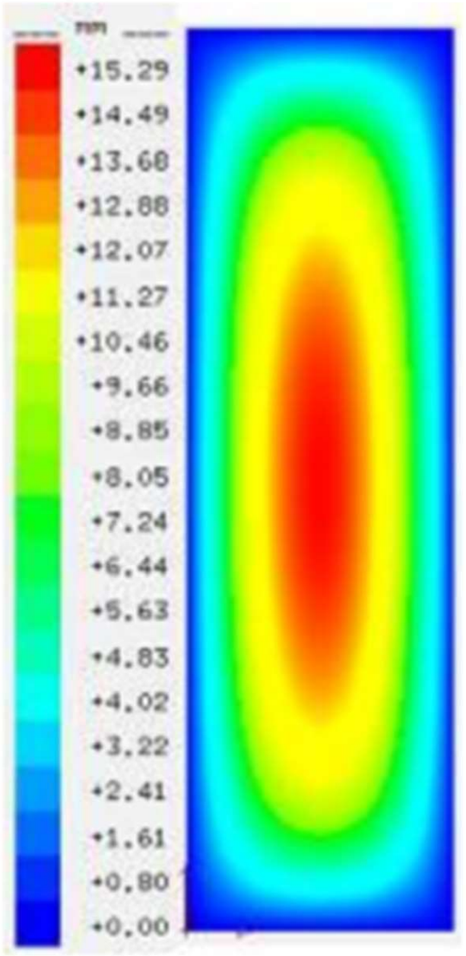
Structural Performance

Structural Performance
Load Path

- Glazing
  - Glass (IGU) functions to transfer wind loads into the vertical and horizontal framing
  - Wind load goes into outer pane of IGU, then through air gap, “air cushion” effect, then into inner pane of glass



Deflection for 6-mm THK Panel

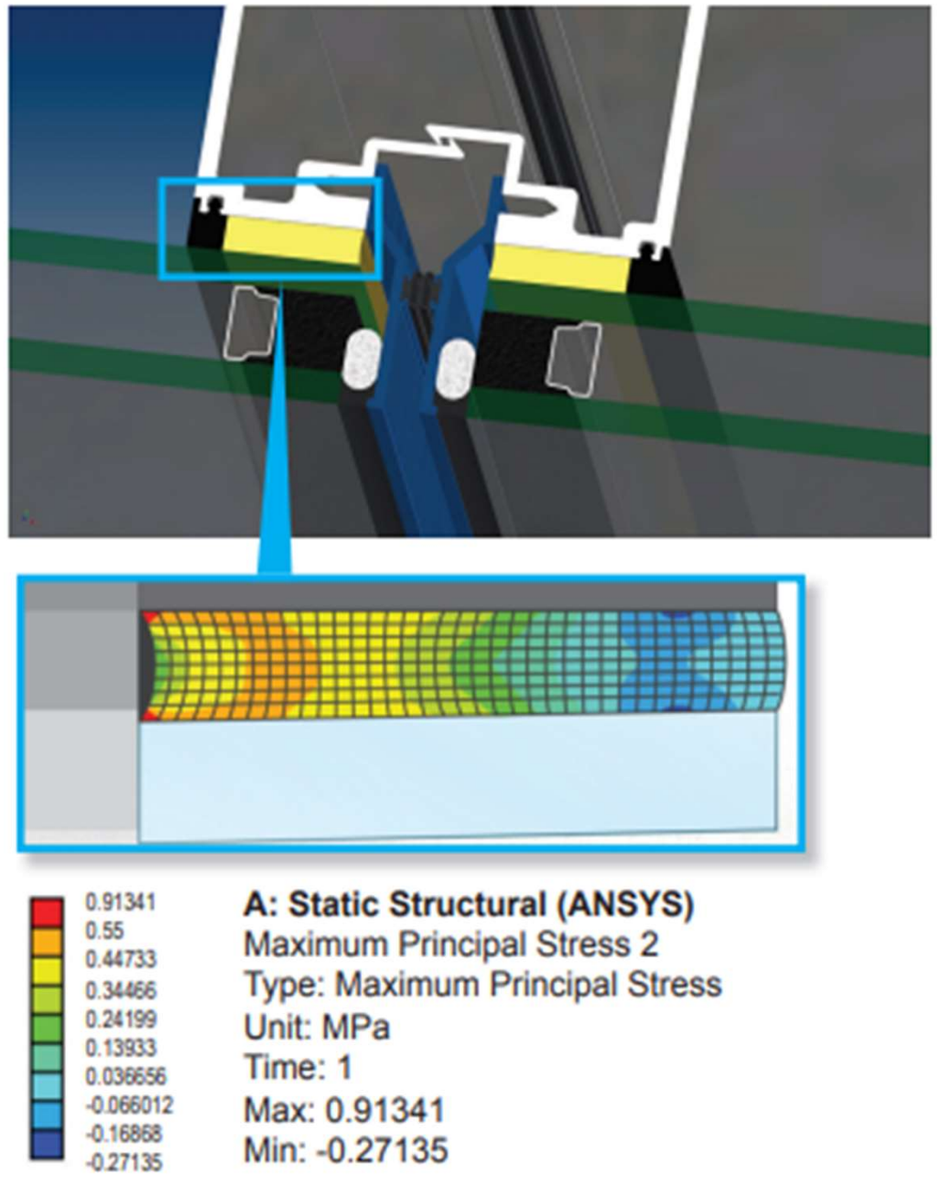


Deflection for 8-mm THK Panel

Displaced Shape of the Panel for the Governing Load Case

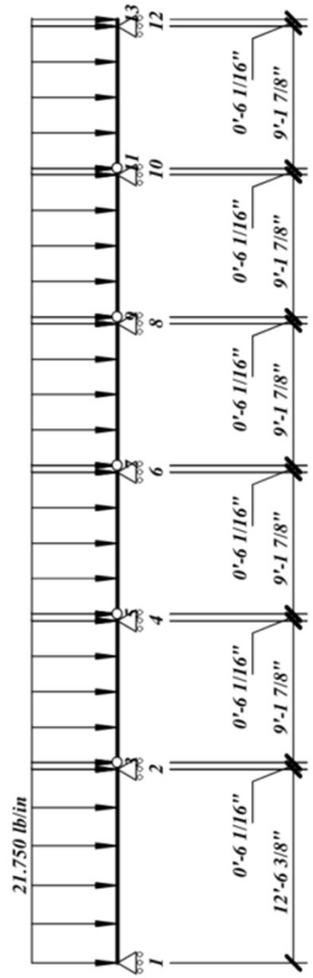
Structural Performance

- Aspect ratio of glass will determine the load transfer path into the framing based on which way the glass is spanning across the opening
- Wind load from inner pane of glass must be transmitted through the structural silicone before it reaches the mullion
- Glass is not accounted for as a stiffening or bracing element for framing



Structural Performance

- Aluminum Framing (Mullions and Transoms)
  - The “back section” of mullion extrusion is the primary contributor to structural performance
  - Framing is rigidly connected at joints which fasteners and shear blocks
  - All loads ultimately transfer into the vertical mullions



Maximum distributed load value shown only, see distributed load table for detailed information.

Beam Results

Max. Span Deflection	=	-0.6223"	(Span 11, @	57.70")
Cantilever Deflection	=	0.1127"	(Span 12, @	6.10")
Max. Positive Moment(1)	=	57882"#	(Span 1, @	71.44")
Max. Negative Moment(1)	=	-7290"#	(Span 1, @	150.40")
Max. Positive Moment(2)	=	32635"#	(Span 11, @	54.95")
Max. Negative Moment(2)	=	-7673"#	(Span 10, @	0.00")

Member Information

Span	Length(in)	I(in^4)	S(in^3)	E(psi)
1	150.400	24.380	2.849	1.0e+007
2	6.100	24.380	2.849	1.0e+007
Splice				
3	109.900	6.170	2.849	1.0e+007
4	6.100	6.170	2.849	1.0e+007
Splice				
5	109.900	6.170	2.849	1.0e+007
6	6.100	6.170	2.849	1.0e+007
Splice				
7	109.900	6.170	2.849	1.0e+007
8	6.100	6.170	2.849	1.0e+007
Splice				
9	109.900	6.170	2.849	1.0e+007
10	6.100	6.170	2.849	1.0e+007
Splice				
11	109.900	6.170	2.849	1.0e+007
12	6.100	6.170	2.849	1.0e+007

Distributed Load Information

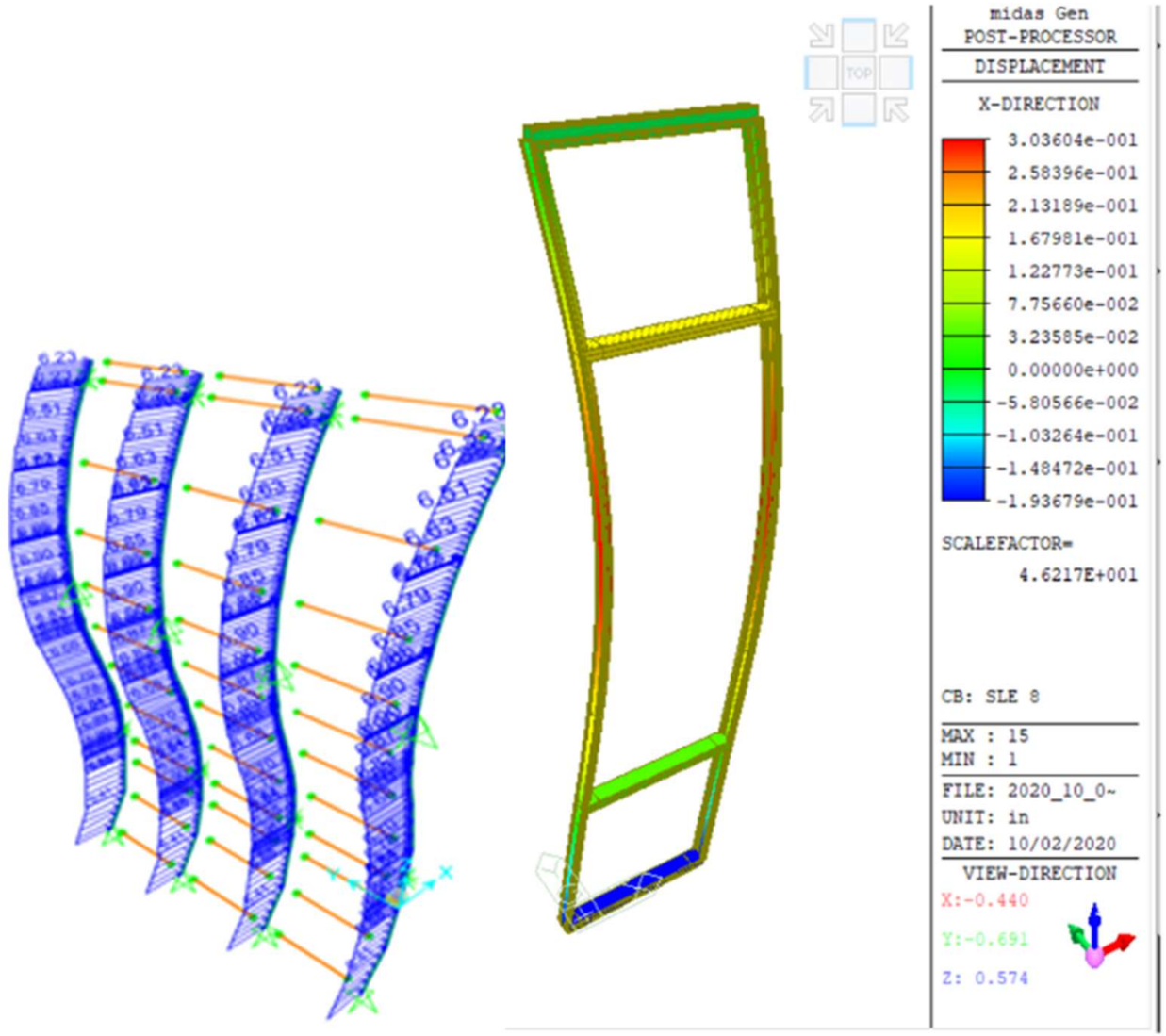
Span	W1(#/in)	W2(#/in)	X1(in)	X2(in)
1	21.750	21.750	0.000	150.400
2	21.750	21.750	0.000	6.100
3	21.750	21.750	0.000	109.900
4	21.750	21.750	0.000	6.100
5	21.750	21.750	0.000	109.900
6	21.750	21.750	0.000	6.100
7	21.750	21.750	0.000	109.900
8	21.750	21.750	0.000	6.100
9	21.750	21.750	0.000	109.900
10	21.750	21.750	0.000	6.100

Continue on next page...

Deflection

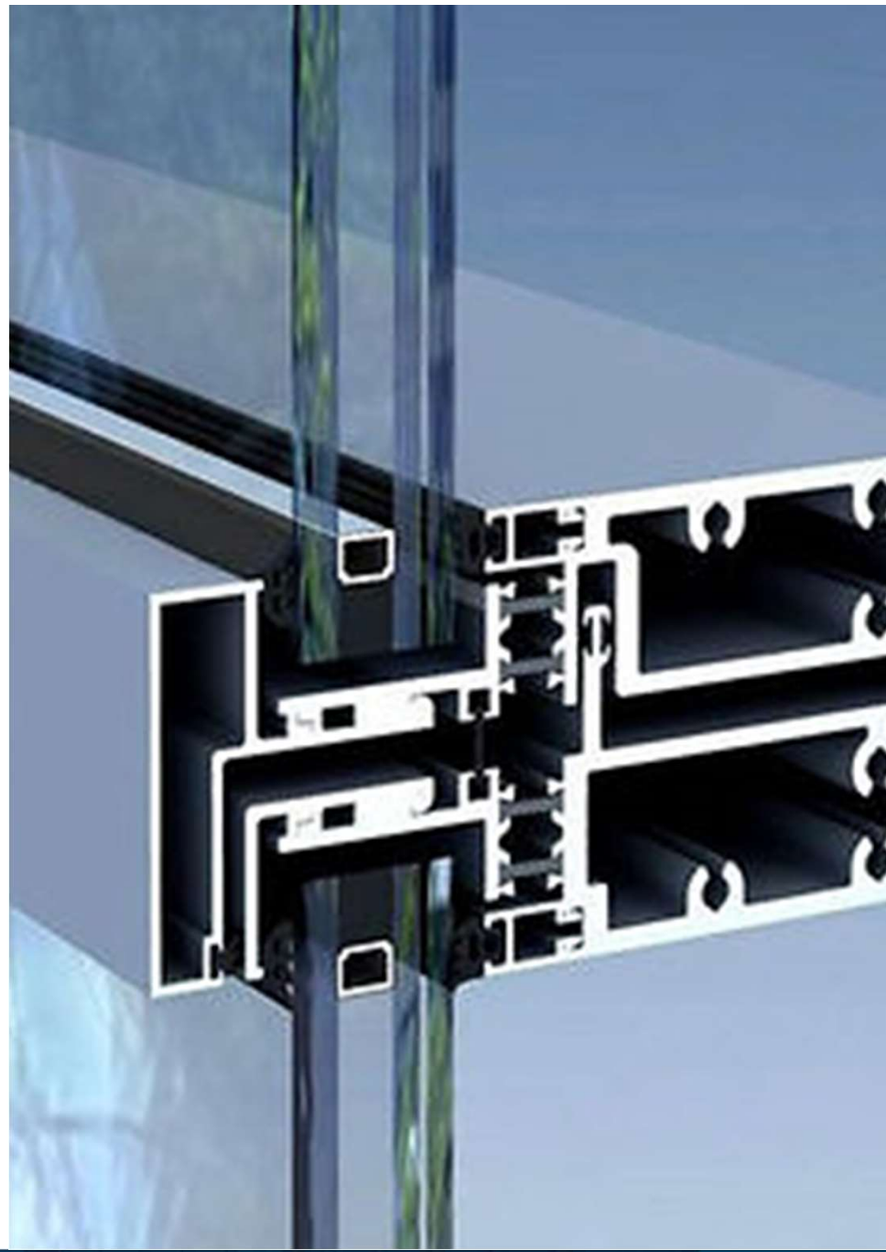
- Structural Performance Criteria of Mullions
  - L/175 under maximum design wind load for spans up to 13’-6” or L/240 plus ¼” for greater spans
    - Example: for 75PSF and curtain wall span of 14’-0”
    - 14’X12” = 168”/175 = 0.96” max permitted deflection

Reference standard: AAMA TIR-11



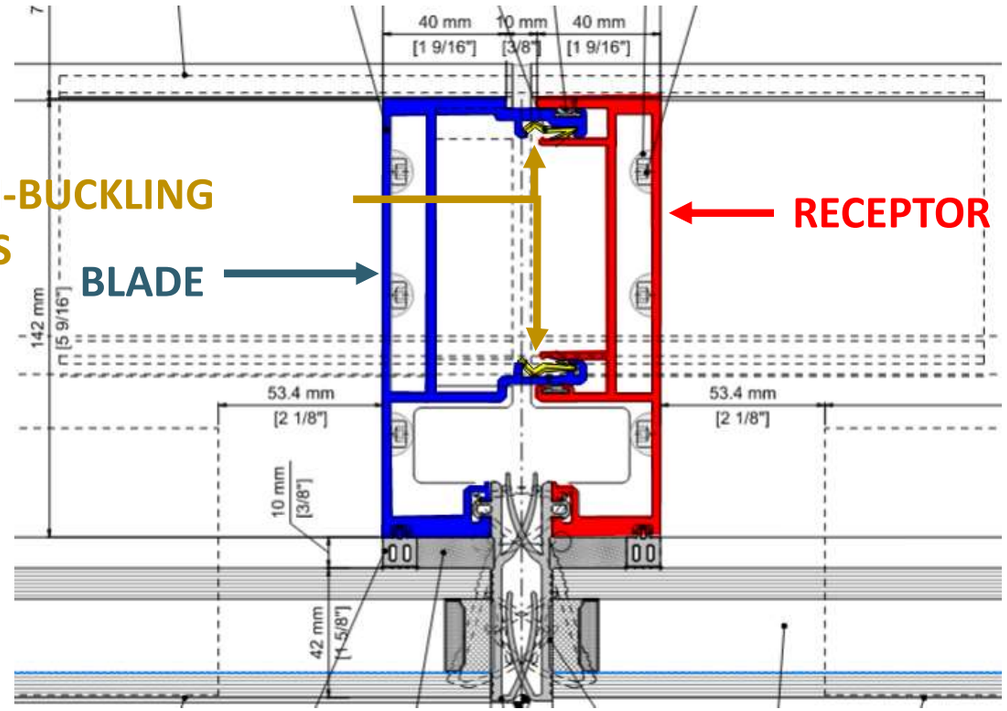
Deflection

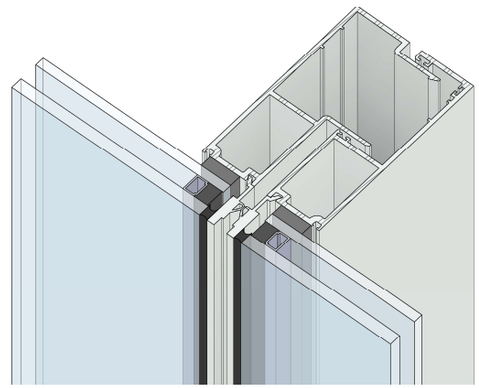
- Criteria is derived from:
  - Required stiffness to keep glass from falling out or having insufficient edge support
  - Required stiffness to minimize bending stress on the IGU seals
  - Required stiffness to minimize stresses on air/water seals at frame joints between vertical and horizontal framing
  - Psychological comfort of occupants
- Deflection criteria may need to be more stringent if mullion deflection could cause mullion to come into contact with brittle interior finishes



Vertical Mullion

- Vertical Mullions are two half mullions joined together to function as one whole mullion
- Under wind load there is potential for the slender mullions to buckle under load
- Anti buckling clips prevent the buckling issue.
- Vertical male/female receptors also help to stabilize the mullion





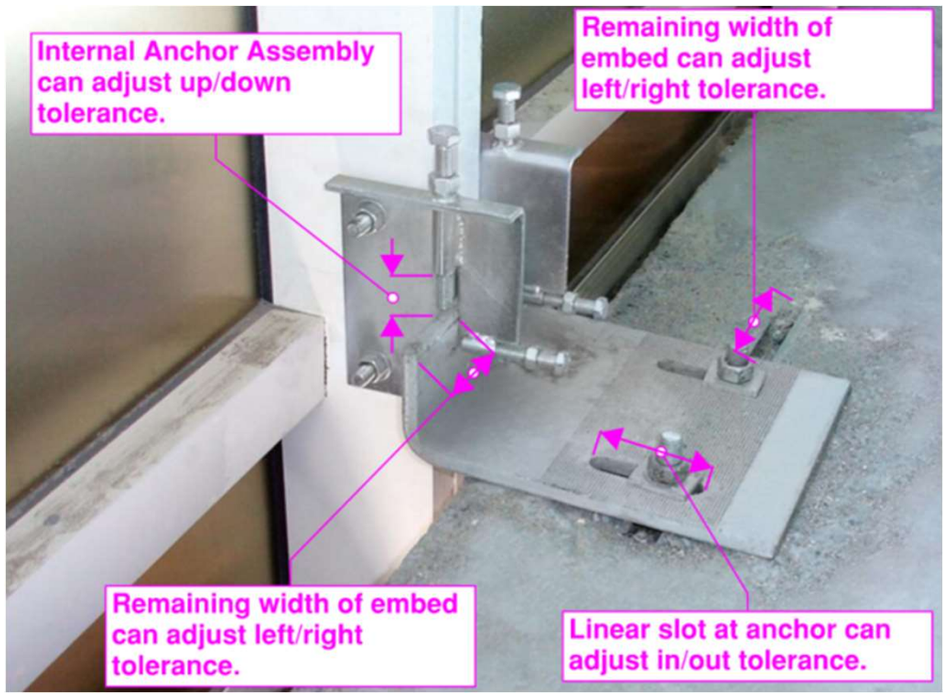
Anchorage

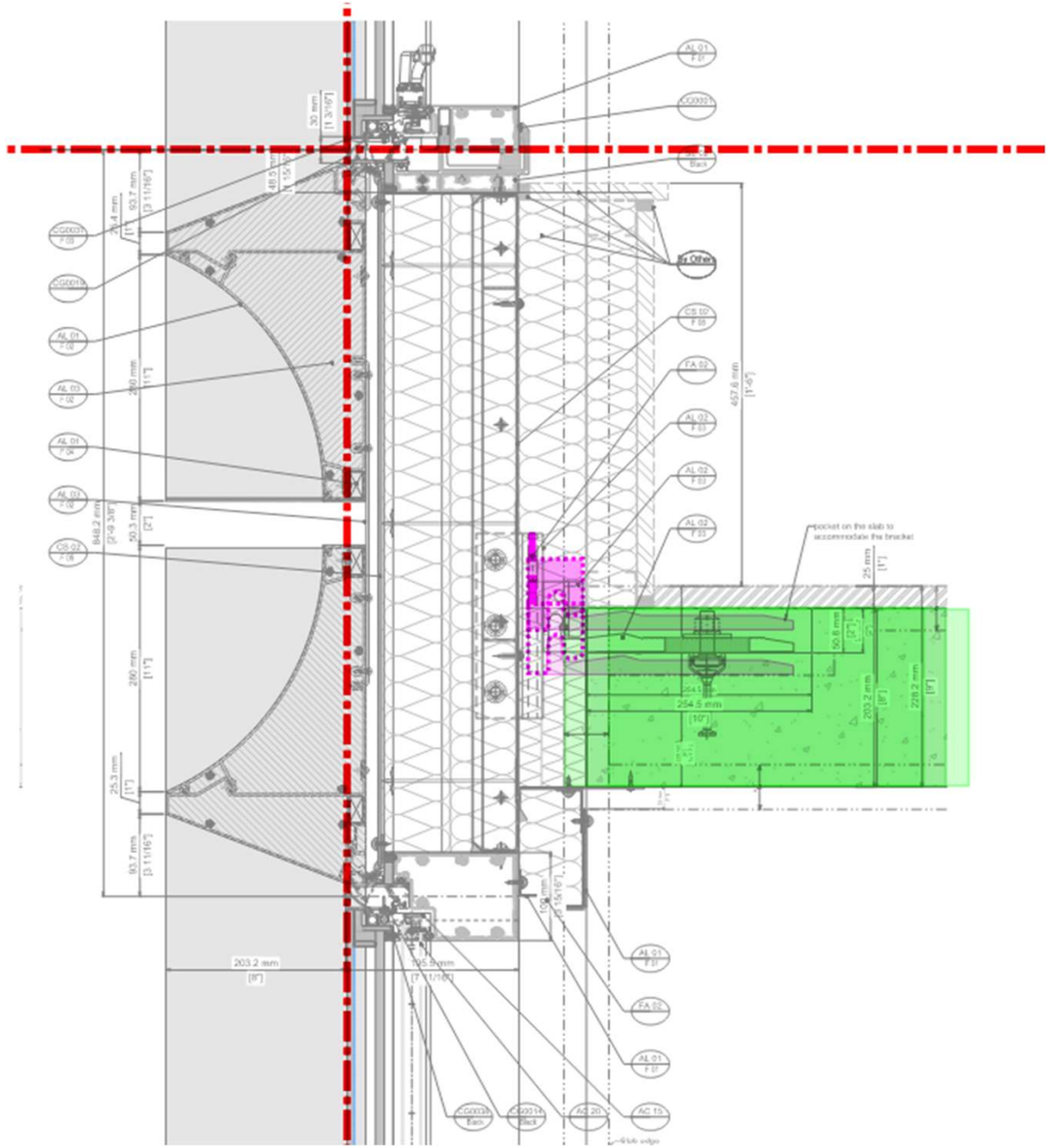
Anchorage from Curtain wall to Structure

- Typical anchor transfers dead and wind load from curtainwall to structure.
- Hook shaped aluminum plates (Fist Anchor) bolted to wall of mullion, transmit load from mullion into anchors
- Fist Anchor sits lowers down on the top of the L-shaped anchor bracket (Erection Anchor)
- Erection Anchor is bolted to the structure with embed channel

Anchorage

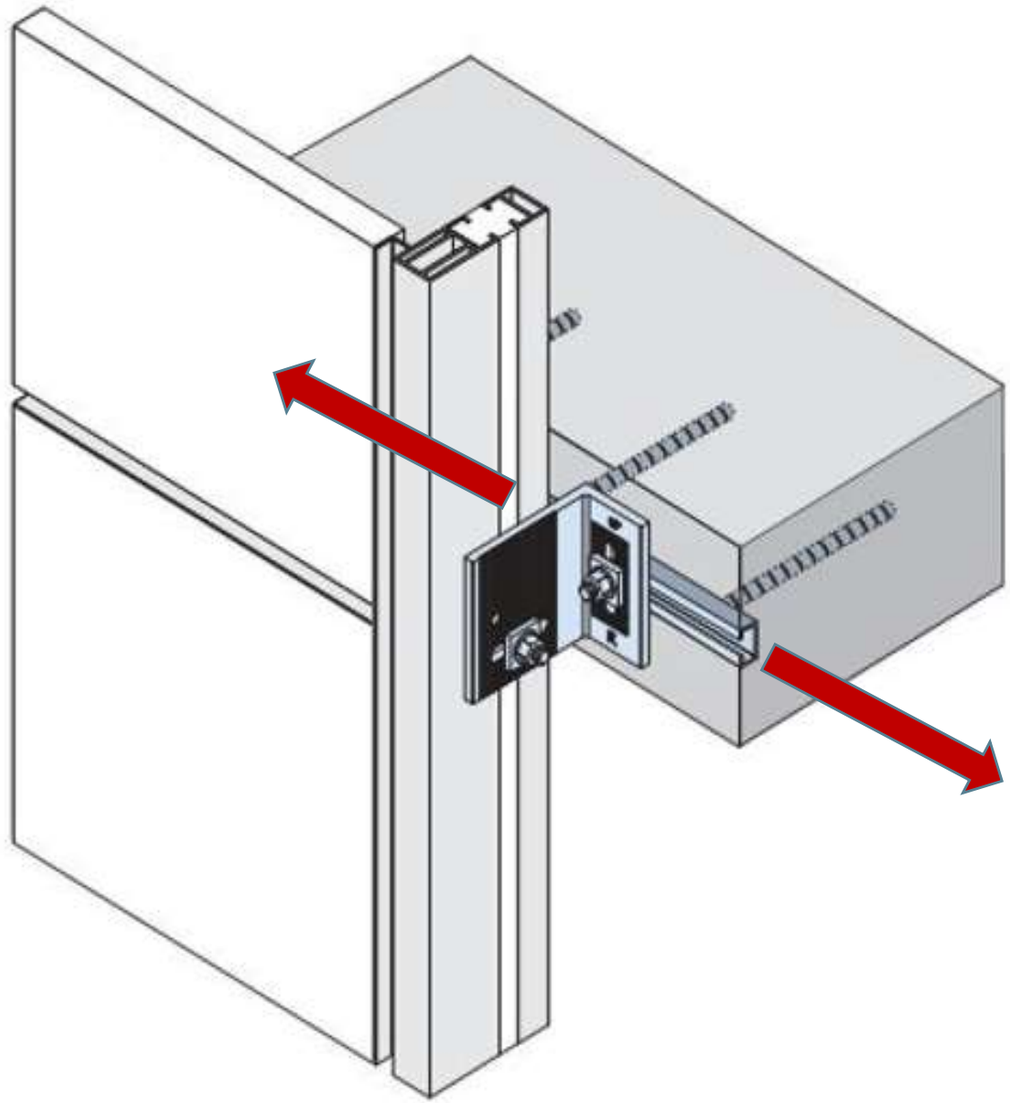
- Virtually all tolerance adjustment for maintaining façade plumb and true is accomplished with adjustable anchors





Anchorage

- Most curtain wall anchors will be top of slab but there are other conditions where this is not possible:
  - Shear walls
  - Anchor located at face of slab
    - Must plan for this in design phase because space is required for the system, anchor, in/our adjustment
    - Not enough space: anchor with virtually no adjustment tolerance



Common Problems

Incorrectly Installed Flashing & Trim Covers

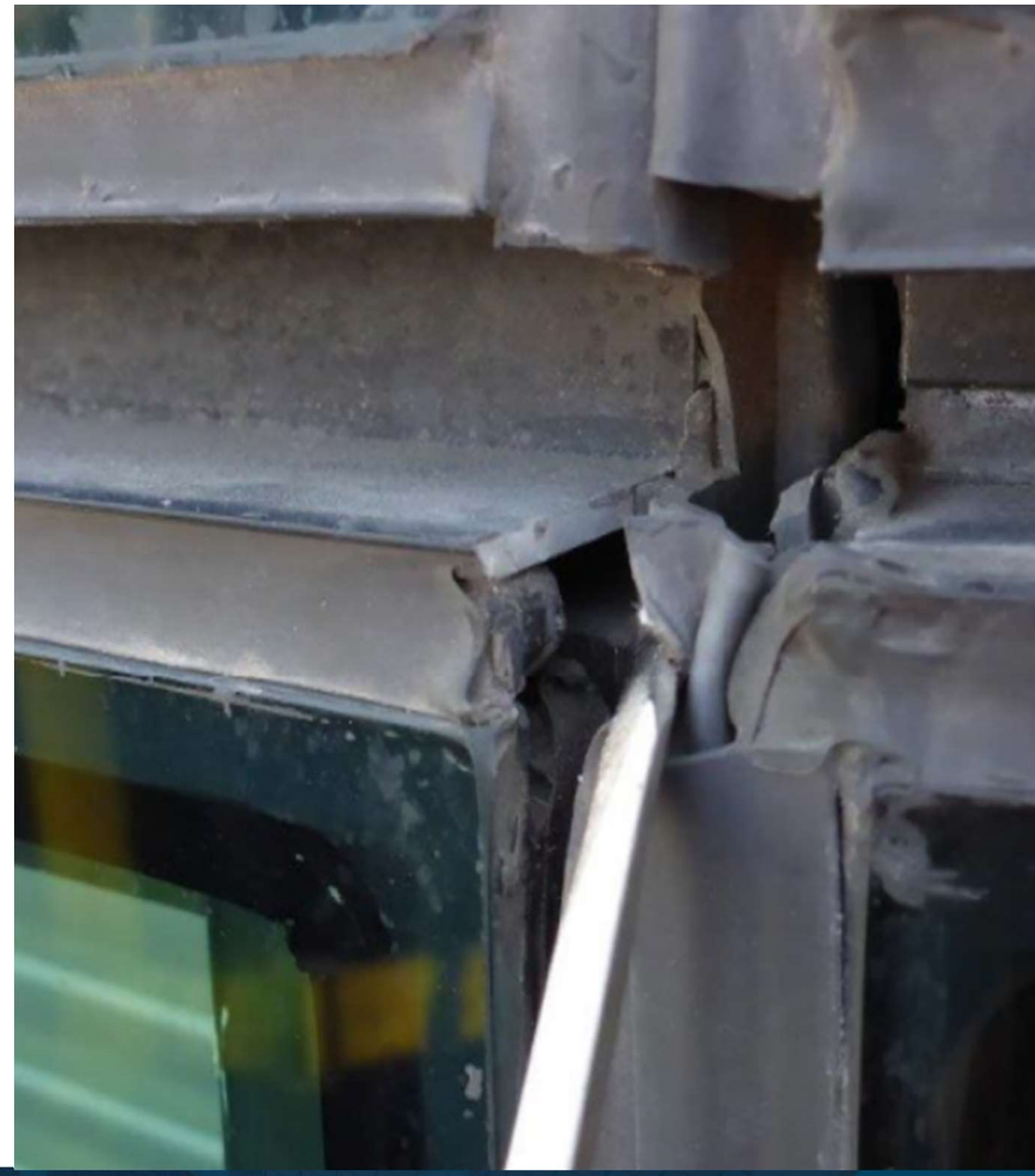
- Failure to correctly size or properly position weep holes in the curtain wall pressure plates and covers
    - The drainage path and the size, type, location, and frequency of weep holes vary by manufacturer
- Ensure the correct screws are put in at the proper place with the appropriate torque

Gasket and Seal Degradation

- Air spaces are created in the gaskets due to shrinkage

- The dried gasket admit air and moisture into the curtain wall leading to

    - Condensation
    - Drafts
    - Water intrusion



Gasket and Seal Degradation

- Common example of perimeter visual gasket degradations are:
    - Discoloration
    - Brittleness
    - Shrinking or pulling away from the surface
    - Gaps and Holes

Missing or Incorrectly Applied Sealant

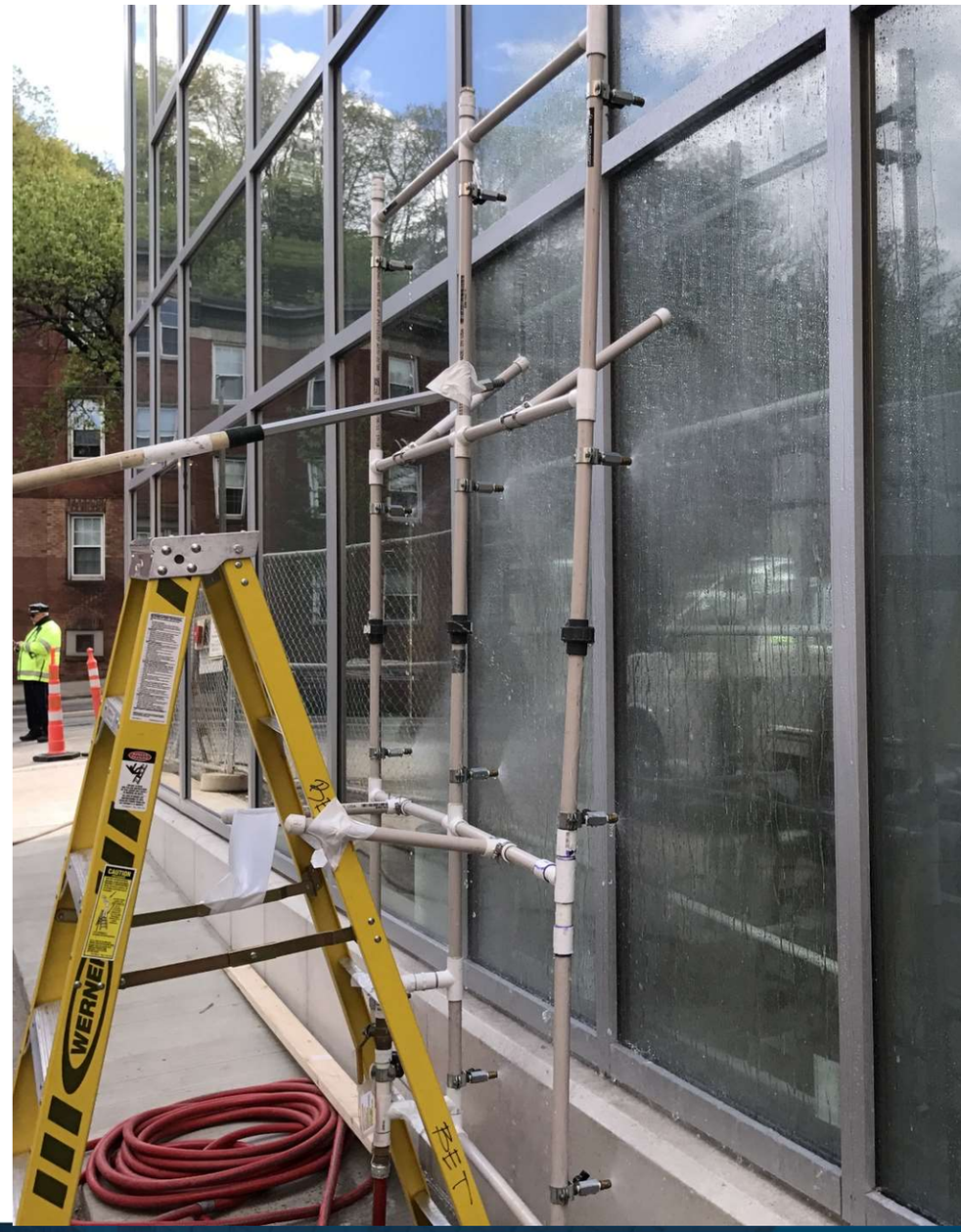
- Failure to seal around:
  - the front of shear block
  - Along the front edges of horizontal transom to vertical mullion
- Can lead to air and water infiltration

- More sealant is not better
  - Don't need to add sealant at snap cap cover

- Too much sealant can plug weeps and mask leaks making troubleshooting very difficult

Preventative Measures

- Consult a façade consultant to review the details and shop drawings
- Examine the products and evaluate the installation methods
- Perform periodic field-testing during construction
- Construct a proper maintenance plan recommended by the manufacturer



Combining Stick Built and Unitized Systems

Halo Tower

Architect: INOA Architects

Developer/Client: ACIER Holdings

Size:
900,000SF
3 towers—38 stories, 42 stories, and 46-stories
949 residential rental units on six-story podium base

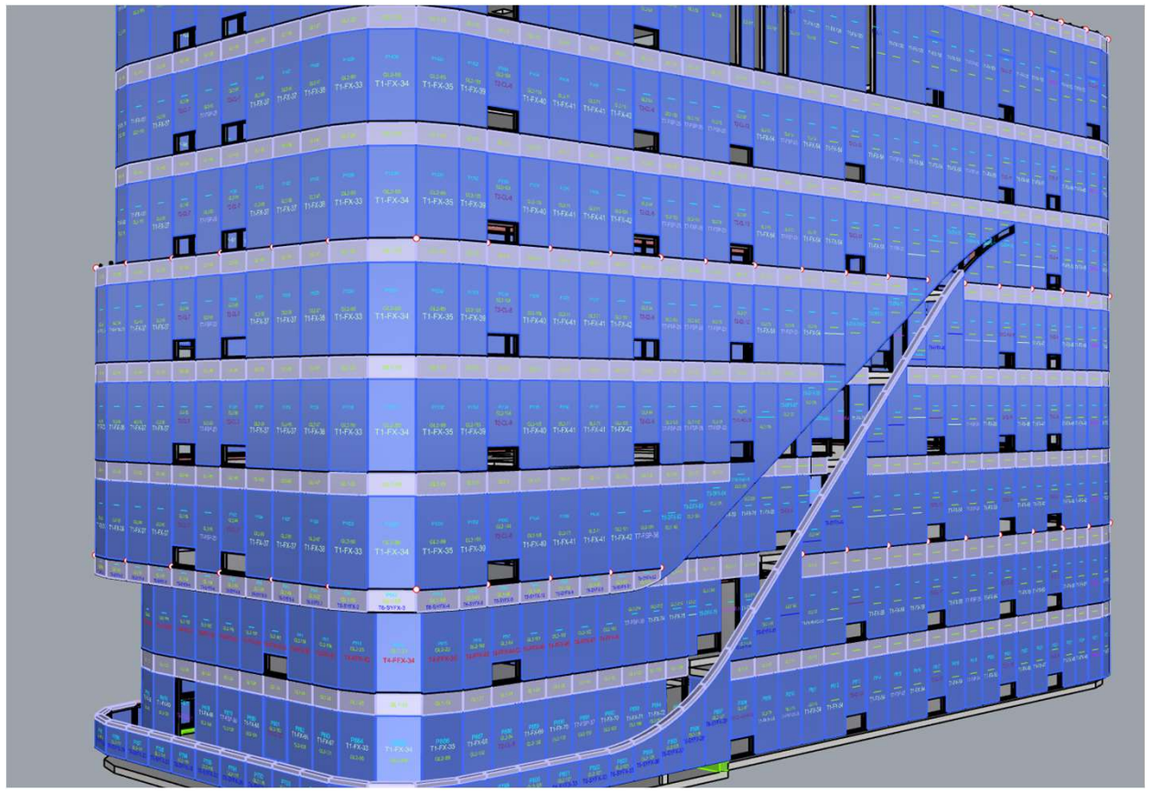
Height: 565’

Amenities:
Automated parking, terraces, “garden level amenities,” “sky lounge amenities,” rooftop pool

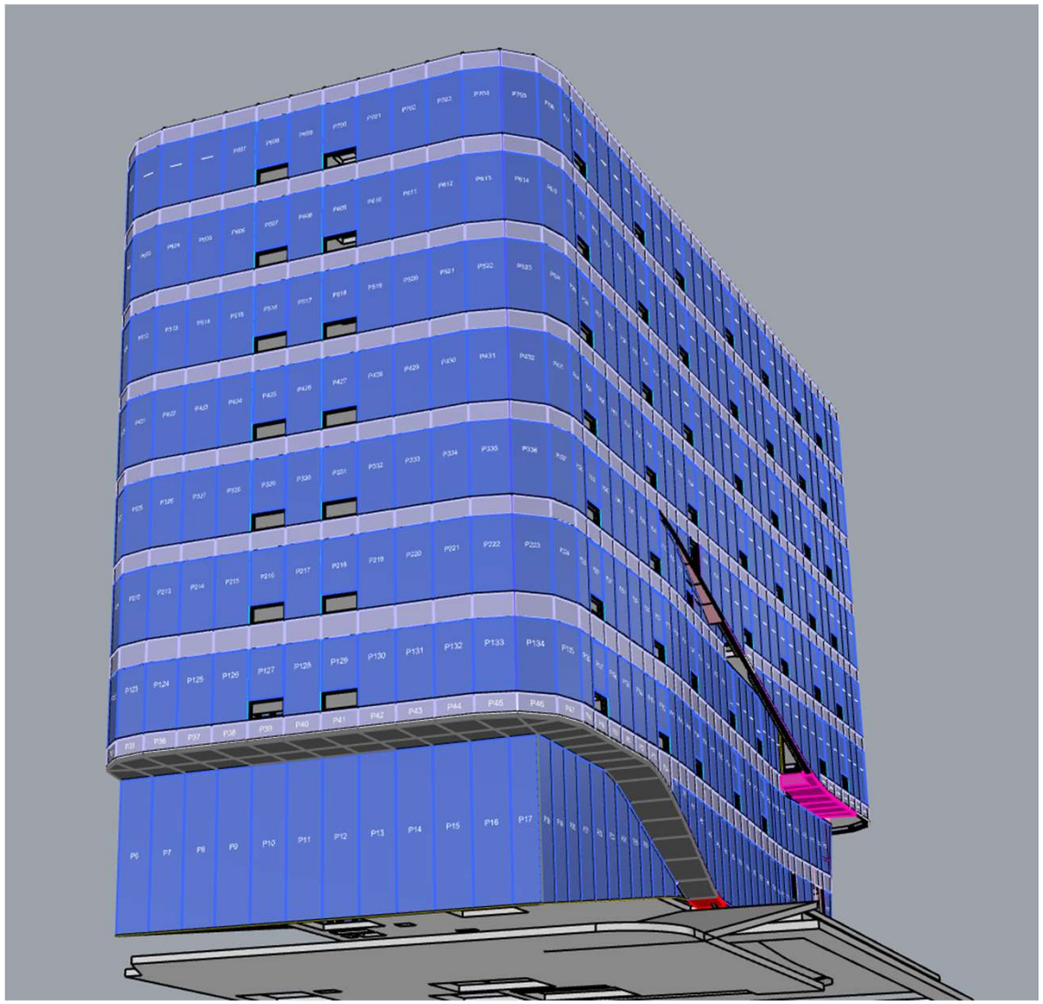
Completion: 2024

Facade Installation

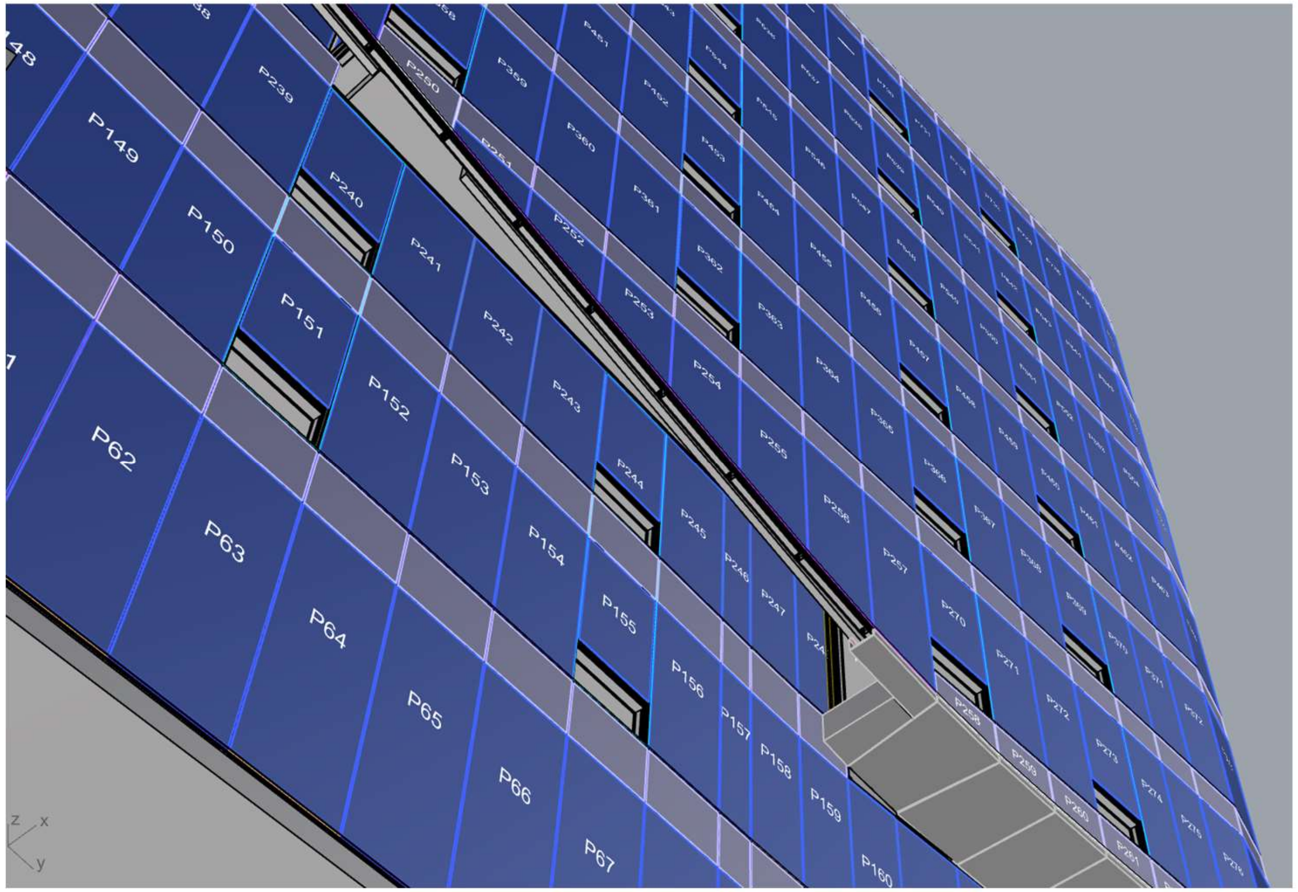
Curtain Wall at Sky Garde

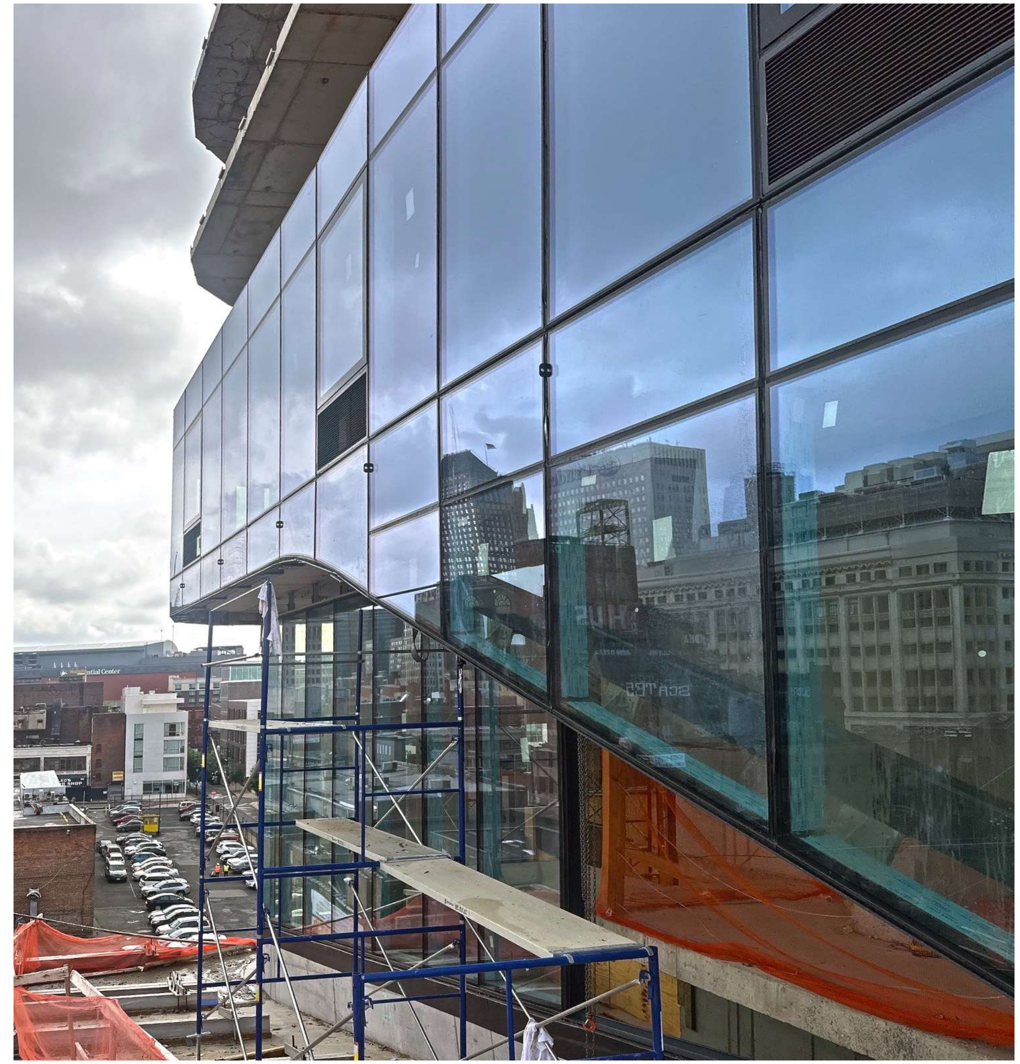


Facade Design and Execution



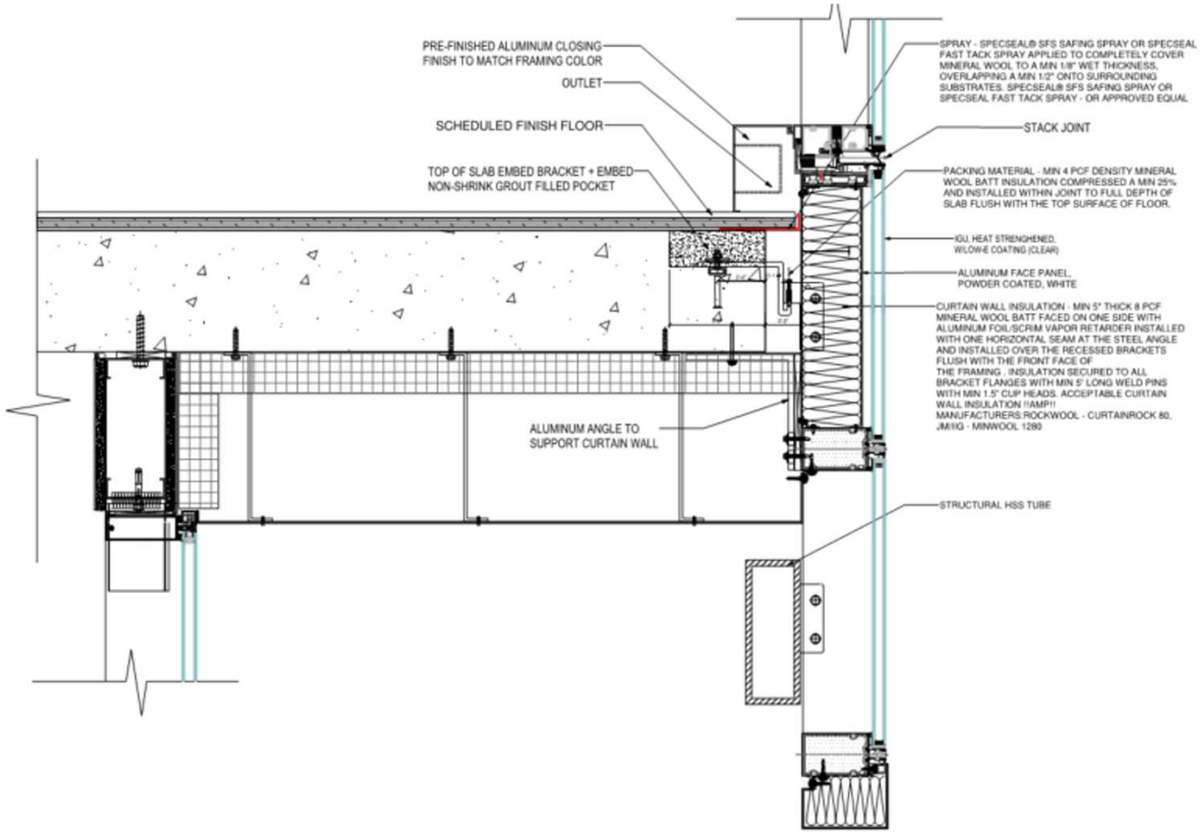
Facade Design and Execution

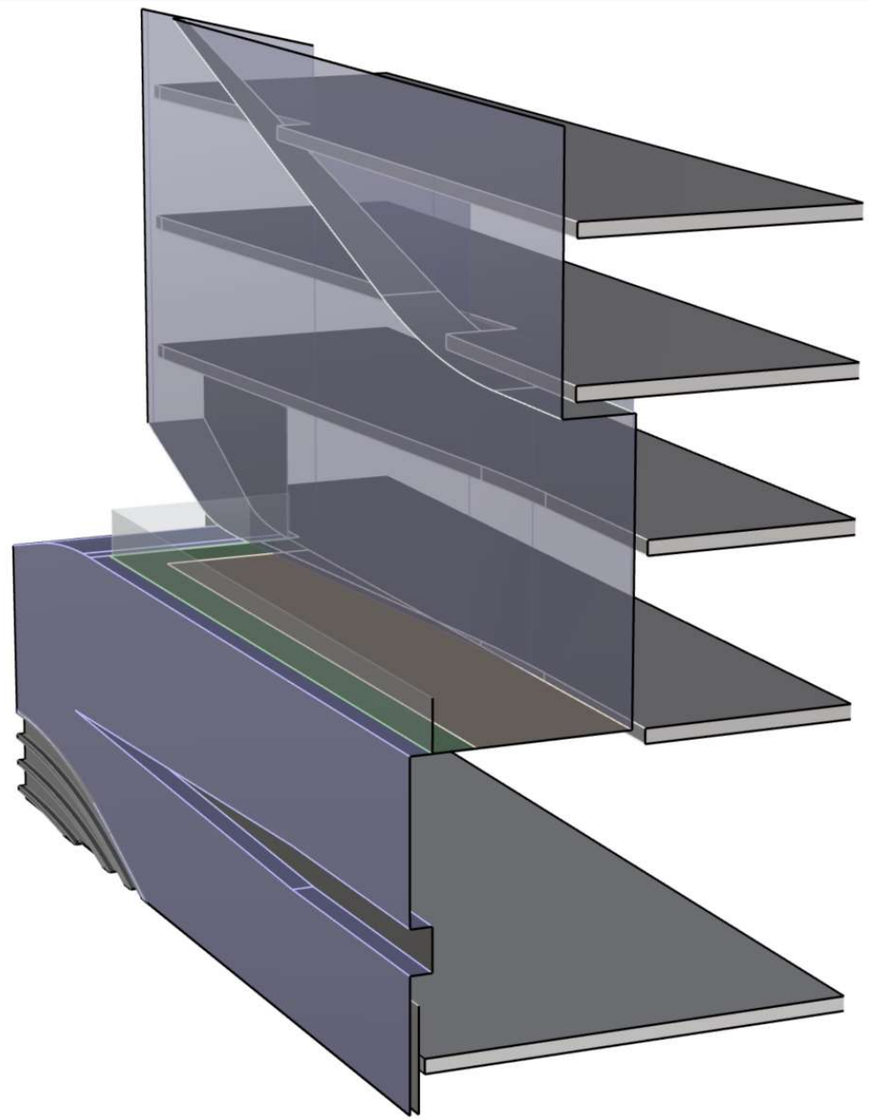




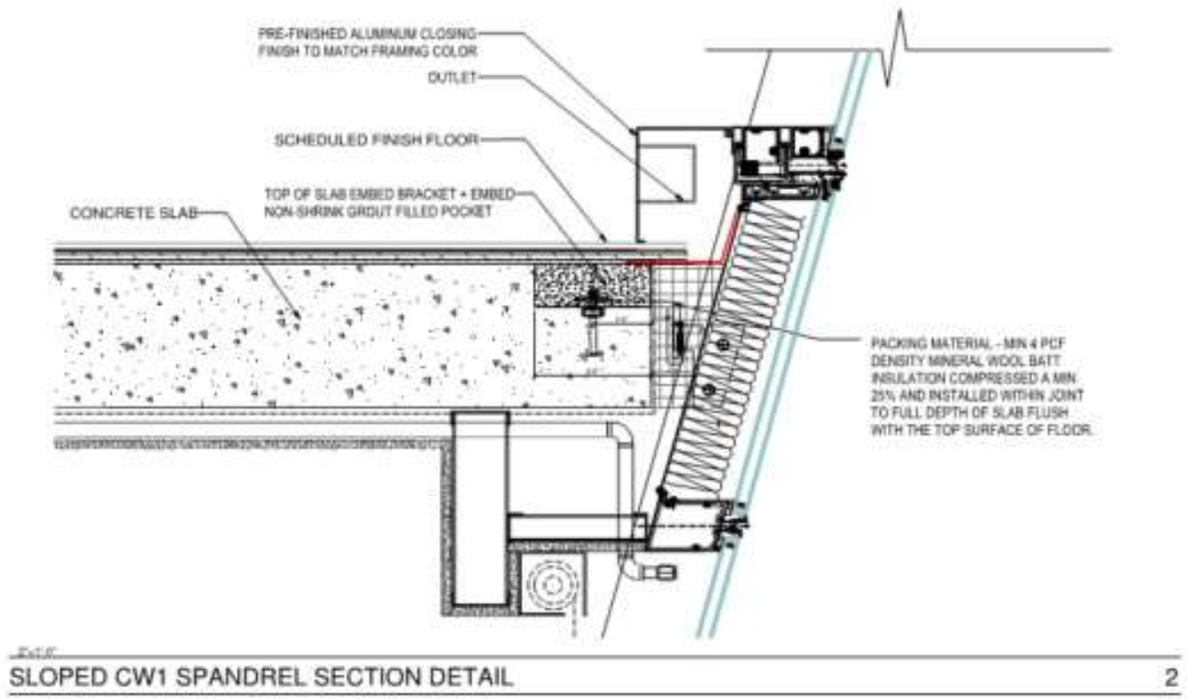
Facade Design and Execution

Terraces

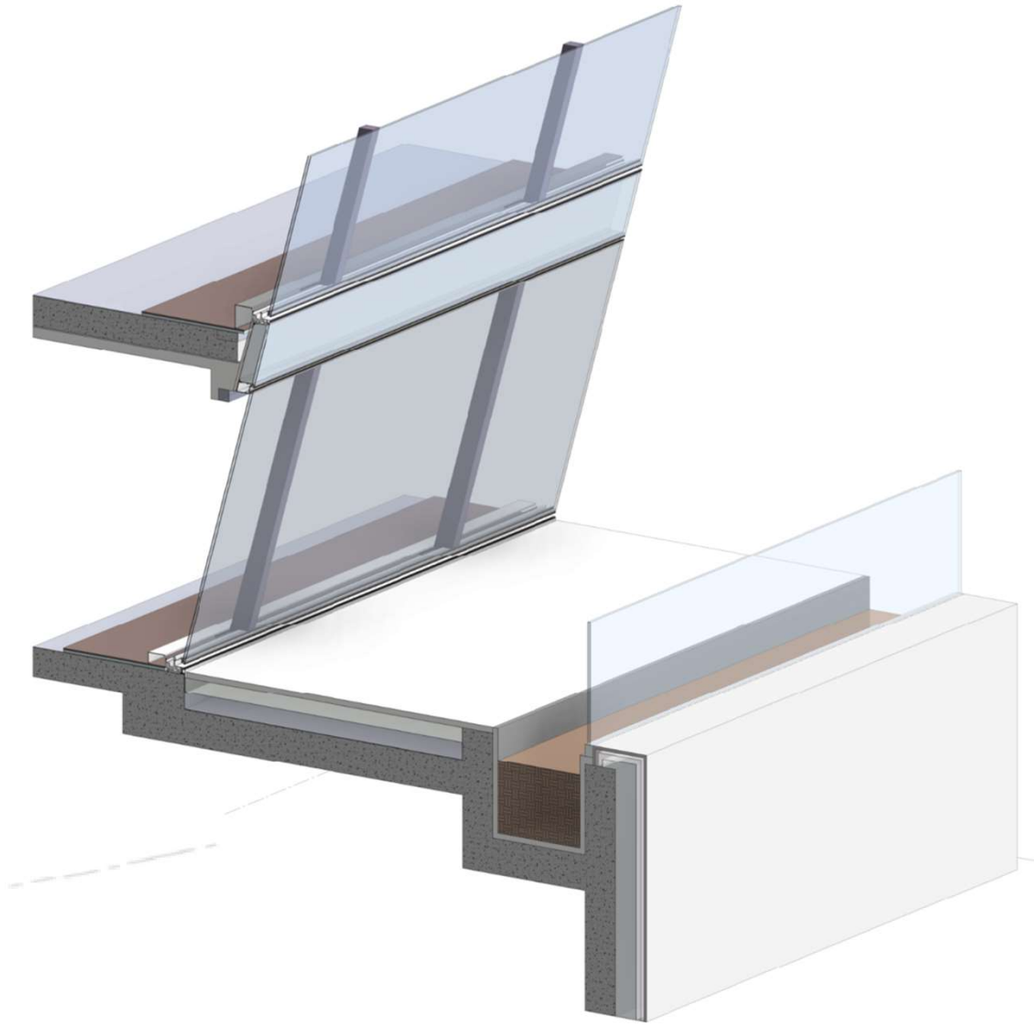

PRE-FINISHED ALUMINUM CLOSING
FINISH TO MATCH FRAMING COLOR
OUTLET
SCHEDULED FINISH FLOOR
TOP OF SLAB EMBED BRACKET + EMBED
NON-SHRINK GROUT FILLED POCKET
ALUMINUM ANGLE TO
SUPPORT CURTAIN WALL
SPRAY - SPECSEAL® SFS SAFING SPRAY OR SPECSEAL FAST TACK SPRAY APPLIED TO COMPLETELY COVER MINERAL WOOL TO A MIN 1/8" WET THICKNESS, OVERLAPPING A MIN 1/2" ONTO SURROUNDING SUBSTRATES. SPECSEAL® SFS SAFING SPRAY OR SPECSEAL FAST TACK SPRAY - OR APPROVED EQUAL
STACK JOINT
PACKING MATERIAL - MIN 4 PCF DENSITY MINERAL WOOL BATT INSULATION COMPRESSED A MIN 25% AND INSTALLED WITHIN JOINT TO FULL DEPTH OF SLAB FLUSH WITH THE TOP SURFACE OF FLOOR.
IGU, HEAT STRENGHENED, W/LOW-E COATING (CLEAR)
ALUMINUM FACE PANEL, POWDER COATED, WHITE
CURTAIN WALL INSULATION - MIN 5" THICK 8 PCF MINERAL WOOL BATT FACED ON ONE SIDE WITH ALUMINUM FOIL/SCRIM VAPOR RETARDER INSTALLED WITH ONE HORIZONTAL SEAM AT THE STEEL ANGLE AND INSTALLED OVER THE RECESSED BRACKETS FLUSH WITH THE FRONT FACE OF THE FRAMING . INSULATION SECURED TO ALL BRACKET FLANGES WITH MIN 5" LONG WELD PINS WITH MIN 1.5" CUP HEADS. ACCEPTABLE CURTAIN WALL INSULATION !!AMP!! MANUFACTURERS:ROCKWOOL - CURTAINROCK 80, JM/IG - MINWOOL 1280
STRUCTURAL HSS TUBE



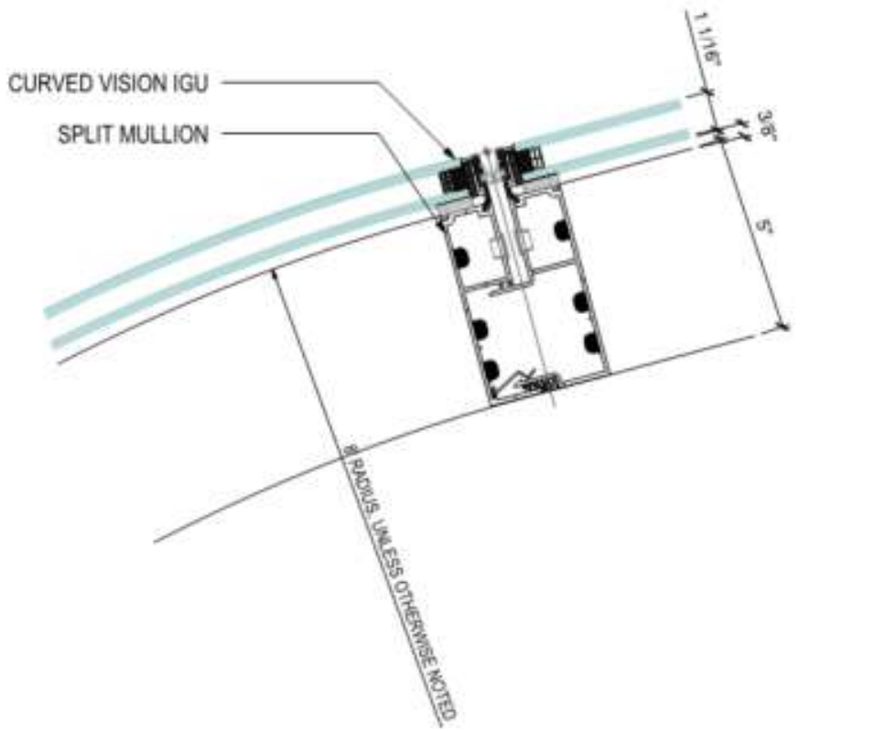
Incline Glass



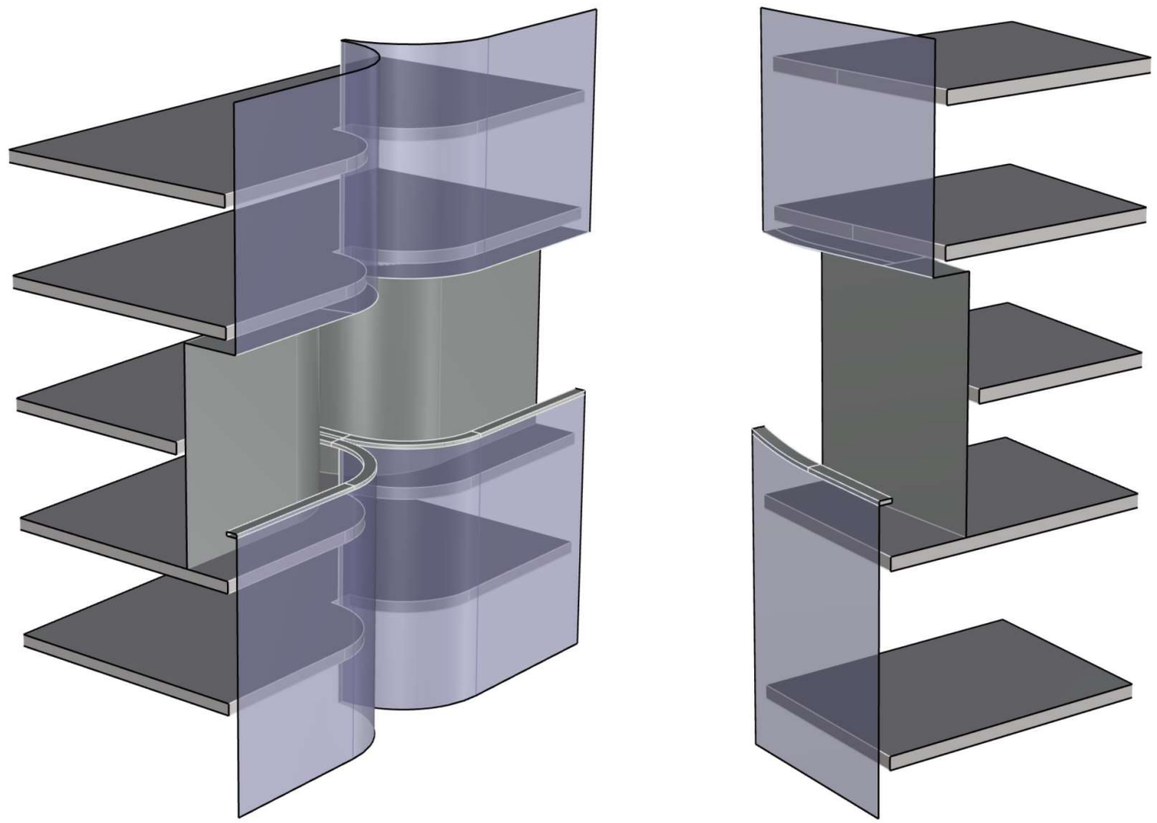
SLOPED CW1 SPANDREL SECTION DETAIL 2



Curved Glass



CW1 CURVED CORNER MULLION DETAIL 6



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Manan Raval, PE is Partner for Facades and Envelopes at Hatfield Group. He is widely recognized as an industry expert in facade design and specialty glass systems. He has led facade engineering for complex buildings worldwide, among them high-profile arts institutions, residential developments, and mixed-use hubs.

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