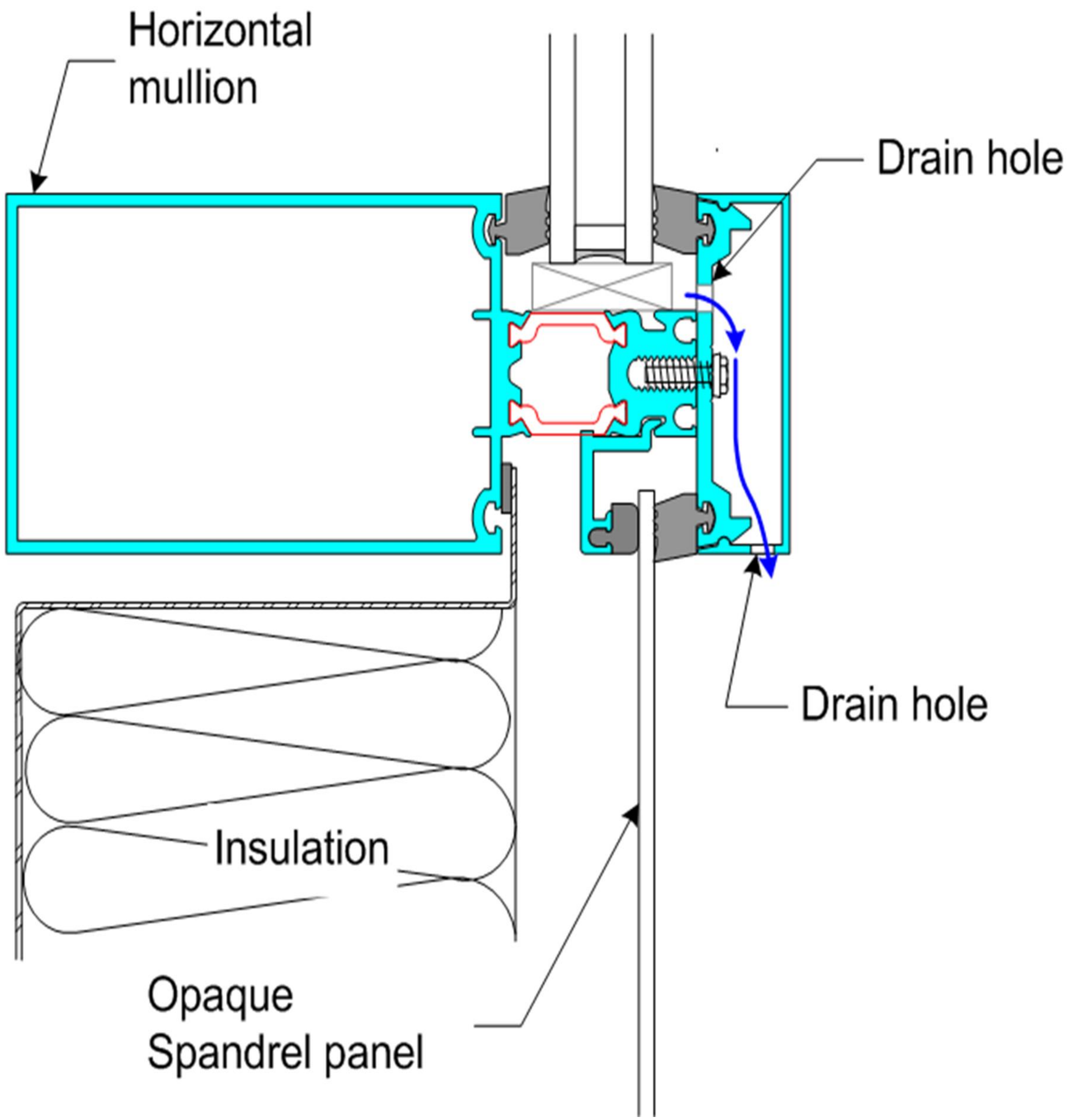
Glass Curtain Wall

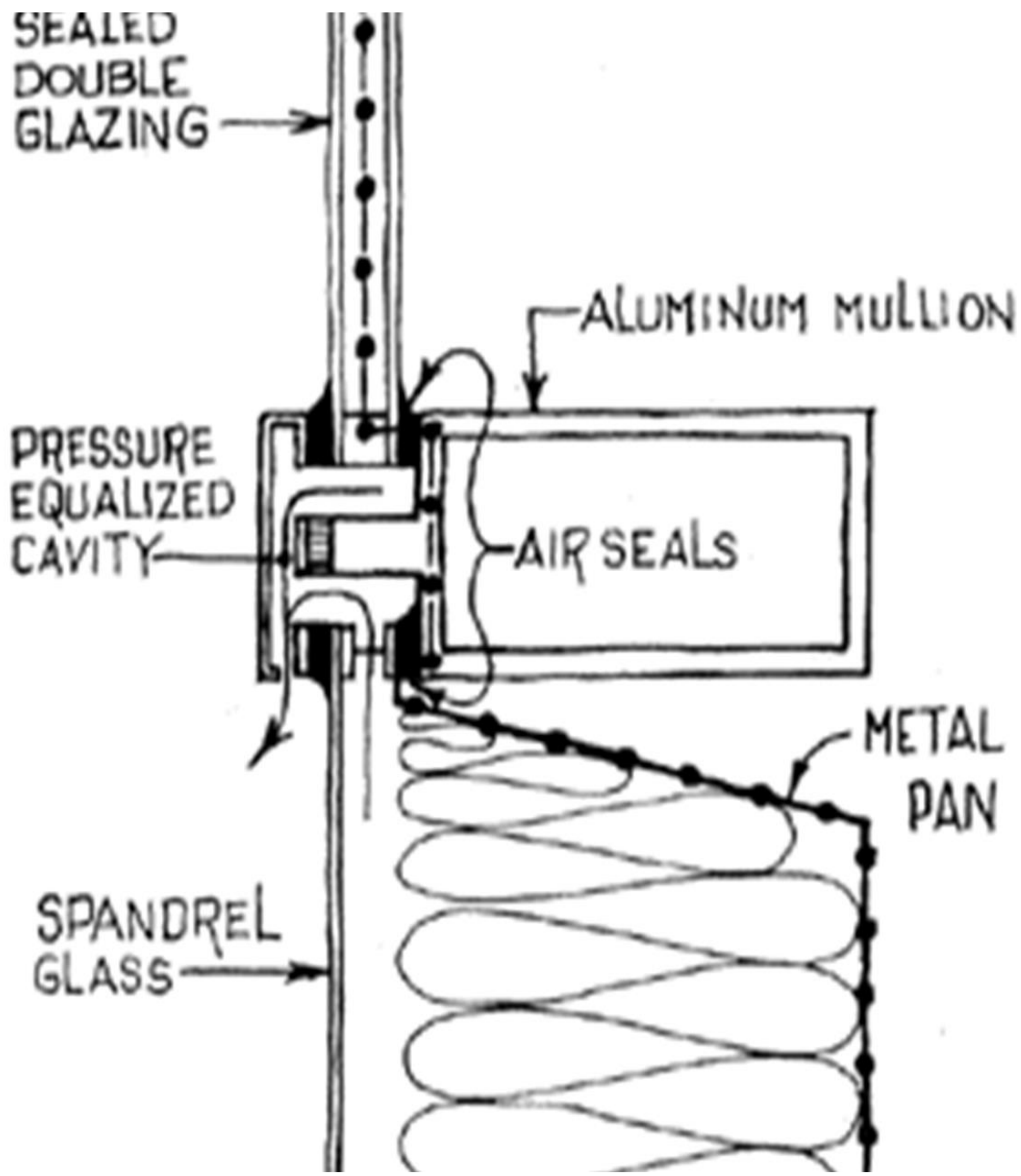
Juliana Pipola
Christopher Legarda
Guranter Multani

1. Air Barriers & Sealants



- Air tightness & air leakage control are met by glass curtain wall systems because the air barrier of the wall is essential in the structural properties of the glass.
- The endurance of the air barrier is achieved by the endurance of the glass panel through the air seal at the shoulder flanges of the tubular mullion and aluminum mullion.

1. Air Barriers & Sealants

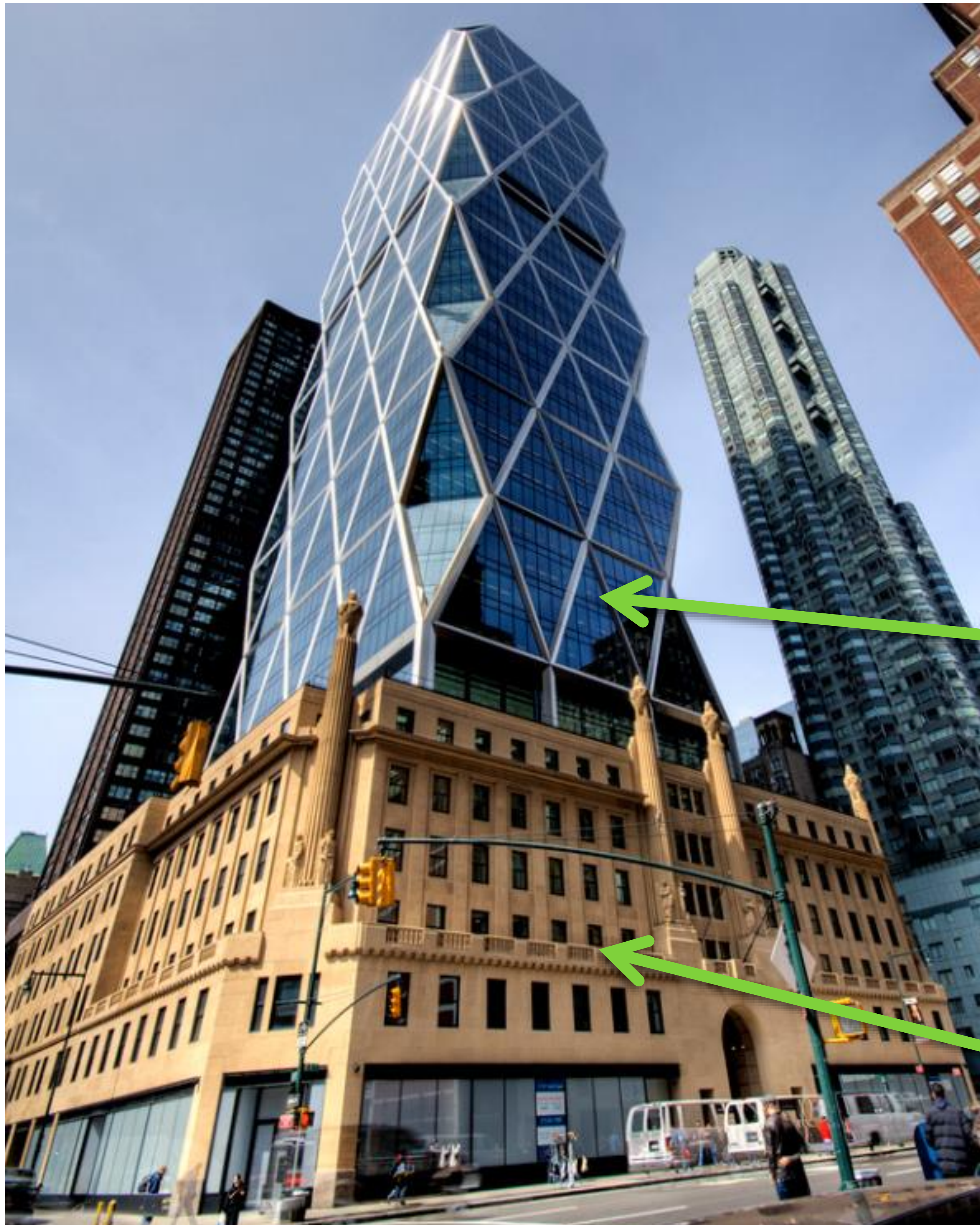


» The control of heat flow is normally achieved through the use of insulation. The glass curtain wall system uses significant insulation behind spandrel glass panels. The glass is a highly conductive material, so you have to take in the fact of interior condensation. To limit the condensation from occurring the curtain wall is incorporated with a sealed double glazed window & a thermally broken mullion.

» A sealed double glazed window unit can hold an indoor humidity up to about 35% at an outdoor temperature of -25 ° C with little condensation appearing on the glass.

» The thermal break also ensures that the structural mullion is thermally stable.(not subject to extremes of expansion and contraction.)

2. Case Study 1: Time & Cost



» <u>Hearst Tower</u>
» Architect: Sir Norman Foster
» Location: 300 W 57th St, New York, NY 10019
» Construction started: 30 April 2003
» Construction completed: 2006

The tower is 46 stories tall, standing at 597' with 860,000 sq. ft. of office space. Total construction cost: was $500 million.

The building was completed in 1928 by architect Joseph Urban. Construction cost of $2 million and contained 40,000 square feet

2. Case Study 1: Systems

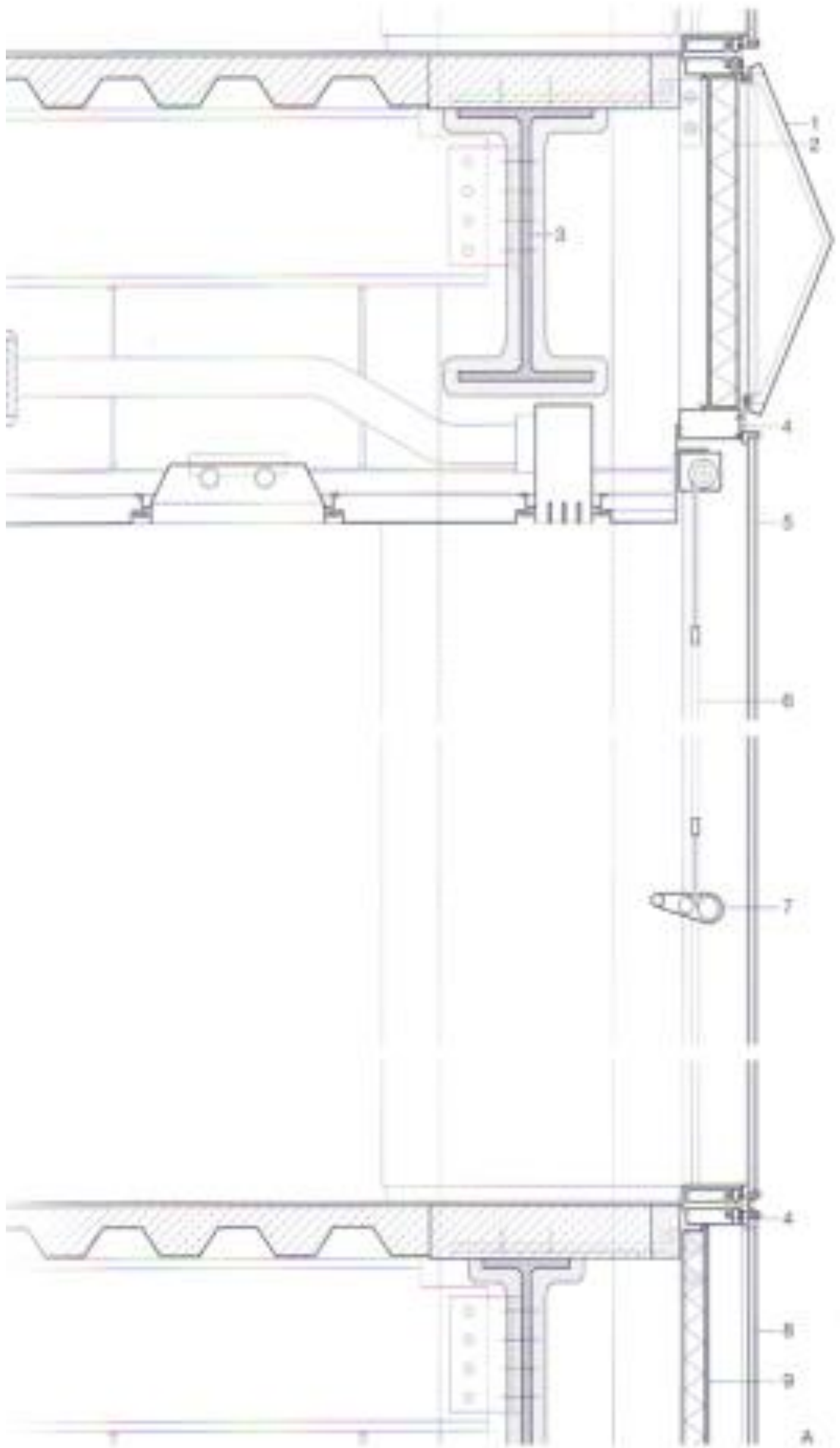


- The tower's complex design with a geodesic-like shape sporting triangular steel bracing from the 10th floor up
- This triangular framing pattern is known as a Diagrid.
- Required 10,480 tons of structural steel – reportedly about 20% less than a conventional steel frame.
- The building received the 2006 emporia skyscraper award(citing it as the best skyscraper in the world completed that year.)
- The complex exoskeleton required extensive harmonization within the design and construction to create panoramic views at the corners using the triangular bracing concept.
- The triangle braces are efficient for both gravity and lateral loads, requiring 21 percent less steel tonnage than a conventional building of its size.

2. Case Study 1: Systems

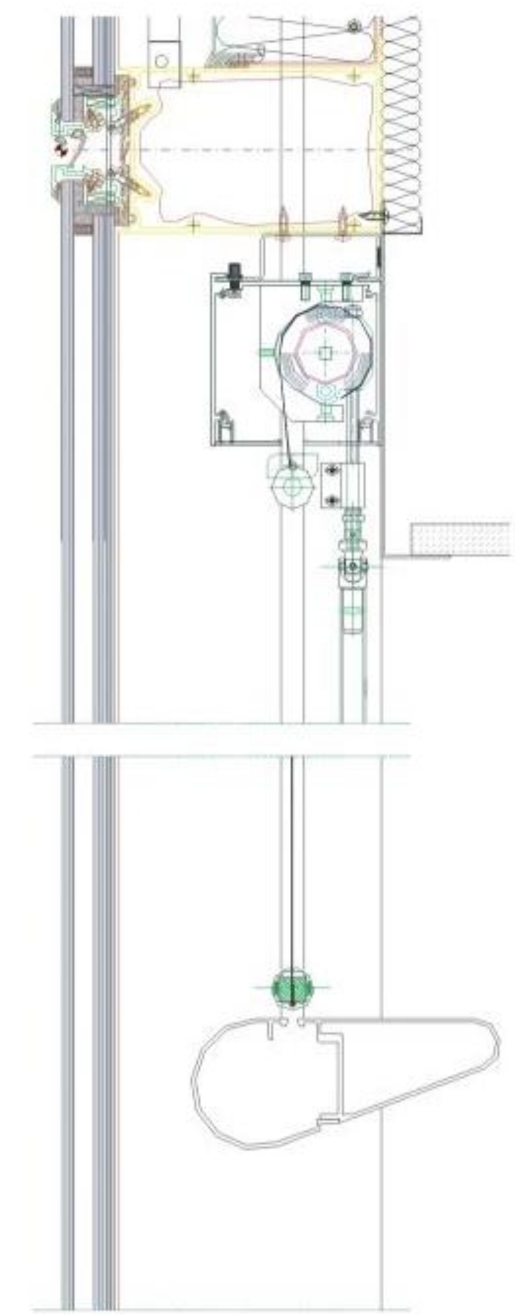
- The design also allows for 22,000-sq.-ft floor plates, further accenting the open space theme.
- The grid section begins at the 10th floor
- The structure rests on mega columns stretching to the foundation that allow for large open sections housing the lobby, a cafeteria, meeting rooms and other public spaces

2. Case study 1: Systems joints & connections

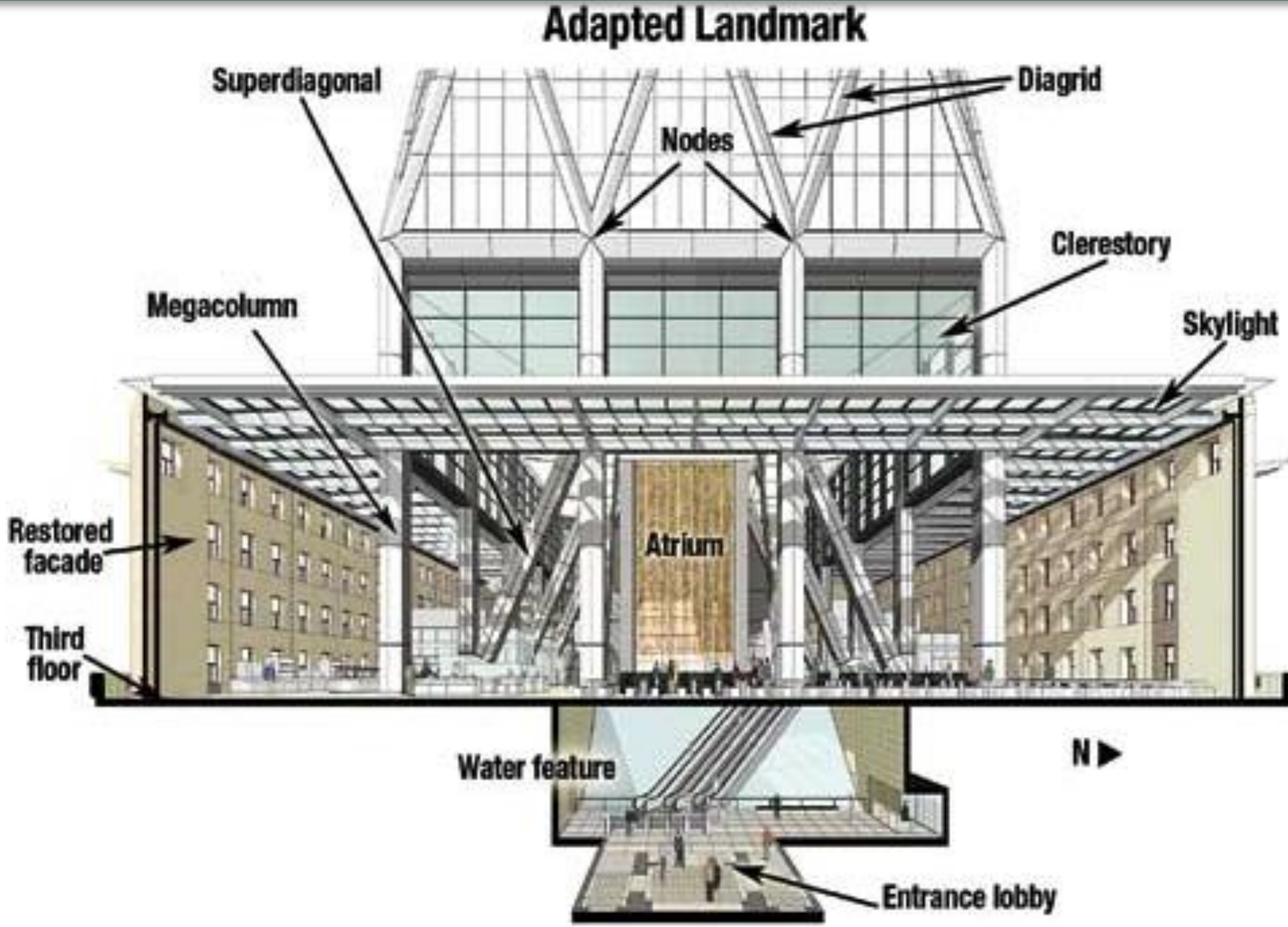


1. 3 mm sheet-stainless-steel cladding masking load-bearing structure, bent to shape and polished
2. 80 mm panel: sheet-aluminium with thermal insulation
3. steel I-section edge beam 700 mm deep with fire-resisting coating
4. extruded-aluminium facade rail
5. solar-control double glazing:
6. internal sunscreen blind
7. extruded-aluminium balustrade with integral anti-glare blind
8. double glazing as cladding over edge of floor:
9. 70 mm panel at edge of floor: colour-coated sheet aluminium with thermal insulation

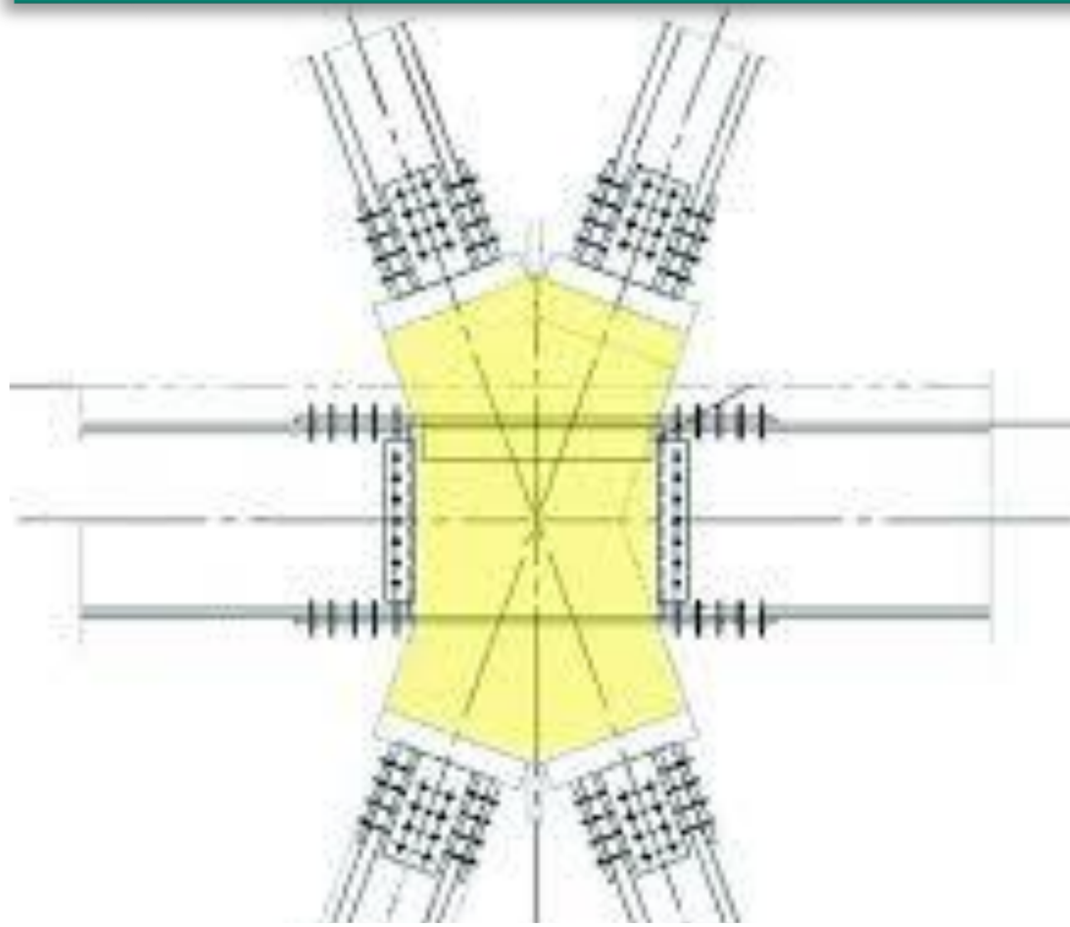
300 West 57th Stre

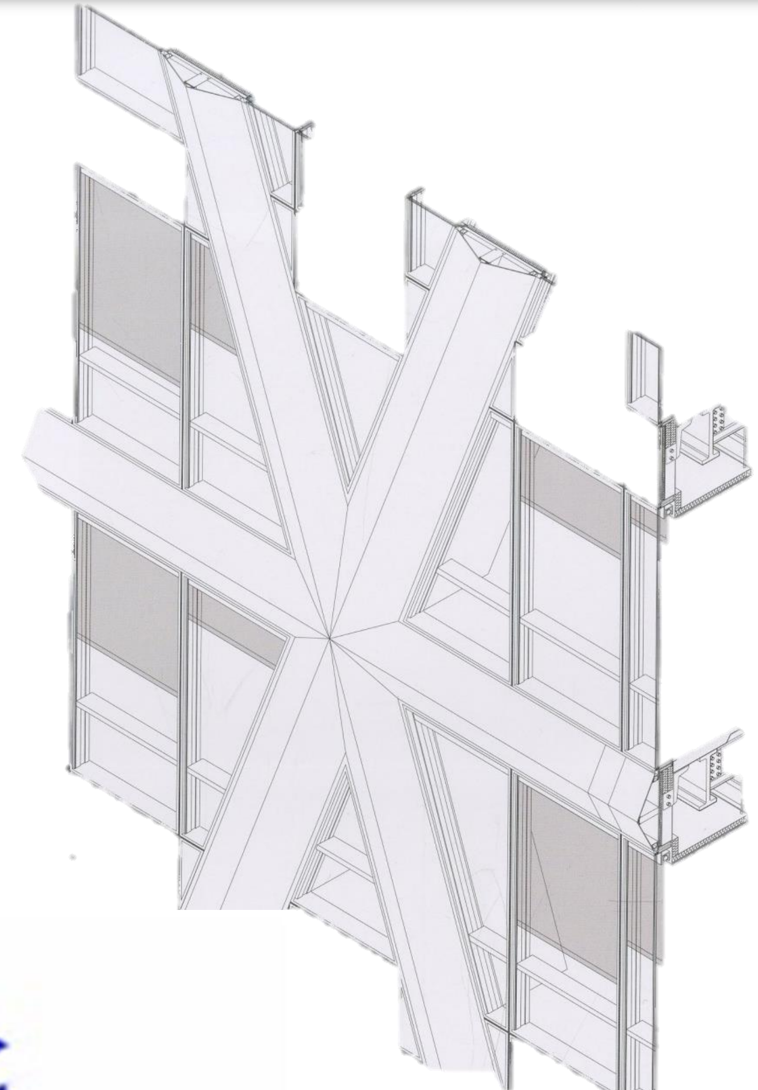


2. Case Study 1: System joints & connections

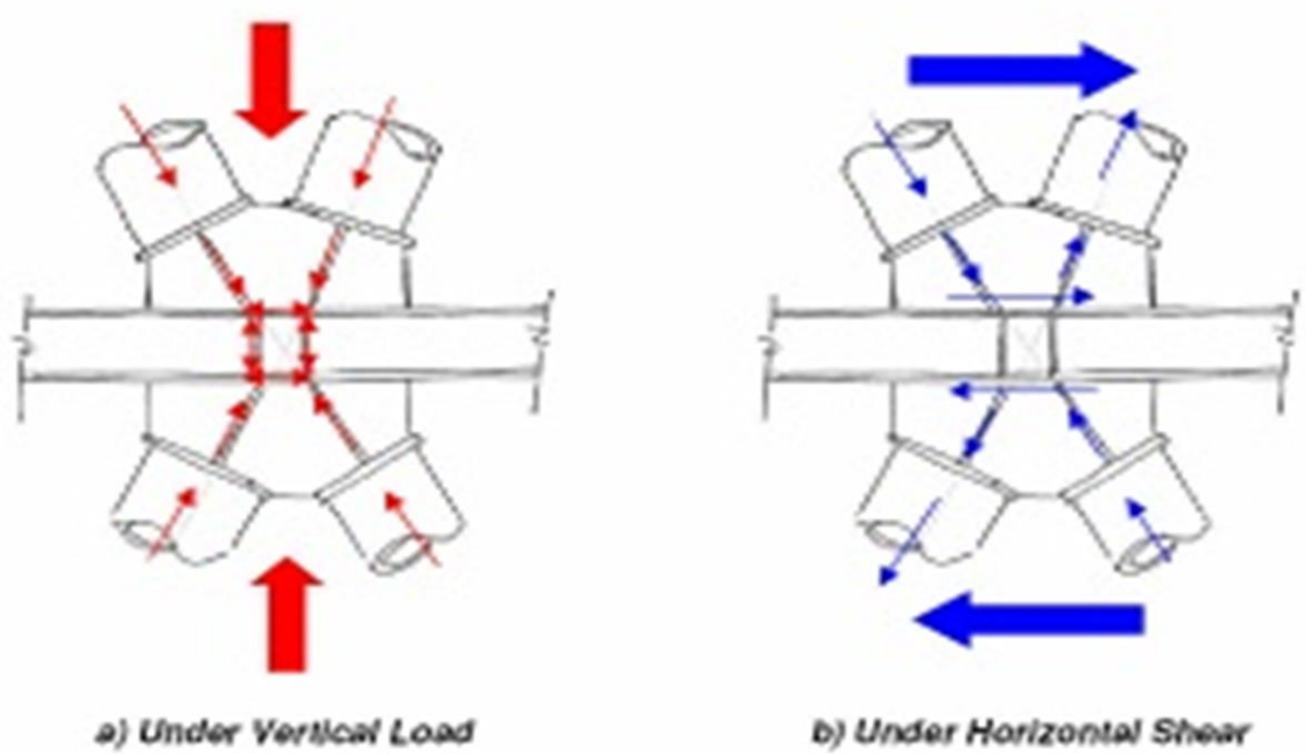


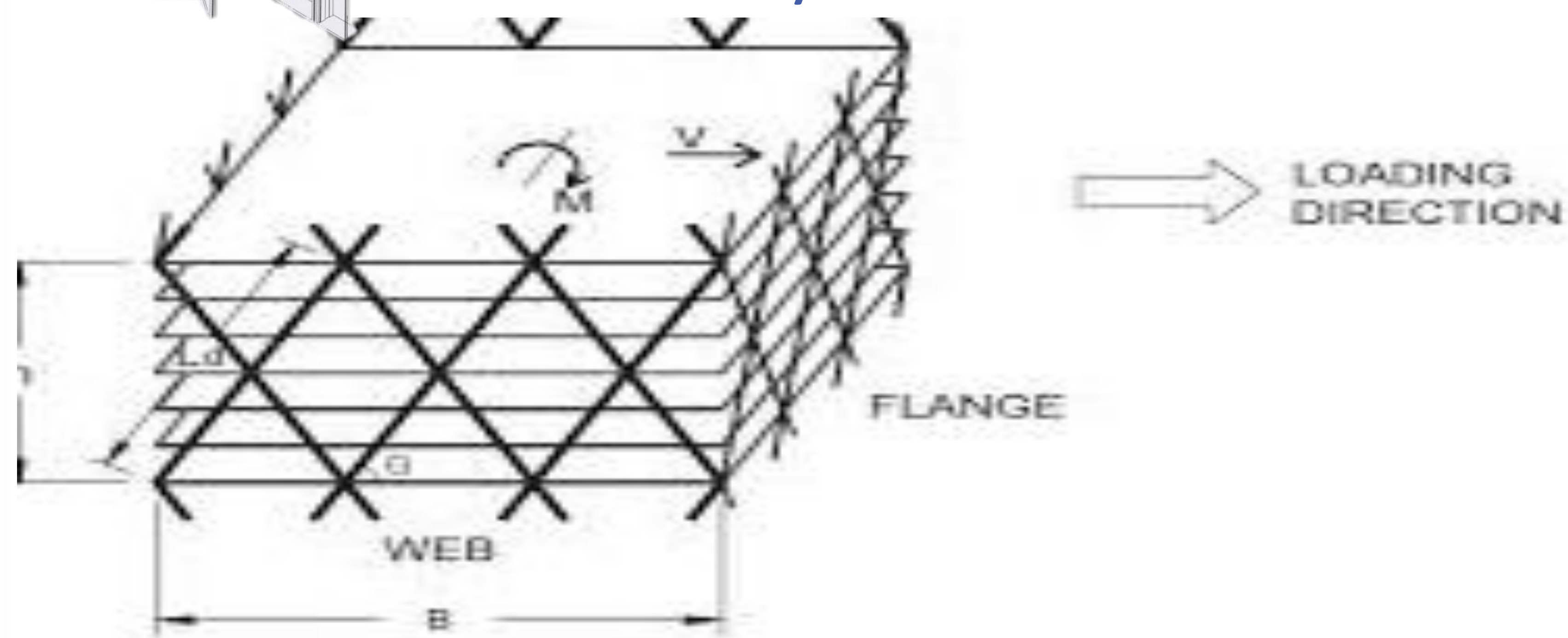
2. Case Study 1: System joints & connections



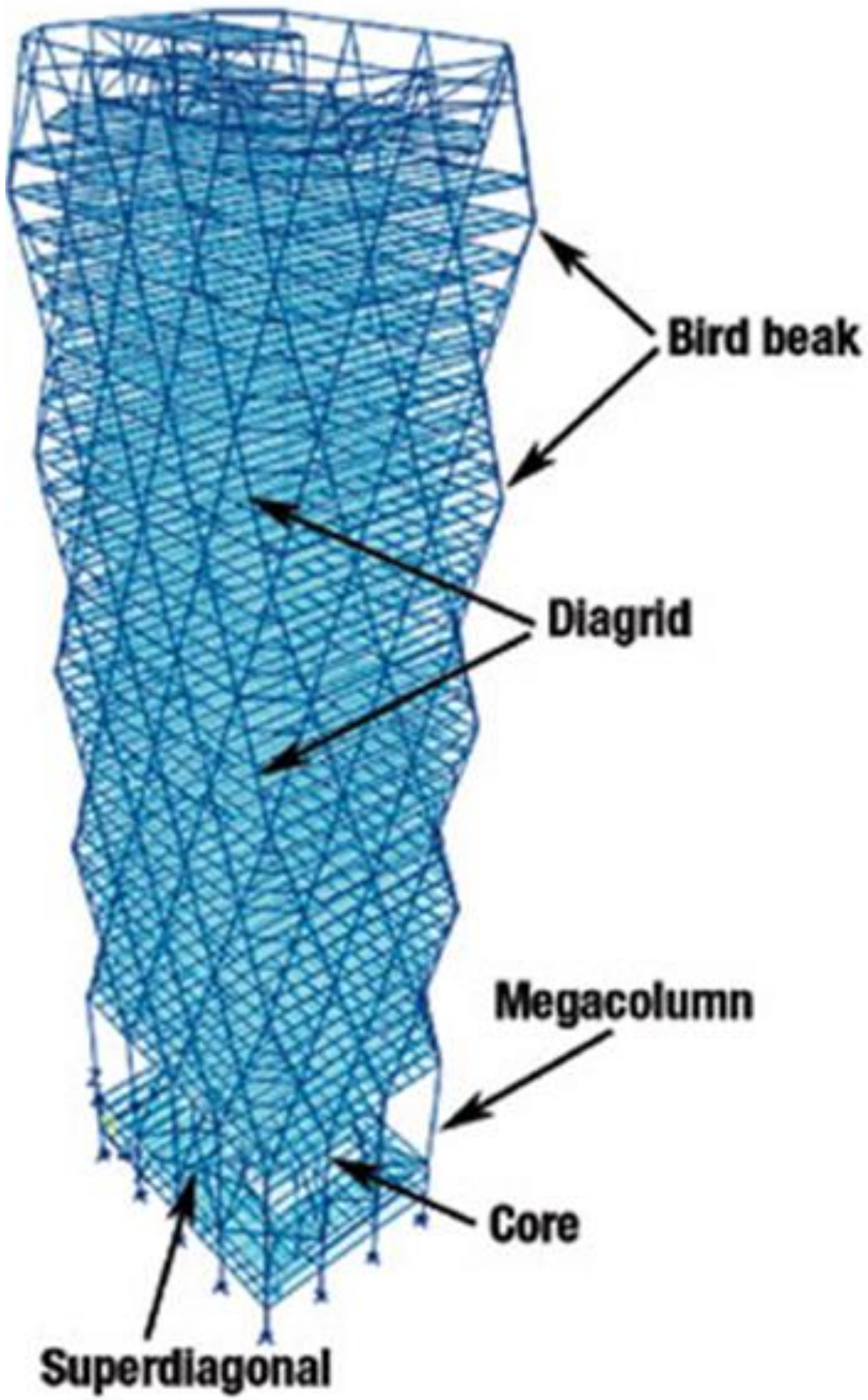


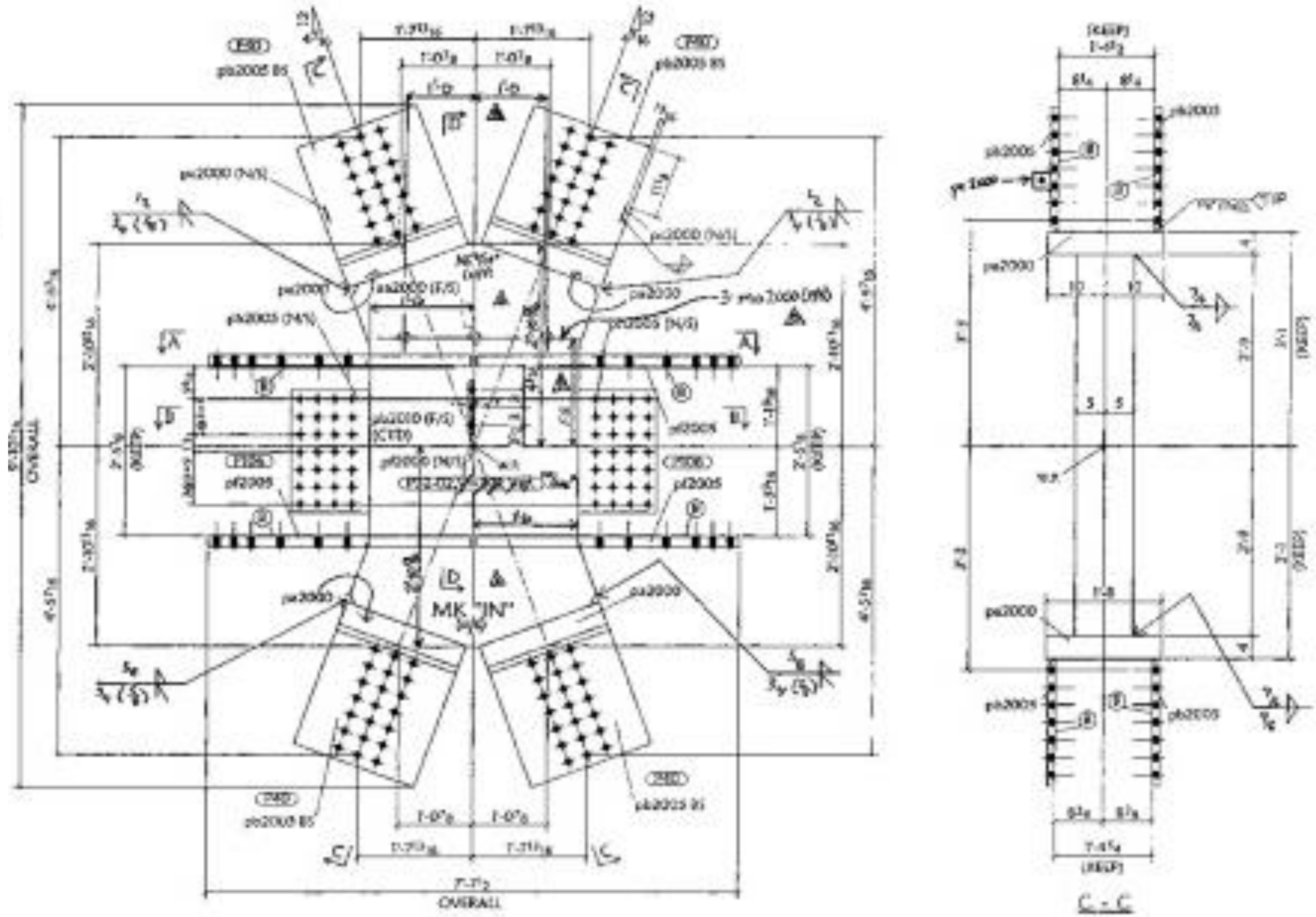
- The Diagrid frame that holds up the tower is assembled in a way that stops thermal bridges from occurring.
- The recycled steel columns are sprayed with an insulating material, and then surrounded by heavy duty stainless steel sheets.





2. Case Study 1: System joints & connections





This detail shows a typical node for the building. Eighty-four similar pieces were fabricated from 10"-thick machined steel plates.

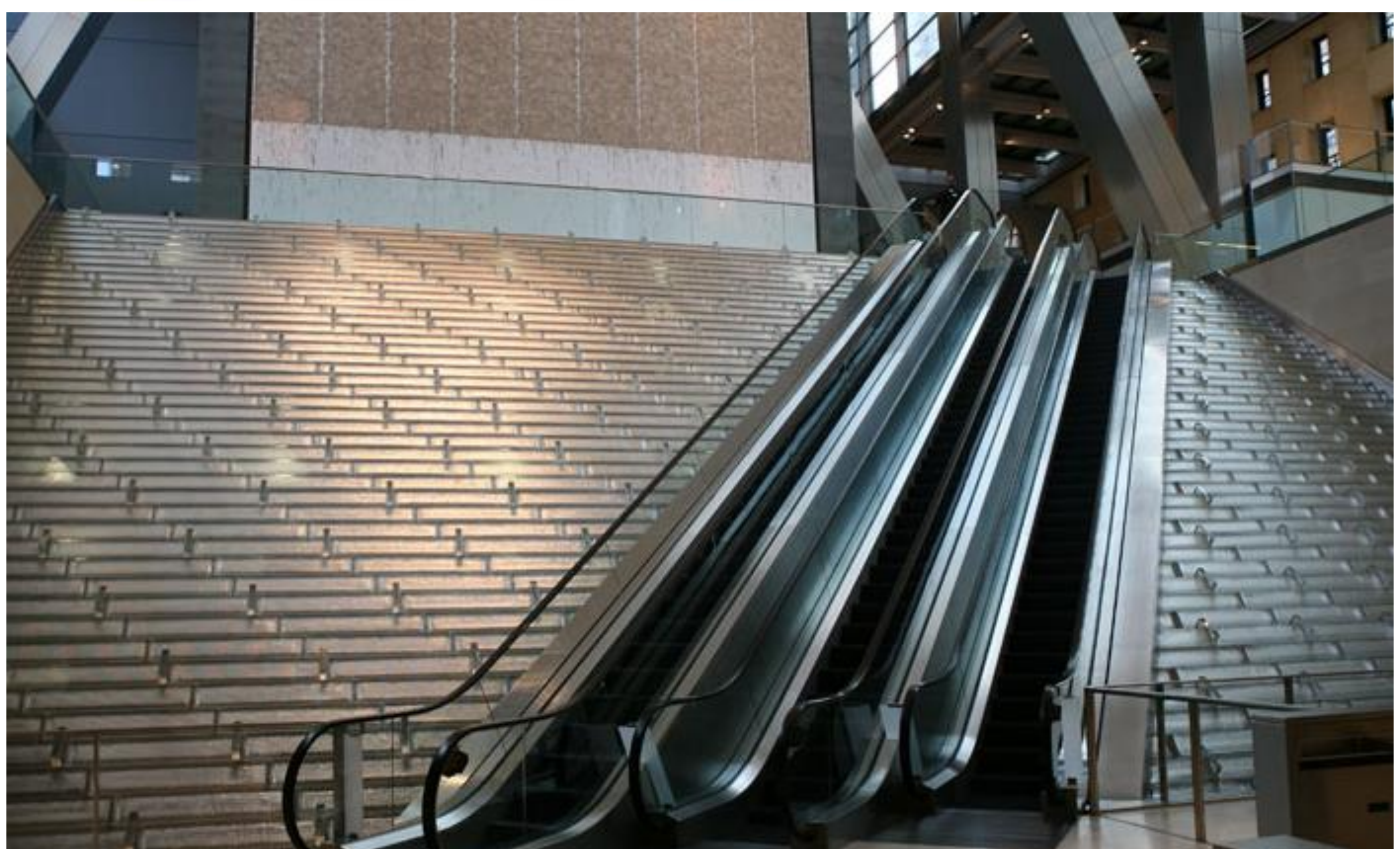
2.Case Study 1: Environmental Implications

- Hearst Tower was the first "green" high rise office building completed in New York City.
- The floor of the atrium is paved with heat conductive limestone.
- Polyethylene tubing is embedded under the floor and filled with circulating water for cooling in the summer and heating in the winter.
- Rain collected on the roof is stored in a tank in the basement for use in the cooling system, to irrigate plants and for the water sculpture in the main lobby.

2.Case Study 1: Environmental Implications

The LEED 3.0 scorecard tallies points in seven credit categories:

Sustainable Sites (SS) – 26 pts.
Water Efficiency (WE) – 10 pts.
Energy and Atmosphere (EA) – 35 pts.
Materials and Resources (MR) – 14 pts.
Indoor Environmental Quality (EQ) – 15 pts.
Innovation in Design (ID) – 6 pts.
Regional Priority (RP) – 4 pts.



- 85% of the building's structural steel contains recycled material
- The building has been designed to use 26% less energy than the minimum requirements for the city of New York, and earned a gold designation from the United States Green Building Council's LEED certification program, becoming New York City's first LEED Gold skyscraper.
- The atrium features escalators which run through a 3-story water sculpture titled Icefall, a wide waterfall built with thousands of glass panels, which cools and humidifies the lobby air

2. Case Study 1: Historical systems compared to contemporary systems:

- The original cast stone facade has been preserved in the new design as a designated Landmark site.
- The main entrance is flanked by Comedy and Tragedy on the left and Music and Art on the right. Sport and Industry are above the corner at 56th Street and Printing and the Sciences are located on the building's major corner at 57th Street.
- The perimeter and corner views are free of vertical columns. The steel framework forming a diagonal grid visible, showing the four-story-tall, grade-65 steel triangles prefabricated by the Cives Steel Co. of Roswell, Ga.

2. Case Study 1: Systems comparisons

CHOOSING BETWEEN STICK and UNITIZED CURTAINWALL SYSTEMS		
Selection Criteria	**Stick Curtainwall**	**Unitized Curtainwall**
Project Size	Small	Large
Wall Configuration	Complex (Many changes in plane, e.g. soffits, corners, etc.)	Monolithic (Large expanses of flat wall)
Joint Pattern	Random	Uniform horizontal sill line
Glazing	Field	Factory
Inter-story Movements	Very limited	Inter-locking frames accommodate movements
Quality Control	Subject to site variables (Both environment and equipment)	Controlled factory conditions
Modification	Can be cut-to-fit in the field	Pre-engineered
Sealing	Subject to site variables	Minimal field sealing
Field Labor Cost	High (Many parts to track and assemble)	Low
Field Labor Duration	Slow	Fast (Often setting 75 sqft or more per unit)
Access and Safety	Exterior access required	Set from the interior (Exterior optional)

2. Case Study 1: Systems comparisons

Product Comparison Chart / Acoustics

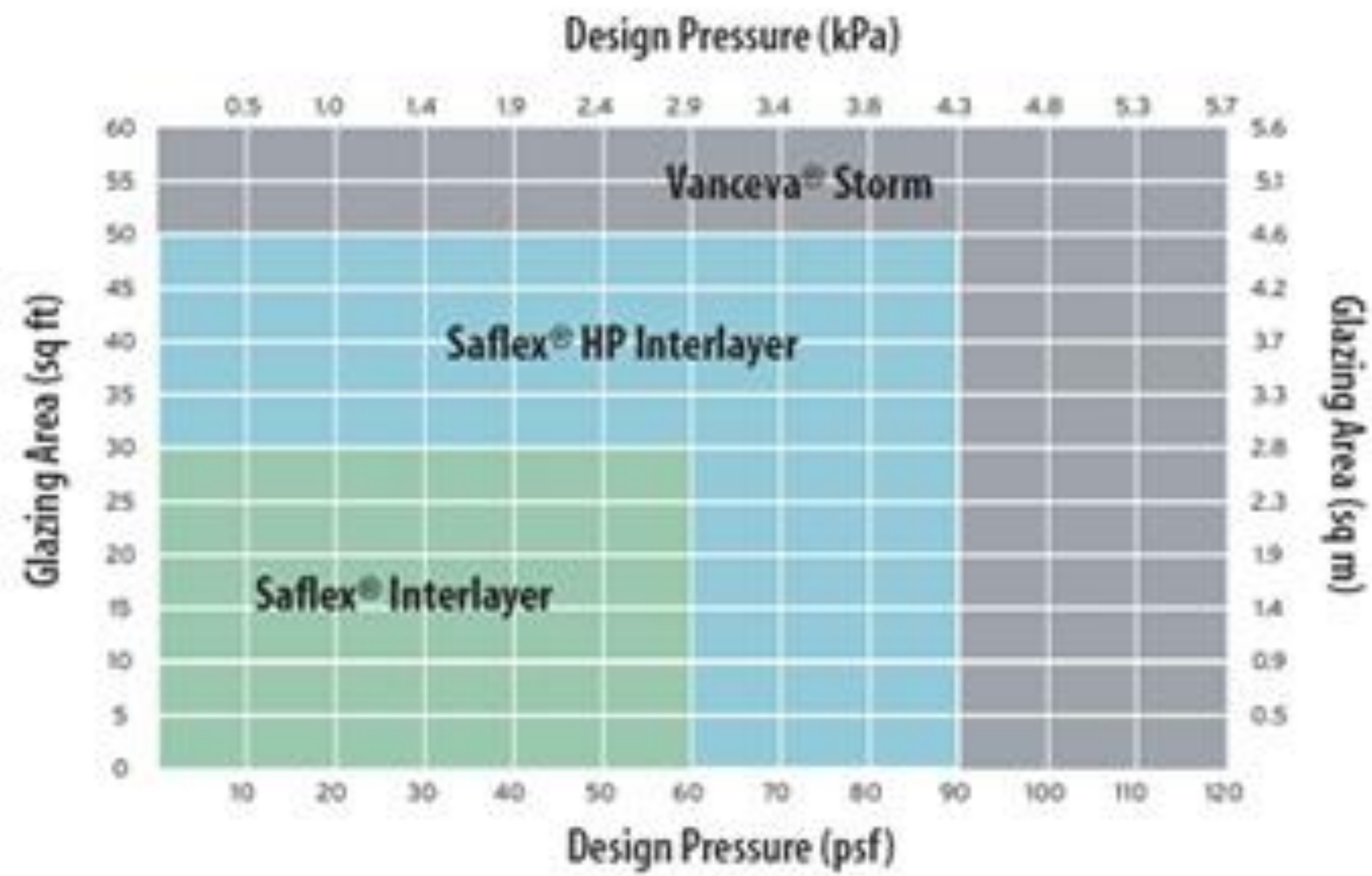
	Fire-rated product	Maximum fire rating	Meets safety impact standard	Passes hose stream test	Heat barrier	Complies with energy codes	Provides acoustic barrier	Advantages/Disadvantages
Thin	Ceramic glass	90 min.		✔				+ Heat resistance of ceramic - Low impact resistance
Thin	Ceramic glass with surface applied fire-rated film	3 hrs.	✔	✔				+ High impact resistance - Possible abuse to surface film
Thin	Laminated glazing	3 hrs.	✔	✔				+ Durable laminated construction + High impact resistance
Thin	IGU	3 hrs.	✔	✔		✔	✔	+ Energy efficient + Acoustic barrier + Wide choice of appearances
Thick	Transparent wall panel	2 hrs.	✔	✔	✔	✔+	✔	+ Floor-to-ceiling glass designs + Reduces heat transfer + Tested as a wall - Can be heavy

+In an insulated glass unit (IGU) make-up

Courtesy of Technical Glass Products

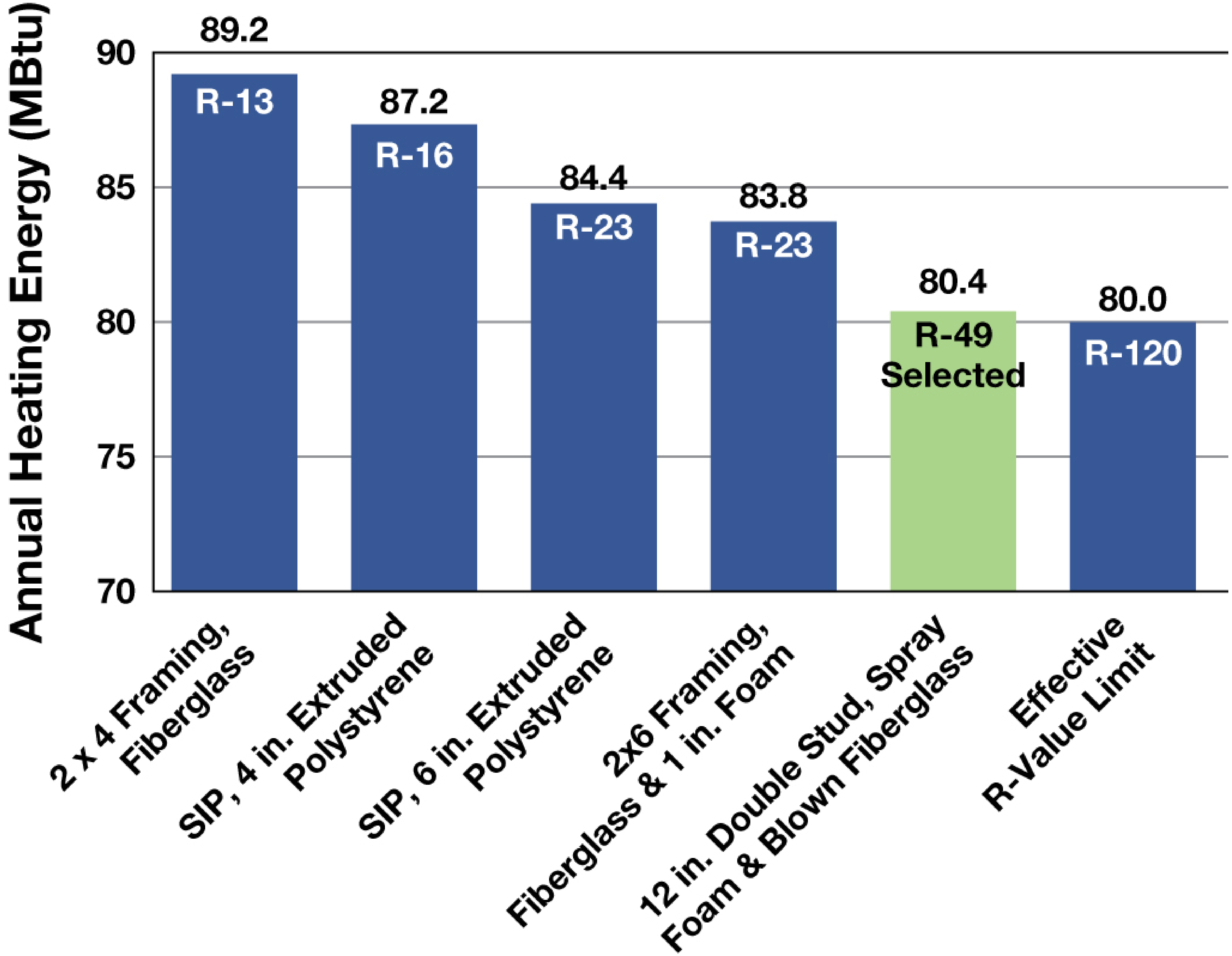
2. Case Study 1: Systems comparisons

Typical Glass Performance for Standard Four Side Glazing Using Recommended Conditions.

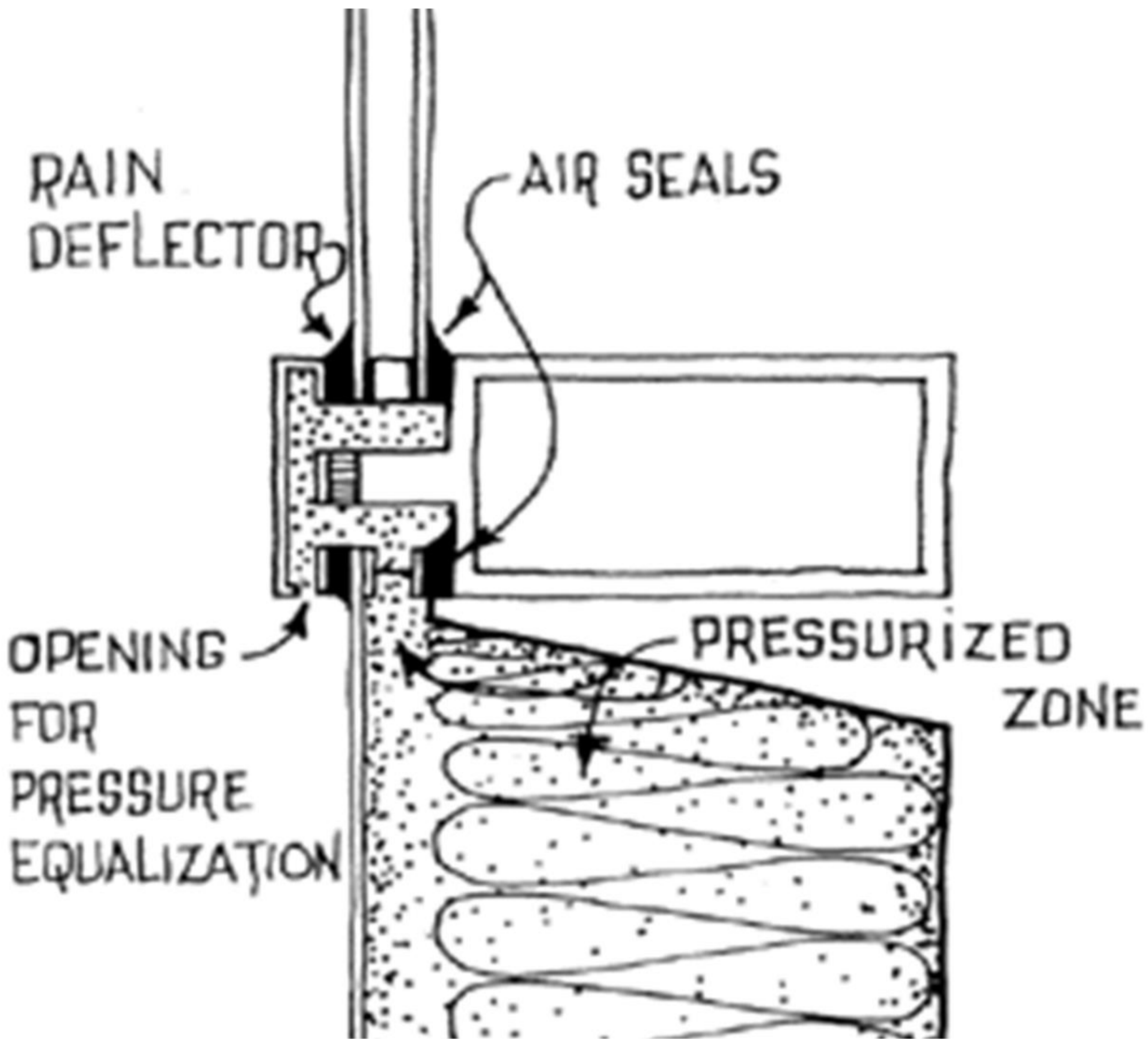


Note: Experienced product performance. Based on panels glazed with structural silicone, minimum 12 mm (1/2 in) glass bite; standard test temperatures 15 - 35 degrees C (59 - 95 degrees F). Not guaranteed for all samples.

2. Case Study 1: R - Value



3.Rain Penetration & Moisture Control



- Using the rain screen principal limits the penetration and control the moisture coming into the building.
- If the air that leaks through cracks of a facade while a rain storm most of the water impinging on the facade would go straight down the surface and little would penetrate the wall.
- A rain screen is a cavity behind the exterior surface that is connected to the exterior but sealed tightly to the interior. The inner surface. (known as the air barrier of the wall.)

3.Rain Penetration & Moisture Control

» Water vapor always tries to migrate from a region of high water vapor pressure to a region of lower pressure. The inner pane of the sealed double glazed unit and the aluminum/ steel inside surfaces of the mullion provide the necessary water vapor diffusion control. Sealants also contribute to the continuity of the vapor barrier.

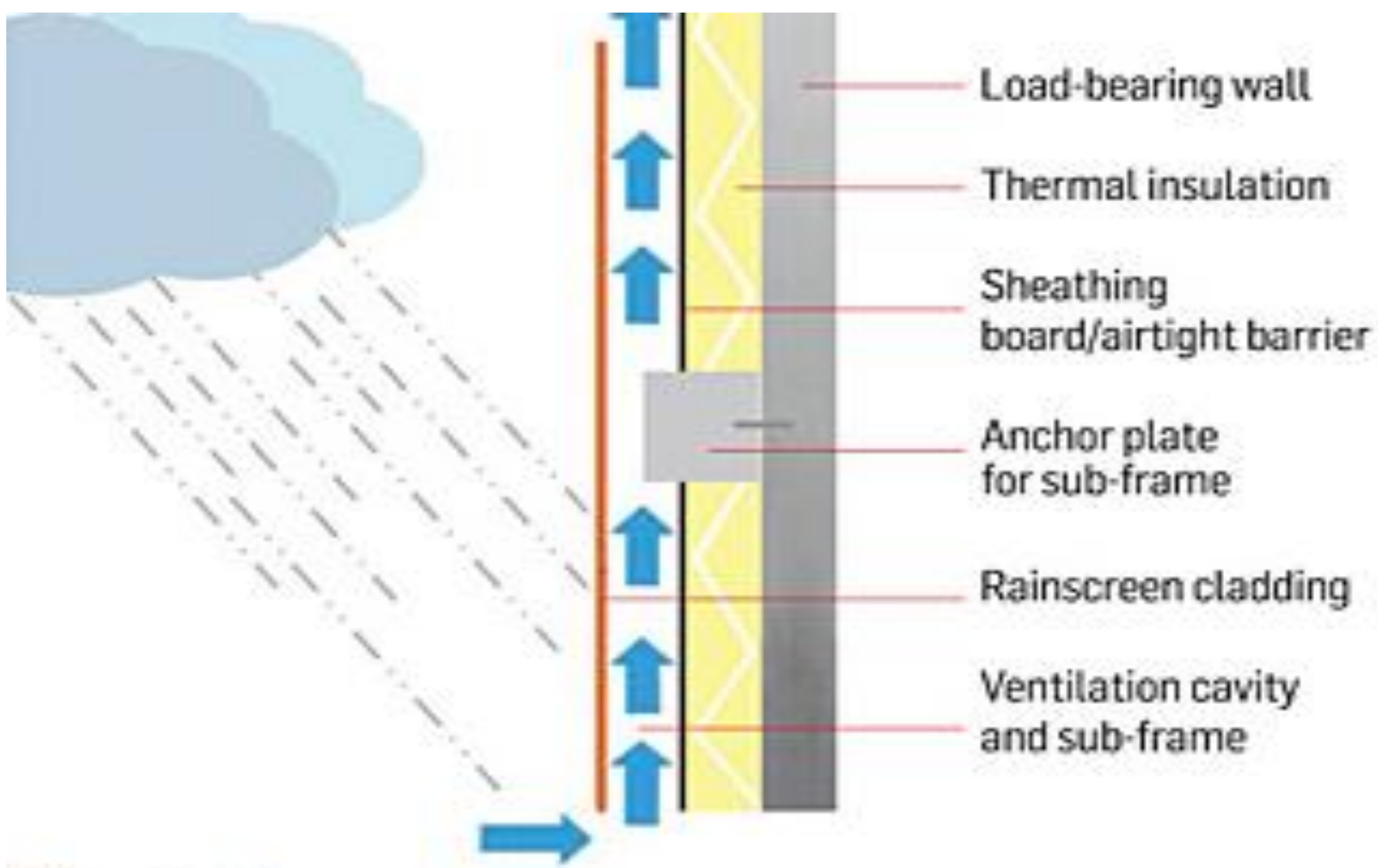


Diagram A
Fixing system for solid-wall construction

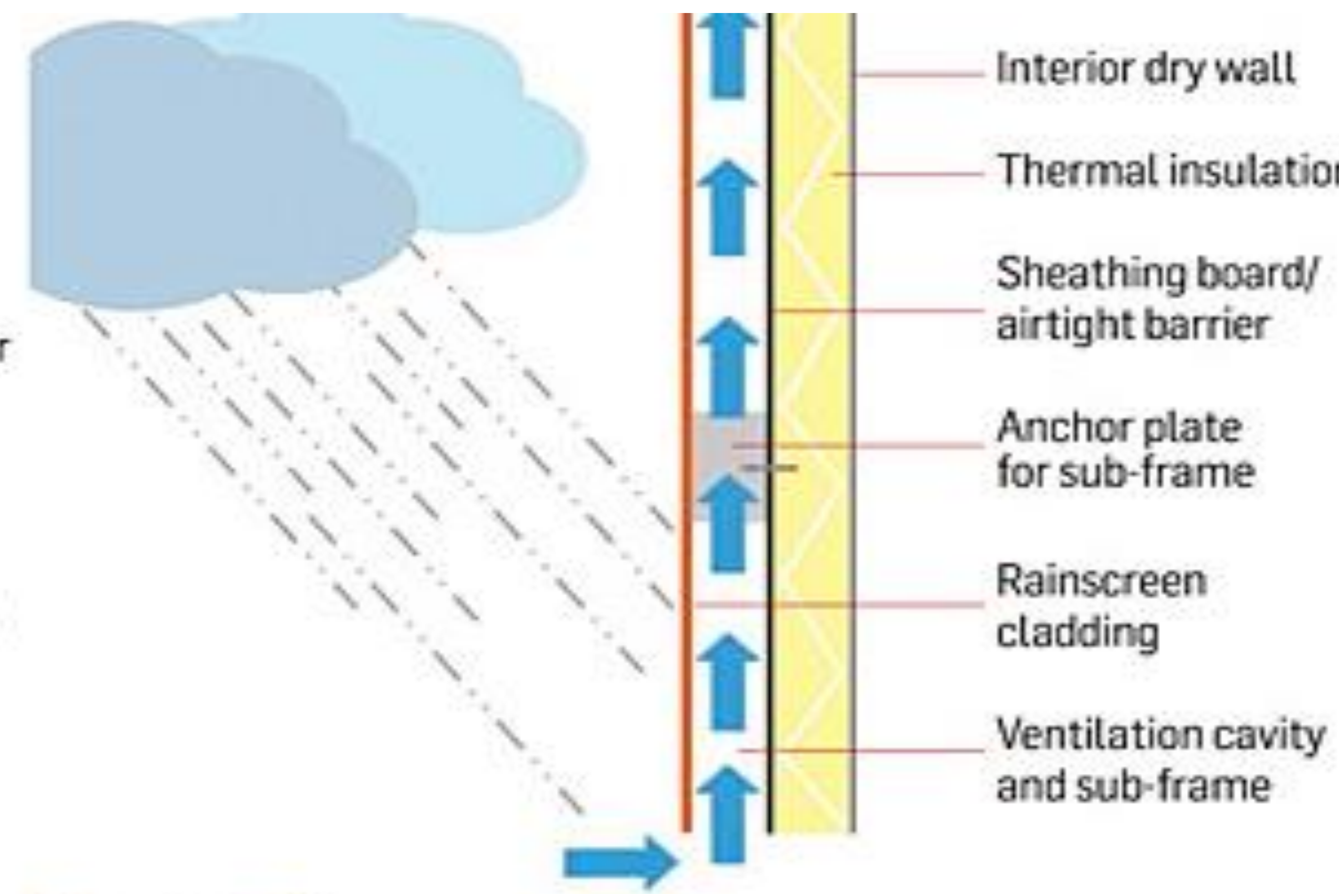
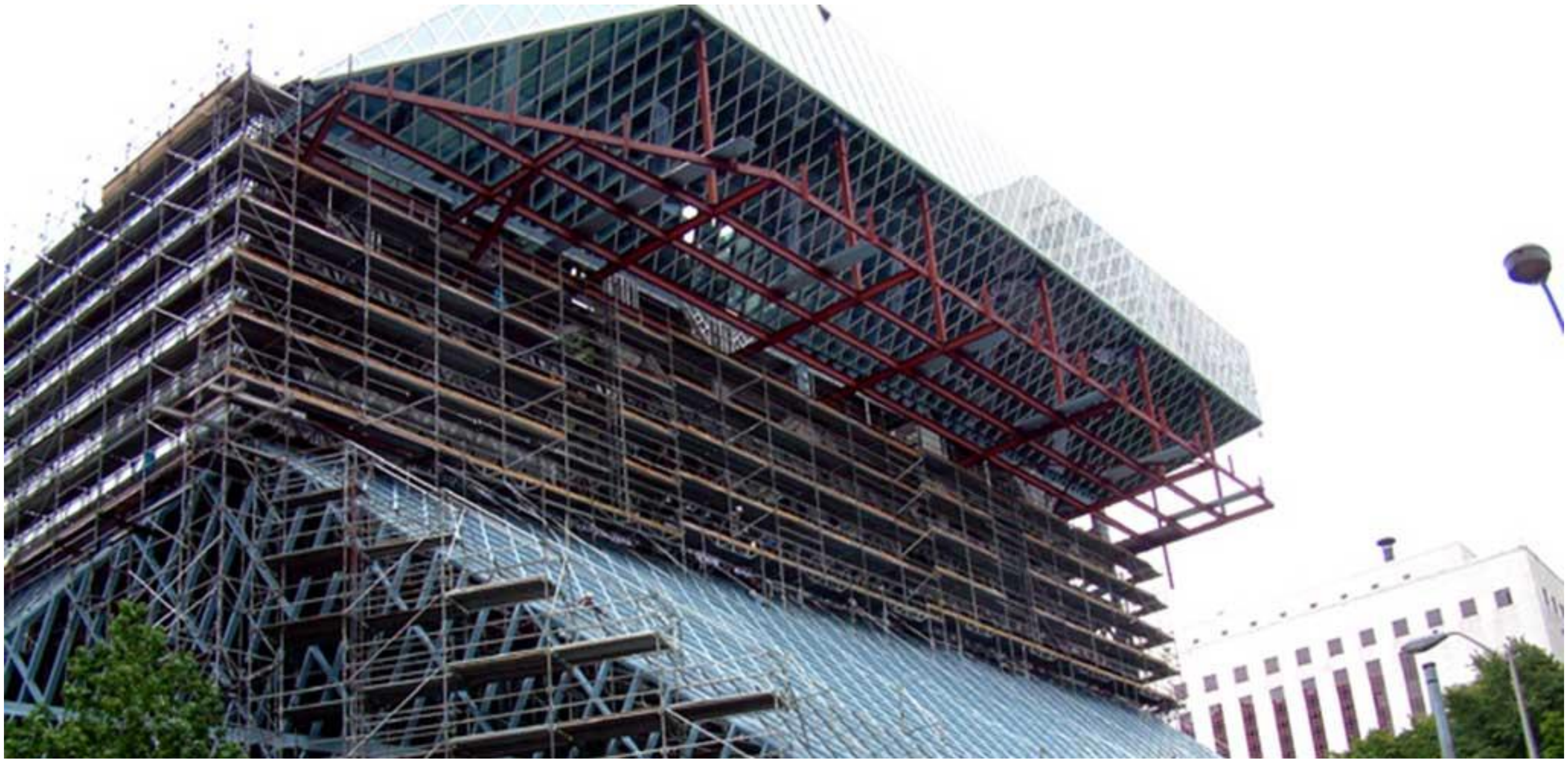


Diagram B
Fixing system for modular construction

CASE STUDY 2: seattle public library

ARCHITECTS; OMA + LMN
LOCATION: SEATLE, WASHINGTON, USA

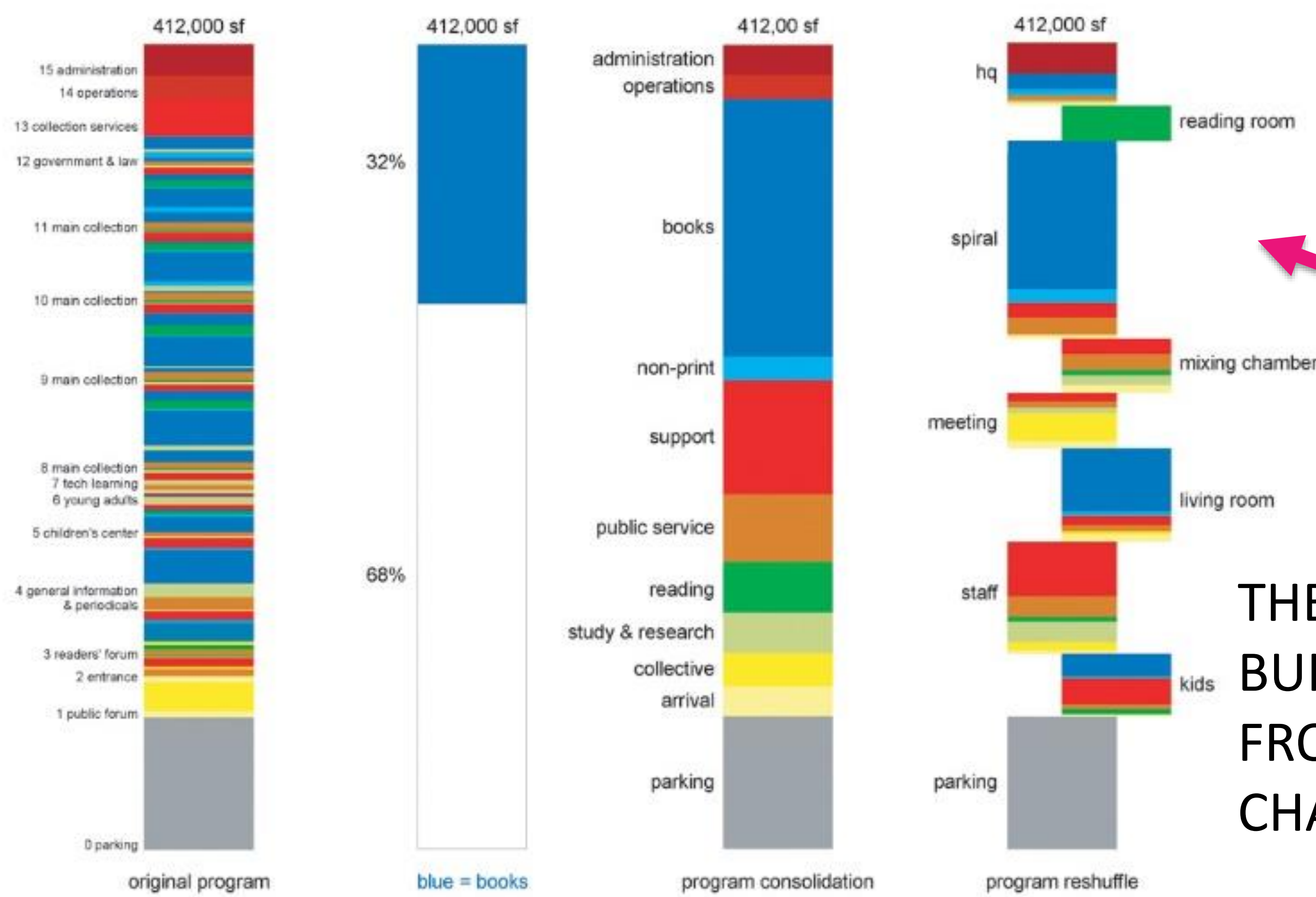
CONSTRUCTION AND TIME



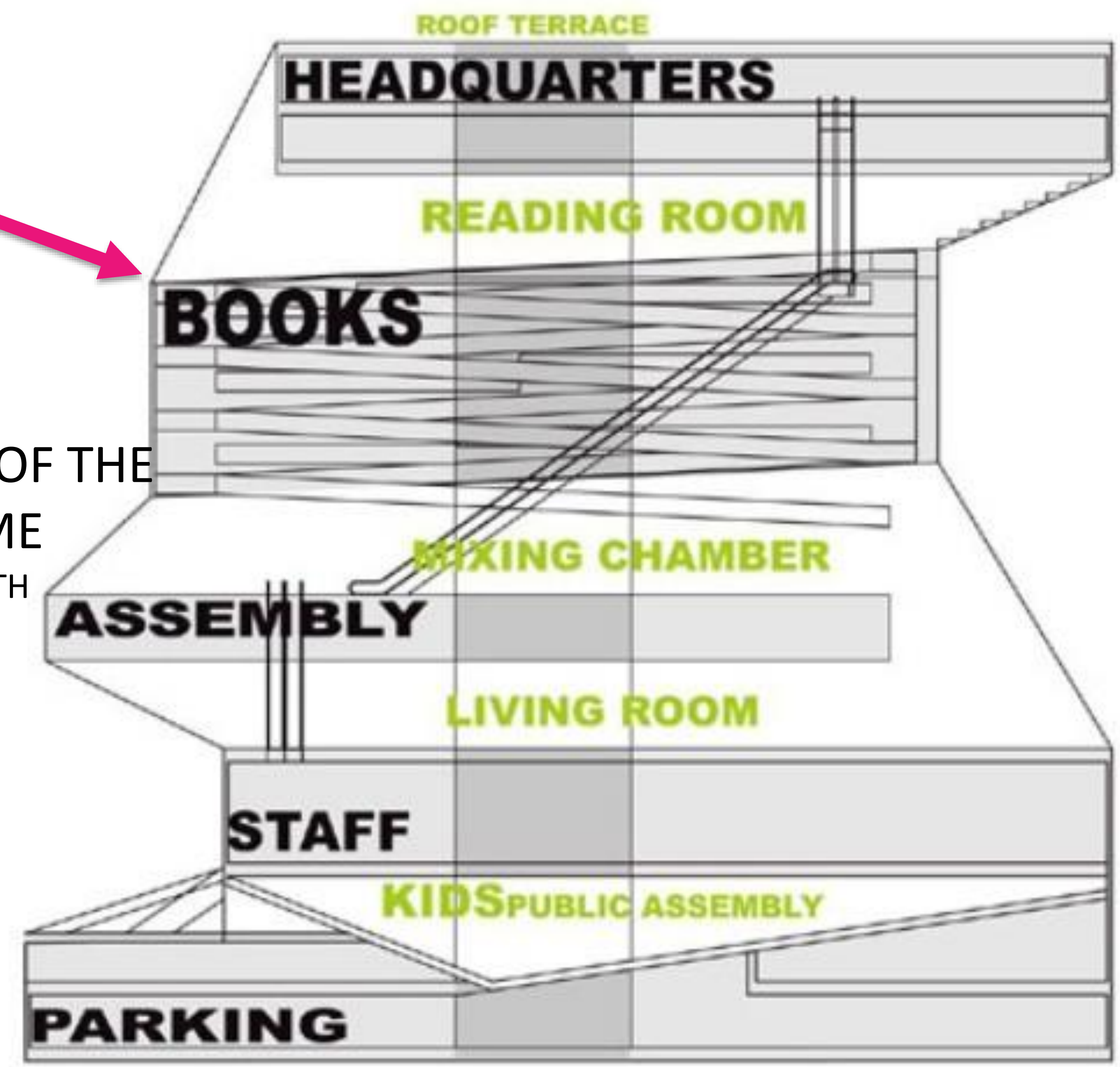
PROJECT YEAR: 1999-2004

BUDGET: US $169.2 M

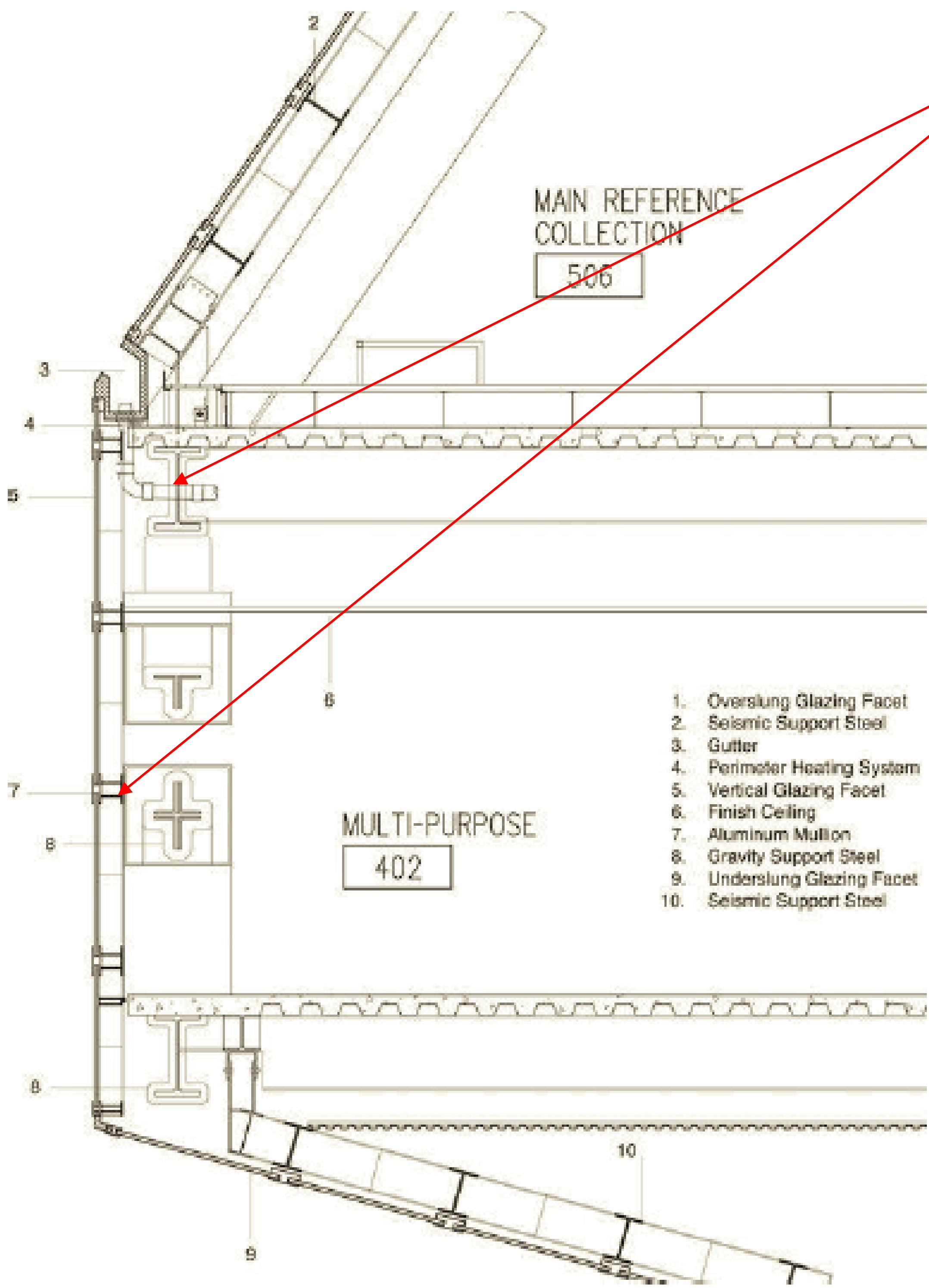
System flexibility forms, sizes, effective spacing



THE DESIGN OF THE BUILING CAME FROM THE 4TH CHART

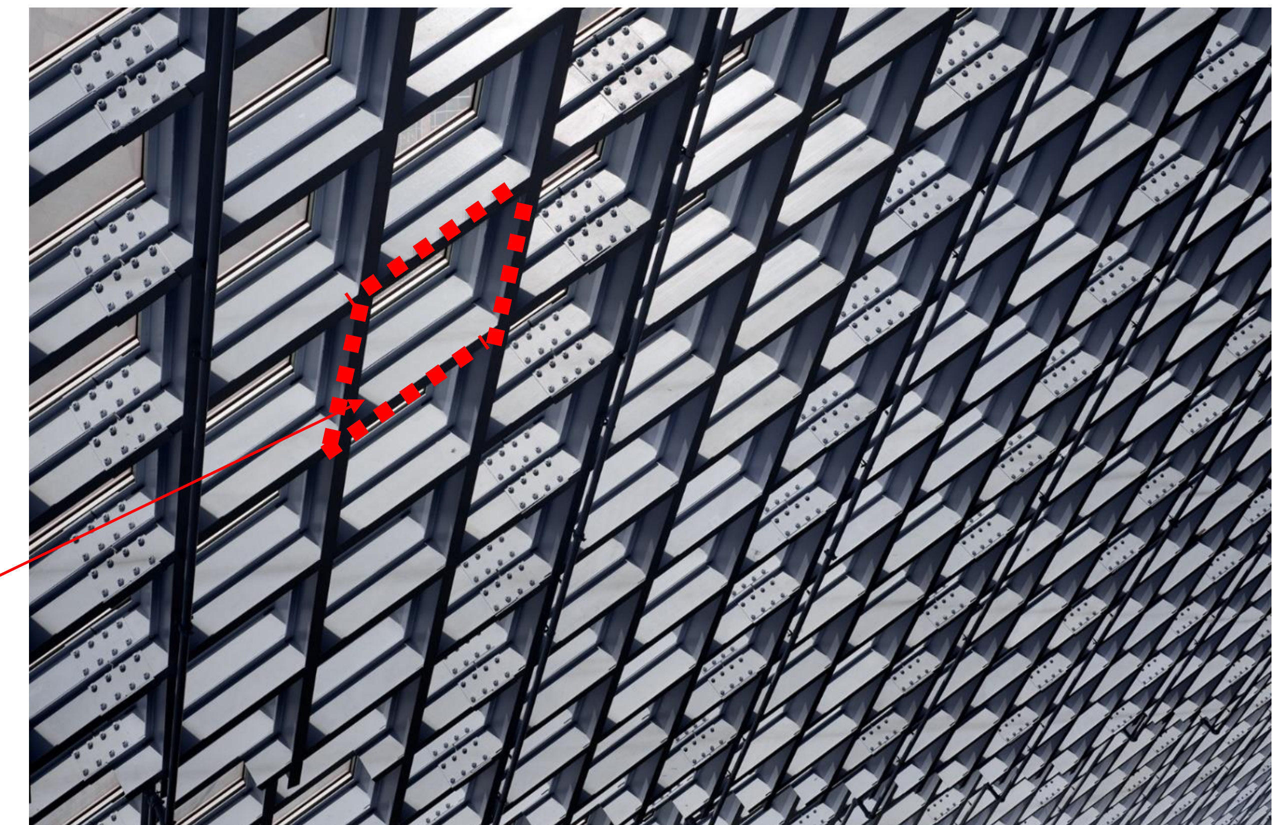


System movement and seismic resistance

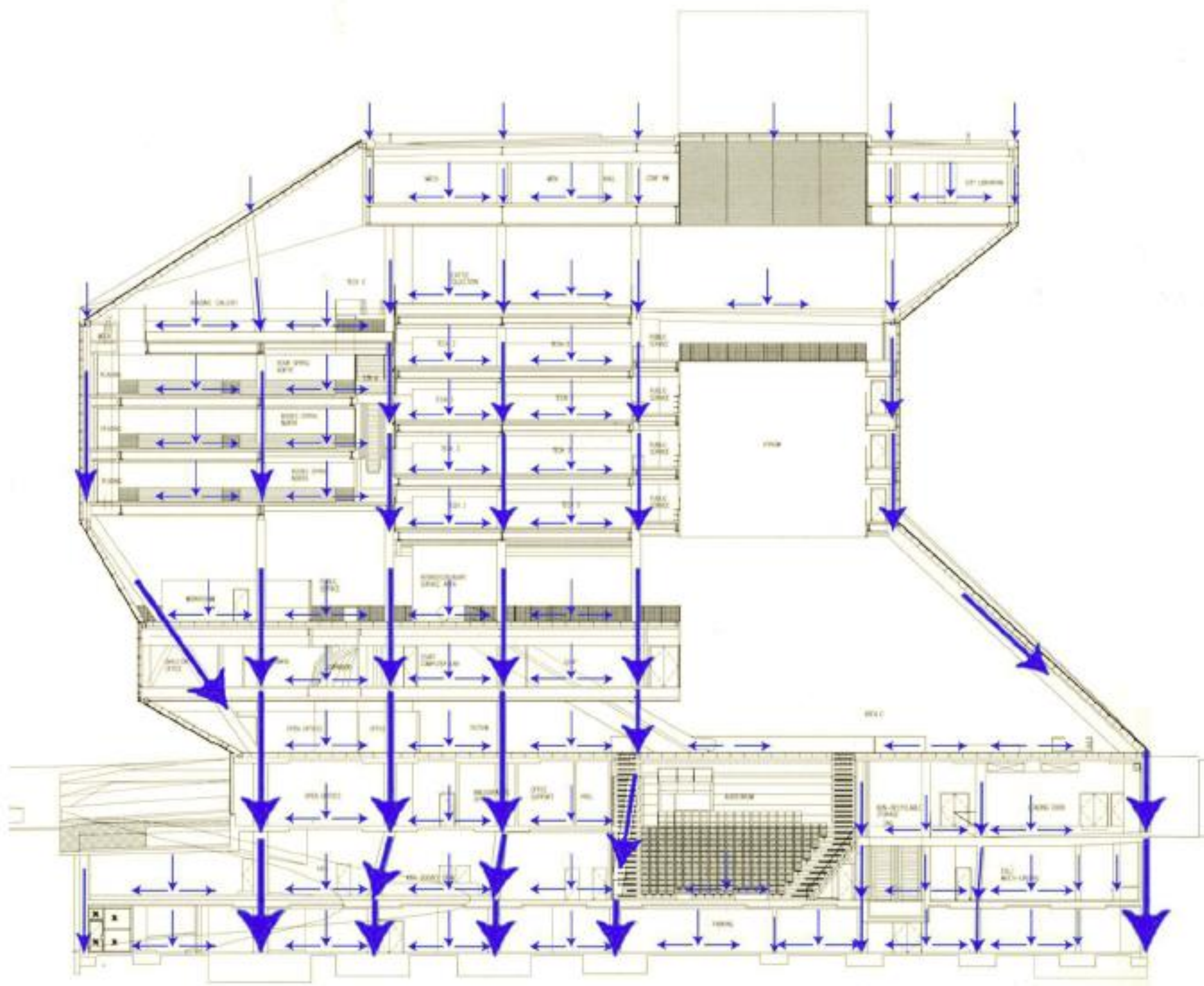


Lateral and gravity loads: split the structure in half.

Works like a giant brace frame.



System movement and seismic resistance



Sección transversal / Cross section

References:

- http://en.wikipedia.org/wiki/R-value_(insulation)
- http://en.wikipedia.org/wiki/Curtain_wall
- http://www.wbdg.org/design/env_fenestration_cw.php
- http://archive.nrc-cnrc.gc.ca/eng/ibp/irc/bsi/82-curtain-walls.html
- http://en.wikipedia.org/wiki/Hearst_Tower_(New_York_City)
- http://www.hearst.com/real-estate/history.php
- http://newyork.construction.com/projects/TopProjects04/Hearst.asp
- http://www.engr.psu.edu/ae/thesis/portfolios/2004/bjg181/documents/report/full_report.pdf
- http://en.wikipedia.org/wiki/Diagrid

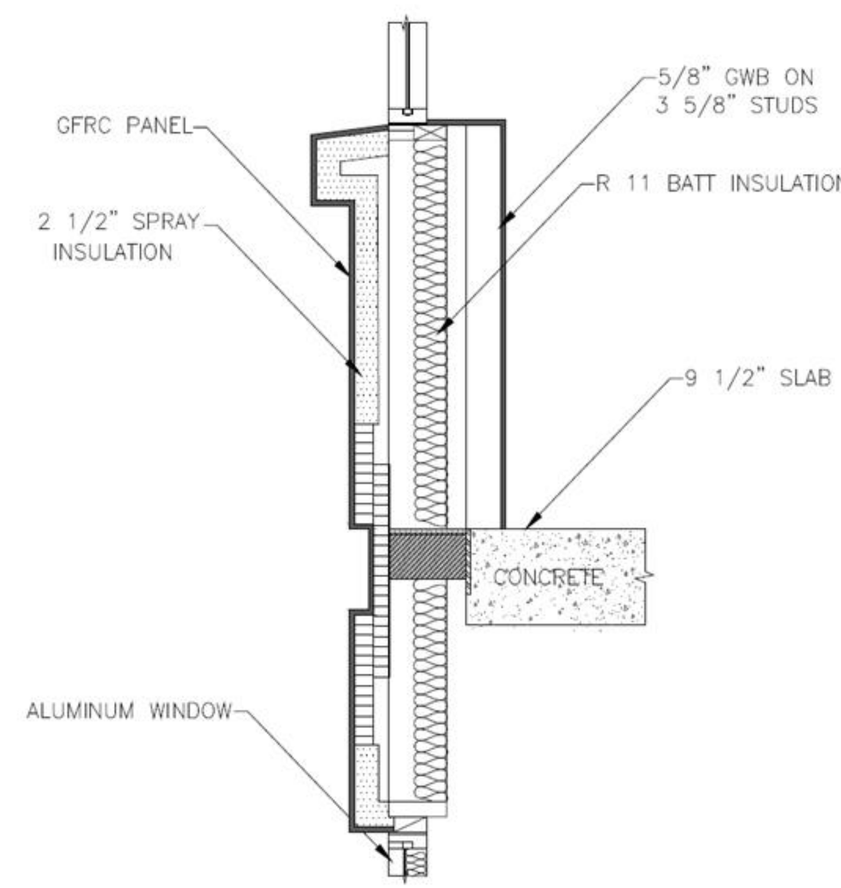
Glass fiber reinforced concrete

1. Systems flexibility & Sizes

- HIGH TECH- fast construction and flexibility allow GFRC to be an ideal for high tech offices and facilities.
- HOTEL/HOSPITALITY- casinos, hotels and resorts benefit from GFRC panels speed, design freedom and durability.
- HOUSING- with its qualities developers can maximize the value of development.
- STADIUMS/SPORT VENUES-benefit from the speed and flexibility of the GFRC cladding system.
- SIZES
- Maximum size of GFRC panels is 14' x 45' but because of simple transports typically 8' x 14' to 12' x 24'

2. Case Study

- Baltimore Washington Medical Center
- (BWMC) is a hospital in Glen Burie, Maryland that is part of the University of Maryland Medical System.



2. System Comparisons w. Thermal Insulation/R value

R-Values and U-Values for Exterior Insulation Finishing System (EIFS)			
Components	Thickness (in.)	R-Value / Thickness (in)	R-Value (hr ft^2 °F/BTU)
Sto Essence DPR Finish	-	-	-
Sto Primer/Adhesive-B	-	-	-
Sto Reinforcing Mesh	-	-	-
2" Sto #1 EPS Insulation	2	4.00	8
Sto Primer/Adhesive-B	-	-	-
Sto Guard Moisture Protection	-	-	-
5/8" DensGlass Gold Sheating	0.625	-	0.67
3 5/8" Metal Studs	-	-	-
R11 Batt Insulation	3.5	-	11
5/8" GWB	0.625	-	0.67
	Total R-Value	hr ft2 °F/ BTU	20.34
	U-Value (∑ 1/R)	BTU/ hr ft2 °F	0.0492

Table 12: R-Values and U-Values for GFRC

R-Values and U-Values for Glass Fiber Reinforced Concrete (GFRC)			
Components	Thickness (in)	R-Value / Thickness (in)	R-Value (hr ft^2 °F/BTU)
GFRC Skin	0.50	0.14	0.07
2 1/2" Spray Insulation	2.5	6	15
3 5/8" Metal Studs	-	-	-
R 11 Batt Insulation	3.5	-	11
5/8" GWB	0.625	-	0.67
	Total R-Value	hr ft2 °F/ BTU	26.74
	U-Value (∑ 1/R)	BTU/ hr ft2 °F	0.0374

» The type of thickness of the material used for a system can vary the thermal quality of a building façade. Thermal impact a façade has on the building is determined the R value. The R-value calculates the U-value for the entire façade system. The lower the U- value, the better it is at insulating. Based on these charts, GFRC is the best insulating system.

2.System Comparisons w/ Construction time and Cost

Life Cycle Cost for EIFS							
EIFS	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Cash Outflow
Initial Cost of System	-$670,272						-$670,272
Description of Maintenance							
Cleaning		-$15,890	-$18,421	-$21,355	-$24,756	-$28,699	-$109,122
Re-coat Panels					-$165,042		-$165,042
Replace Joint Sealant			-$16,127		-$21,673		-$37,800
						Total Cost :	($982,237)

Table 19: Life Cycle Cost for GFRC

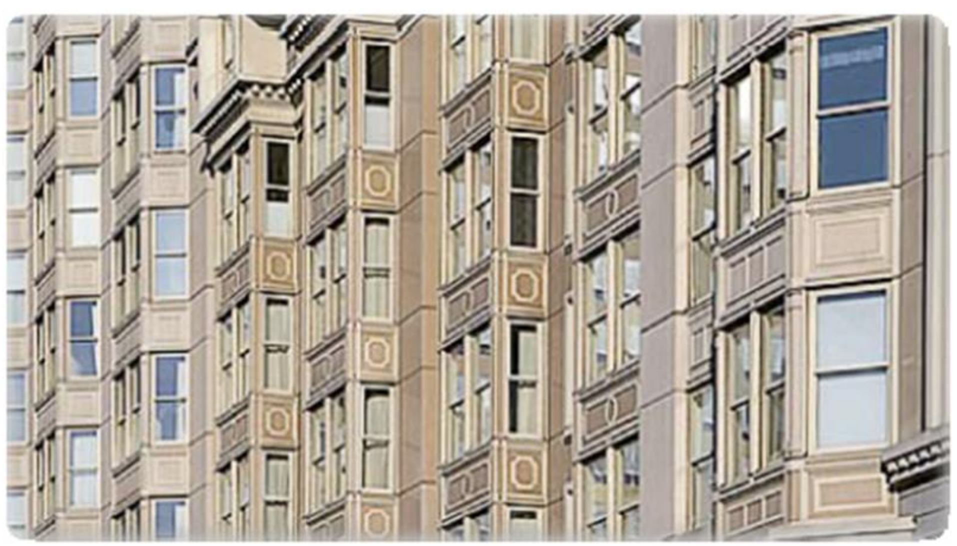
Life Cycle Cost for GFRC							
GFRC	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Cash Outflow
Initial Cost of System	-$2,228,758						-$2,228,758
Description of Maintenance							
Replace Joint Sealant					-$21,673		-$21,673
Cleaning						-$68,879	-$68,879
						Total Cost :	($2,319,310)

Façade Schedule Duration Comparison	
	Duration (Days)
EIFS	122
GFRC	29
Difference (Days)=	**93**

» When comparing this two system, the GFRC panels can be installed much faster than the EIFS panels. This is because the GFRC panels, which include metal studs, are prefabricated in a factory, the duration of this for these panels is very short. Whereas the EIFS panels can not be fabricated in factories so each layer of the panels needs to get installed on the site. This process of each layer is labor intensive. Due to the onsite installation, the duration are longer than the GRFC panels.

3. External Architectural Finishes and Durability

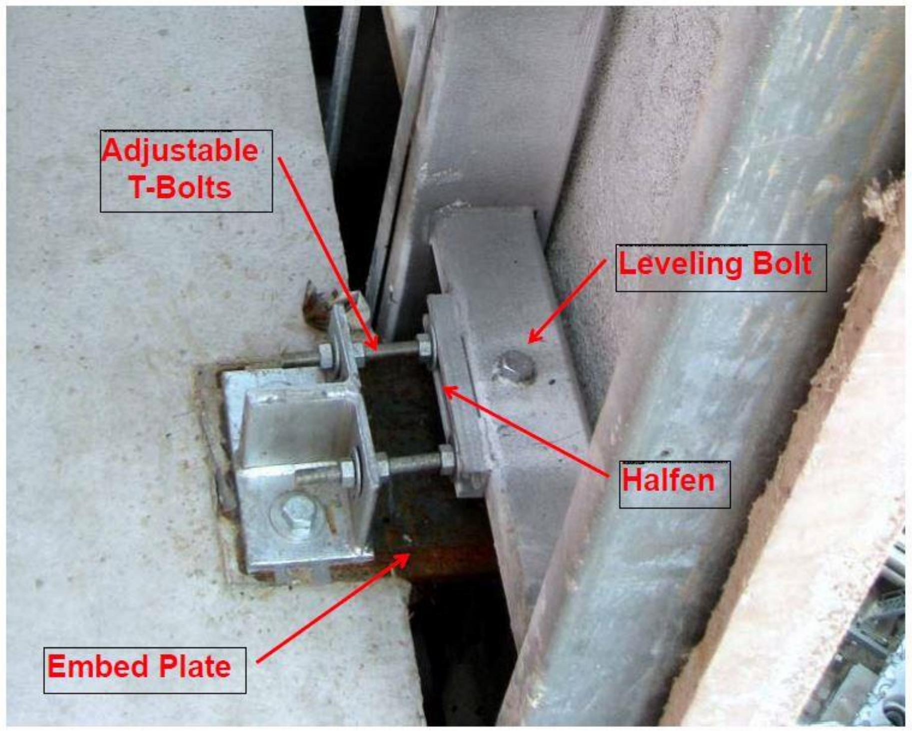
3. External Architectural Finishes and Durability

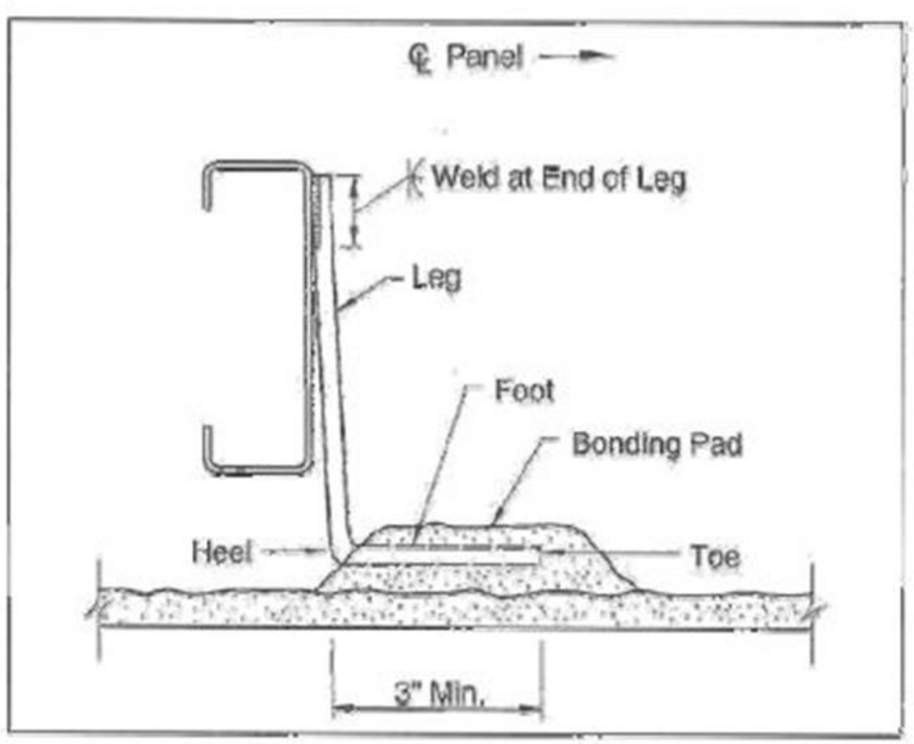


Art Institute Chicago IL

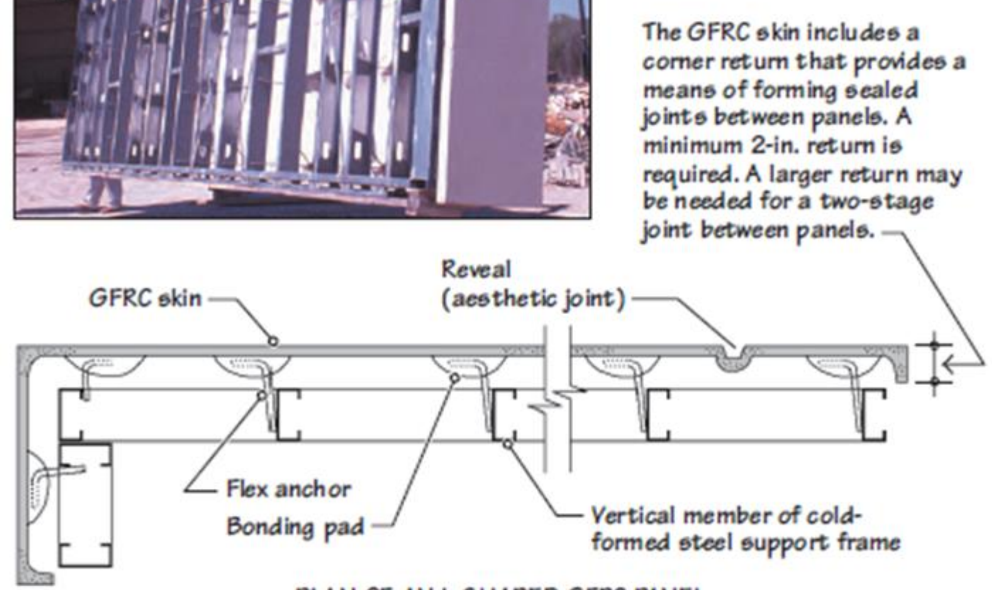
- GFRC is a highly moldable material which allows for complex shapes to be formed
- Panels can be incorporated with freeform curves, complex cornices & intricate details
- Panels can include reveals, window sills, copings, soffits, & special shapes
- The panel sizes are usually limited by transpiration constraints
- Panels can be transported up to 1 story-high to be delivered vertically

4. Attachment systems





Typical flex anchor

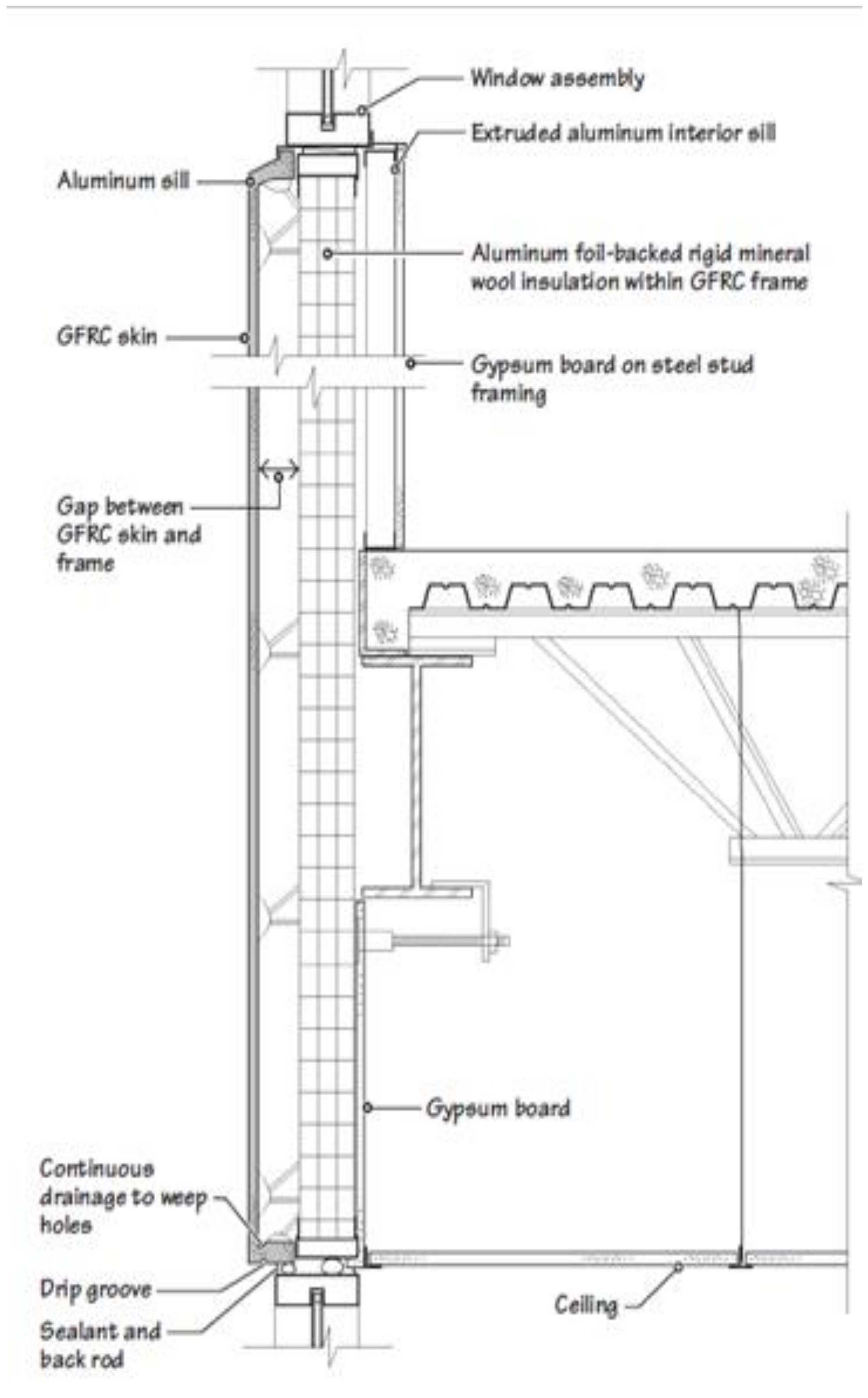


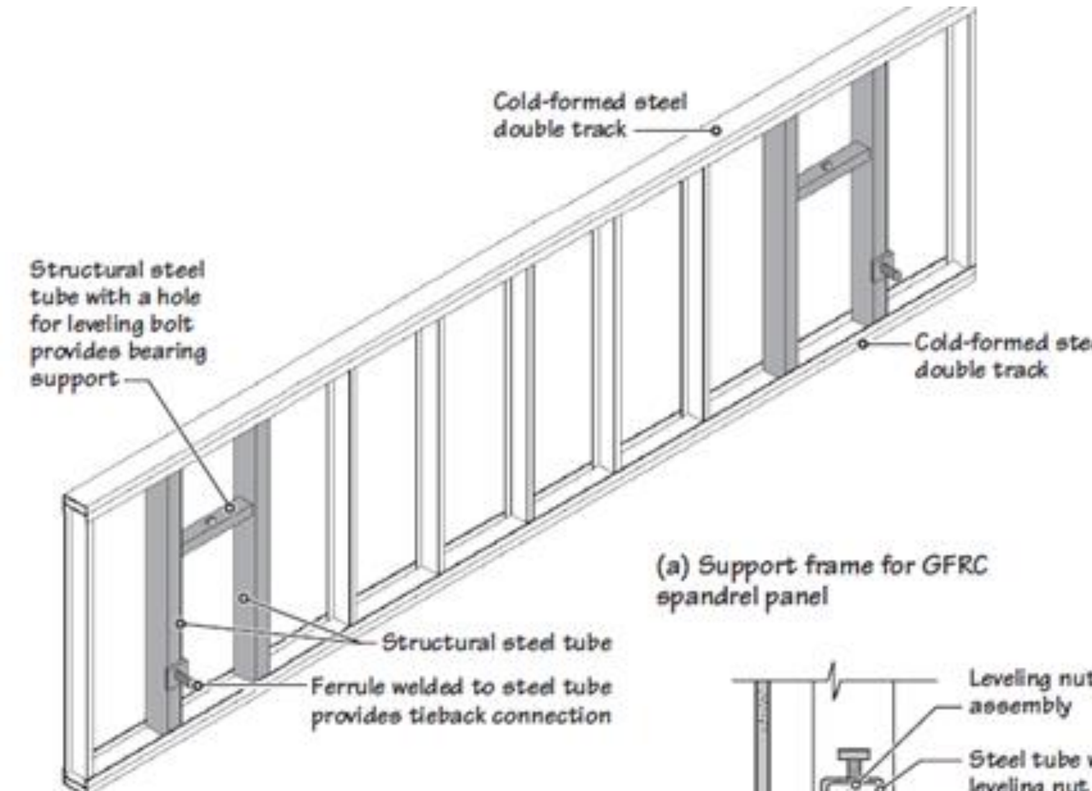
PLAN OF AN L-SHAPED GFRC PANEL

Flex anchors

- Rods (usually bent stainless steel)
- Act as attachments to hold the GFRC skin to the metal stud frame and allow some minor movement between
- The GFRC face of the cladding and the steel frame.
- Attaches GFRC skin to frame
- Transfer wind loads to frame
- Allows differential movement between the GFRC skin and
- Supporting frame

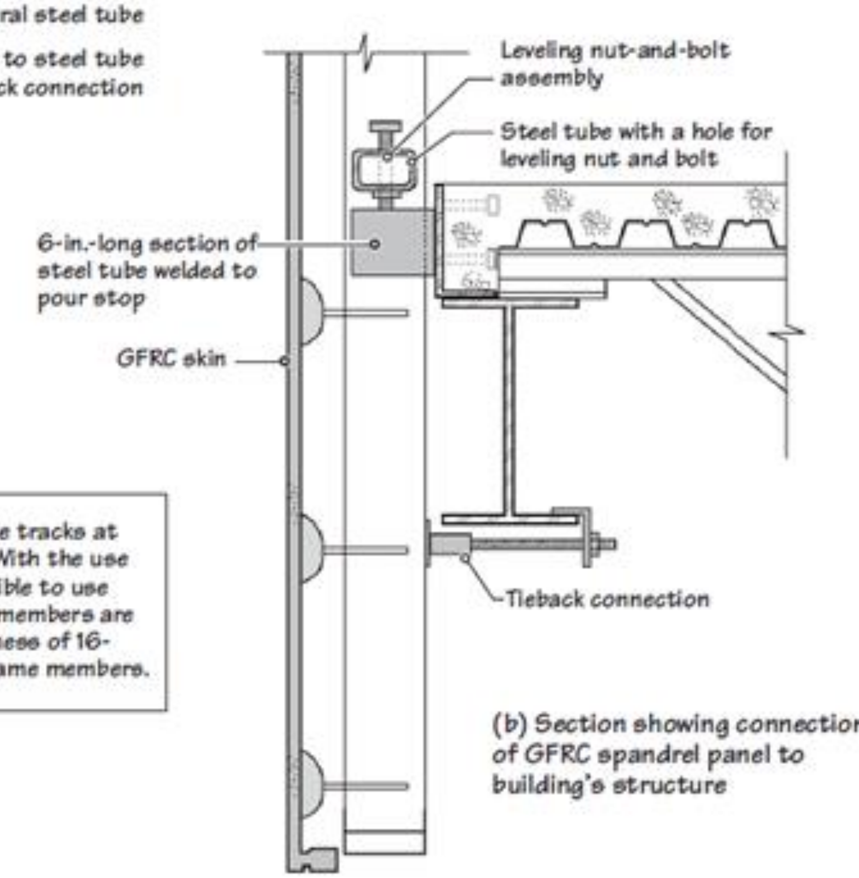
4. Attachment systems





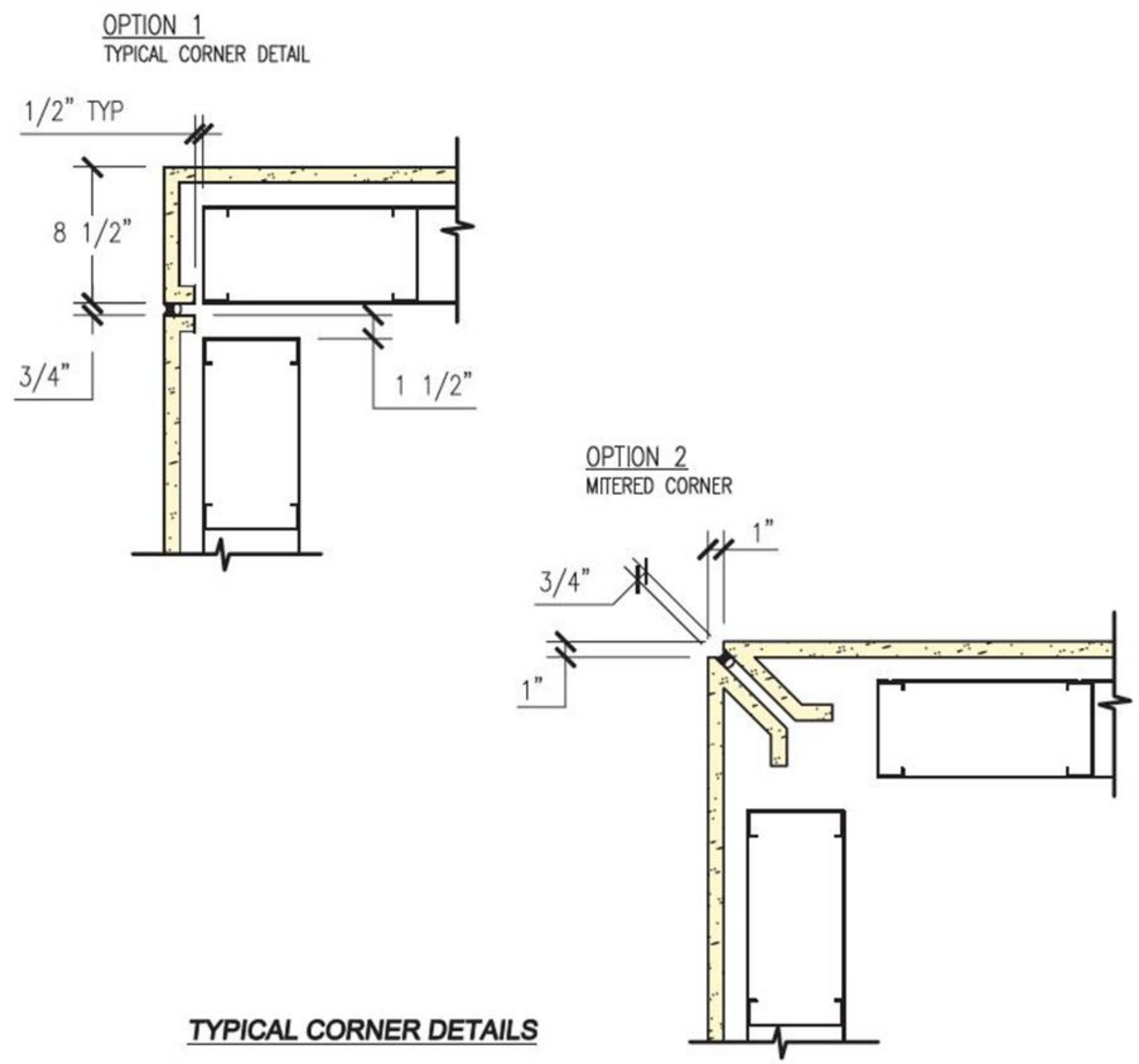
(a) Support frame for GFRC spandrel panel

This frame shows the use of double tracks at the top and bottom of the panel. With the use of diagonal braces, it may be possible to use only single tracks. Because frame members are welded together, a minimum thickness of 16-gauge is required of light-gauge frame members.

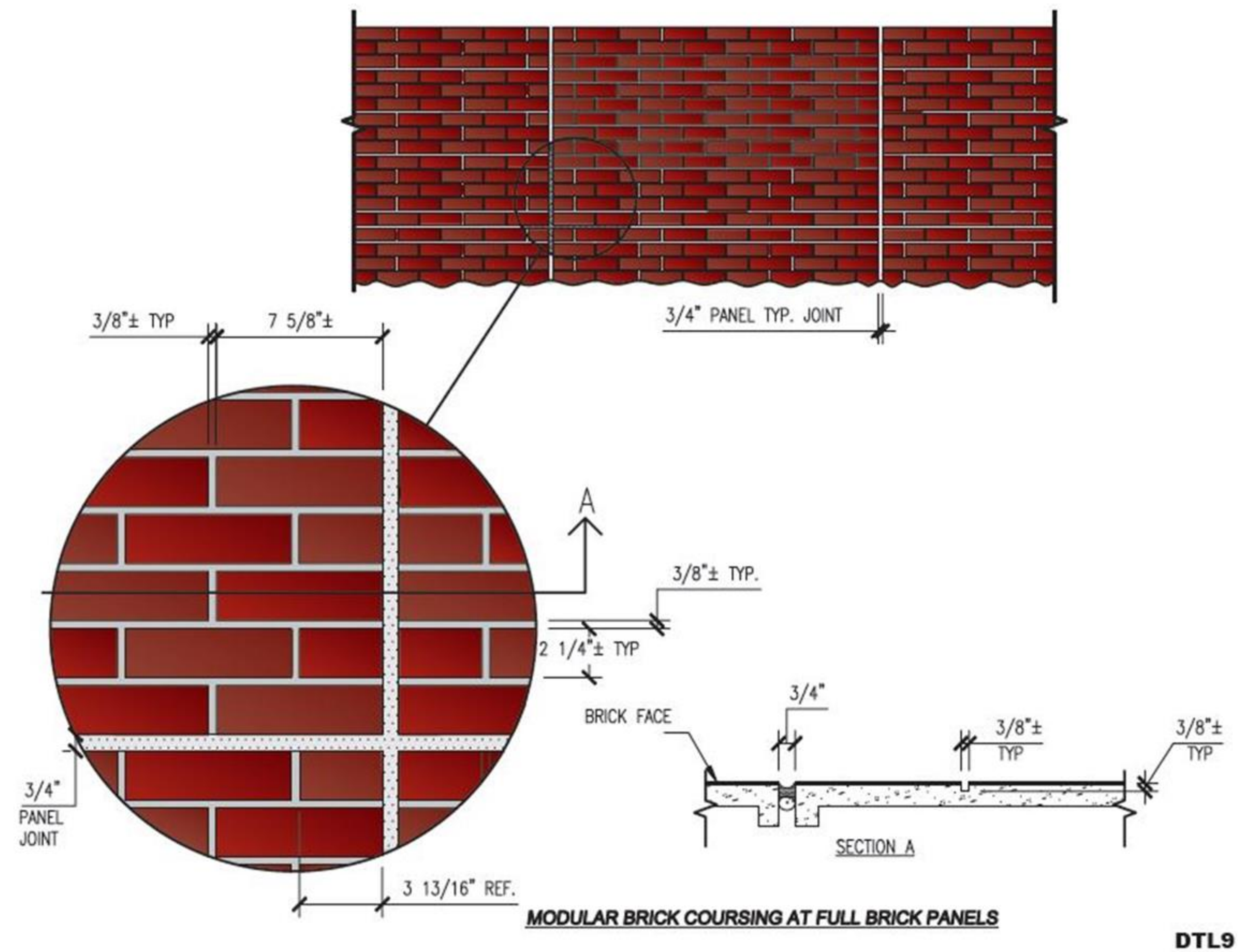


(b) Section showing connection of GFRC spandrel panel to building's structure

5. System joints & connections

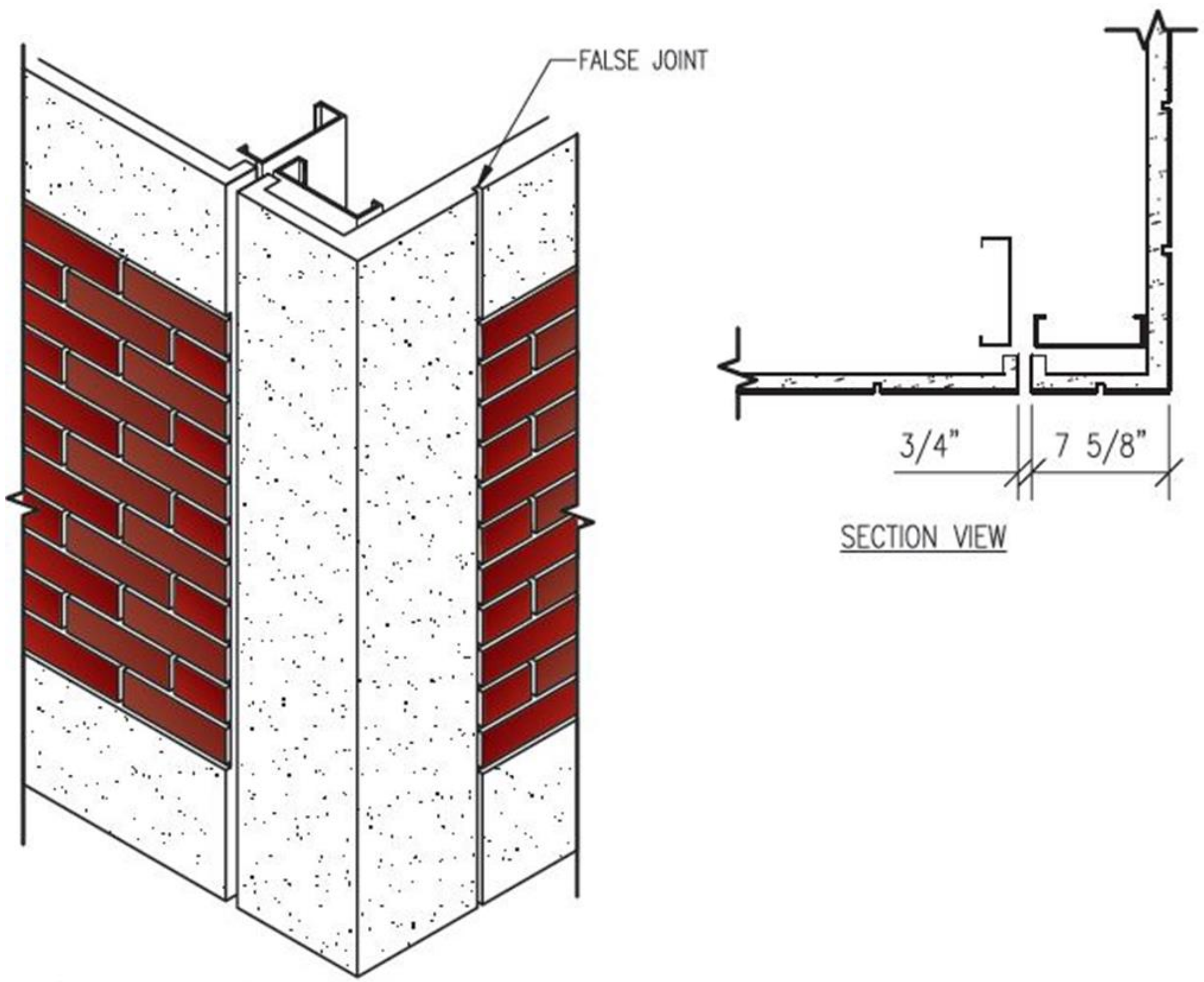


Stromberg GFRC Cladding Panels

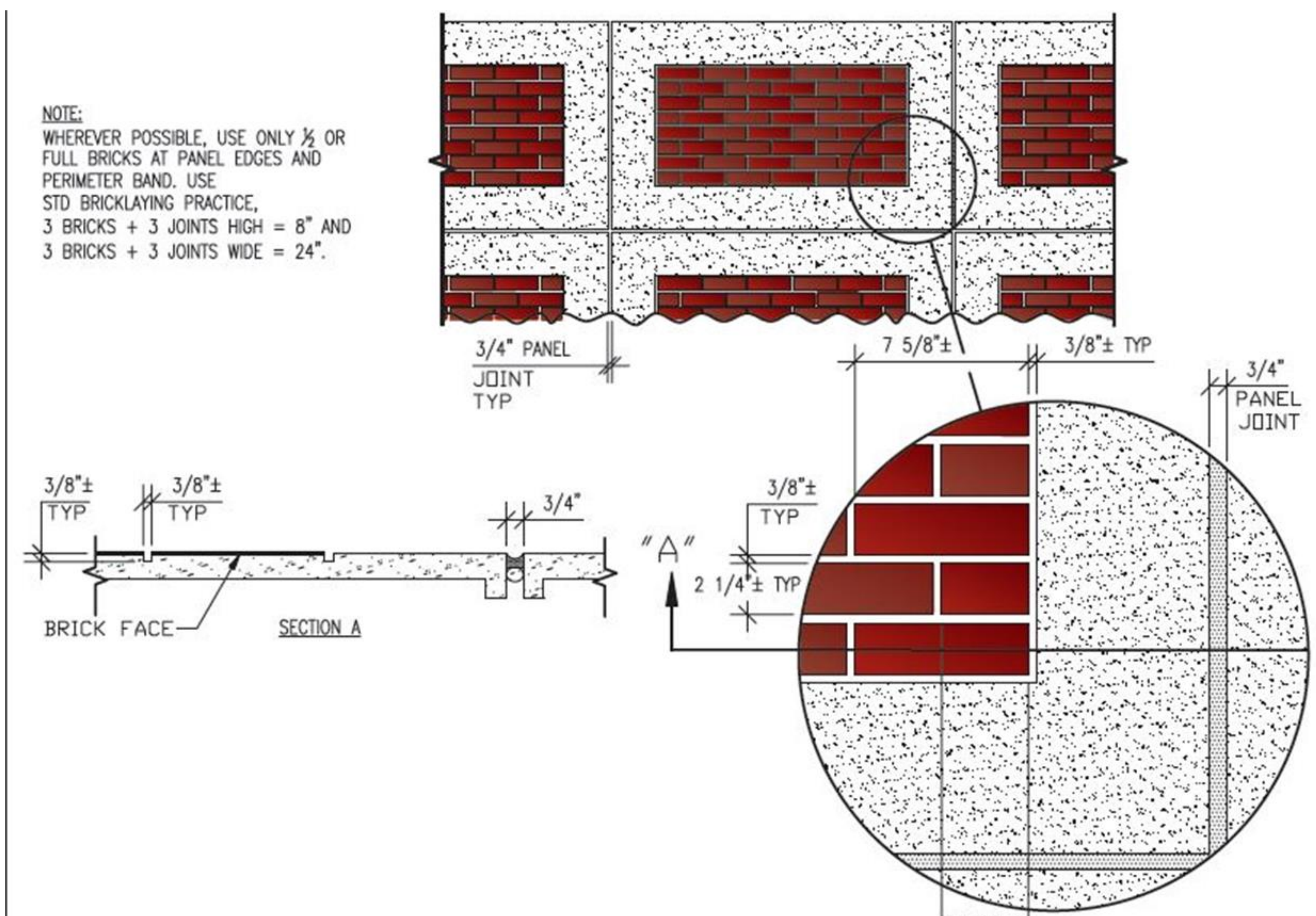


5. System joints & connections

- Panels perimeter can be cast with false joints to simulate a cast stone, cut stone or architectural precast band.



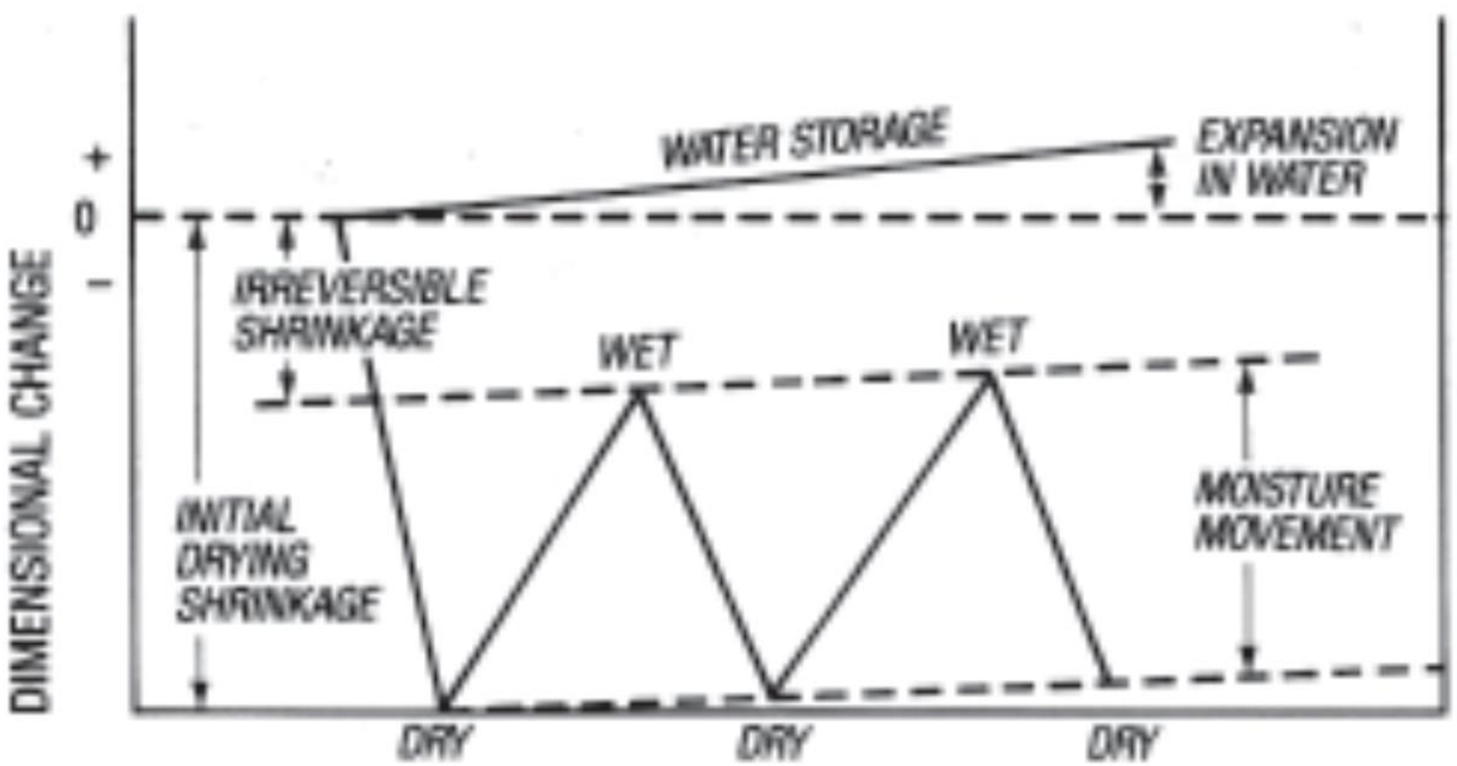
CORNER RETURN



MODULAR BRICK COURSING AT GFRC PERIMETER BAND

DTL10

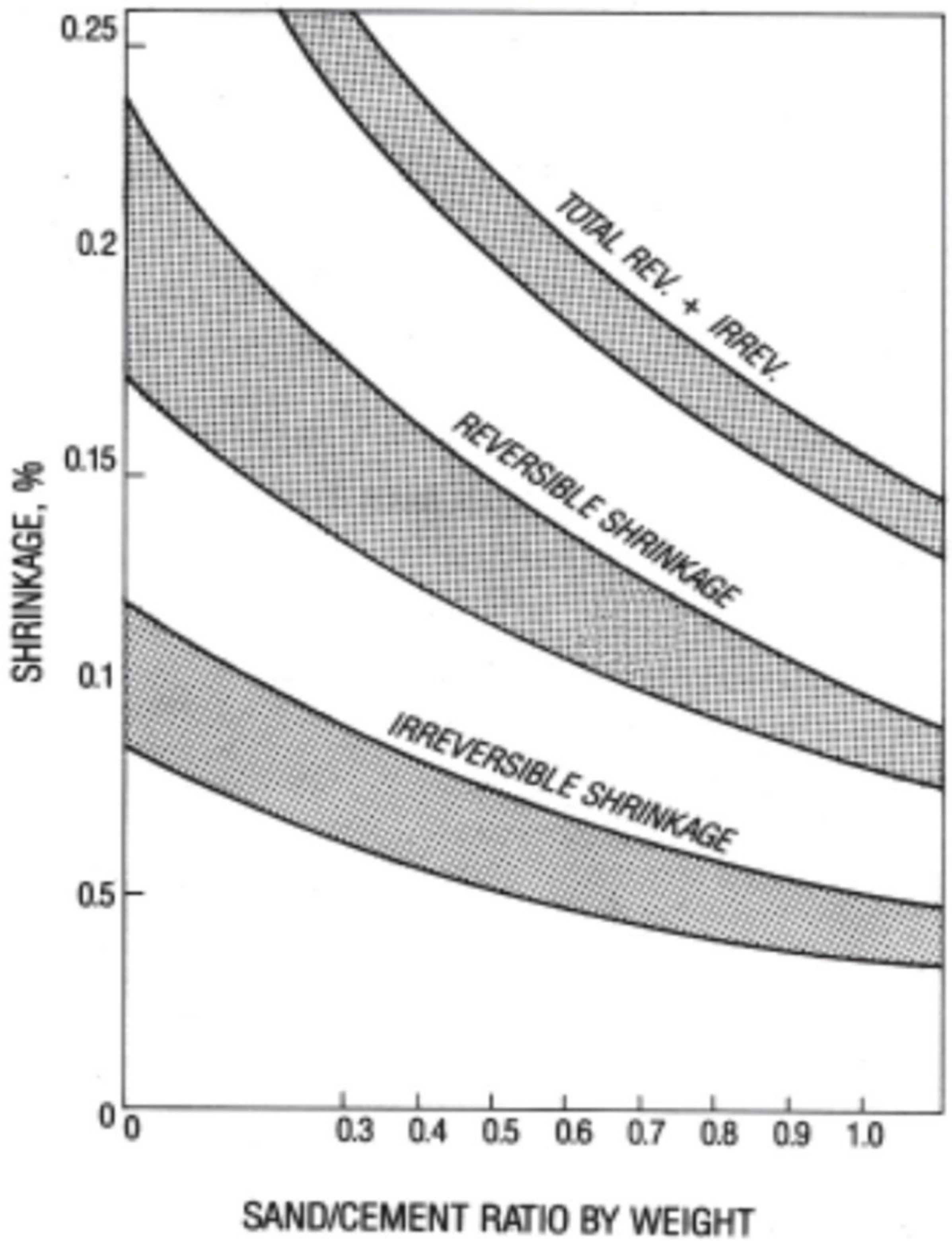
6. Rain penetration &moisture control



Moisture movement of GFRC panels.

- GFRC is subject to shrinkage on drying and partial recovery on wetting.
- Moisture movement is dependent upon several factors including the water-cement ratio, the sand-cement ratio, curing, & the age of the composite.
- The effects of moisture on GFRC are irreversible drying shrinkage occurs during the curing stage, & is largely dependent on the sand-cement ratio and the water-cement ratio.
- Moisture movement causes a reversible dimensional (or volume) change during subsequent wetting & drying.
- Moisture movement is largely directed by the sand-cement ratio and decreases somewhat with age.
- The incorporation of sand, a standard practice,
- reduces the amount of shrinkage; but shrinkage is
- still greater than that exhibited by precast concrete
- because of the higher cement content.
- Shrinkage induces internal stresses which can lead to cracking, particularly in components constrained by shape, variable section thickness, embedded materials, or external restraint.

6. Rain penetration &moisture control



Effect of sand addition on shrinkage behavior.

- » Moisture absorption varies according to the
- » density of GFRC but will normally be in the range
- » of 11 to 16 percent by weight. Moisture content in
- » an environment of 65 F and 60 percent relative
- » humidity will reach equilibrium in the range of 4 to
- » 8 percent by weight.

References:

- Tech Analysis 3.pdf
- Zoho_Stone_GFRC_Cladding_Commercial (1).pdf
- gfrc-panel-details.pdf
- gfrc-cladding-panels.pdf
- gfrc_guidebook.pdf
- 20-Physical propertiesofGFRC.pdf