Double-Skin Cable-Net Facade Case Study: Loyola Information Commons

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Original paper and presentation for BESS2010: High Performance Building Enclosures - Practical Sustainability Symposium at Cal-Poly Pomona.

The Richard J. Klarchek Information Commons at Loyola University, designed by the architecture firm Solomon Cordwell Buenz, is a 4-story digital library on the Lake Shore Campus of Loyola University Chicago. The building is sited along the Western shore of Lake Michigan, on Chicago's North side. The building is glazed along its entire east and west facade, parallel to the long axis of the building. The 150' structural glass facade made the building highly transparent, satisfying the wishes of the owner that the lake be visible from the courtyard to the west of the building. These large glazed areas in the harsh climate of Chicago created a thermal comfort challenge, solved with an array of sustainable design strategies that ultimately led to a 47% reduction in expected building energy use compared to a similar traditional structure.

The most visually striking facade element is the west wall, which is a double-skin glass structure. The outer wall is a cable net supporting 8' tall by 5' wide monolithic glass panes. The 3' air space between the inner and outer skins serves as a thermal buffer for the building. A stack effect in the cavity helps to draw in cool air from operable windows on the lakefront east facade. On the double wall, the blinds are in the cavity, a superior shading strategy. The combined effects of the glazing system and other green features earned the building a LEED Silver rating while offering a beautiful, iconic structure to the campus.

1 INTRODUCTION

The Loyola Information commons is a stunning digital library completed on the campus of Loyola University Chicago in 2007. The building is glazed from top to bottom on the east and west facades, creating a four-story transparent box with two monumental limestone bookends. Architecture firm Solomon Cordwell Buenz designed the building as the modern, transparent eastern boundary of a new quadrangle formed by the building and its neighboring historic structures on the campus. The east facade is a custom designed grid of insulated glass panels. The west facade features a double-skin. A cable net supported wall of monolithic glass serves as the outer skin. The inner skin is the same system found on the east elevation. As a completely digital library, the structure contains no books. Instead, a series of reading rooms, study rooms, meeting rooms, and computer labs occupy the 70,500 square feet of space on four floors. The digital-only content represents a modern addition to a traditional environment, much like the building itself.

2 SITE CONTEXT

The building sits mere feet from the water line of Lake Michigan (Figure 1). This provided motivation for the transparent design. Said Loyola's vice president of capital planning Wayne Magdziarz, "We wanted people to realize that the lake was on the other side of the building," (Gonchar 2008). The 150-foot long glass facades on the east and west elevations certainly accommodated this vision requirement, but also created a challenge for assuring thermal comfort in Chicago's harsh climate. The cold winters of Chicago as well as the direct lake exposure indicate a heating dominated climate, though there exists a cooling requirement in the summer and ample opportunity for natural ventilation in the summer and shoulder seasons.

The design team ultimately developed a hybrid "mixed-mode" system that was highly responsive to the climate, taking advantage of natural ventilation strategies when possible and using mechanical comfort control otherwise (Gonchar 2008). The highly effective HVAC system, which is discussed later in the study, contributed greatly to the building's overall energy efficiency.

3 BUILDING LAYOUT

The building has a ground floor entry into an open layout computer lab. Seminar rooms on the ground floor are found in the building bookends. The second floor offers a similar layout but integrates a centrally located reference desk and study rooms on the periphery of the open space. The third floor features another large open layout computer lab in the central area. Reading and study rooms are located in the bookends. The top level features a large meeting room abutting a green roof and opening to a terrace. On the bottom three floors, chairs facing the east window are often filled with students taking advantage of the lake views.

Figure 1: The building sits along the western shore of Lake Michigan just north of Chicago, Illinois.

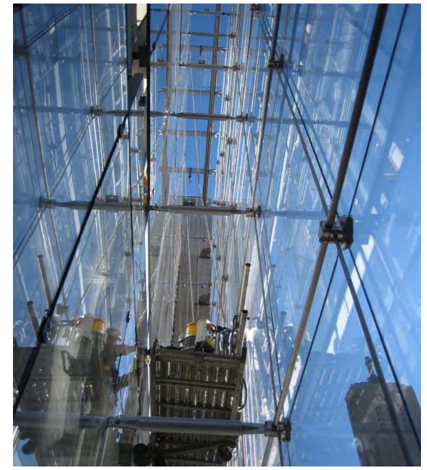
4 BUILDING ENERGY DESIGN

The building was designed with an array of sustainable features, ultimately requiring only 53% of the energy of a standard building. The features are designed to interact with and complement one another, while simultaneously defining the building aesthetically.

The east facing glass has operable shading on the inside. Though less effective than the cavity-based west facade, the system is able to reject heat gain and still allow daylight penetration in the summer when morning heat gain would be detrimental to the building.

Mechanical cooling is provided through radiant cooling embedded in the concrete ceilings. The campus has a centralized chilled water plant that provides cooling for most buildings. The unique design of the system in the Information Commons allows for the building to use return water for its cooling. This raises the campus-wide efficiency of the centralized cooling system. The HVAC system is controlled by a Building Automation System that responds to a preset seasonal operating mode and a host of internal and external climate conditions.

The extensive use of glass reduces the need for electrical lighting during the day. When high levels of natural light would create uncomfortable brightness of glare, the mechanical shades are dropped down. The lights in the building are continuously dimmed in response to available daylight, and vaulted ceilings optimize the dispersion of diffuse light from the T5 fluorescent lighting system (Fortmeyer 2007).



5 FACADE

5.1 East Curtain Wall

The eastern facade is constructed with the VS-1 glazing system, a proprietary product provided by Innovation Glass. The floor-to-ceiling IGUs are supported only by a vertical mullion. No horizontal supporting element is used in the system. The edge of the glazing panel is not directly attached to the mullion. Rather, a cast fitting extends from the mullion and clamps the glass in place, offsetting the glass plane from the support system (Figure 3). The clamp passes through the space between adjacent glazing panels, requiring no drilling or perforation of the glass. After installation, the joint between panels is weather sealed with field-applied silicone.

5.2 West Curtain Wall

The VS-1 system is also used as the inner skin on the west facade. Both walls are glazed with glass provided by Viracon. The vertical mullion system consists of an aluminum extrusion. A glass fixing component sits in a channel in the front face of the mullion and extends outward, passing through the space between adjacent panels and clamping the glass in place. This creates a flush glass facade with a butt-glazed joint using Dow Corning 756 silicon sealant. The VS-1 system relies on a stick assembly facade with three parts and an overall measurement of 5' wide by 16' tall. The vision glass portion is a 5'x12' IGU with fully tempered ¼" inner and outer lites and ½" airspace. Above that sits a 5' x 2'-6" IGU that is operable for natural ventilation. Above that is a 5' x 1'-4" metal spandrel panel.

5.3 West Cable Net

The outer skin is supported by a grid of pre-tensioned cables, known as a cable net. The cable net consists of 6 horizontal cables and 29 vertical cables, arranged in an 8' high by 5' wide grid. At the vertex of each vertical and horizontal cable is a special node assembly that clamps the cables together and fixes the corners of all four pieces of monolithic glass (Figure 5). The space between the outer and inner skin is roughly 3 feet (Figure 4), except for the entry space where the inner skin curves inward to form a vestibule that is part of the cavity buffer between inside and out.

The horizontal cables are secured to the limestone bookends via a "sharkfin" connection (Figure 6). To do this, a sharkfin shaped 1" thick horizontal metal plate was prefabricated, complete with a round channel for the cable. This plate was field welded to a second 1" steel plate embedded in the building bookends. Workers ran a cable from one sharkfin anchor to its match on the opposite bookend, then pre-tensioned the cable to 44 kips with a hydraulic tensioning jack.

The vertical cables experience two different terminating conditions. At the top, the cables are connected to an HSS "hangman," an angled piece of steel projecting up from the roof plate and out 4' from the inner skin. The vertical cables attach to the end of this cantilever. The 7 kips pre-stress force in the cables induces a large reaction load in the hangman. Pulling down on the cantilevered extension introduces an overturning moment that must be accommodated. To do this the horizontal arm is joined to the vertical arm with a moment connection and the hangman is braced back to the building at the roof with a cable tensioned to 8.5 kips to stabilize the system (Figure 7).

At their bases, the vertical cables tie to a concealed spring assembly (Figure 8). The spring is slightly compressed and installed at the bottom terminus of the cable. The assembly is designed to provide for the predicted deflection of the vertical cables. A deflection of the glass facade will further compress the spring, accommodating deflection without overstressing the cable while also mitigating the shock effect from rapid load changes. In returning to its pre-deflection shape, the spring brings the cable to its original tension and stabilizes the system.

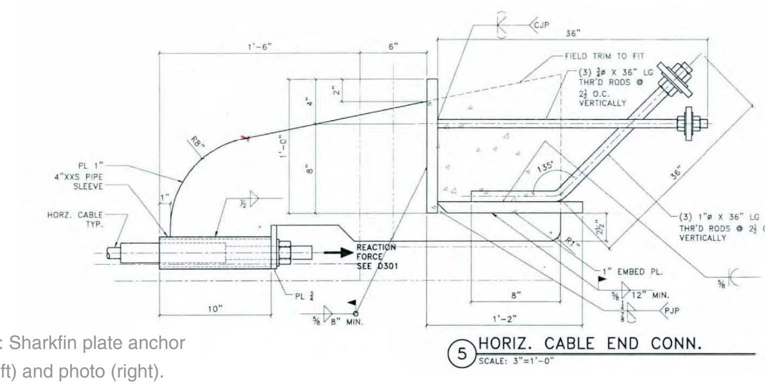
Vertical columns spaced every 30' support the building gravity loads. However, these columns are also used to stabilize the cable net. Considering the 5' spacing of the vertical cables, every 6th cable runs directly in front a structural column. The horizontal cables create 6 cable intersection points, or nodes, that are directly in front of a column. At these points, a steel strut is connected between the column and the grid node. The bracing component transfers some of the lateral loads incident on the facade to the building structure.

Opposite page:

Figure 3 (left): The VS-1 glazing system is used along the east facade which uses cast stainless steel fittings to clamp the IGUs.

Figure 4: The interior skin of the west wall (middle) encloses a cavity interior wide enough to accommodate window washing units (right).

Figure 5: View of west entry and exterior cable net (left) and vertex clamp (right).



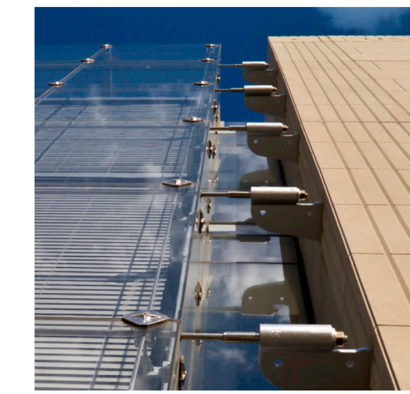
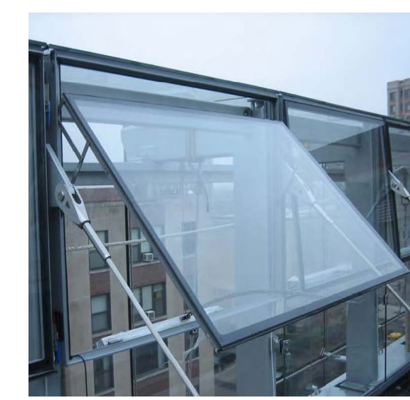


Figure 6: Sharkfin plate anchor detail (left) and photo (right).



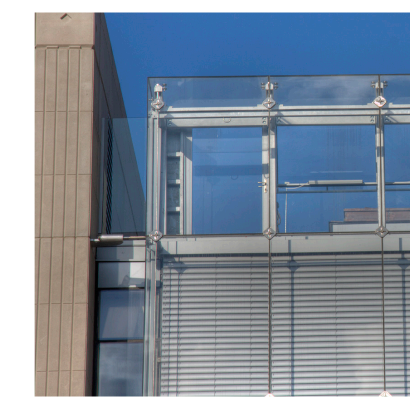


Figure 7: Hangman steel at cavity return (right) and motorized vent (left).

Figure 8: Detail of the vertical cable base spring connection. This keeps the system in tension while allowing for cable deflections under load.

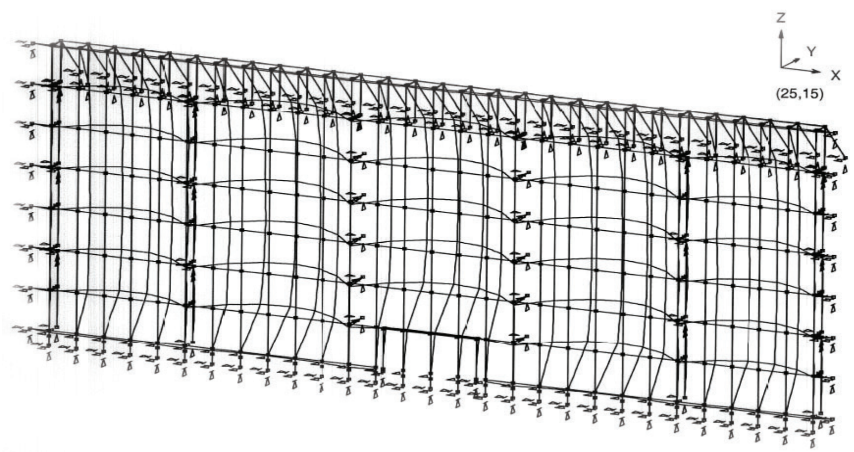


Figure 9: SpaceGASS structural analysis model with superimposed deflection profiles (magnified for clarity).

Glazing on the west exterior wall is a fully tempered, 1/2" thick monolithic glass supplied by Viracon. The panel is 5' wide by 8' tall, to match the grid spacing of the cable net. Each piece is point-fixed at each corner by a custom 4-part stainless steel casting that clamps to the horizontal and vertical cables at their intersection. The casting picks up the corner of all four pieces of glass meeting at the node. Weather sealing is provided by a 5/8" butt-glazed silicone joint. The sealant is Dow Corning 756 and is field applied.

A third type of glass is located at the top of the double wall cavity. This glass, which caps the cavity space, is 5/16" laminated glass with a clear PVB. It slopes slightly in towards the building for drainage.

The corner condition of the cable net structure presented a challenging design condition for Advanced Structures Inc., the system designer. The outer skin does not terminate at the bookend, instead stopping a few feet short and returning back to meet the inner wall. This creates both a 90 degree all-glass corner and a condition where the horizontal cable has to pass through the glass to continue to the sharkfin connection. The designers created a special strut that extends from the last exposed structural column and incorporates glass clamps to fix the return glass along its length (Figure 10). To allow for passage of the cable through the space between panes, a semicircular cutout was made in the top and bottom of adjacent panes, providing a perforation in the glass membrane. The gap between cable and glass was sealed in a manner consistent with the rest of the installation.

The design of the curtain walls involved advanced modeling and calculation by specialty facade engineers. The cable net was subject to complex deflection from lateral loads, primarily wind loads of 30 psf. The horizontal cables were anchored at each end and to a strut at each column crossing. Each anchoring point represented a spot of zero deflection. The maximum deflection in each of these cables would occur in the center of the mid-column span, in this case 15' from a column. However, the horizontal cables were tied to the vertical cables at their intersections, resulting in a double curvature that was the product of the horizontal and vertical cable contributions. Unlike the horizontal cables, which were anchored at multiple points along their length, all vertical cables between columns were anchored only at the top and bottom. As such, the deflection of the vertical cables was maximal at the mid-point of the vertical span. The resulting point of maximum deflection for the doubly curved surface was then at the mid-point of the vertical span and the midpoint between columns, occurring at four locations due to the column layout (Figure 9).

Because the vertical cables could be expected to deflect more, design measures were taken to allow them to do so. The spring loaded base terminus of the cables allows for deflection under loading and returns the net to its proper pre-stress after a load event. Additionally the vertical cables are pre-tensioned to only one-sixth the force of the horizontal cables and, at 16mm outer diameter, are noticeably thinner. The horizontal cables are fixed at multiple points by column struts and suffer less overall deflection when subject to lateral loads. Additionally, the sharkfin connections allowed for only a very small amount of cable movement. To meet this condition, a larger cable, 28mm in diameter, was used in the horizontal direction. The four-part cast steel node clamps contained channels sized appropriately for the two different cable diameters. The maximum allowable deflection for the cable wall was L/50 = 7.2". SpaceGASS structural analysis software verified the system was within the allowable range, ultimately showing a maximum deflection of L/58 = 6.2".

Figure 10: Horizontal cable penetration through the glass. The vertical rail below is part of the motorized blind system.

6 CONCLUSION

Upon completion, the Richard J. Klarchek Information Commons sported one of the largest structural glass facades in the United States. The cable net outer skin on the double-skin west facade was well designed, relying on a set of unique terminating mechanisms for the cables to properly respond to loads. It was fitted with expressive and elegantly crafted cast steel fittings and struts appropriate to an exposed structural system. The double-skin facade allowed for a highly advanced thermal control system that took advantage of the stack effect and created a thermal buffer on the vulnerable west side of the building. The VS-1 glass system, which serves as both the exterior east wall and the interior west wall, facilitated natural ventilation in accordance with the Chicago Building Code, thereby furthering the energy efficiency of the building. The efforts of the architect, supported by various consultants, produced a building that uses nearly half the energy of a similar traditional building. The structure was ultimately rewarded with a Silver Certification from the United States Green Building Council. It stands as both an expression of the University's commitment to green architecture and a powerful example of the opportunities presented by structural glass facades.

ACKNOWLEDGMENTS

The project was completed with collaboration between many firms, individuals, consultants and contractors. Key project team members include; Loyola University Chicago (owner), Solomon Cordwell Buenz (architect), Halvorson & Partners (structural engineer), Elara Engineering (mechanical engineer), CDC (glazing consultant), Charter Sills & Associates (lighting consultant), Shiner + Associates, Inc. (acoustical consultant), Transsolar (climate consultant), Pepper Construction (general contractor), Enclos Corp & Advanced Structures Inc. (facade contractor/engineer), Viracon (glass manufacturer), Innovation Glass (glazing system), Sieban Energy Associates (LEED consultant).

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