Let There Be Light

BY IAN COLLINS, PH.D.

Novum Structures

An expansive, innovative skylight in Chicago sets a U.S. structural and architectural precedent.

IT WOULD SPAN 148 FT BY 137 FT, 80 FT ABOVE GROUND LEVEL. It would be a precise, carefully engineered union of steel and glass—and the first of its kind in the United States.

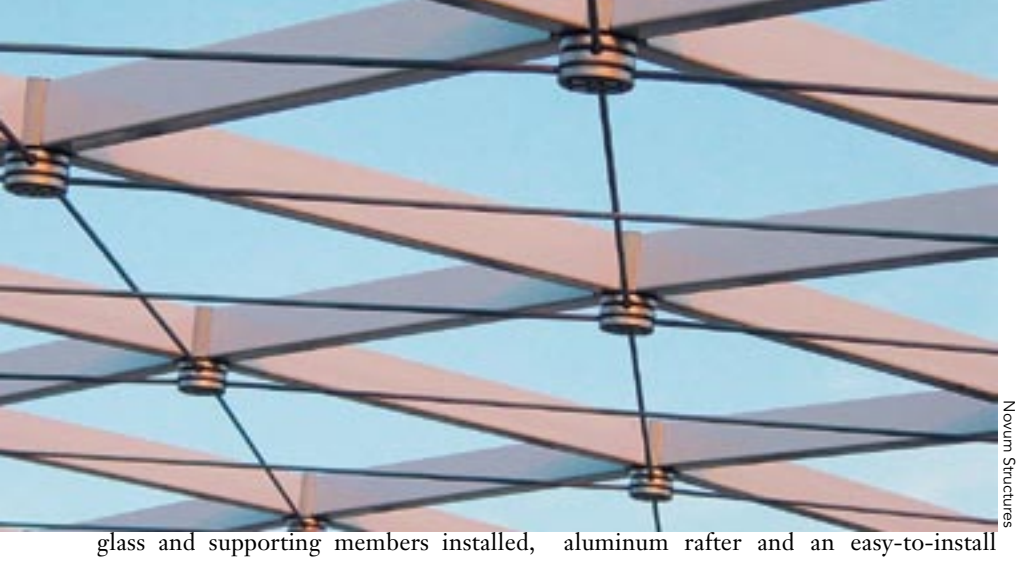
This glazed skylight, through which natural light floods, now tops the atrium of the 153,000-sq.-ft William Wrigley Jr. Global Innovation Center on Chicago's Goose Island. An enormous, highly irregular, "diamond" shaped structure, it was envisioned with incredible transparency to seamlessly allow natural light to pass through to support abundant plant life along the atrium's floor.

A Ground-breaking Challenge

To bring the challenging design to life, Chicago-based architectural firm Hellmuth Obata + Kassabaum (HOK) contacted Novum Structures, a specialty contractor for high-technology spatial architectural structures and enclosures. HOK's initial design objective called for a single-layer skylight spanning more than 130 ft. To further complicate the endeavor, the budget was tight and site logistics difficult, as the atrium was located a significant distance from the building's outside perimeter. Because of this, larger, more expensive crane equipment would be necessary to handle the huge reach, putting greater strain on the project's budget.

"One of the challenges was just getting the whole 12,000-sq.-ft skylight in the center of the building to coordinate and interface with the rest of the building, because the rest of the building was built first and then the skylight system followed," says Jeff Geier, project executive at Power Construction, the project's general contractor. "All the tolerances had to be worked out."

The challenge was to economically resolve the nearly mutually exclusive objectives of large span and transparency. For the limited budget of approximately $150 per sq. ft, including all



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Concealed mechanical connections allowed for very high-quality factory finishing.

glass and supporting members installed, the architect essentially wanted the look of a 5-in.-deep conventional skylight frame that would span more than 130 ft. In Chicago, where heavy snow loads must be considered, conventional skylights typically span only 40 ft.

In an effort to adhere to this norm, Novum's initial concept used intersecting three-dimensional trussing supports to break up the span into 40-ft by 40-ft skylight modules. However, HOK rejected this initial design. It became clear early on that the firm was resolute on the single-layer concept, and Power Construction strongly reinforced the need for a guaranteed budget.

Innovative Systems Create a Solution

Resolving the span with such a thin shell was difficult and put Novum to the test. The team found the answer in using steel "mullions" to form a structural grid while introducing triangulation of some kind. Possibilities included:

- a full triangulated grid with bolted connections;
- a stiffened orthogonal shell using some double layer construction; or
- a post-tensioned system using a cable triangulation method. To maximize the transparency objective, it became clear that the third option was the best choice.

Triangular glass panels are extremely expensive, so Novum immediately sought to maximize the number of rectangular panels by tweaking the architectural form of the double-curved atrium into a sphere. This allowed for the use of square glass lites of uniform sizes while maintaining non-warping, flat glass panels. Custom panels were required at the perimeter as panels were fit in to the diamond shape borders. The flush-glazed, fully caulked glass panels were attached directly to the steel support structure using a very thin aluminum rafter and an easy-to-install toggle bolt attachment.

While the square grid geometry is ideal for glass economy, it is not stiff structurally and thus cannot be relied on to span large distances. The fully triangulated structural grid would resolve the problem structurally but not aesthetically or within budget. Hence, Novum proposed a post-tensioned two-way diagonal system of very thin (14 mm) stainless steel cables using attractive disc-like clamps at each node to secure the tensioning elements to the structural grid. The clamping device allows cable to intersect with some space between, and the effect is to provide a very transparent triangulation of the grid so it acts like a shell and can then thrust to the perimeter. In dealing with this thrust, lateral deflections of the interface of shell to edge condition have to be controlled in order to avoid potential geometric instabilities in the roof. Therefore, most of the perimeter is comprised of vertically cantilevered wide-flange steel beams oriented for stiffness.

The structural grid spanning the field of the skylight allowed for four-sided support of the glass panels. Thin, rectangular members (3 in. by 5 in.) are attached to block-shaped, forged nodes via a moment-resisting double-bolt connection concealed within the steel tube. This technology takes advantage of very tight tolerance production and the ability of the structural grid to be stiff enough to install without triangulation. Triangulation is later provided via post-tensioning before the glazing is placed. An additional advantage of the mechanically attached grid from an economic and quality standpoint is that it can be prefinished in the factory, eliminating field paint that is less reliable and more costly.

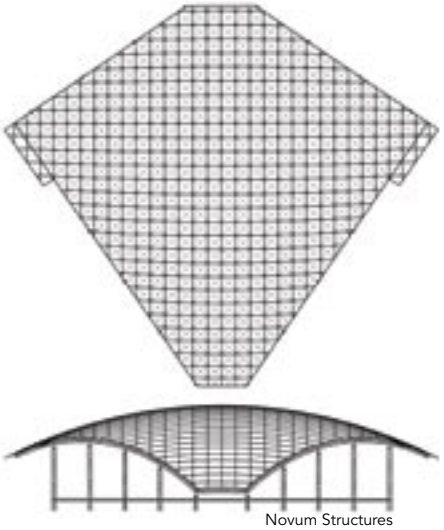
A Milestone is Met

The structure was erected from outside the building in multiple preassembled sections set onto beams and shoring towers established to support the shell at the correct temporary heights. Each new section is tied in the air to the previously installed portions. The extremely tight tolerance production available with the system allowed for the necessary, excellent fit. Then, tension cables were run below the structure and attached via the clamping devices and post-tensioned prior to glazing activities.

"[The skylight] is strong in both load of snow and weather on the top side, as well as uplift and suction from wind," says Todd Halamka, design principal/director of design with HOK. "It creates a very thin, very transparent, visually quiet structure to meet the goal we wanted to achieve for Wrigley: this simple, thin transparent membrane creating a year-round garden that feels like you're outside."

In guaranteeing a budget for the complete glazed structure, Novum took a single-source approach in engineering, sourcing, manufacturing, and installing the complete enclosure, including horizontal and vertical glazing, edge beams, the structural grid system, and all required post-tensioning materials.

The resulting glass and steel structure is an architectural beauty to behold. Its presence is tremendous, yet represents even more than meets the eye. As the enormous skylight in the William Wrig-



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A tilted spherical form and superimposed square grid helped to economize the use of glass panels for the atrium.

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Structural component system: an accessory system for the very elegant and lightweight tension stiffening of grids comprised of other Novum structural systems.

ley Jr. building is the first such post-tensioned steel shell ever built in the U.S., it's an appropriate accomplishment when considering the building's use as a Global Innovation Center.

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