Structuring Science

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A university in northern Minnesota turns to long-span trusses to support its state-of-the-art science building.

IN RECENT YEARS, THE UNIVERSITY OF MINNESOTA DULUTH (UMD) RECOGNIZED A SIGNIFICANT OBSTACLE TO ACHIEVING ITS VISION AS A PREMIER CAMPUS FOR SCIENTIFIC STUDY AND RESEARCH. In particular, the chemistry and life science buildings, 56 and 36 years old, respectively, were rapidly becoming outdated. Ventilation problems, safety issues, and a lack of modern equipment left the facilities inadequate to meet the needs of today's science students.

Along came Jim Swenson, a successful businessman and 1959 graduate of UMD. Swenson's deep gratitude for the education and guidance he received at UMD as a chemistry major prompted him to donate $7.5 million to help finance the construction of a new science classroom building. Named for its benefactor, the 110,000-sq.-ft James I. Swenson Science Building is the new home of the university's chemistry, fresh water research, and biology departments.

The university was presented with several building layout options and eventually selected a T-shaped three-story building. This option was selected as the best fit for the existing campus space constraints as well as plans for a new southern courtyard and wild rice wetland.

The 50-ft by 450-ft east-west wing houses sixteen teaching laboratories, which combines classroom and laboratory functions within the same space. The 60-ft by 150-ft north-south wing houses the research laboratories and is accessible only to designated students and faculty.

Settling on Steel

The structural engineer initially investigated three distinct structural systems for the main building wings: a wide module cast-in-place concrete system with concrete column frame action; a composite structural steel system with braced frames; and a hybrid of the two systems. Preliminary typical bay studies and details were submitted to the project cost estimator early in the process to determine the most cost-effective structural system. The design team eventually selected steel as the project's structural system, as it was deemed to be more economical in the initial estimates due to three driving factors.

First, the selected layout included an 80-ft span over Kirby Drive, a significant campus circulation corridor. This element was no trivial design exercise, as the entire span would be occupied by two stories of classroom and laboratory space with a

The skywalk structure (far left, above) consisted of trusses spanning approximately 76 ft with an 8-ft cantilever near the existing building.

design live load of 100 psf, plus an enclosed mechanical penthouse space at the roof. Due to excessive estimated formwork costs, a story-deep steel truss system provided greater project economy than post-tensioned concrete beams, along with a more attractive exposed structure.

Second, a ribbon window extends along 90% of the building's perimeter, requiring thousands of connections to support the building façade and window head and sill conditions. While connection to embedded plates in a concrete frame system would have been possible, the structural steel framing option provided a greater degree of flexibility during design and, during construction, required less coordination in the field.

Third, the architectural layout did not permit vertical alignment of the lateral force resisting system of the building. The offset orientation of bracing elements quickly eliminated masonry or concrete shear walls as practical solutions. The design team selected a combination of chevron and K-shaped braced frames over a concrete column frame option.

Final Framing Selections

One of the more significant framing challenges of the project was the design of trusses to carry the three-story, 80-ft span. The lower trusses are 16 ft deep, with bottom chords supporting the first structured level and top chords supporting the second structured level. Typical chord sizes are W24s and W21s with HSS8×8 and HSS6×6 web members.

The uppermost story consists of a mechanical penthouse. Due to the unusual curved geometry of the space, a central truss was designed to carry the penthouse floor and roof, similar to the two classroom levels below. At the spandrel (edge) condition of the low roof, 6-ft-deep trusses with W10 and W8 chord members and 3-in. and 4-in. double-angle web members were used.

The structural engineer designed all connections on the project, including the truss web and chord connections, and during the submittal phase of the project worked closely with the fabricator to work out final geometry of the truss and connecting elements. This effort was critical to the overall aesthetic success of the project, as the project architect did not conceal the full-story truss elements. Rather, the symmetrical beauty of the Pratt truss design was incorporated as a visual architectural element of the building.

The final gravity system in the majority of the classroom spaces consisted of a 4½-in. concrete slab over 2-in. composite deck (a total thickness of 6½ in.) spanning approximately 8 ft between W14 purlins. The purlins frame to W18 girders, supported by W12 columns. The building is supported on conventional spread footings. The final lateral force resisting system consists of HSS tubes arranged in staggered chevron and K-shaped layouts.

The Atrium

Other unique structural challenges on the project were associated with the feature bridge and wall in the student commons and atrium space located at the intersection of the two building wings. The layout included a 50-ft by 50-ft opening in the third floor with a special pedestrian bridge extending through the space. The architectural vision for the 5-ft-wide feature bridge was a single centered tube element beneath the bridge with outriggers supporting the full walking surface.

Due to deflection and vibration concerns, the engineer selected a built-up 26-in. by 20-in. tube section as the primary structural element of the bridge. The tube walls consisted of 2-in.-thick top and bottom plates and 1-in.-thick side plates.

The feature bridge spans from the north laboratory wing to the "double helix" exterior stairway that leads to the south courtyard. The stairway symbolizes DNA and the "science on display" theme permeating the building.

The 40-ft-high interior feature wall serves to attract people to the commons area. It also serves to collect natural light from the roof skylights and reflect it into the commons area. Sloping steel members support the architectural finishes in this unusual assembly space.

A further structural consequence of the atrium floor opening was to separate the building into distinct lateral load resisting systems. Each distinct area is designed to resist wind loads without significant contribution from the others. Strut elements surrounding the commons area provide redundancy in transmitting the load to adjacent frame elements.

Constructability Concerns

Because site constraints and the sprawling nature of the building prevented efficient use of a tower crane, the larger lifts were made with two "crawler" cranes. According to the general contractor, there were two lifts that were deemed "critical" on this project. (A lift is defined as critical if it exceeds 80% of the crane's tabulated capacity or is extremely complex.) The first such lift was

On the north and west sides of the building, one level is approximately 15 ft below grade. Cantilever retaining walls allowed for early backfilling, providing additional area for staging construction activities.

a skywalk linking the new Swenson building to the existing Life Science Building. The second was the "pick" of the feature bridge.

The skywalk structure consisted of two trusses spanning approximately 76 ft with an 8-ft cantilever near the existing building. The long span was required due to a network of underground utility tunnels present between the Swenson Building and the Life Science Building, which made placement of additional footings uneconomical. The lift had a difficult geometry due to the relative skew and elevation difference between the two buildings. The engineer detailed a 2-in. expansion joint that also provided erection tolerance between the end of the trusses and the existing brick face.

The feature bridge came to the site shop fabricated, with only the grating and handrail yet to be installed. With much of the building already erected, this was a tight lift: Only 1 in. of tolerance was allowed at the north end of the bridge. At the request of the contractor, the engineer designed a bottom flange extension on the adjacent wide flange beam to allow for a wider bearing surface for the bridge.

Construction Schedule

The north and west sides of the building perimeter are one story (approximately 15 ft) below grade, while the south and east sides are located at grade. Accordingly, the "walk-out" nature of the building creates large unbalanced earth pressures. Two options were considered for supporting these loads. The first was using the first-floor diaphragm to transfer this lateral force to the vertical braced bays. The second option, which was eventually selected, evaluated the basement walls as cantilevered retaining walls. This approach permitted the contractor to backfill large areas of the site early in the construction phase. Additionally, when backfilling was complete, the contractor had valuable additional space for staging of structural steel and other building activities. By anticipating construction issues, MBJ was able to facilitate the contractor's schedule and help bring the project to a timely conclusion in 21 months

Achieving the Vision

The structural steel framing system was fabricated and erected with few problems or unusual challenges. In fact, despite vandalism of the project site that caused more than $8.2 million in damages during construction, the James I. Swenson Science Classroom Building opened on time and under budget.

Structural steel provided a flexible and dependable building system for the project. The long-span trusses in particular were the perfect solution to a challenging and unique space, meeting owner expectations and the architectural vision. MSC

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