EMERGING TECHNOLOGY

Advances in building systems and materials

Bending steel to support unique designs

By Gordon Wright, Senior Editor

Unusual requirements challenged the designers and builders of two recently completed projects that incorporate exposed structural steel extensively.

The Rock and Roll Hall of Fame and Museum utilizes bowstring trusses to support its sloped glass wall. Other structurally related features include an auditorium that cantilevers beyond the main structure.

The Cockrell Butterfly Center's designers developed an unusual system of primary trusses that minimized the typical amount of bracing that was required on the interior of the structure. This lessens the possibility that butterflies will fly into structural members, injuring their delicate wings.

Aerial view of the Rock and Roll Hall of Fame and Museum in Cleveland highlights the sloped-glass "tent" that consists of two sections, one triangular and the other a parallelogram. This sloped curtain wall is supported by 16 bowstring trusses. Photo: Mort Tucker Photography

Rock and Roll Hall of Fame features bowstring trusses, cantilevers

The 143,000-sq.-ft. Rock and Roll Hall of Fame and Museum on Cleveland's lakefront, which opened in September, features a striking design by architect I.M. Pei that combines geometric forms and cantilevered spaces. It houses 50,000 square feet of exhibition space beneath a soaring "glass tent" that engages an eight-story, 165-ft. tower that contains the Hall of Fame.

The "tent," which slopes at a 45-degree angle to a height of 112 feet, consists of two sections. The primary section is a triangle, and the adjacent one is a parallelogram that is set back from the triangle. Together they extend the museum's atrium lobby to its 275-ft. width. The surface of the triangle is about 13 feet higher than that of the parallelogram. Both sections frame into an angled, 200-ft.-long truss — the triangular portion into its top chord and the parallelogram into its bottom chord.

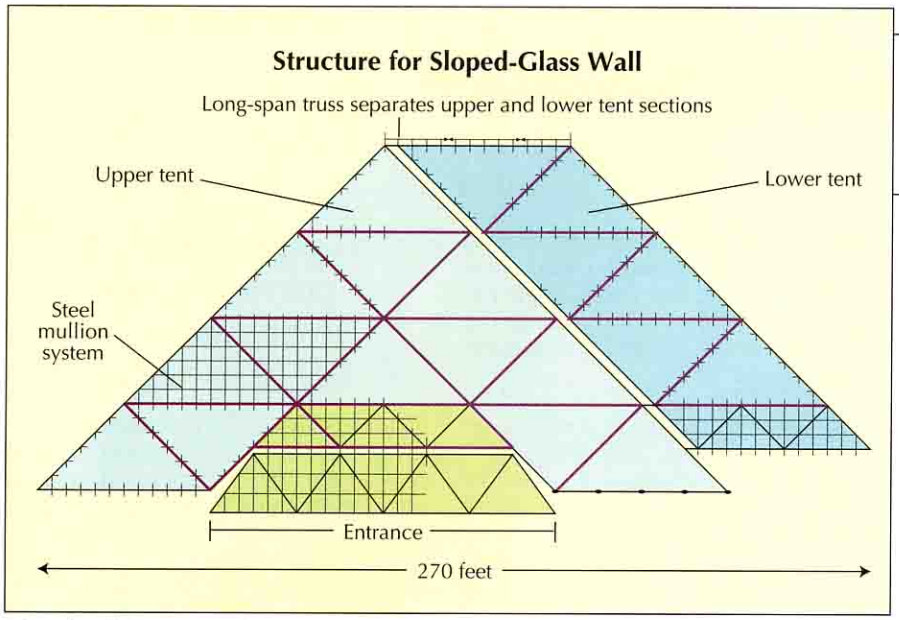
The sloped glass wall is supported by 16 bowstring trusses constructed of round steel tubing. These trusses, which are perpendicular to the glass, have flat top chords and curved bottom chords. The trusses provide support for a steel grid system which, in turn, supports the aluminum mullions for the glass. The two vertical glass walls of the tent area are supported by a framework of 14-in.-diameter exposed steel tubes.

The bowstring trusses vary in length from 54 feet to 162 feet and in depth from zero at their ends to a maximum of 6½ feet at their center. Top and bottom chords of 10-in. pipe are joined by diagonal members of 6-in. pipe.

Bowstrings provide double bonus

In addition to being an aesthetic feature, the bowstrings are efficient, according to Daniel Sesil, project manager with the project's structural engineer, Leslie E. Robertson Associates of New York City. This is because they provide the greatest strength and stiffness at midspan, where these attributes are most needed. Sesil compared the curve of the bottom chords to the surface that would result if a uniform pressure were applied to an imaginary flexible membrane attached to the edges of the tent.

Frank Hondlik, president of steel fabricator Kilroy Structural Steel Co., said the diagonal members of the bowstring trusses generally were welded to the chords at angles of less than 90 degrees. This, in combination with the curved chords and the relative shallowness of



The colored framing members indicate the locations of the bowstring trusses. The triangular and parallelogram sections of the sloping curtain wall are joined by an angled, 200-ft.-long truss. Plan: Leslie E. Robertson Associates

The museum's 75-ft.-diameter circular exhibit is supported by a single column rising out of Lake Erie. Steel plate girders attached to a steel ring at the top of the column cantilever outward to support the exhibit.
Photo: Mort Tucker Photography

the trusses, required the use of greater than usual precision for their fabrication.

David McQuaid, project manager with steel erector American Bridge Co., said the project was replete with unusual erection challenges. For example, as the tower framework was being erected, it had to be canted five-eighths inch from vertical so that it would be plumb when the load of the cantilevered auditorium was added.

The complexity of the museum's steel framing was evident prior to the enclosure of the building. The cantilevered auditorium is under construction at left, and the circular exhibit at right.
Photo: Schueman Architectural Photography

Preloads determined with weights

In order that the curtain wall would meet specified tolerances for location, the bowstring trusses were preloaded with ballast weighing approximately the same amount as the glass and mullion frames that would be erected later. After the entire tent was ballasted, the ballast was shimmed solidly to the ground. As dead loads were added to the structure, the ballast weight was transferred from the trusses to the ground. When all the curtain wall had been applied, the cables from which the ballast was suspended were nearly slack, and the weight of the ballast was fully supported on the ground.

Another quality-control requirement was to grind the welds of all architecturally exposed structural steel extremely smooth, since minute surface imperfections would be magnified when paint was applied, McQuaid said.

A 170-seat auditorium for live performances cantilevers from the main structure over Lake Erie. Its roof slopes both toward the lake and toward one of the auditorium's corners. The auditorium cantilevers 60 feet on one face and 80 feet on the other. The main truss that supports the auditorium is 14 feet deep, spans 130 feet and weighs 92 tons. Both a barge-based and a land-based crane were used for steel erection, McQuaid said.

The museum incorporates a 75-ft.-diameter circular exhibit, separate from the main tower but connected by a bridge, that is supported by a single concrete column rising out of Lake Erie. Steel plate girders attached to a 10-ft.-diameter steel ring at the top of the column cantilever outward to support the exhibit. The tower also is supported by a foundation rising from the lake.

Acknowledging the challenges of implementing the structural design, engineer Sesil observed that the erection of the Rock and Roll Museum's structure "wasn't like flying beam steel into place." The project required 1,925 tons of structural steel.

"The building was very complicated, and very tight," said Richard Diamond, project manager with New York City-based architect Pei Cobb Freed & Partners. "Because a lot of the structure is exposed, we had to be very careful about detailing," he said. Precise construction tolerances and close interaction between the architects and the structural engineers were critical, he noted.

The Rock and Roll Museum's general contractor was the Cleveland office of Turner Construction Co. in association with local firms Colejon Corp., Choice Construction Co. and Bradley Construction Co. The joint venture was awarded the base building contract on its $46 million guaranteed maximum price bid. The project cost, including land, fees and exhibits, was $84 million.

The project's associate architect was Robert P. Madison Inc. of Cleveland. Peter Arendt was the owner's director of design and construction.

Design, site complicated logistics

Summarizing the challenge of constructing the Rock and Roll Museum, Turner project manager Robert Celli said, "It's a unique structure and a lot of it is cantilevered. There are really no two pieces of the building that are alike."

The 4-in. by 7-in. steel tubes that support the curtain wall had to be aligned to within one-quarter inch to permit the curtain wall framing to be installed precisely.

Contractors had to follow the structural engineer's strict guidelines pertaining to sequencing construction. This involved, for example, pouring concrete on one side of the structure and making certain that full penetration welds were completed on the other side. Some full penetration welds of the bowstring trusses required two weeks to complete, McQuaid said.

The site — which is bounded by active streets on two sides, as well as the lake and a new science museum under construction — presented a host of logistical challenges.

"In designing this building, it was my intention to echo the energy of rock and roll," said architect I.M. Pei. "I have consciously used an architectural vocabulary that is bold and new." □