GRAND ENCLOSURE

The latest addition to the Opryland Hotel in Nashville is a 179,000-sq.-ft. skylight covering a large restaurant, man-made river and other attractions

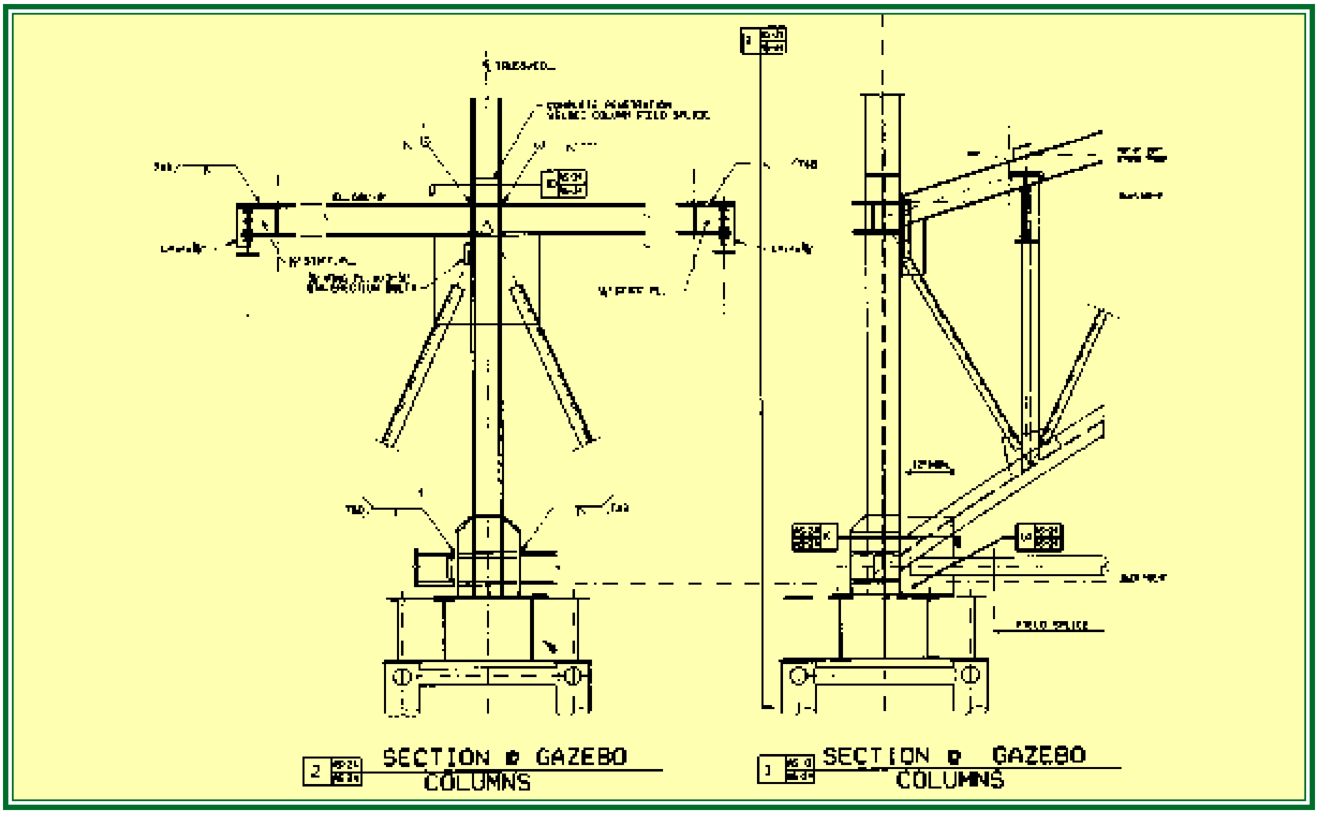
By James H. Parker, S.E., and Thomas C. Schaeffer, P.E.

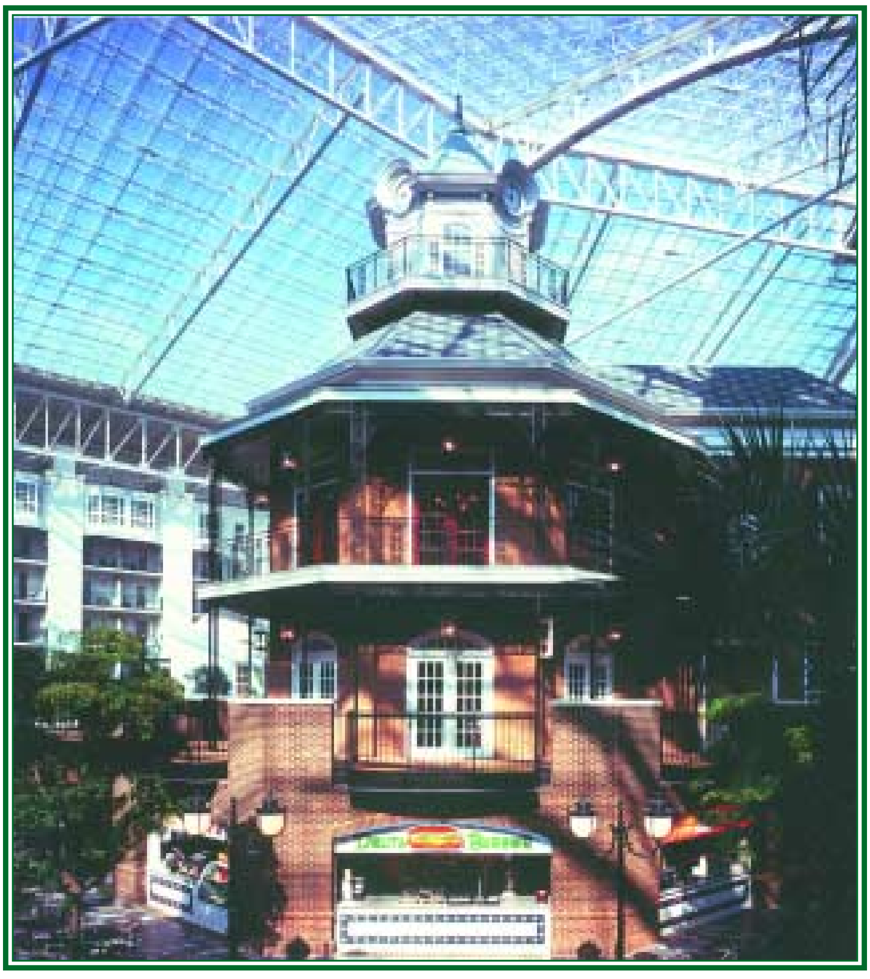
ONE OF THE LARGEST—AND MOST INTERESTING—HOTELS in the United States is the Opryland Hotel and Convention Center in Nashville. First opened in 1977, it has undergone three expansions, with the most recent one, known as the Delta, consisting of a giant, 179,000-sq.-ft., steel-framed skylight covering 4.2 acres.

Under the skylight is an antebellum mansion housing a 400-seat restaurant that overlooks a lazily flowing quarter-mile-long "river". The river runs around a New Orleans-style island village, complete with riverboat rides, retail shops, a jazz bar, food court and meandering walkways that connect the addition to the convention center and other areas of the hotel. Full-size trees—including a 40'-tall West Indian Mahogany—fit easily into

the landscape, as do fountains, a 110'-wide waterfall, and a wedding gazebo.

The owner, Gaylord Entertainment in Nashville, and architect, Earl Swensson Associates, also of Nashville, envisioned for the Delta a unique area designed to mesh with earlier additions to the hotel—the Cascades and Conservatory—while providing a new and different experience. After careful study of hotel traffic patterns, the addition was placed on the west side of the facility to serve as a connector between the convention center and the hotel. The goal was to give conventioneers and meeting attendees an environment "away from it all" to relax, grab a bite to eat, and unwind. In addition, it was also designed to accommodate other hotel guests and visitors, who





could explore the shops, people watch and take a lazy trip down the river. The use of full-grown trees, flowers and other foliage would enhance the feeling of outdoors. However, the soaring 15-story glass skylight is double-paned to ensure energy conservation, human comfort, safety and plant growth.

The challenge to the structural engineers at Stanley D. Lindsey and Associates, Ltd., was to provide a structural system to support the 4.2 acre skylight that would be aesthetically pleasing while also providing a column-free interior that would complement the roof lines of the Conservatory and Cascades areas.

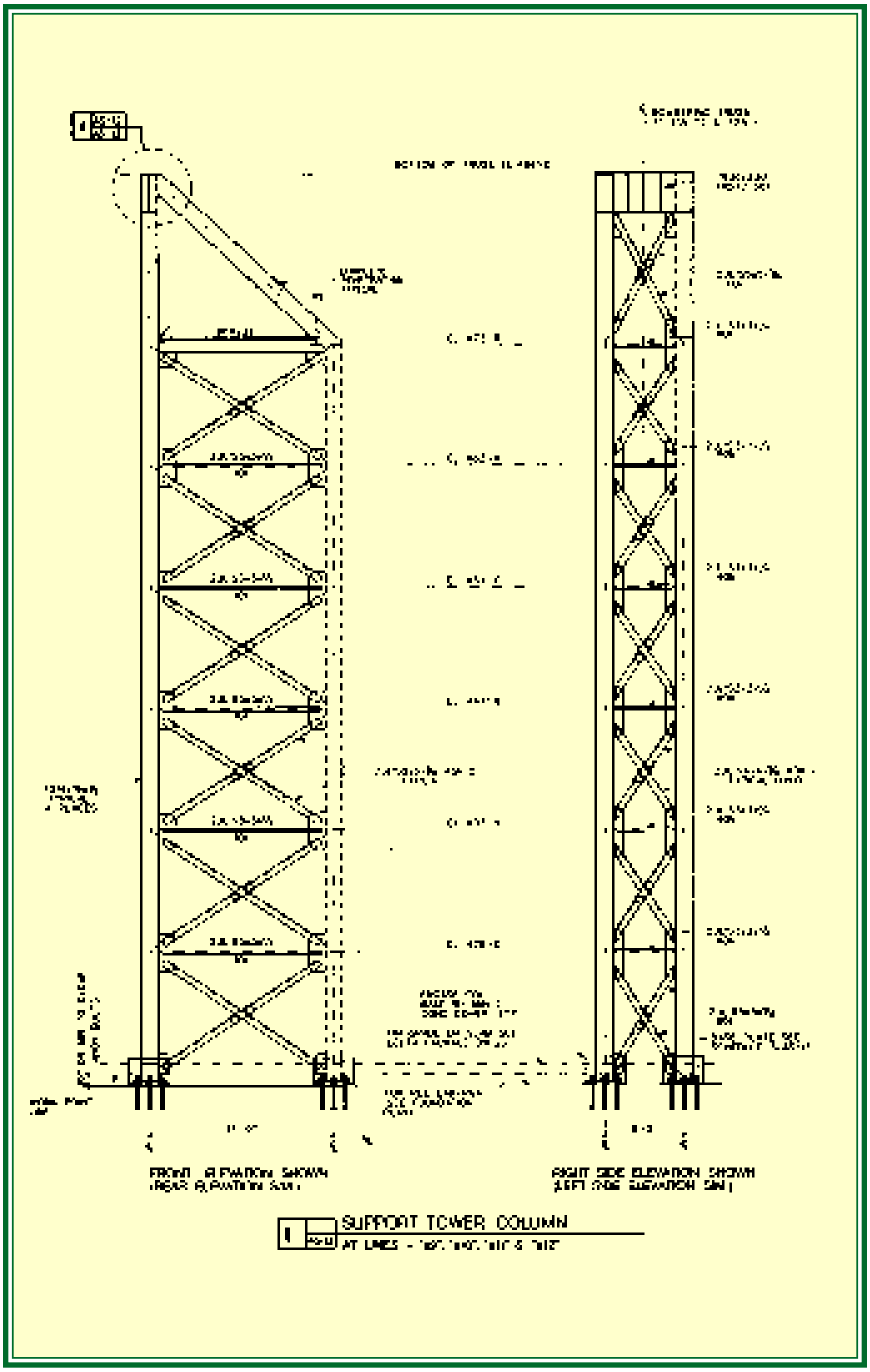
The resultant bar joist and tied-arch roof system is light and elegant, as well as structurally sound. The gabled top chord and circular arched bottom chord of the trusses are aesthetically pleasing and create a roof line that complements the adjacent roof areas. Additionally, the tied-arch truss configuration permitted the use of a shallower truss profile and also minimized the thrust forces at the supports. The support design was thereby more economical than other systems since the design was governed by lateral wind forces as opposed to thrust forces.

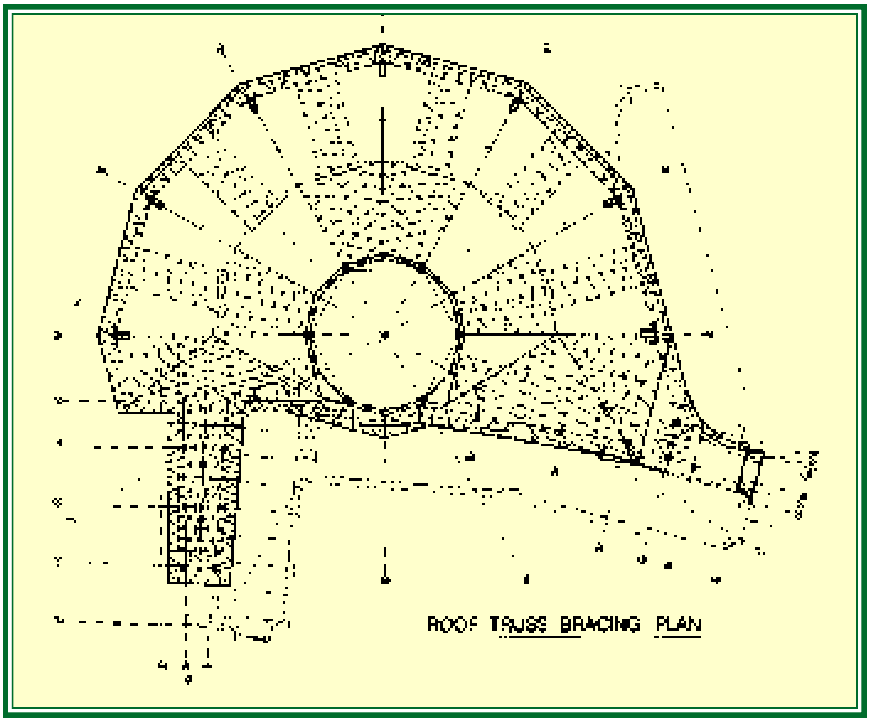
Structural Details

The design for the Delta roof evolved from the construction of the previous additions. The Conservatory roof consisted of long-span bar joists and truss girders supported by steel tube columns. Since a larger column-free space was desired for the Cascades, a system of tied-arch trusses spaced at approximately 27’ on center and spanning up to 165’ was selected. This structural system and concept for column-free space carried over to the new Delta skylight.

The complex structural system for the skylight is comprised of seven tied-arch trusses that radiate from a somewhat central gazebo structure. These tied-arch trusses clear span up to 214’ between the gazebo structure and X-braced, box-type vertical trusses at the skylight’s perimeter, which creates a distinctive column-free “interiorscape”. With tributary widths of approximately 100’, the tied-arch trusses’ member sizes are much larger than those of the Cascades. The top chord of the tied-arch truss is a W14 and the bottom chord is typically a W24. The curved bottom chord member is turned on its weak axis to minimize bottom chord bracing where this member is in compression. The tension tie member of the tied-arch truss is an 8”-diameter, double extra strong HSS.

Spanning between the ridge of the tied-arch trusses is a 10’-deep, parallel chord truss. The ends of the tied-arch trusses opposite the gazebo structure are tied together by two parallel chord trusses approximately 17’ apart. The ridge truss and perimeter trusses span between 100’ and 160’. The trusses are typically comprised of W14 top





and bottom chords, and double angle web members. These trusses support conventional truss girders spaced equally between tied-arch trusses. Bar joists, approximately 26" deep, frame between the truss girders to support the skylight system.

The Delta skylight has two hipped roof sections on opposite sides of the gazebo. A tied-arch truss is located at the ridge of the hip with parallel chord trusses framing into the peak to create the hip. The remaining framing in this area is similar to the typical roof area.

The gazebo is a 12-sided structure whose structural function is to support one end of the tied-arch trusses. In addition, the gazebo structure also resists a portion of the lateral loads from the roof structure. Architecturally, the gazebo was designed as a visual focus point. A 15'-deep ring truss at the tied-arch truss-bearing elevation acts as a tension ring to support gravity loads and resists lateral forces through frame action. Approximately 20' above this level is a second tension ring truss to support the gazebo roof. The compression ring at the top of the gazebo roof is a 24"-deep wide flange section fully welded together in a 12-sided "ring". Framing between the tension and compression ring are W24 rafters radiating from the top. A combination of wide flange sections and bar joists span between rafters supporting the skylight section. A smoke evacuation cupola comprised of wide flange sections frames on top of the compression ring.

The Delta skylight structure is bounded by previous construction phases not designed to support the new roof structure. Therefore, the roof structure is a completely independent structure supported by the gazebo structure and seven, box-type vertical shear trusses. These shear trusses use 16" square HSS and double-angle X-bracing to resist gravity and lateral loads.

The complex shape of the roof led the design team to enlist the services of the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario to perform a wind tunnel study to establish the actual design wind pressures. These wind pressures were used in the three-dimensional analysis and design of the structural members. The three-dimensional model also was used to distribute the lateral loads between the lateral resisting shear trusses and the gazebo. The in-house analysis and design program SANE was used to design the members.

The glass skylight system is incapable of acting as a diaphragm to brace the trusses and transfer lateral forces to the resisting elements. To create a diaphragm, a system of diagonal rod bracing in the plane of the joist top chord is provided. Compression forces are specified for the joist top chords, which also participate in the lateral bracing system for the roof trusses.

Fabricator on the $178 million project was AISC-member Wylie Steel. Erector for the 2,000-ton steel project was Structural Steel Erectors, Mt. Juliet, TN. Detailer was Steel Con, Inc., in Cordova, TN.

System Advantages

The tied-arch truss also is more economical compared to a conventional truss of similar geometry because the arch is typically in compression instead of bending, minimizing the material required. Turning the bottom chord compression member on its weak axis also allowed a larger distance between bracing points, reducing the amount of bottom chord bracing.

The tied-arch truss also is an efficient configuration for limiting the deflection of long-span members. Deflections of the structure had to be limited to satisfy glass deflection criteria and prevent leaks within the skylight system. The tied-arch trusses also participate with the supporting vertical box trusses and central gazebo structure to resist large gravity loads along with lateral wind forces.

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