Glass Acres

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Innovative steel designs for the massive atrium roofs at Orlando's Gaylord Palms Hotel create bright and airy spaces for guests to enjoy.

Hotel guests usually notice the size of their rooms, the quality of the bath towels and the friendliness of the staff; but rarely is the roof a major point of interest. However, when a hotel roof spans unsupported across a 10-story-high atrium for several hundred feet, and supports four acres of glass, perhaps some people will take note of the structural spectacle.

Such roof-gazing is entirely plausible at the new Gaylord Palms Resort and Convention Center in Orlando, FL, where guests have the rare treat of enjoying an airy, sunny, semi-tropical Florida environment—in an enclosed and air conditioned space. The $350 million Floridian-themed hotel surrounds three glassed-in atria with entertainment spaces for visitors. A huge two-acre atrium features towering palm trees, cascading waterfalls and mock historic buildings. Thornton-Tomasetti Engineers designed the structural systems of these atrium roofs with careful attention to both structural efficiency and aesthetic detail.

The resort was designed by architects at Hnedak Bobo Group of Memphis, TN, and structural engineer of record Uzun & Case of Atlanta, GA. The entire complex covers 60 acres and includes 1,400 guest rooms, 200,000 sq. ft of convention space and 150,000 sq. ft of meeting rooms, in addition to the facility's signature atria features. The central atrium is themed to recall the historic Florida city of St. Augustine, while smaller atria on either side resemble Key West and the Everglades. Each atrium includes spaces for public entertainment, shopping and dining. The boundaries of the atria vary from adjacent hotel buildings to glass walls and open clear spans.

SMALLER ATRIA

The Key West and Everglades atria posed several major engineering challenges for engineers. Each large roof covers an acre of land, and has continuous support only on the two sides nestled into the corner of an L-shaped hotel building. The third side runs parallel to the face of one of the main hotel

Opposite page: The Everglades Atrium features an acre of glazed roof. Four Pratt trusses, 11' deep, form the primary structure.

Left, top: The Grand Atrium contains 100,000 square feet of landscaped space under glazed canopy 150' above.

Left, bottom: Gaylord Palms Resort and Convention Center under construction. The Grand Atrium is the central feature of the resort.

buildings, and the fourth side bears on a 70 ft tall wall of windows subject to severe wind loads during hurricanes. Further complicating the design was an architectural requirement for a 150 ft by 170 ft, column-free space below the glass roofs. Super-efficient drainage also was required to prevent pools of water from collecting on the glass roofs during tropical cloudbursts.

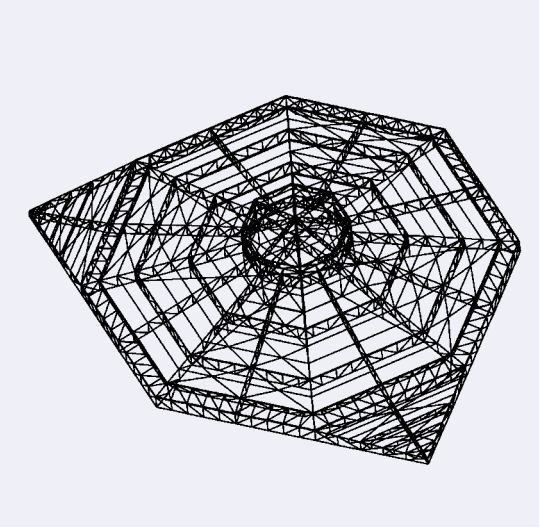
The resulting solution was a clean and simple one. Four Pratt trusses 11 ft deep form the primary roof framing. They are composed of steel wide-flange chords and verticals with double-angle diagonals, and span 150 ft from posts behind the glass wall to supports on the L-shaped hotel building. Triangular trusses of WT and wide-flange elements span 56 ft between the main roof trusses, creating three gabled roofs that provide good drainage. Guided bearings permit thermal movement and truss-end rotations where the roof framing rests on surrounding buildings. At the same time they resist forces due to gravity, lateral winds and uplift.

The glass wall is supported by 5-ft-deep vertical trusses of 6-in., 8-in. and 10-in. square steel tubes. This mix of sizes allowed for economical "stepped" welded connections suggested by detailing consultant Ferrell Engineering. The trusses are spaced at intervals of up to 19 ft, delivering wind loads to a ground-floor concrete base wall and to the atrium roof framing. Where the main roof trusses meet the glass wall, the vertical trusses are built in pairs and connected by "middle chords" for extra weight-bearing capacity to carry the roof.

THE GRAND ATRIUM

The central, St. Augustine-themed space, or "Grand Atrium," is significantly larger than the Key West and Everglades atria. It contains 100,000 sq. ft of ground-floor planting areas, streams, and walkways covered by a glazed canopy located more than 150 ft above. This roof presented the most complex design challenge of the entire project due to its tremendous size (spanning 364 ft between supports), atypical support arrangements and extreme loads. The canopy bears on the roof levels of the two buildings at the atrium's perimeter, eight to nine stories above grade. Because the canopy rests on two separate structures, it had to be designed to tolerate simultaneous movements in different directions while maintaining its shape. Moreover, its rooftop location places the glass canopy in an elevated and exposed position that subjects it to increased wind pressures. These pressures are at least 60 psf throughout the roof, rising as high as 80 to 120 psf in some areas for both inward and outward (uplift) directions.

The Grand Atrium roof takes the form of an octagonal faceted dome topped with a cupola. The radial ribs of the dome are tied arches that reach 46-ft deep at the center of the roof. Each rib includes a 13-ft-deep steel truss of wide-flange and double-angle members. The trusses carry roof framing and resist unbalanced loads. Beneath each rib, a wide-flange bottom tie member resists the dome's outward



Above: A schematic view of the framing for the Grand Atrium.

Right: Completed view of the Gaylord Palms Resort.

thrust, since the surrounding buildings are not relied upon to resist spreading. At the edge of the roof, circumferential trusses form a tension ring that provides additional resistance to spreading while also supporting joist and cross-truss infill framing that carries the glazed roof.

Stability against lateral buckling comes from both a 5/8 in. diameter steel rod X-bracing in four of the dome's facets, and a 14 ft wide horizontal perimeter ring truss. Unlike traditional dome structures that rely on infill material for structural behavior, the overall atrium roof will not be affected by damage to or replacement of any glass panels. The domed roof bears only on the eight corner points plus two more points at extensions beyond the octagon, so each bearing plays an important role. The bearings allow lateral movements of up to 5 1/2 in. in both plan directions, rotation of nearly 0.5 degrees, gravity loads of up to 425 tons and net uplifts of up to 163 tons. Working together with bearing supplier Cosmec, engineers developed unique and complex bearings for use on the dome.

Atop the Grand Atrium dome sits a 90-ft-wide glass cupola that expands the airy openness of the space. At its peak the cupola rises 28 ft above the top of the main roof. The design team worked to achieve a good balance among the openness below the cupola, lightness of structural framing and efficiency of the roof system. A compression ring at the base of the cupola could have kept it completely open, but the ring would have needed bulky steel framing to resist unbalanced roof loads. Bringing all eight ribs to the center would eliminate ring framing while creating a major barrier below the cupola. The solution was a system in which only four of the eight main ribs meet at a central hub. A light compression ring is included to receive forces from the four shorter ribs and from infill framing. This system provides a visually light and open appearance, resists unbalanced loads efficiently and allows for straightforward fabrication and erection.

ATRIUM CONSTRUCTION

Steel for the Grand Atrium dome was erected using a single, main erection tower, thanks to the roof's symmetric design. This avoided both the scheduling complications of relocating shoring during staged roof construction and the excessive localized deflections and stresses that can result from the use of temporary supports. The work of other trades could continue below the roof during erection thanks to close coordination with the engineers at Williams Erection.

All together, Thornton-Tomasetti's design, Williams's erection methods, FabArc Steel's fabrication and Southern Steel's detailing produced a quick, methodical system to fabricate, ship, stage and piece together the structural steel, joists and glass systems in only a few months. This allowed time-consuming landscaping work to move ahead under atrium enclosures and turn a construction site into miniature versions of St. Augustine, Key West and the Everglades. The openness of the atrium designs at Gaylord Palms provides bright and airy environments for the Floridian locales mirrored in Orlando's new hotel. And even if the hotel guests don't stop to look up and appreciate the roof that protects them from the central Florida weather, they are certain to enjoy the sunny, airy (and air conditioned) atrium spaces during their stays.

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