Show Stopper

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By Jaime E. Vasquez, P.E.

Innovative engineering and structural steel combined to provide nearly 1 million sq. ft of exhibit space with 180' clear spans for the Orange County Convention Center in Orlando, FL.

The Orange County (Florida) Convention Center recently completed its Phase V expansion, adding 3 million sq. ft to nearly double the capacity an existing facility. Constructed on 230 acres of land, the $748-million expansion includes approximately 1 million sq. ft of unobstructed exhibit hall space designed and built on an aggressive schedule.

The project was planned on a fast-track schedule, with only 42 months for design and construction. Through early coordination, the design team and construction manager devised a plan that reduced the risk associated with early packages. The strategy was to compress the schedule by prioritizing early construction documents based on the intensity of architectural coordination needed and the likelihood of revisions required after the packages were issued.

Early packages of structural components, influenced more by function than aesthetics, were completed and issued first. Aesthetic elements that required intensive design and coordination were issued last. Three months into the construction document phase, foundation permit drawings were issued. Construction started just six months after the start of schematic design. One month later, bid documents for the primary steel structure were issued, seven months prior to the completion of the construction documents phase.

Simplification, repetition and symmetry also helped meet the tight schedule. Complex geometry was reduced to simple symmetric elements that met the design intent. Detailing was simplified by including bending coordinates in the construction drawings as part of the geometry for the roof arches.

Construction-sequence studies indicated that the structure, approximately the size of 25 city blocks, should be divided into three distinct segments: The exhibit hall in the center, and North and South concourses. The 1,200'-long North and South concourses house lobbies, prefunction space, public circulation, meeting rooms and back-of-house support facilities.

Steel was an obvious choice for the long-span exhibit-hall roof trusses. 180'-long spans are only attainable with steel structures. The trusses provide support for the roof and mechanical penthouses, and they provide a rigging grid (bottom chord) for exhibit loads. In addition, structural steel was the only material that could efficiently frame the complex geometry of the entry lobby shells.

Trusses Go the Distance

The 18'-deep trusses spanning 180' in two directions are the backbone of the convention center exhibit hall. Secondary trusses, 180' long and spaced 30' on center, are supported by primary truss girders of the same length. They form 30 typical roof panels that cover the exhibit hall area. Continuity at the supports increases efficiency and makes this truss assembly

Above: The steel structure of the roof over North and South concourse takes a leading role in the finished architecture (inset, right).

Right, middle: The complex geometry of the sloping roof did not preclude the use of clean and relatively simple connections.

Right, bottom: Steel trusses, braced by movable erection towers, are assembled in the field.

behave as a space frame. Performance and efficiency were increased further by tapering the secondary truss top chords. Truss depth vary from 17′ at the center to 18′ at the supports. Tapered truss top chords also ease roof drainage. The truss system, in combination with the roof filler beams, weighs only 21 psf.

At the supports, truss girders connect to a box-column and base-plate assembly. The typical interior pre-fabricated assembly consists of steel-plate box columns flanked by 2″-thick gusset plates along the orthogonal axis, welded to round base plates, 8′-8″ in diameter. Using this plate assembly simplifies the problem of connecting the massive trusses with relatively large reactions to concrete columns. It also helps develop the rigidity needed by the steel/concrete hybrid moment frame. At expansion joints and expansion-joint intersections, 1′-wide voids along the column centerlines divide the concrete columns in halves and quarters respectively. At these locations, the expansion joints reduce the column cross section to the point that the base-plate assemblies cover the column cross sections almost in their entirety without leaving space for anchor rods. To transfer shear and uplift forces, steel box columns are welded to the underside of the base plates and embedded in the concrete columns.

The use of repetitive structural elements simplified detailing, fabrication and erection. Pre-assembled truss segments were delivered to the site and then assembled to complete the 180′-long roof trusses. The truss bottom chords support a network of steel catwalks totaling 2.8 miles in length that service the entire exhibit hall. They also support a steel rigging grid of 30′-by-30′ panels designed to support exhibit loads totaling 30,000 lb per secondary truss, or 60,000 lb per primary truss girder.

Mechanical and electrical equipment required to power and ventilate the 3-million sq.-ft facility are housed in three 60′-wide by 900′-long mechanical penthouses located on top of the exhibit-hall roof structure. One is located over the center and the other two along the north and south extremes.

The steel fabricator secured 19,072 tons of structural steel and more than 200 tons of bolts, and detailed the structural components in more than 10,000 shop-drawing sheets. The roof structure alone required approximately 8 miles of 18′-

Completed segments of the pedestrian bridges were assembled nearby and then trucked into place and erected during the convention center's limited down-time.

deep steel trusses and 36.7 miles of steel beams.

Let in the Sunshine

The exposed roof structure shelters the 80′-wide by 1,200′-long column-free lobby. The criss-crossing pattern of wide-flange sections extends to the main lobby entrances and meets with elliptical main roof shells. The roof structure also merges with the glass-walled front for daylight entry. The design concept braces the glass-front structure and provides lateral support to the concourse.

Intricacy of design was minimized through the use of three-dimensional computer models and renderings, which offered visual identification of opportunities and potential problems during design. The steel fabricator assembled a full-scale mock-up section of the roof structure to provide visual control of the finished structure and to identify and correct potential field fit-up problems.

Not a Shell Game

Each roof shell structures frames a 44′-tall glass portal, which cascades down to cylindrical, three-dimensional minor structures. These minor cylindrical structures straddle a steep-sloping roof surface that merges into exposed-steel bus canopies. These multipurpose shells are visual icons that direct the public to the main entrances.

The elliptical geometry of the roof shells is derived from angled cylinders with a truncated vertical face. The opposite end of the cylinder intersects a sloping roof plane. The geometry at both ends of the structure results in elliptical shapes. The roof shells are framed with 12″-deep wide-flange elliptical arches, equally spaced, that rise along the axis of the cylinder. The array of elliptical arches is laced with round HSS bracing members that complete the surface of the shell. Geometric coordinates of all the curved structural elements were included in the construction documents to simplify detailing and fabrication. The highest point on these structures rises more than 150′ above the ground floor.

For erection, the large elliptical voids through the two levels of framing below made scaffolding nearly impossible and costly. However, the design methodology simplified construction. The structure was assembled on top of a 36″-deep girder and curved along a sloped elliptical roof opening at the base of the shells. Its major axis is approximately 154′ long. Layers of steel arches and bracing members were erected slices at a time, and each erected segment became the erection platform for subsequent arch layers.

Pedestrian Pathways

Pedestrian bridges with minimal structural depth were provided to connect the new expansion to the existing convention center, more than 1,400′ away across International Drive. Profiles of the 200′-span sky bridges were required to match floor heights and provide vehicular access below. Walter P. Moore optimized the design and vibratory performance of these shallow structural depth bridges using time-history dynamic analyses with forcing functions appropriate for their intended use. Field vibration testing confirmed the calculated structural natural frequencies and acceleration values.

One of the bridge segments spans from the existing convention center across a pond, where it meets the second segment that spans over International Drive. On-going events in the existing convention center did not allow access to the construction crew, and daily traffic presented additional construction constrains. There were only a few hours when the intersection could be closed for any continuous length of time, typically from 8:00 p.m. to 6:00 a.m.

The project team executed a solution that made erection possible. The 200′-long segments were assembled in a staging area adjacent to the bridge's final location. Metal deck for the composite concrete deck and handrails also were installed. After assembly, the high-performance paint finish was applied. On the nights of erection, mounted on two mammoth crawlers, the pedestrian bridge segments slowly began their journey from the staging area, across International Drive and over the pond where construction crews waited. A few hours later, the bridge segments only needed to be cleaned before the paint finish was touched-up.

Steel Shelters

Y-shaped steel canopies flank the lobby. Sets of slim arms, spaced 15′ apart, cantilever from 15′-tall central round HSS steel supports. The slender look of each of these tapered arms was achieved with steel plate assemblies, radiused at the ends, with varying depth from 10″ to 20″. The 2″ width of the arm's cross-section consists of 1″-thick steel plates between two ½″-thick steel plates. These arms connect to rounded gusset plates mounted through the steel columns, to provide a total span width of 34′. A series of round pipes links the steel arms at the ends and also at mid length to provide torsional stability. Masts extend from every other column above the roof, from which stainless steel cables straddle to the tip of the arms.

Steel Made the Difference

Steel's versatility, efficiency, and aesthetic, combined with structural ingenuity and team collaboration made this proj-

Y-shaped exposed steel bus canopies are framed with tapered members.

ect a success. From the exhibit hall trusses and criss-cross framing in the concourses to attractive pedestrian bridges, steel stole the show. ★

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A joint venture:
Helman Hurley Charvat Peacock, Orlando
Hunton Brady Architects, Orlando
Thompson, Ventulett, Stainback and Associates, Atlanta

General Contractors
A joint venture:
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Clark Construction, Orlando
Construct II, Orlando

Structural Engineer
Walter P. Moore, Orlando

Structural Sub-Consultants:
Brindley-Pieters & Associates, Orlando
Martinez Kreh & Associates, Miami
TLC Engineering, Orlando

Steel Fabricators
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Addison Steel, Orlando (AISC, SEAA member)

Steel Erector
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Engineering Software
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