Aerial Innovations

Music City Masterpiece

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A curvaceous new convention center in Nashville evokes the city's musical prowess and natural setting.

NASHVILLE IS WIDELY KNOWN as "Music City USA," and when a new convention center was proposed by the city to replace the existing one, it was aptly named the Music City Center.

But the facility's connection with Nashville's country music heritage goes deeper than the name. (For example, the ballroom is shaped like a guitar, with curved outside walls extending throughout the building.) It also connects with the city's natural surroundings; Nashville is located in the rolling hills of middle Tennessee, and the architects incorporated the local geography into the design of the building. The eight-acre exhibit hall roof is curved in two directions, and half of it is a vegetated green roof to mimic rolling hills and mitigate storm water runoff.

The Music City Center, which opened in May, contains 1,200,000 sq. ft of occupied space and 900,000 sq. ft of enclosed parking for 1,800 cars on the 16-acre site. The building is one block wide and three blocks long, with Sixth Avenue passing under the building in a tunnel. The lower floors up to grade are reinforced concrete, and the upper floors and roof are framed with structural steel weighing in at just over 14,000 tons. The building consists of three primary elements—the exhibit hall, the ballroom and the grand concourse and entrance lobby.

Exhibit Hall

The architects, tvsdesign, had previously designed a building in China using pretensioned catenary cables as the bottom chord of the roof trusses, and they wanted to use a similar system for the 480-ft by 720-ft exhibit hall of the Music City Center. The structural engineer, RBA, evaluated

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Articulated W30 beams and columns and curved bar joists at the concourse roof.

A slightly different angle from left photo, with the 120-ft-tall, 36-in.-diameter columns in the background.

the system and determined that solid bars connected by a system of clevises would perform better as the bottom chord than would tensioned cables. The final design has the roof framed with 33 catenary roof trusses 240 ft long, and each catenary truss has a different profile to create the rolling hill effect. Some catenary trusses have straight, sloping top chords while others have segmentally curved top chords. Typical top chords are double W24×117 members and bottom chords are double 3¾-in.-diameter A354 bars segmentally draped to a curved profile. HSS10×0.375 members were used as king posts between the top and bottom chords. Truss depths vary from 16 ft to 22 ft and the trusses are arranged in three bays, with 11 trusses spaced at 30 ft in each bay and supported by 14-ft-deep rectangular steel trusses spanning 90 ft. The resulting column spacing in the exhibit hall is 90 ft by 240 ft.

The steel erector chose to assemble the catenary trusses in their vertical position on the exhibit hall floor slab and hoist them up 36 ft into place using four 110-ton strand jacks; they were assembled in three sets of three and one set of two for hoisting, with each of the three truss assemblies weighing 210 tons. The end columns and supporting trusses were used as a platform to mount the strand jacks, and the columns were configured to facilitate lifting and fit-up. The steel column is a built-up section of two W24 shapes ranging in size from W24×131 to W24×370. The two W24 sections are connected by a ⅝-in. web plate 48 in. wide. After erection, the steel sections were encased in a 72-in. by 48-in. concrete column to resist lateral loads as a part of a truss moment frame. The steel erector developed an innovative way to hold the plumb posts temporarily that allowed the top chord arched beams and the bottom chord rod members to be assembled around the plumb posts. The trusses do not have any diagonal web members that are normally used to stabilize the truss during assembly.

The catenary trusses cannot resist net uplift forces; therefore, the weight of the green roof was an important element in the design and the area was reduced from 350,000 sq. ft to 175,000 sq. ft. The roof was analyzed to determine the location of maximum uplift forces due to wind, and the green roof was located in those areas to provide proper ballast.

Ballroom

The 210-ft by 270-ft clear span ballroom is shaped in plan like a guitar. Many of the columns also slope and the sloping columns were evaluated for eccentric loads, and drawing sections were cut at 15-ft centers around the ballroom to confirm the geometry. The floor and roof members were erected with a combination of cranes: two tower cranes located within the footprint of the building and two hydraulic truck cranes located on the exhibit hall floor slab, and multiple hydraulic truck cranes at grade outside the building.

The ballroom roof consists of seven 270-ft-long 21-ft-deep rectangular trusses spaced at 30 ft on center. The entire area of the ballroom floor level was left open during construction of the roof. The seven roof trusses were assembled in one set of three trusses and two sets of two trusses on the exhibit hall floor slab, then hoisted vertically almost 100 ft by four 110-ton strand jacks to their final location. The steel bar joists, vertical bracing and horizon-

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▲ Exhibit hall roof trusses and columns.

◄ Exhibit hall roof columns at the base.

tal bracing were installed in the assemblies before hoisting to minimize work in the air. The three-truss assembly weighed in at 400 tons, and every truss section, crane pick and crane outrigger placement was engineered to ensure the exhibit hall floor slab was not overloaded. The engineers also designed special horizontal bracing to distribute lateral forces imposed on the building around this large opening during construction.

After the roof trusses were hoisted and placed, hydraulic truck cranes came in underneath the roof steel and erected the heavy ballroom floor steel trusses over the exhibit hall floor slab, a project in and of itself. The 90-ft by 90-ft two-way trusses were designed as continuous trusses to increase the natural frequency to over 6 Hz to reduce the perceptible vibrations in the ballroom. Bell-Clark JV established an extremely tight schedule of having the 7,000-ton ballroom erected, detailed and decked in six months; the erector worked seven days a week and achieved that goal.

Concourse and Lobby

The grand concourse consists of pairs of 36-in.-diameter pipe columns varying in height from 40 ft to 120 ft and 58 40-ft-long W40×199 cantilever beams around the north and west sides of the building. The entire

▲ Ballroom roof truss assemblies in position.

➤ Ballroom trusses with exhibit hall column.

roof of the building is a wavy roofline and this is most noticeable in the grand concourse. The curviness of the roofline made erection more challenging since very few things were level and at right angles. The entrance lobby has a series of curved vertical columns that act as the featured architectural element in a building laced with architectural elements. The original design called for vertically curved outside walls with interior columns, but the architects wanted to remove the interior columns. The structural engineers responded by designing vertically and horizontally segmented beam/column elements using the heaviest W30 shapes available to create this column-free space.

Horizontally curved walls around the ballroom and the exterior of the building were created using horizontal W10 and W12 purlins spanning 30 ft between columns. The outside flange was removed, the web was cut to follow the curved pattern and a ¼-in. plate was welded to the web to create the final curved shape. Type B steel deck was placed spanning vertically between the purlins to conform to the curve.

The facility has hit the ground running. By the time it opened just a few weeks ago, more than 120 meetings had been booked. This represents more than one million hotel room nights—exactly what the owner wanted. MSC

Owner
Metropolitan Government of Nashville and Davidson County

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