Convention center's bold architectural style is supported by creative structural engineering.

One Challenge, *Several* Answers

BY GREG DIANA, P.E.
PHOTOS BY DATUM ENGINEERS

THE NEW IRVING CONVENTION CENTER at Las Colinas is at the intersection of Northwest Highway and John Carpenter Freeway in the heart of Las Colinas, Texas. It is visible from the Four Seasons Resort and Club and its championship golf course, immediately across the highway, where the Byron Nelson Championship is played every year. The city wanted to take advantage of this prominent location with its high visibility to market the use of the facility.

The owner's goals were to obtain statement architectural expression and an identifiable landmark structure with high visibility while maintaining optimal functionality of their marketable space. The building's architects, RMJM (formerly Hillier), provided a striking stacked and rotated design that accomplished the owner's goals in an exciting way.

The master site plan includes the convention center and parking garage, along with a 350-room hotel and a 190-room boutique hotel, due to complete construction in 2011, plus a future performing arts center, residential, and retail space. The lower podium contains the main exhibit hall, along with office and mechanical space. The exhibit space is approximately 190 ft by 270 ft, column-free, with 35 ft of clear headroom above the exhibit floor. The office space is divided between the main floor level and a mezzanine. The mechanical space is on an additional mezzanine level above the office space.

The native soil in Las Colinas is highly expansive, with potential vertical rise (PVR) values in excess of 5 in. However, because large areas of the exhibit floor space are open, with no sensitive finishes, partitions, or doors, engineers used a mix of foundation systems for the ground floor structure. In the large, open exhibit space, a slab-on-grade foundation over 12 ft of moisture-conditioned soils was used. This reduced the predicted heave due to expansive clay to 1 in. and allows the exhibit floor to economically support 350 psf live loads. A structured pan-joist system over a crawl space was used in the main entry lobbies, prefunction space, first floor office space, and other ground floor areas with sensitive finishes and lower live load requirements to isolate the floor structure from the highly expansive soils.

The upper building structure contains two additional floor levels. One level supports 20 meeting rooms, each approximately 1,000 sq. ft. Eight of the meeting rooms are created using moveable partitions, which, when opened, create a 60-ft by 120-ft junior ballroom to allow greater flexibility for use of the floor space. The top floor is primarily for the main ballroom. The column-free ballroom is approximately 115 ft by 180 ft, plus a separate prefunction area. This level also contains the kitchen space and a mechanical mezzanine. The elevated structure is rotated 20° from the orthogonal podium grid, causing the corners to cantilever out beyond the lower building spaces.

◄ The 20° rotation of the upper portion of the Irving Convention Center with respect to its base creates a stunning, signature presence, leveraging its high-visibility location.

Between the podium and the upper structure, an outdoor terrace level connects to the ground level below and the meeting level above via exterior stairways. This terrace level also cantilevers above the two main glass entrances in the southwest and southeast corners of the podium. An interior/exterior concrete elevator tower serves all floors and creates part of the architectural expression.

The podium and elevated structures are clad on all sides with a combination of embossed and perforated copper paneling. These perforations create a lantern effect on the south facade, causing the illuminated interior to shine through the perforations and silhouetting the exterior steel structure behind the copper panels. The perforations also create a view from the interior to the surrounding skyline.

Engineering Considerations and Project Goals

Two key goals had to be met to make this project a success:

- Meet the owner's budget challenges while providing the architect's unique design, without sacrificing building performance or functionality.
- Provide the building to the owner in time for the required opening date.

Early in the design phase of the project, the building construction cost estimates exceeded the owner's construction budget of $85 million by 25%. The design team needed to eliminate cost from the building without impacting the function of the various building spaces and uses. During this phase, engineers worked to economize several key areas of the structure.

Additionally, the owner wanted to begin preselling the space up to two years prior to the building opening date. This required a commitment from the entire design and construction team to meet the aggressive opening date long before construction documents were issued.

The structural engineer worked with the owner and design team to create a strategy for achieving both of these goals, while also improving the building's performance.

Solution 1: Long-Span Elevated Floor Structure

The stacked-and-rotated design meant that multiple floors, plus the roof, would have to be supported above the column-free exhibit space on the first floor. In order to achieve this, Datum-Gojer proposed a system of long-span trusses on a 30-ft module. The trusses span the 190-ft direction of the exhibit floor.

The initial pricing was based on conventional truss shapes of various depths, up to 20 ft. It quickly became apparent that this concept would require more steel and possibly not achieve adequate deflection and vibration performance. It would also require A993 Grade 65 high-strength steel, which would need to be imported. Given the lead time for the high-strength steel and the cost associated with the extra tonnage, these conventional structural systems negatively impacted both the budget and the construction schedule. In order to make the supporting structure deeper, the building would have to grow taller vertically, which would create additional cost in copper skin and mechanical systems for heating and cooling the larger volumes.

The engineer began exploring structural steel options that would both eliminate the need for imported steel and reduce the tonnage. The first proposal was to use a set of segmented catenary trusses. Rather than being limited to the space below the meeting level and above the 35-ft exhibit headroom, this proposal would extend the structural system to the ballroom level, creating a structural system that would be 35 ft deep rather than 20 ft deep. The added depth also would improve vibration and deflection performance. The primary disadvantage of this system was the disruption that the catenary chord would cause to the meeting room floor spaces, which the architect would need to work around.

The second proposal was to use arch trusses that would extend to the underside of the ballroom level, similar to the catenaries. This system had similar advantages to the catenary—similar steel tonnage required, improved deflection performance over conventional truss systems, and all domestically-produced steel. The main disadvantage was also the same—the overhead arch chord would disrupt floor space on the meeting level.

The solution was to use a combination of these two truss options. The majority of the floor is supported by three catenary trusses, spaced at 30 ft to 60 ft on center, along with one arch truss at one end. The catenary truss chords are located between meeting rooms and in back-of-house spaces and away from useful floor space. This approach coordinated the structural and architectural requirements to reduce the disadvantage of the deeper catenary trusses. On the west end of the floor, the catenary would have extended outside the building; therefore, the arch was used on this end. This combined solution eliminated approximately $3 million from the construction budget and allowed the use of all domestically available structural steel, while also improving deflection and vibration performance. In order to reduce sway due to unbalanced live loading conditions, additional diagonal bracing was provided within the truss, below the meeting room level and in the exposed exhibit ceiling space.

▼ This deep catenary-like truss is one of three spanning the 190-ft direction of the new Irving Convention Center's exhibit floor.

Greg Diana, P.E., is a structural engineer in the Dallas office of Datum Engineers. He joined the firm in 1999 and currently serves as project manager. His project experience includes convention centers, healthcare, churches, and higher education facilities. Greg holds a bachelor's degree in civil engineering from the University of Texas at Austin.

Three catenary trusses support the majority of the floors above the exhibit hall, with an arch truss at the end of the building where the catenary would have extended outside the building.

Solution 2: Long-Span Roof Structure

The second challenge was to reduce the required tonnage on the four perimeter trusses clad in copper and supporting the high roof. The rotated grid at the upper structure caused the four corners of the building to cantilever beyond their supports. The layout of the occupied spaces also greatly reduced the number of support locations that extend to the ground without interrupting the various occupancies within the building. Finally, three of the four corners are upturned and all four corners cantilever, and the architectural look prevented the use of supports at the corners.

After studying column opportunities on each floor, four column locations were identified that would make the box stable. However, the southeast face of the elevated structure remained unsupported, spanning almost 300 ft. To reduce this span and improve deflection performance, a fifth support was needed. Datum-Gojer decided to make use of the architecturally exposed concrete elevator core. Using a truss to cantilever from an interior column, over the concrete elevator core, and out to the southeast face of the elevated structure reduced the span of the southeast truss to 190 ft.

Given the exposed nature of the exterior trusses from the interior and through the perforated copper cladding from the exterior, the architect was greatly interested in the exterior appearance of the trusses. The truss web members needed to be coordinated with the regularly-spaced copper panel joints as well as the randomly located column supports. Over several weeks involving both architectural and structural input, a truss layout was devised that met both the structural and the architectural requirements.

Because each of the four corners cantilever, the bottom chord is in compression and requires midspan support. However, the four perimeter trusses extend below the ballroom level but not to the meeting room level, with the steel below that cantilevering beyond the structural bottom chord. The bottom chord of the truss is pulled away from the fourth floor structure, so struts were used to brace the compression segments of the bottom chord back to the structure.

These trusses vary in overall depth from 20 ft to 62 ft, with a maximum structural depth of 42 ft. The upper box is 282 ft by 296 ft, and the longest cantilever is 117 ft. By working directly with the architect, Datum-Gojer was able to reduce the structural cost by more than $600,000 while keeping the building's exterior appearance intact.

Solution 3: Terrace and Main Entries

Early architectural renderings of the two main entries showed the entry glass spanning from the ground floor to the soffit of the terrace level without additional structural backup. While the most economical way to frame this would have been to introduce structural columns behind the glass to create a conventional beam-and-column floor system, the added elements would have greatly disrupted the architectural appearance. To avoid the additional columns, the engineer proposed to cantilever the floor structure at these two corners.

The concrete elevator core provides a fifth support point on the south side of the structure, reducing the required truss span from 300 ft to just 190 ft.

Cantilevering the floor structure over the two main entries allowed the area to remain column-free.

➤ Many of the convention center's steel connections, particularly in the perimeter trusses, are very complicated.

Because the longest cantilever is approximately 153 ft, the bottom chord of the truss would see a significant compression force. The bottom chord of the trusses also creates the soffit of the entry and braces the copper cladding and entry glass under wind loading. Therefore, a horizontal bracing truss was provided in the soffit behind the main bottom chord to reduce the unbraced length of the main truss cantilever bottom chord and to take the imposed wind forces. A 3-in. deflection joint was provided at the head of the curtain wall to isolate the glazing system from the long cantilever support structure above. This system allowed the architect to economically maintain the desired appearance at the primary front door to the building.

Solution 4: Long Spans and Vibration Control

The long-span floor support conditions created a need for serious study of vibration. The engineer, along with the contractor and steel fabricator, reviewed and considered several structural floor-framing systems: normal weight versus lightweight concrete floors, purlins spaced at 7ft 6 in., 10 ft, and 15 ft, and conventional wide-flange versus castellated beams. The vibration performance for the meeting room and ballroom occupancy and building uses also needed to be weighed against the costs associated with providing a stiffer structural system.

The engineer proposed using castellated beams at 15 ft spacing with a lightweight concrete slab. This system provides improved vibration performance for the same structural cost as a similar wide-flange system. The lightweight concrete slab could be thinner than a normal weight slab and still achieve the required two-hour fire separation. This change alone resulted in significant savings to the overall project because the heavier, normal weight floors would have required more steel tonnage and larger, deeper piers. Additionally, the increased purlin spacing reduced the number of steel pieces, decreasing fabrication and erection time while improving vibration performance.

Solution 5: The Fast Track Process

At the end of the design development process, the design team met with the owner, contractor, and steel fabricator to discuss the budget and the remaining schedule. The contractor stated that to meet the owner's required opening date, the building would need to be issued for construction in just seven weeks. Given the level of completion of the design at that time, along with the complexity of the building, everyone agreed that was an impossible task.

While brainstorming ways to meet the owner's schedule, the engineer noted that certain elements of the project were time-critical. In particular, the concrete and foundation elements required only a minimal amount of time from design to construction, while structural steel procurement, fabrication, and delivery would require far more lead time. Additionally, not all of the steel would be required on the first day of construction as steel erection was scheduled to take several months. The length of time between the first steel order and the last steel delivery allowed the steel to be issued in multiple packages.

The design and construction team agreed to issue a minimum of 60% of the steel tonnage for mill order within the contractor's seven-week window. Engineers worked with the steel fabricator to determine the longest lead items for fabrication, while also working to complete and provide steel based on the sequence of erection and the erection timeline provided by the steel erector. Through this process, the engineer was able to issue 90% of the steel tonnage in the first mill order package.

The mill schedules indicated that certain shapes would be closing well ahead of the seven-week window. In particular, column sections in the W14×90 through W14×132 group would close at the end of four weeks. The following week, W36×231 through W36×441 would close. These two early mill closings meant that design of columns and floor trusses would need to be completed after only four and five weeks, respectively.

Subsequent to the mill order package, the design team issued several other advanced bid, permit, and construction packages, including foundations, concrete, and miscellaneous metals. The engineer also issued weekly detailing packages, one sequence per week, for the mill-ordered steel until the final "Issued For Construction" package was sent. This process allowed the steel fabricator to begin issuing shop drawings well ahead of the for-construction drawings. Approximately 15% of the steel on the project was reviewed, approved, and in fabrication prior to the final construction package.

Conclusion

The project is currently under construction and on schedule to be completed in January 2011. The solutions provided by Datum-Gojer were instrumental in maintaining the construction schedule. In addition, the construction cost was significantly reduced from the original construction cost estimates. The building is now well within budget, and the structural solutions played a key role in achieving the necessary savings in addition to contributing to the owner's desire for an identifiable landmark facility. MSC

Owner's Representative
Beck Group, Dallas

Architect
RMJM (formerly Hillier), Princeton, N.J.

Structural Engineer
Datum Gojer Engineers, LLC, Dallas (Datum Engineers and Charles Gojer & Associates)

Steel Fabricators
North Texas Steel, Fort Worth, Texas (AISC Member)
W&W Steel, Oklahoma City, Okla. (AISC Member)

Steel Erector
Bosworth Steel Erectors, Inc., Dallas (AISC, IMPACT and SEAA Member)