Project Profile:

Irving Convention Center

The Art of Structure

By Thomas Taylor, PE, Datum Engineers Inc.

The 275,000 sq ft Irving Convention Center, in Irving, TX is recognized for its unique architecture and vertical design. Located in a highly visible stretch of North Texas, the City of Irving wanted to make the most of its prominent location by creating something truly unique – and unique, it truly is.

The building's architect, RMJM North America stayed true to the owner's goals: create a distinctively identifiable landmark structure while maintaining optimal functionality of their marketable space. The building meets these goals in an exciting way. Designed as two boxes, stacked and rotated to create cantilevered corners that offer shaded outdoor areas, the majority of the building is surrounded in glass. It is also curtained with a perforated copper façade that will age to a natural copper patina. This provides not only a distinctive appearance, but also reduces energy consumption. The facility has received a LEED (Leadership in Energy & Environmental Design) Silver certification. The master site plan includes the convention center and parking garage, along with a 350-room hotel and a 190-room boutique hotel, plus a future performing arts center, and residential and retail space.

The native soil in Las Colinas is highly expansive, with a 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 was poured over 12 ft of moisture-conditioned soils. This reduced the predicted heave due to the 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, pre-function space, first floor office space, and other ground floor areas with sensitive finishes and lower live load requirements.

The elevated structure is rotated 20° from the orthogonal podium grid, causing the corners to cantilever out beyond the lower building spaces. 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.

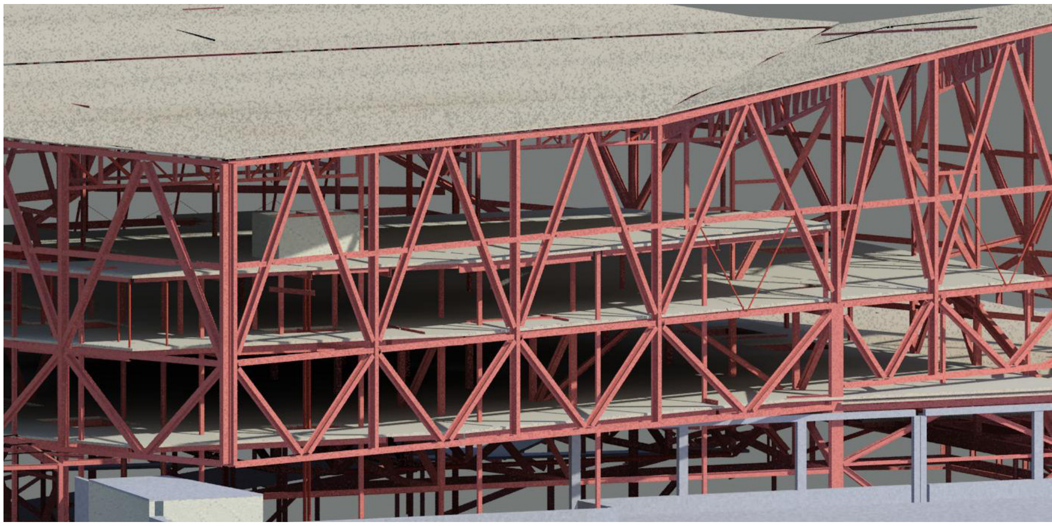
The podium and elevated structures are clad on all sides with a combination of embossed and perforated copper paneling. These perforations create a lantern effect on the south façade, causing the illuminated interior to shine through the perforations while silhouetting the exterior steel structure behind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

Early in the design phase, 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 functionality. During this phase, Datum worked to economize several key areas of the structure. Additionally, the owner already had a convention commitment and wanted to begin pre-selling 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.

Datum's Proposed Process

To meet the tight schedule, the contractor wanted structural drawings issued in just three months. Everyone realized this was unrealistic on such a complex project. Datum was called to a meeting with the owner, contractor, subcontractors and the architect to confirm the schedule could not be met – a decision that would likely kill the project.

Datum asked the steel erector to explain how long it would take to erect the steel and also how the erection would be phased. The answer was seven months of erection, in five phases. We then suggested that they could deliver one phase in three months and one phase per month for five months.



This approach was highly applauded, allowing the project to proceed and to be completed in time for the first scheduled event.

The Art of Structural Engineering

Throughout the structural design process, Datum engineers came up with various unique project solutions. Below are four that offer valuable insights into the way that engineers solve difficult problems.

Solution 1: Create Super Strength in a Long-Span, Elevated Floor Structure

The stacked-and-rotated building design required that multiple floors plus the roof be supported above the column-free 190 ft x 270 ft exhibit space on the first floor. In order to achieve the required strength, Datum proposed a system of long-span trusses on a 30 ft module over the exhibit floor. The trusses spanned 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. 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.

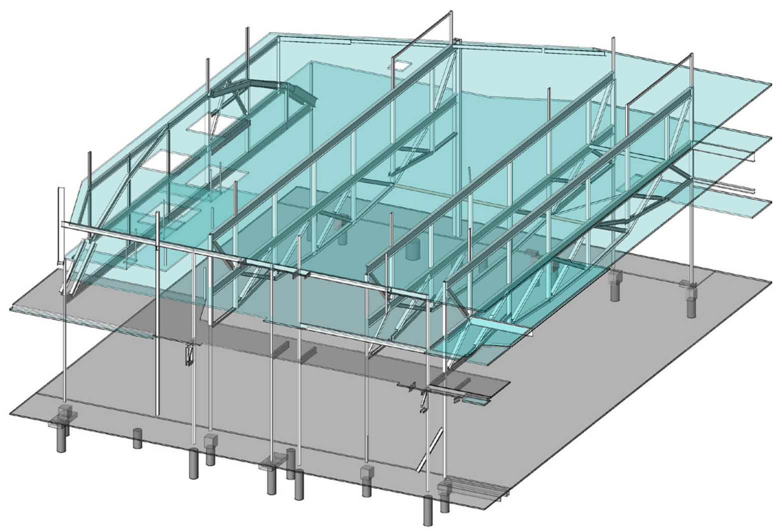
In order to make the supporting structure deeper, the building would have to grow taller vertically, which would create additional cost in copper skin, and mechanical systems for heating and cooling the larger volumes.

All these challenges led Datum to explore additional structural steel options that would both eliminate the need for imported steel and reduce the tonnage. Our first proposal was to use a set of segmented catenary trusses. Rather than being limited to the 20 ft 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 could cause to the meeting room floor spaces, which the architect would need to work around.

Our 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 could 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 that end.

This combined solution eliminated approximately $3 million from the construction budget and allowed the use of all domestically available structural steel —all while also improving deflection and vibration performance. We also designed a solution to reduce sway due in unbalanced live loading conditions. We recommended diagonal bracing within the truss, below the meeting room level and in the exposed exhibit ceiling space.

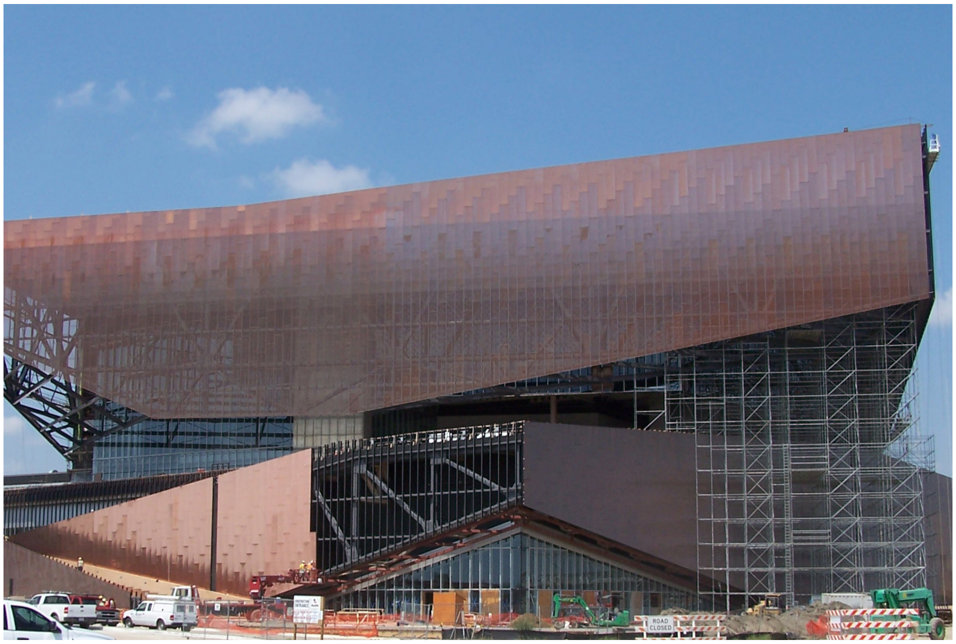


Solution 2: Architects & Structural Engineers Partner to Solve Long-Span Roof Structure Challenges

The second challenge was to reduce 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 occupancies within the building. In addition, three of the four corners are upturned and all four corners cantilever. The architectural appearance 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 decided to make use of the concrete elevator core. The architect then exposed the concrete walls that express their structural relevance.

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.

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 was able to reduce the structural cost by more than $600,000 while keeping the building's exterior appearance intact.

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Solution 3: Terrace and Main Entries: Solving Wind & Compression Force Issues

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 greatly disrupt the architectural appearance. To avoid the additional columns, Datum proposed to cantilever the floor structure at these two corners.

Because the longest cantilever is approximately 153 ft, the bottom chord of the truss could create significant compression force. The bottom chord of the trusses also creates the soffit for the entry and braces for the copper cladding and the 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. Datum proposed a 3 in. deflection joint at the head of the curtain wall to isolate the glazing system from the possible deflections of the long cantilever support structure above. This system allowed the architect to economically maintain the desired appearance at the primary building entrances.

Solution 4: Long-Spans and Vibration Control: Saving Money & Solving Problems

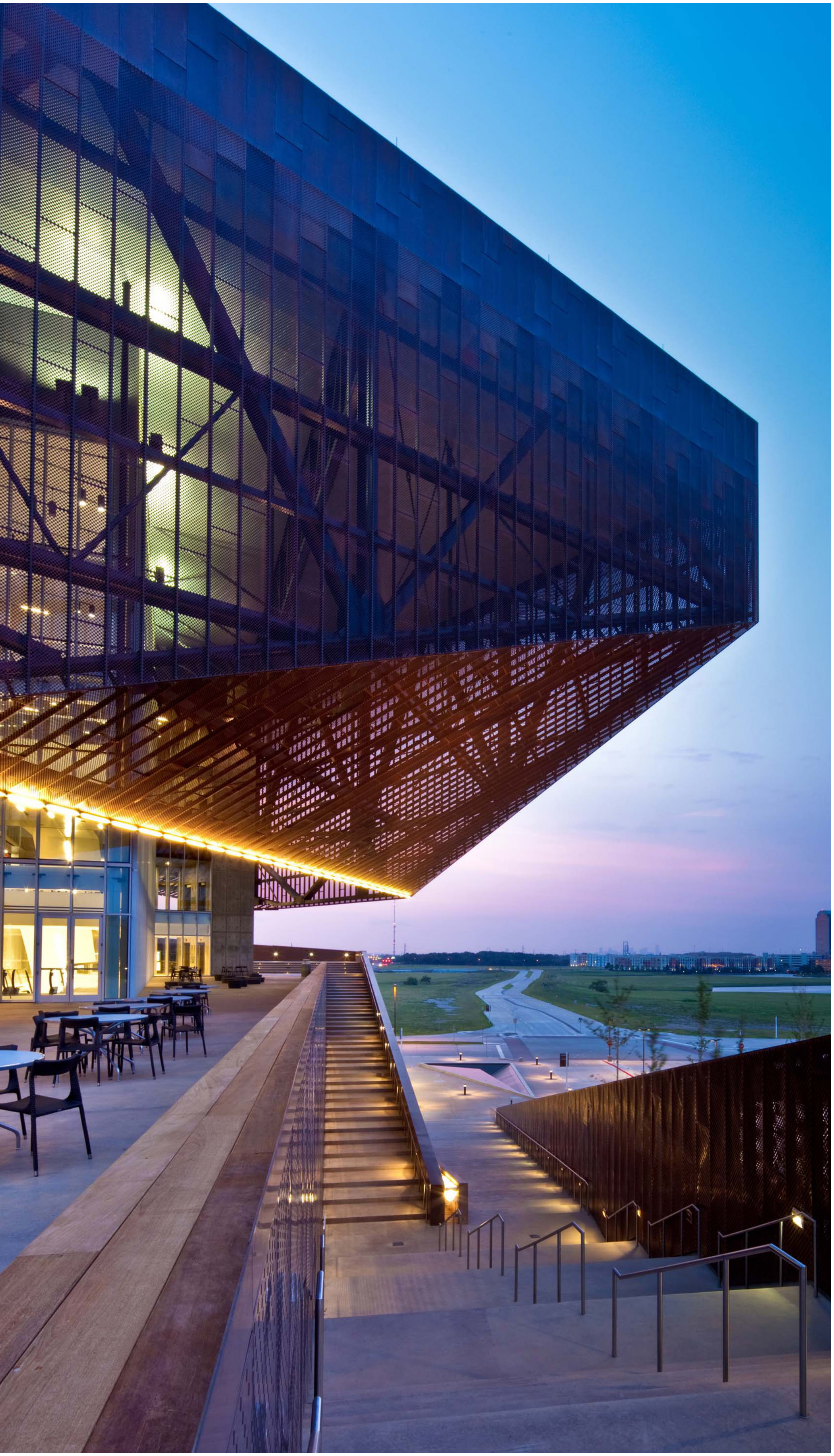
The long-span floor support conditions created a need for serious study of vibration issues. The engineer, along with the contractor and steel fabricator reviewed and considered several structural floor-framing systems:

- Normal weight versus lightweight concrete floors
- Purlins spaced at 7ft 6 in., 10 ft, and 15 ft,
- 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. Datum proposed using castellated beams at 15 ft spacing, with a lightweight concrete slab. This system provided improved vibration performance for the same structural cost as a similar wide-flange system. The lightweight concrete slab is thinner than a normal weight slab and yet still achieves the two-hour fire separation code requirements. This change alone resulted in significant savings to the 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: Critical Issues: The Fast-Track Process Proposed by Datum

Datum agreed to issue a minimum of 60% of the steel tonnage for mill order within the contractor's seven-week window. Datum then 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.

Datum worked with the mills to determine the rolling schedules. 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, Datum issued several other advanced bid, permit, and construction packages, including foundations, concrete, and miscellaneous metals. We 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.

A Landmark Result

The Irving Convention Center did open on-time, within budget and was a celebrated moment for the entire project team. We at Datum were particularly proud to know that our process and structural solutions were instrumental in maintaining the construction schedule. In addition, the structural solutions played a key role in creating savings that shaved significant cost from the original construction costs estimates. The result is architectural beauty, engineered strength, and a building that meets the diverse needs of a world-class convention center.