# **The Epitome of Form & Function**

### Structural Design Solutions Support Decades of Expansion for One of America's Largest Convention Centers

By Thomas Taylor, PE

The Kay Bailey Hutchison Convention Center is a convention and entertainment venue in downtown Dallas, Texas. As one of the nation's largest convention centers, it is an economic driver for North Texas, bringing millions of visitors, and billions in tourism dollars to the region annually. The original structure, known as the Dallas Memorial Auditorium, was designed by George Dahl in 1957. Its name was changed to the Dallas Convention Center and it was renamed in 2013 in honor of former Texas senator, Kay Bailey Hutchison. It was the first major convention facility named for a woman.

Its renovation in 2002 marked the creation of the largest columnfree expansion space in the world at that time. Incorporating the latest in technology and design innovations, architect SOM created a unique, world-class architectural statement and Datum Engineers worked beside SOM to achieve award-winning engineering feats. However, this was not the first time Datum had created exceptional structural designs for this venue. In fact, the firm was first brought on the project team for a \$31 million first phase 1 million square-foot addition to the Dallas Memorial Auditorium that was completed in 1973. Additional renovations were completed in four phases over a five-decade time span.

Many of the structural decisions made early in the expansion process were pivotal choices that impacted all future phases of the project. Of special concern was the need for the facility to

span over downtown Dallas streets and adjacent rail lines for the Dallas Area Rapid Transit (DART) system. In total, six roadways and four train lines had to be taken into account.

In addition, planning was impacted by the location of underground utilities, some documented, some not. During construction, the foundational designs were impacted when the contractor encountered several unknown structures buried within the site. These circumstances created conflicts with the foundation designs, requiring creative structural modifications.

Additional foundational issues occurred during the third phase of the project. The structure's foundation, supported by limestone on its east end, became more complex as the building expansion proceeded westward toward the shale found in the Trinity River bottom. As the limestone became thinner to the west, the foundations were drilled through the limestone and founded in the shale.Special testing was required to identify the exact drilling locations.

The engineering of the Dallas Convention Center (now known as the Kay Bailey Hutchison Convention Center) was featured on the cover of Engineering News-Record and was recognized by the Texas Chapter of the Consulting Engineers Council with the Eminent Conceptor Award, naming it the outstanding engineering accomplishment of the year.

### **A Unique Roof Structure**

The convention center roof is a structural steel frame hung from twin 400-ft. parabolic arch trusses, each 50 ft. tall and 4 ft. in diameter. A 5-ft.-2-in. thick connection sphere at the end of each parabolic arch ties into the connection truss. The roof was designed as a space truss with columns spread out at 300 ft. x 300 ft. to provide maximum flexibility for diverse convention use.

The roof system design had to satisfy several constraints. Convention planners required a spacing of 120 ft. between

columns in the exhibit hall, and future expansion schemes required these spans to be maintained along the building's perimeter. Efficient mechanical design required a large air conditioning system to be centered on the roof of each exhibit hall. Consequently, the combination of long spans and heavy loading capabilities necessitated structural steel trusses for the primary structural frame.

All roof elements, including ductwork and other building services, had to be located 35 ft. above the exhibit hall floor. To minimize the building height, Datum chose to run the ductwork through Warren trusses, which were selected to

provide sufficient room within the major ducts. These trusses also provided an attractive appearance for the roof structure which is visible from within the building.

Datum determined that the optimum spacing between trusses was 30 ft. While spacings of 20 ft. and 40 ft. (both equal divisors of 120 ft.) were studied, each would have resulted in increased steel tonnage. A benefit of the 30 ft. spacing is that it matches the planning module for traditional convention center layouts, and corresponds to the arrangement of service boxes for the exhibit hall floors.





To stabilize the major roof trusses, bracing trusses were spaced at 30 ft. intervals to address both gravity and wind uplift loading. These bracing trusses also support the roof joists, which are located at panel points to eliminate local bending in the truss chords. An added benefit is that the bracing trusses resist cladding reactions at the bottom chord elevation, thereby minimizing the vertical span of the cladding. The top chords of the trusses are sloped to provide roof drainage, while the bottom chords are horizontal. All trusses are cambered to compensate for dead load deflections.

The final scheme incorporated structural steel trusses with spans of 80-to-150 ft. with 30 ft. spacing. The trusses support 24-in.deep steel joists, also spanning 30 ft. A 3-in. metal deck spans 15 ft. between supports and an acoustic liner controls helicopter noise. After consulting with steel fabricators and erectors, the structural engineers suggested that the trusses be limited to 14 ft. in depth, which allowed unrestricted highway transportation of the building materials. Erection splices permitted the transport of 60to-75 ft. sections.



Due to the long spans for the roof, the engineering team was concerned about designing the trusses as simple-span. While this solution would allow for the most efficient erection of the roof structure, there was also potentially a long-term effect from rotational movement at the truss supports. This led to an engineering study to explore the impact of making the trusses continuous and the connections rigid. From this study, it became clear that this solution would make more efficient use of materials, reduce live load deflections and eliminate rotational movement at the supports. However, early analysis ruled out the use of fully continuous trusses, because chord connections at the supports would need to transfer the full axial capacities of the chord members, which were too large for economical connection detailing. Lateral stability of the bottom chords was also a concern for fully continuous trusses.

Datum's research confirmed that the roof trusses should be designed as simple-span for dead loads, and continuous for live loads and wind loads. There are several benefits in this solution:

- 1. straightforward erection, since members are simple-span for dead loads;
- reduced quantity of materials due to continuity at the supports;
- reduced deflections due to continuity under long-term loading;
- manageable chord forces at the support connections since no dead load chord forces are transferred through the connections; and
- 5. no stresses in the chord connections under long-term loading.

The average weight of the roof structure (not including from the mechanical room area) is 9.2 lb./sq. ft., which represents a reduction in tonnage of steel resulting from continuity. This weight includes primary trusses, secondary trusses, bracing trusses, OWSJ and bridging.

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Detailing of the roof structure went smoothly, with clear and open communication between the fabricator's steel detailer and the structural designer. The roof structure proved economical in its design and it was efficient to construct, using a mobile crane that operated on a grillage system on the exhibit hall floor.

Hanging-load capacity from the roof structure panel points for the exhibitors was established at 10 psf over and above the code's requirement for the roof's live load. Originally, to create a venue that would boost the city's efforts to compete for the Olympic Games, the owners requested that Datum raise the roof from 30 ft. to 40 ft. and eliminate all columns. This would have created a 425 ft. x 550 ft. column-free space with a clear height of 40 ft.

To properly function as a convention center, the coiling design required maintaining a 30 ft. x 30 ft. grid and making the roof a horizontal plane for hanging banners and for running electrical and communications lines. Datum's engineers interpreted this criterion to mean that they would need to place the long-span structural elements on top of the roof and design the roof to hang from the bottom chord of the structure. This would maintain the same ceiling configuration as well as the 30 ft. x 30 ft. grid found in the existing convention center. Datum evaluated five concepts and then generated computerized images of the final concept, which allowed the project team to study the relationship of the arches in relation to other structural elements.

### **Other Structural Considerations**

A project spanning so many phases and so many years required a long-term view. As the structural engineers worked through the design changes over time, several key structural component decisions are worth mentioning.

### **Design Loads**

Design loads include the dead load weight of the building components, a 20 psf roof live load, a 10 psf hangingload allowance for exhibitors, wind loads and the effects of temperature. Over the center bay of each exhibit hall is a 10,000 sq. ft. fan room, containing all the HVAC equipment for the building. Lateral forces are resisted by the concrete columns, which act as cantilevers from the exhibit hall floor level.

### Expansion

All basic parameters in Phase I were established for the structural design—except one. After having six years in the facility, the management team recognized that they could accept a column spacing smaller than the 300 ft. x 300 ft. lengths originally requested. In response, Datum designed a box truss and bar joist roof with spans of 90 ft. and 120 ft. This design, compared to the original 300 ft. x 300 ft. structural steel space truss achieved a savings of over \$1.5 million—more than 4 percent of the total budget.

### **Exhibition Floor**

The exhibition floor is a 400 ft. x 400 ft. column-free space designed to support 350 lbs. per sq. ft. live load. Datum evaluated structural concepts to create the column-free space during the first phase. While Dallas lost the bid for the Olympic Games, the convention center management team was so pleased with the functional benefits of the column-free space and the high-profile appearance of the arches, they instructed the engineering team to continue with the design.

Spring isolators protect the exhibition floor from vibrations from the six roadways and four train lines running beneath the structure.

## TIMELINE

### PHASE I

Datum was involved in the planning and maintenance of the convention center system since the first phase was designed in 1968. That portion of the project was a 1 million square foot \$31 million addition to the Memorial Auditorium, completed in 1973. Datum performed local associate work for Harrell & Hamilton Architects.

### PHASE II

In 1978, Omniplan commissioned a joint venture of Datum and Skilling, Helle, Christiansen and Robertson as the structural engineer for the Phase II expansion that continued west over Griffin Street. This \$34 million expansion added 400,000 sq. ft. to the convention space.

### PHASE III

In 1986, Datum was selected by HLM Design and LMN Architects as the structural engineer for the Phase III expansion and an elevated vertiport. The elevated vertiport was to have a 360 ft. runway that would accommodate vertical takeoff or landing of aircraft weighing up to 46,300 lbs.

### PHASE IV

In 2002, the city of Dallas voted to compete for the 2012 Olympic Games. As part of that effort, Datum was asked to alter expansion plans for the convention center, which was already in the design phase.

### The Entry

The entry, running 900 ft. long and rising 85 ft. tall is an imposing visual element composed of exposed architectural concrete. Pouring architectural concrete is always a challenge typically requiring a unique pour sequence and special concrete mixes. In addition, due to the complexity of this building, Datum incorporated additional structural design features into the wall to enhance the architectural finish and to control cracking. The structural decisions included:

- flexible foundations to release stresses in the wall;
- concrete control joints to minimize cracking; and
- specific detailing for the reinforcing steel.

The Kay Bailey Hutchison Convention Center is unique in that expansion efforts have upgraded the beautiful George Dahl facility into a modern venue, building upon Dallas' heritage of strength, innovation and leadership. Decades of improvements underscore the facility's enduring quality of excellence in architectural and engineering design.

### **About the Author**

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