Arch Action

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The steel-framed arched roof of Dallas' American Airlines Center is as skillfully articulated as the action beneath it.

When American Airlines Center opened with an Eagles concert in July 2001, it captivated fans, media and the community at large. The center is the latest jewel in Dallas' growing list of world-class civic buildings. Home to the NBA Dallas Mavericks, the NHL Dallas Stars and other entertainment events, the new building headed off efforts by suburbs to attract the teams away from downtown. Its crossed-barrel-vaulted roof structure inspires "wows!" as fans admire the graceful arch that spans 140,000 sq. ft with a structural depth of close to 13 ft.

The American Airlines Center is a multi-purpose arena that seats 19,200 for NBA basketball, 18,500 for NHL hockey and 20,000 for center-staged events such as concerts and convocations. The seating bowl incorporates 138 private luxury suites on two levels, separated by a club level featuring 2,000 premium seats and three restaurants. Located north of the historic Dallas West End and east of Interstate 35E, the arena anchors the mile-long, 60-acre, "Victory" development, an 8 million sq. ft, master-planned entertainment, office, retail, hotel and residential complex.

The rectangular arena building measures 390 ft by 500 ft, and is bounded on all sides by city streets at the main concourse level. Signature arches define the building's four entry points, while minor arches define the building corners at street intersections. Canadian brick and glass are the predominant façade materials, with limestone accent bands and granite integrated into the design.

ORIGINALITY AND INNOVATION

The structural steel roof-framing system is a unique and economical response to a complex architectural roof

Opposite: The American Airlines Center anchors a 50-acre planned development.

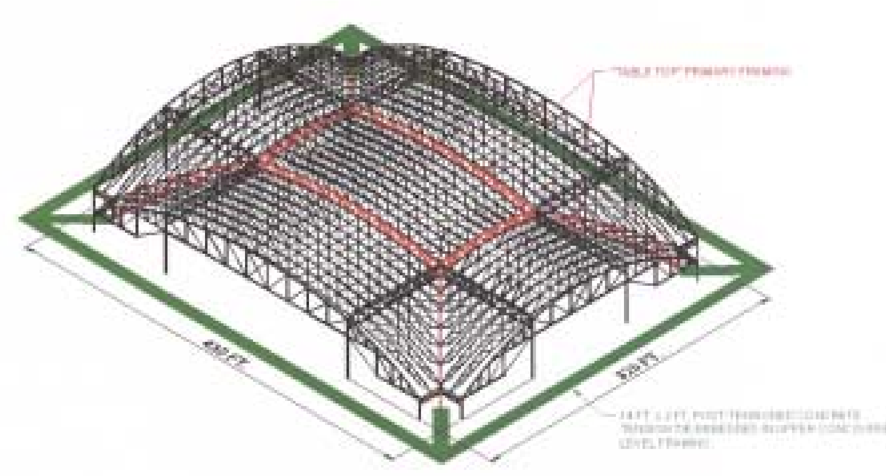
Left, top: Front façade under construction.

Left, bottom: The roof structure was erected using four temporary erection columns.

Seats
18,500 hockey
19,200 basketball
20,000 concert
Sports Teams
NHL Dallas Stars
NBA Dallas Mavericks
Construction Cost
$212 million
Area
840,000 sq. ft
Clear Roof Span
330 ft × 430 ft

shape. The American Airlines Center demonstrates that this form can be structured economically using structural steel, but with a twist.

- Walter P. Moore added an external, post-tensioned-concrete tension tie embedded in the upper-concourse floor framing to economically provide the lateral resistance usually provided by buttresses in traditional barrel-vault construction. This unique mix of structural steel and post-tensioned concrete results in a design that takes maximum advantage of the structural depth created by the arch shapes of the cross-vault form.
- Internally tied structural systems have been utilized on many recently completed NBA/NHL arenas. However, the application of such a system typically requires that the building height be increased to provide unobstructed fan sightlines. By using the external tension tie, the building was effectively shortened by 15 ft, resulting in structural frame-cost savings of an estimated $2 million, as well as savings in building façade and mechanical systems. The design also provided a long-span roof erection method that was simple and safe.
- An innovative show-rigging support system is integrated into the roof-truss design to improve economy, safety, aesthetics, and to streamline building operations. By establishing a truss spacing of approximately 11 ft, and designing the truss bottom chords to resist rigging loads along their length, the engineers eliminated the need for a separate rigging grid. This integrated solution provides riggers with safe and easy access from the catwalk system, which in turn enables the center to attract and prepare for a variety of show events.
- A mix of structural steel, concrete masonry units, cast-in-place concrete, and site-cast concrete arch panels are used to support the complex building façade. The architectural plan and elevation definition of the façade is highly articulated, and does not dimensionally relate well to the interior floor plates. To resolve these incompatibilities, engineers developed a cladding support system that stacks all load from the full height of the façade down to the ground level. Brick is supported using load-bearing, grouted concrete masonry units, which were placed in plan to easily follow the brick. Structural steel tubes and wide flanges support window walls. Brick arches are supported on arched, site-cast concrete panels. Three site-cast concrete panels, erected to form a true arch, support the four large entrance arches. The



Schematic view of the steel framing for the barrel-vaulted roof.

A view of the completed American Airlines Center.

three-piece, site-cast arch is, in turn, supported by cast-in-place concrete.

- Innovative pour strips in the five levels of reinforced-concrete concourses eliminated the need for expansion joints in the huge building, reducing costs and improving the efficiency of construction. Pour strips were located at the mid-length of each side of the building, dividing it into four quadrants. The strips allowed the contractor to speed construction by constructing and sequencing four separate buildings, which were then interconnected.

SIMPLIFICATION WITHOUT COMPROMISE

The American Airlines Center design illustrates how a complex architectural roof form can be simplified and framed economically using readily available techniques and materials.

In the original architectural design, the cross-vault intersection occurred at a common elevation at the center of the building. Given the rectangular plan form, this resulted in very complex vault radii and intersection conditions. At the structural engineer's suggestion, this geometry was greatly simplified by the architect without compromising the desired roof form. This approach saved money and improved the building's function. To standardize truss shapes and simplify truss connections, cross-vault intersections were established at 45 degrees with matching vault radii in the corners of the building. This created framing in the corners that was symmetric about the valleys and was identical in all four corners, which improved economy and construction simplicity. The long-side vault radius was flattened between the corners, and its apex was raised slightly relative to the short-side vault, resulting in the definition of a central framing rectangle 110 ft by 210 ft. The primary load-carrying structure is a "table-top" system: Four primary trusses occur at the perimeter of the central rectangle, or "table"; and four "leg" trusses extend from the corners of the rectangle at the valleys to the tension-tie elevation at the upper-concourse level.

The externally-tied, roof-framing system allowed a column-free span of 330 ft by 430 ft to be framed with trusses having depths of only 13 ft. This shallow depth allowed for shop-welded fabrication of the trusses and shipping of complete truss sections in lengths of up to 60 ft, saving both time and money.

The apex elevations of the two intersecting vaults differ by 5 ft, with an average elevation 65 ft higher than the tension tie at the upper concourse level. This large structural depth, combined with the stiff 14 ft by 2 ft concrete tension tie, resulted in an extremely stiff roof structure. As planned, the long-span roof deflected only 3 in. when the four erection towers were removed.

Collaboration between the architects and engineers resulted in simplification of the building geometry without compromising the desired roof form.

STRUCTURAL COMPLEXITY

The cross-vaulted exterior architectural roof design presented a complex structural engineering challenge, but the problem was complicated by additional architectural constraints. First, the interior form of the roof needed to match the exterior form. Second, internal tension ties were discouraged, even if unobstructed sightlines were provided. Last, no catwalk or rigging framing was to be suspended below the bottom chord of the roof trusses.

The ingenuity of the roof's structural-steel design solution lies in how it simply satisfies these complex and competing structural criteria without compromising economy or functionality.

Integration of a radial-building grid for the arena-seating bowl into a rectangular building geometry further complicated the design. Rectangular public spaces located in the lower levels of the building occurred directly below upper-seating sections, resulting in column placements that were not vertically compatible through the building. Many upper-level columns had to be creatively and economically transferred to match lower-level column positions. Non-uniform seating sections caused by the unique building geometry complicated the raker beams. In some cases, adjacent raker beams were offset both in plan and in elevation.

The desire to create an intimate setting in the bowl required the seats and seating levels to be as close to the event floor as possible. This imposed constraints on the structural depth at the front of each level. These challenges were met with a series of solutions: attachment of pre-cast fascia panels to the end of a 6-in. cantilevered slab at the suite levels; and use of raker beams at the club and upper-concourse levels, which support the first seating riser from behind, instead of from below.

EXCEEDING THE OWNER'S NEEDS

The owner's goal in building The American Airlines Center was "to create an atmosphere that is people friendly, attractive and fills the community with civic pride." The redevelopment of a brownfield site has transformed an eyesore into a city icon and clearly meets the needs of the owner and the City of Dallas.

Revenue from naming rights and advertising exceeded all projections, allowing the owner to increase the original construction budget to include many unplanned amenities. Despite the additional project scope, the center was completed on the original schedule. Construction cost savings of over $2 million were achieved through the use of the innovative, structural steel roof.

No one can visit The American Airlines Center without appreciating that engineering excellence in steel was a crucial element of the building's beauty, function and success.

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SOFTWARE
SAP2000