

Reliant Stadium

Houston

Juror Comment

“An impressive structure accommodating a myriad of complex requirements. The scale of the opening roof and the supporting supertrusses are recognizable feats of structural design.”

Photograph courtesy Mark Green.



Reliant Stadium – home of the Houston Texans and Houston Livestock Show and Rodeo, is the National Football League’s largest stadium, covering more than 12 acres and comprising 1.9-million sq. ft. It is also the first NFL stadium with an operable roof, and at 3.75 acres it is the largest such roof in the United States. The translucent fabric roof is an architectural landmark for the City of Houston.

The retractable roof structure solves a challenging tenant program by offering the flexibility to play football games in either an open-air environment or in air-conditioned comfort. For the Houston Livestock Show and Rodeo—a major tenant for two weeks every year in late February—the rodeo and its concert events can be held in a closed-building atmosphere, much like an arena. The roof will support 170,000 lb of rigging load for major concert events, comparable to any modern arena. Despite numerous challenges, the project achieved every goal,

and in the end was completed within budget and within a fast-track schedule of 30 months.

The distinctive operable portion of the roof consists of two panels that bi-part at the 50-yard line to park behind the end zones. Each 385’-by 500’ panel is framed with five arched trichord trusses, which are clad with PTFE fabric and tensioned between trusses by a major valley cable to form a distinctive anticlastic roof shape. Electric motors connected to roof carriers housing standard steel wheels drive the operable roof on a single 175-lb crane rail to open and close in as quickly as 10 minutes. Use of only two wheels per carrier ensures a determinate system that avoids unpredictable wheel-load redistribution due to rail deflection.

Several other design and engineering innovations were incorporated, including a 4-bar stress-relief linkage invention that isolates the retractable panels from differential rail lateral movements of up to 21” and a first-of-its-kind computerized clamping system that keeps the pan-

els from “flying away” during high winds. A detail incorporated into the supertrusses allowed the roof rail to be adjusted after construction to meet the tight mechanization tolerances.

An efficient steel structural system supports the operable roof. Two massive trapezoidal supertrusses clear span 650’ between concrete supercolumns along either field sideline. The bottom chord of each supertruss is arched to accommodate the sightlines of the seating bowl, creating a truss with minimum depth of 50’ at midspan and increasing to 75’ at the supports. Beyond the supercolumns, the supertruss cantilevers 164’ further to support the roof in the open position. The depth of the supertruss also serves as a closure wall for the building through a series of tensioned fabric cones woven through the filigree steelwork.

The supertruss responds to its architecturally dictated form through composite action between steel and concrete. To shift moment from the narrow midspan to the deeper regions over the support,

the steel supertruss was made integral with the concrete supercolumn to form an enormous composite portal frame. For further economy, the concrete slab atop the supertrusses—required as a working surface for mechanization access—was made composite with the truss top chord to carry compression. The composite steel/concrete supertruss/supercolumn system is believed to be the largest ever used in a building structure.

There are more than 1.5 total linear miles of primary long-span trusses in the roof. A fixed area of fabric roof above the end zones, similar to the movable trichords above, extends the bright expanse of fabric roof to the edge of the stadium. Beyond the fabric roof, two box trusses at each end zone span 366' to support the NFL's largest scoreboards, as well as a significant portion of the mechanical rooms. A hard roof above the sideline seating areas spanning from the supertrusses to the perimeter bowl columns completes the stadium roof. This joist-metal deck side roof is engaged to brace the exposed wall of the supertrusses laterally back to the seating bowl, reinforcing the concept of a unified, composite structural system.

The extensive engagement of concrete in composite action to augment the primary steel system required that several structural models be prepared to examine the variation in properties that could exist in the concrete elements. Three complete structural models were prepared in SAP2000, and the final steel design represents an envelope of all. In addition, extensive finite-element analysis was conducted on the composite action between the supertruss steel top chords and the slab. Bracing provided by the steel floor beams proved critical to enabling the slab to develop its full capacity without buckling.

Providing the integral moment connection between the supertruss and the supercolumn presented a major challenge due to the limited space. Seventy-eight 2.5" diameter anchor rods extend 20' into the top of the supercolumn to transfer the moment, the magnitude of which was best quantified in kip-miles. Walter P. Moore prepared a three-dimensional digital placement diagram of the anchor bolts and the maze of reinforcing bars atop the supercolumn to aid the contractor in placement.

Throughout the roof, ASTM A913 Grade 65 steel was used to reduce tonnage. Steel details were developed in co-

operation with AISC-member Hirschfeld Steel to facilitate efficient fabrication. Coordination also occurred with the steel detailer, the steel erector, and the fabric supplier through extensive electronic data interchange of structural models, AutoCAD models, and Xsteel models. For example, structural models were provided to the steel erector for use in the detailed analysis of the erection sequence.

The operable roof of Reliant Stadium is the product of countless hours of exceptional effort by engineers, fabricators, and erectors, cumulatively responding to an architectural vision for the City of Houston that could only be realized in structural steel. ★

Read more about Reliant Stadium in the July 2003 issue of Modern Steel Construction at www.modernsteel.com.

Architects

Houston Stadium Consultants (HSC), a joint venture of Hermes Architects, Houston, TX and Lockwood Andrews Newnam, Houston, TX

Stadium Consultant

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Structural Engineer

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Contractor

Manhattan/Beers, a joint venture

Roof Mechanization Consultant

Uni-Systems, Inc., Minneapolis, MN

Roofing Fabric

Birdair, Amherst, NY

Steel Fabricator

Hirschfeld Steel Co., San Angelo, TX (AISC member)

Steel Erector

Derr Steel Construction Co., Euless, TX (AISC, SEAA member)

Steel Detailer

Dowco Consultants, Toronto, CA (NISD member)

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SAP 2000

Detailing software

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