Enron Field Hits a Home Run

By Douglas G. Ashcraft, P.E., S.E.

This past spring, the Houston Astros got a new home. Enron Field, a 42,000-seat ballpark, opened to rave reviews from players, fans and media alike. Designed by Helmuth, Obata and Kassabaum (HKO) of Kansas City, the field follows the trend of retro-styled sporting areas in the vein of Baltimore's Camden Yards and Indiana's Conseco Fieldhouse. Modeled to complement the adjacent 1911 Union Station, Enron Field has the look and feel of an early 20th-century ballpark with all of the amenities expected of a 21st-century stadium. However, the real applause is not for its position as baseball's newest venue but rather for the use of tried-and-true engineering fundamentals and a few creative applications of structural steel.

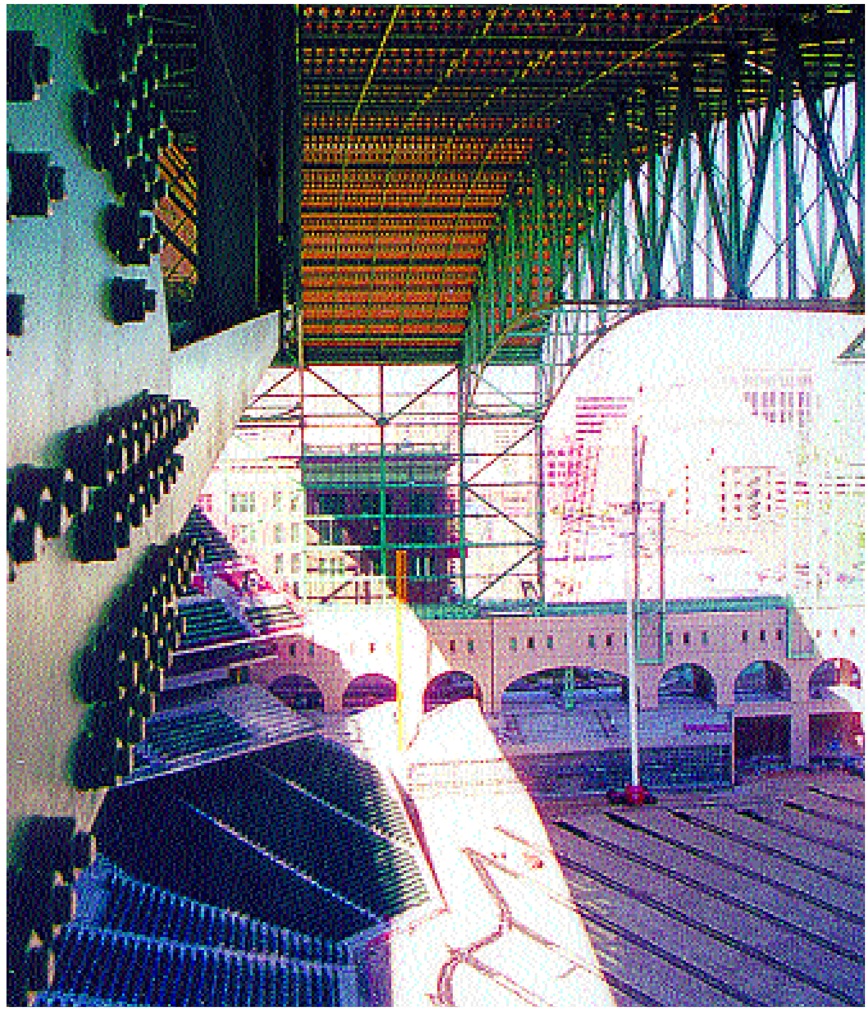
Completed in less than four years, Enron Field set new standards for economy and cost control in sports arena construction. By implementing careful planning at every stage, innovative design and some new construction techniques, the project achieved every goal and came in on its $250 million budget.

When the citizens of Houston voted to fund the construction of a new downtown ballpark, the owners turned to Walter P. Moore and Associates, Inc. (the structural engineers for the Astrodome), but this time they threw in a twist. The plans for the new venue called for the roof to be retractable, therefore offering a more traditional, open-air experience when environmental conditions warrant. Furthermore, the retractable roof allows for a grass field, which protects the knees, ankles and career duration of the players—the team's most valuable investment by far.

The asymmetrically curved roof, meant to mirror the flight trajectory of a batted baseball, towers nearly 200' above grade before descending to meet the roofline of Union Station beyond the left field wall. The 115' glass wall that rides along with the moving roof not only offers dynamic views both into and out of the stadium but also gives the sense of an outdoor venue even when the roof is closed.

The architectural design required 267,000 sq. ft. of moving, covered roof with spans from 177' to 580'. The entire roof structure can open in 12 to 20 minutes depending on wind speed and was designed to safely resist hurricane force conditions.

In order to meet the projected April 2000 opening day, the structural steel roof package was issued on an accelerated schedule just six months after the initial conceptual design. To further respond to the daunting schedule and tight budget without exposing the project to the potential for costly surprises during construction, the roof structure was designed with simplicity and elegance at the forefront.



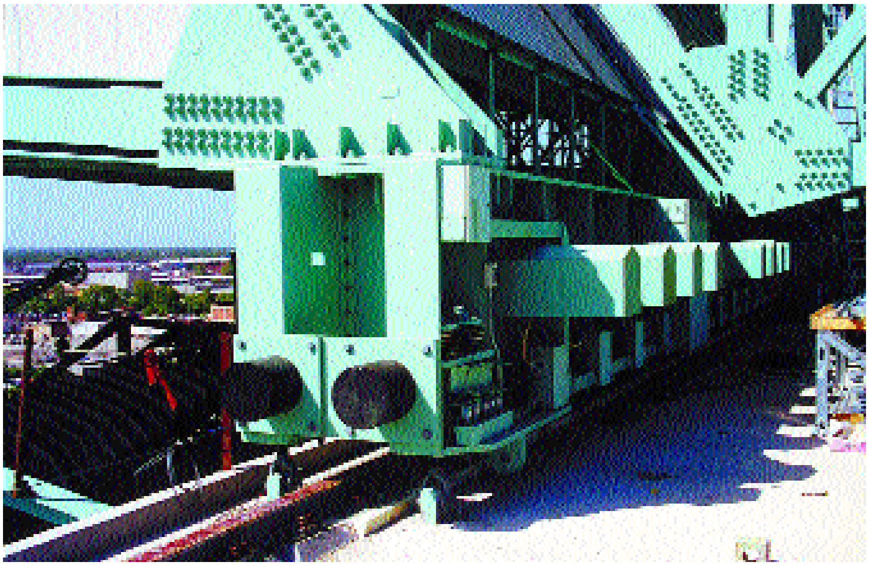
Roof and transporter assembly.

The final designs called for a statically determinant bridge-type design utilizing eight 30' wide variable-depth (29.5' to 40') box trusses spans across the field. The retractable roof consists of three moving panels with two half-width lower panels nesting beneath one full-width upper panel when the roof is open. The two lower panel roof segments, each framed with two box trusses, are 120' wide, while the upper panel is 242' wide and framed with four box trusses. Each box truss connects rigidly to a supporting transporter girder atop the fixed rail at its east end. At their west end, the trusses bear on "pinned supports" atop the vertical trusses that frame the glass wall and are supported on the transporter girders atop the low rail.

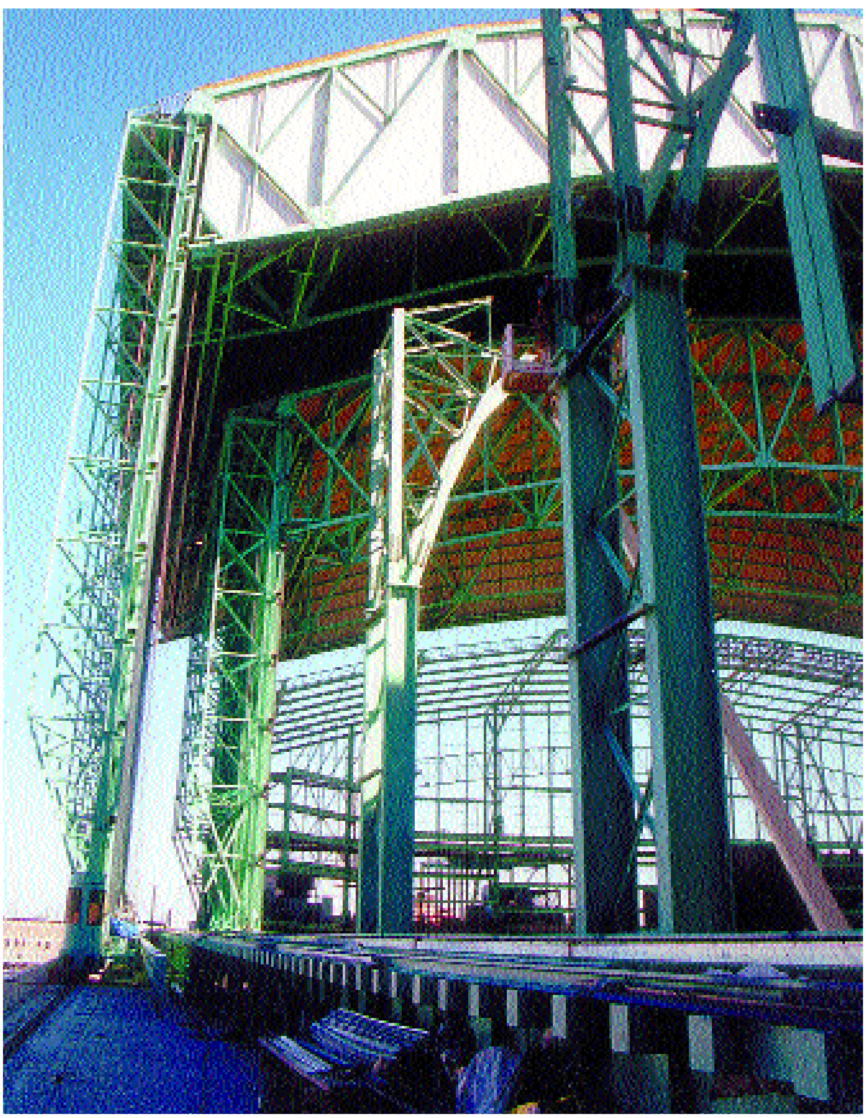
The main tapered box roof trusses, very light and structurally efficient, fabricate easily and erect with stability. The total weight of structural steel in the roof including the west wall, the catwalks and wind girts is 5,380 tons. To expose the outer face of the truss, the metal panel skin was wedged between the truss members and the tube girt system.

Unique to the structural design was the use of 15 hydraulic wind dampers within the roof structure. Recently used in earthquake design applications, these damping devices on this project reduced the dynamic effect of potentially damaging hurricane force winds that frequently strike the Gulf Coast. The simple bridge or gantry crane design relieved the support structure from excessive lateral loads due to thermal effects and greatly simplified the transport system.

To minimize risks and stay on schedule, the Enron Field team tried to emphasize the use of proven and simple technologies. Even so, the mechanization system is one of a kind. Each end of each roof box truss bears on 4'×6' steel transporter girder that consists of a pair of fabricated channel shape sections joined together with vertically oriented W24 sections between each wheel box. The wheel boxes contain 3' diameter steel flanged wheels that ride atop a single 175 lb. hardened rail. A total of 140 wheels support the roof structure with 60 of these wheels being powered by 7.5 Hp, 460 volt, 3 phase electric motors. Power for the system comes from power pick-up trolleys riding on electric feed rails along the low track transporter path. The transporter system is unique because weight distributes evenly over a large



Transporter beam.



Glass wall under construction.

base utilizing a simple urethane spring suspension system. The flexibility of this system permitted more forgiving rail tolerances and an economical shallow foundation system.

Showing cost-effective forethought, the team developed an innovative testing program to get the bugs out of the mechanized assemblies before fabrication. For testing, a prototype of the travel assembly with the actual roof weight simulated was repeatedly driven back and forth on a test track. The continuous three-month test simulated 10 years of actual stadium use. Due to this testing, the team modified several aspects of the wheel assembly design, eliminating the costs and delays that would have been required to "field solve" the problems.

The technique used for erection of the retractable roof allowed concurrent construction of the seating bowl to commence with almost no interruption caused by the roof. A single row of four shoring towers was placed along the northern edge of the site, beyond the edge of the bowl below. The eight box trusses were then built one-by-one on top of the towers and rolled out of the way to make room for the next one. All of the self-supporting segments were transported independently down the line of track structure. The factory-built wheel transporters consisted of 60' sections with prior electrical testing using plug-in connections between segments. Each independently powered segment propelled itself along into the next position, vacating the shoring towers for the next section of roof. This single-location erection strategy gave the construction team absolute confidence that the roof worked from the very start, and resulted in a smooth roof erection process without incident.

Consisting of 1,230 tons of steel, the "high track" supporting the eastern end of the roof trusses consists of a composite concrete roof deck supported on arched trusses spanning

30' between W36 columns. The bottom chord of the truss contains a curved W10 member oriented sideways and attached to the column by a bolted end plate, and the top chord truss is a W30 member that resists the secondary moments caused by the continuous load delivered by the moving transporter girder. The deflection of the truss was limited to ¾" under the load of the roof.

Cantilevered sunscreens provide additional weather protection for fans on three sides of the bowl. Sunscreen support trusses cantilever 60' out from columns on the back of the bowl on the north and south sides and 40' out from the high track on the east side. The sunscreen trusses vary in depth from 13.7' to 3' and consist of WT top and bottom chords and double angle web members. Sports-lighting racks are supported from their ends.

Trusses supporting the club level, upper concourse level and right field mezzanine seating sections cantilever as much as 43' from the concrete bowl. The bottom chord is flat and the top chord slopes to support the precast seating risers. Bolted end plates attach the top and bottom chords at the column line. The mated end plate from the bowl is welded to a strut member that cantilevers out from a wide-flange column that is embedded in the concrete column; this detail ensured that the connection would be at the right elevation when the truss was connected to it. Overall, the steel need to help create the seating bowl came in at 3450 tons.

Still, the most striking effect of exposed steel used at Enron Field is the 10' deep, parallel chord truss in right field. Arching 212' over the scoreboard, an elaborate connection supports the exposed truss to the columns behind it at 42.5'on center and serves as a welcome sign to entering fans.

The Astros' 30-year lease ensures that the team will remain in Houston for at least two more generations, providing major league entertainment, serving as a source of community pride and acting as a cornerstone of renewal for the northeast quadrant of downtown.

Doug Ashcraft, P.E., S.E. is a Vice President with Houston-based Walter P. Moore and served as the firm's project manager on Enron Field.

Owner: Harris County - Houston Sports Authority

Lead Structural, Civil, and Traffic Engineer: Walter P. Moore, Houston

Associate Structural Engineers: Nathylene A. Kennedy & Associates, Inc, Houston and Scientech Engineers, Houston

Detailer: Consteel Technical Services, Ltd., Saltburn, England

Steel Fabricator: Hirschfeld Steel Company, San Angelo, Texas

Software: SAP2000 non-linear and RISA 3D

Mechanization Consultant: Uni-Systems, Inc., Minneapolis, MN

Architect: HOK, Kansas City and Houston

Associate Architect: Molina & Associates

Owner's Project Manager: Schindewolfe and Associates

Construction and Construction Management: A joint venture of Brown & Root Services, Houston; Barton Malow, Atlanta; and Empire Construction, Houston.