



The University of Phoenix Stadium Sets New Standards

By Joseph M. Ales Jr., Ph.D., P.E.

Above left: It is the first retractable roof in North America to ride on inclined rails and its roof trusses provide the longest clear span of any retractable roof stadium in the U.S.

Above right: The distinctive curved retractable roof was secured atop four, 171-foot-tall concrete super-columns in the concluding step of a landmark lift sequence. At 5,400 tons, the lift is the heaviest of its kind in North America. Images courtesy of Arizona Cardinals.

The University of Phoenix Stadium, home to the Arizona Cardinals football club, sets a new standard for covered stadiums, with cutting edge architecture and state of the art operable roof and field structures. The stadium is the second NFL facility to feature a retractable roof, and the first in North America to feature an operable playing field. It is also the first retractable roof in North America to ride on inclined rails and its two main 700-foot long lenticular roof trusses provide the longest clear span of any retractable roof stadium in operation in the United States today. Another signature achievement was realized when a 5,400 ton section of the roof structure was assembled on the ground and lifted into place as a unit in February of 2005.

The University of Phoenix Stadium features an architectural design unlike any other sports facility in America today. New York based architect Peter Eisenman teamed with stadium designer HOK Sport + Venue + Event of Kansas City. The design-build project was headed by Hunt Construction Group (Phoenix, AZ). Walter P Moore (Houston, TX) is the engineer-of-record for the 500,000 square foot retractable, structural steel roof, while TLCP (Phoenix, AZ) is engineer-of-record for the cast-in-place concrete seating bowl structure. The mechanization components for the retractable section of the roof were designed and installed by Uni-Systems, L.L.C. (Minneapolis, MN) and the structural steel fabricator for the roof and operable field was Schuff Steel (Phoenix, AZ).

The signature element of the roof structure is the pair of Brunel trusses, named after

British engineer Isambard Kingdom Brunel, whose Royal Albert Bridge is the archetype of the form used for this stadium. The two 87-foot deep Brunel trusses are spaced at 256 feet, and span approximately 700 feet along the east and west sidelines between the concrete supercolumns. They are the primary support elements of the roof. They support the secondary trusses, which span to the perimeter of the structure, and the fixed trusses, which span between the Brunel trusses at the north and south ends of the stadium. The retractable roof panels, which ride on a rail centered on the top of the Brunel trusses, cover the center opening in the roof which is 360 feet long and 240 feet wide. When the panels are open, the entire field to the back of the end zones is exposed. The two retractable roof panels measure 180 feet long by 270 feet wide and are constructed with 8 lenticular, vierendeel-style trusses composed of square and rectangular hollow structural sections (HSS). The panels are supported at each end by eight sets of wheeled carriers. The carriers ride on a rail that is clamped to a built-up box rail girder that is located at the center of the Brunel truss. The east support for each truss is designed with a linear slide bearing, allowing for up to 18 inches of lateral movement. This prevents the buildup of excessive wheel shearing loads due to Brunel truss lateral displacements, temperature induced expansion and contraction of the retractable panel trusses, and construction tolerances. The fabricated and erected tolerances of the rail itself were quite strict, allowing only a plus or minus 1/8-inch deviation in a 60-foot length

of rail laterally, and a final vertical tolerance of the rail radius of plus 1/8 inches, minus 5/16 inches.

The most daring aspect of the project was the 5,400 ton roof lift, which would transport the two Brunel trusses and the structure in between, 120 feet to the top of the supercolumns. The day of the lift began with rain and cold in the forecast. A constant drizzle and steady winds made monitoring of the roof lift challenging. The procedure began at 7:00 am in morning with the removal of the truss tie-downs. At 11:30 am the roof began to rise as the 700-foot long Brunel trusses slowly began to lift from their supports. At 3:00 pm the trusses cleared the final supports and the roof was supporting itself. Measured truss deflections were 16.75 inches at the center, within 3% of the predicted deflection of 16.25 inches. Once lifted, the actual weight of the entire structure was confirmed. The predicted weight of the roof was 5,422 tons; the actual weight of the roof was 5,425 tons. The roof lift was completed with no major complications, and speedy erection of the remainder of the roof proceeded. The stadium opened on time in August of 2006, and the Cardinals rewarded their cool and comfortable fans with a victory over the defending Super Bowl Champion Pittsburgh Steelers. ■

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