

## Post-Tensioned Steel Trusses for Long Span Roofs

### The Achievement

Telstra Stadium (formerly Stadium Australia) was reconfigured in 2003 to remove the temporary seating in the north and south terraces, which had been used for the 2000 Olympic Games and Paralympic Games. Two new 3,500m<sup>2</sup> roofs for all-weather accommodation were constructed over the stadium ends. The seating stands on the East and West sides of the playing field were placed on moving frames so that the arena could be quickly adjusted for rectangular and oval settings. The reconfiguration cost \$80 million (AU), with the roofing component being around \$10 million, and was completed without disruption to the scheduled events at the stadium. The post-tensioned system for the roof was adopted to overcome difficulties that a business-as-usual design was likely to cause.

The construction system for the new roofs allowed the project to be completed on time and budget, keeping loss of seat revenue during construction to a minimum. The project was completed in time for the 2003 Rugby World Cup, despite a tight timeline for design and construction. The truss members were prefabricated and assembled on the ground outside the stadium, so the concourse around the ground was relatively unobstructed on match days. The two main trusses were erected in a single week, within a six month construction program that saw no serious injuries to workers. The end result is what is believed to be a world-first post-tensioned steel roof for a sporting stadium. The project was awarded the 2004 ASI Structural Engineering Steel Design Award for NSW and the ACT.

### The Innovation

A post-tensioned roof was adopted to avoid problems likely a conventional steel roof that would have required every connection node to be shored until the roof was completed. A forest of roof shores would block sightlines, reducing seating capacity by 9,000 seats at each end of the stadium during construction. Cranes stationed on the arena would kill significant areas of turf. A post-tensioned roof avoided these potential problems.

Post-tensioning has not often been applied to steel frame structures. The behavior of a structure can be predicted by applying loads to a theoretical "string line". Compression domes have been designed this way for centuries. Loads simulating the self weight of the dome are hung from a string, the shape taken by the string is plotted and inverted to form the design of the dome. The tension in the string line is measured and this determines the thickness of the dome structure. A similar process was used for the stadium roof, using 3D computer modeling instead of the physical string line. In this case, the string line shape was not inverted but accepted as the form of the main catenary trusses. The string line approach does not deal with deflection, so sophisticated software was used to model the loads in the members and deflections in the structure. The string line is represented by the post-tensioned cables in the truss bottom chords. These cables are loaded by hydraulic stressing to resist the external forces acting on the structure. All the prefabricated members which make up the trusses are straight lines or simple curves so that, while a very large truss is produced, the components are easily transported and lifted into place. Once assembled, the truss was in effect proof-tested by the stressing process. The approximately six kilometers of stressing cables in the bottom chords of the trusses were stressed by hydraulic jacks then fixed in place with high strength grout once they were in position. The connecting joints for the post-tensioned roof structure are all simple "butterfly", "half moon" and "end plate" connections, so the truss sections were quickly and easily bolted together on site. The trusses were assembled in two relatively small areas on the concourse outside the stadium. A 400 ton and an 800 ton crane on the concourse were used in tandem to lift the main trusses into place. Smaller cranes with long reach capacity completed the assembly, also from outside the stadium. This included the secondary trusses and the 10m x 10m framed polycarbonate panels that finished the roof. The stored energy in the stressed cables reduces deflection under load. This allowed the main trusses to span the 114 meters between the existing roofs without any intermediate support or shores during construction, leaving the seating under the roofs available for scheduled events.

### The Benefits

The main benefits of the post-tensioned roof design and lean construction methods at Telstra Stadium, compared to a more conventional steel roof include saving 50% weight of steel needed to span the roof opening, with associated transport costs, \$3m to fabricate and erect structural steel, 25% in erection time, and 40% in steel fabrication time. Chief benefit to stadium management was minimizing loss of seat revenue during the 2003 NRL, AFL and Rugby Union football season. Conventional approaches would have required some seating areas to be fenced off for six months. Revenue from the 18,000 seats kept available for the six month construction period was \$2.7m. The sporting public benefited from continued stadium use during construction sightline obstruction, and people had continued access to most public areas during construction, an important recreational resource for Sydney. The roof has been compared to the shape of the brim of an "Akubra" hat and is widely accepted as an aesthetically pleasing solution to a difficult geometric problem. The client gave high importance to the new roof looking like a natural extension of the existing roof.

