## Outdoor Stadium, National Sports Complex

# STEEL COMPRESSION RING ROOF

*All photos courtesy of United Engineers (M) Bhd*

*Artist impression of the completed Outdoor Stadium*

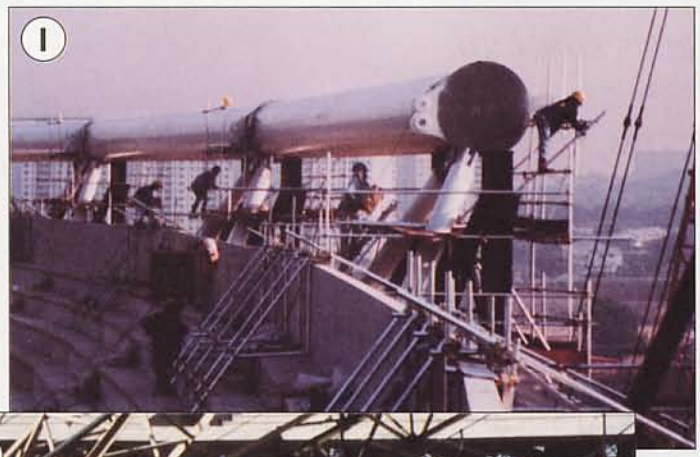
*The Outdoor Stadium under construction at Bukit Jalil, Kuala Lumpur.*

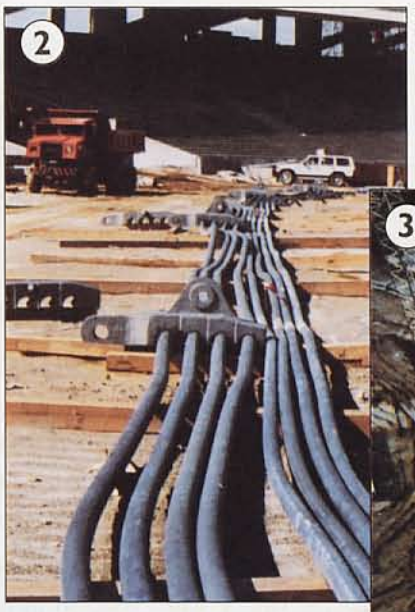
The construction of the National Sports Complex at Bukit Jalil, Kuala Lumpur is nearing completion, with sufficient time for SUKOM to organise events as a trial run before the 1998 Commonwealth Games. If one drives past the construction site, one will not miss the Outdoor Stadium with its white, tent-like roof. The RM65 million roof spreads over a massive 38,256 sq.metres, 48 metres above ground. This, according to the Malaysian Book Of Records, is the largest stadium roof in Malaysia. The roof is also significant because of the use of an advanced membrane stretched across steel compression rings, arches and cables, without any support in the middle.

*Malaysia's largest stadium roof will hang over the Outdoor Stadium at the National Sports Complex. The roof steel ring is designed to be in compression while the rest of the structure, i.e., cables and membranes, are in tension. The roof design allows for expansion and contraction without any moments generated.*

The steel compression ring roof was first used in the Stuggart Stadium in Germany about four years ago. According to Encik Mohd Sabri Razali, senior manager, United Engineers (M) Bhd, advancement in technology has led to the creation of a stronger and more durable membrane for the Outdoor Stadium in Malaysia.

The membrane for the roof is made from a PVC-coated cloth. The coating is both fungicidal and bactericidal. This coating is applied asymmetrically to both sides of the grey cloth in the ratio of 3:2. The upper side of the membrane is thicker for protection against the weather. Other properties of this special membrane are noted in Table 1.

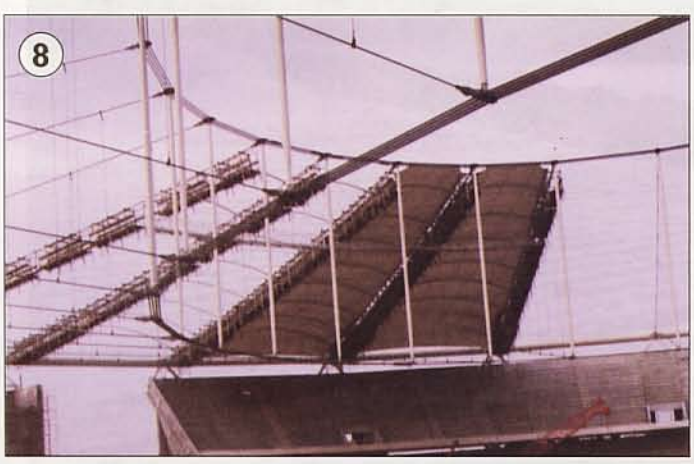











*Outdoor Stadium Roof Construction Sequence*

1. *Connecting the compressing ring on top of triangular supports*
2. *Cable assembly in progress*
3. *Assembly of radial cables and inner ring cables*
4. *Lifting of cables in progress*
5. *Lifting of upper inner ring cables*
6. *Installation of inner centre columns*
7. *Final position of cable structure*
8. *Membrane installation*

**Table 1 - Properties of the Outdoor Stadium Roof membrane**

| | |
|---|---|
| **Support cloth** | High strength, shrink-resistant multifilament polyester yarn |
| **Weave** | Linen or hopsack weave |
| **Surface treatment** | Fluor polymer topcoat (PVDF) |
| **Translucency** | 7-8% at 550nm |
| **Wicking** | Base cloth treated |
| **Resistant to inflammation** | Class B1 as per DIN 4102 |
| **Breaking strength of main membrane** | Warp ≥110kN/m, Weft ≥ 100kN/m |
| **Tear resistance** | Warp ≥ 0.8kN/m, Weft ≥ 0.7kN/m |

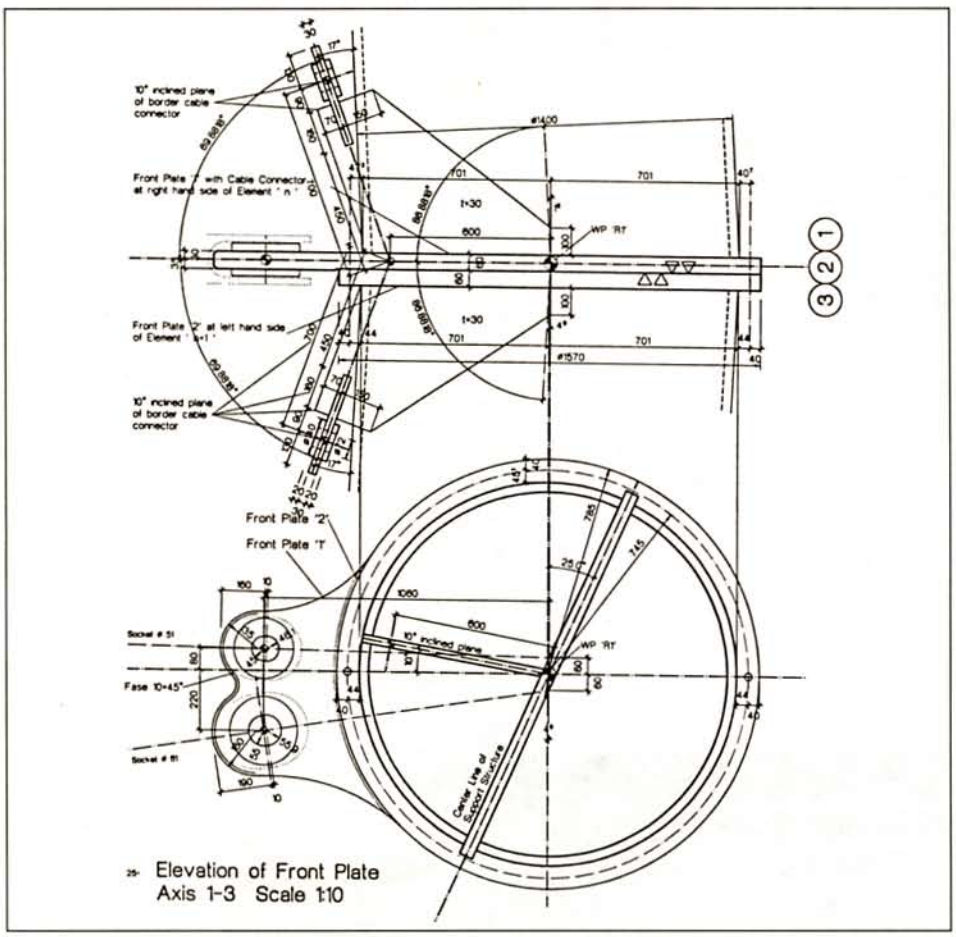



*Diagram 1 - Details of compression ring.*

**Table 2 - Main consultants and contractors for the Outdoor Stadium**

| | |
|---|---|
| **Turnkey Contractor** | United Engineers (M) Berhad |
| **Consultants** | Architect - Wiedleplan Consulting GMBH/Akitek FAA Joint Venture<br>Structural Engineer - Sclaich Bergermann und Partner |
| **Contractors** | |
| ***Roof*** | United Engineers Construction & ACPI Engineering Sdn Bhd |
| ***Steel Compression Ring*** | KNM Steel and Construction Sdn Bhd |
| ***Cables*** | Pfeiffer |
| ***Membrane*** | Koch Hightex |

These special properties contribute to a roof that is relatively maintenance free despite the heavy rain, hot sun and dusty environment in the country.

The Outdoor Stadium roof is also unique in that it does not require support in the middle. Instead, it is held by a perimeter steel compression ring which rests on triangular supports connected to H Columns encircling the Stadium. Tensioned cables and steel arches form the framework for the membrane cover.

The compression ring forming the perimeter of the roof is made up of 36 steel ring tubes bolted together (see Diagram 1). Each tube, made of steel grade 50C, approximately 22m in length, 1,400m in diameter and between 30 and 50 mm thick, weighs a hefty 35 tons. The steel tubes are fabricated at a factory in Malacca. While preparing the end plates, this factory also pre-assembles them to achieve the precision required by the design. Each of these pre-assembled designs would consist of three compression rings joined together. Once the precision is achieved, two of the rings will be sent to the site for erection and installation.

Once on site, the steel rings are lifted by a mobile crane to their final position and installed between 2H columns. One steel tube would be installed adjacent to the other in the pre-assembly sequence. The tubes are bolted together using 72 high strength bolts. The compression ring is connected with pin joints on top of the triangular support (see Diagram 2). These triangular supports are fixed onto bearing plates which are placed on top of the H columns. These supports are designed to allow for the expansion and contraction of the whole steel compression rings caused by temperature changes.

According to Encik Mohd Sabri, the advantage of the steel compression ring roof is that it is able to be in compres-

sion while the rest of the structure, i.e., the cables and membrane, are in tension. The roof therefore allows for expansion and contraction with no moments generated and transferred to the H columns. Another plus point is that the steel ring erection can be done ring by ring without affecting other structural works.

While the compression ring tubes are assembled above the stadium, cables supporting the roof are pre-assembled on the ground inside the Stadium. These are made of upper and lower 65mm radial cables, upper and lower 131mm ring cables and various lengths of suspender cables. All fully locked cables are made from hot-dip galvanised and galfan coated wires. The rated tensile strength of all wires involved in the cable structure is $b_n$=1570N/mm$^2$ for the fully locked cables and 1770N/mm$^2$ for the spiral strands.

Hydraulic jacks, installed at each of the H columns, are used to pull the upper and lower radial cables into the final positions. First the upper radial cables and the upper inner ring cables are laid out. The upper radial cables are lifted together with the upper inner Ring with cranes. Then the center columns are placed in between the upper and lower inner ring cables. The upper radial cables are then installed and bolted followed by the lower radial cables.

Once the cable trusses are in place, the roof membrane can be installed panel by panel to cover the Stadium. Each of the 36 panels of the membrane stretched between two H columns are supported by eight steel arches to give the profile of the final roof covering. The arches and membrane are installed using temporary scaffolding hung underneath the upper radial cables.

Each panel of the membrane is lifted and unfolded onto a temporary membrane and pre-tensioned towards both ends.

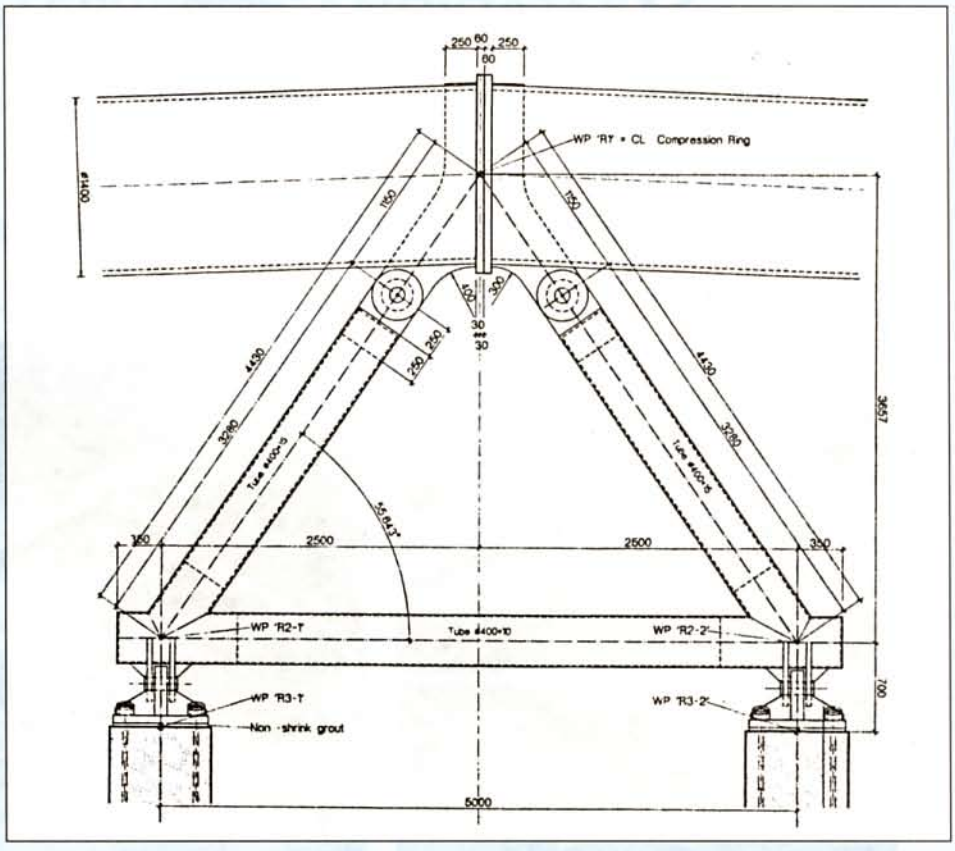



*Diagram 2 - Details of triangular support.*

The membrane is pulled over the arches using special hydraulic equipment to its final position and fixed by stainless steel bows. Each panel of membrane at adjacent sides is welded using a hot-air welding machine. The whole process is then repeated for the rest of the roof.

The Outdoor Stadium roof was 75% completed at the time of writing. When fully completed, the Stadium will have a seating capacity of 100,000. It will have nine tracks and 60m warm-up track under the spectator seats. It is connected via a tunnel to the National Sports Institute for athletes passageway and emergency exit to a helipad. The stadium is also equipped with the state of the art technology for second reinforcement and public address system, floodlighting system, videomatrix colour scoreboards, and medical and doping control facilities.

The Outdoor Stadium is one of three stadiums within the National Sports Complex. The other two are the Indoor Stadium (13,000 permanent seats and 3,000 retractable seats) and the Swimming Complex (4,000 seats). The indoor stadium is designed as a multipurpose hall which can be used for various events such as exhibitions, indoor sports, concerts, motorcross and conventions. It is built with a reverberation time of 2.5 seconds, meaning the audio quality is good for Pavarotti on one extreme and Michael Jackson concert on the other. The swimming complex has a futuristic roof membrane which hangs from 100 meters, inclined at an angle.

All three buildings are entering the final stages of works. The current contract completion date for the National Sports Complex is end June 1998, but UEM is targeting an earlier completion at end December 1997. As one of the venues of the Commonwealth Games, the National Sports Complex is expected to be a new landmark for local and international visitors.

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