Soccer City becomes pot of many peoples

The upgrading of South Africa's Soccer City in Soweto to become the major venue for the 2010 World Cup came together within a circular pot structure as the dominant design motif built largely around structural steel.

While the stadium was first constructed in 1987 consisting of a playing field surrounded by embankment seating with an elevated seating tier on the western side only, the redeveloped 89,000-seater venue has elevated seating on all sides housed within the new bowl structure all finished in time to host both the opening match and the final of the 2010 FIFA World Cup.

The circular plan format of the pot which encircles the rectangular seating bowl and field was selected to ensure that all façade detailing could be consistent in plan and section for an easier detailing, manufacture, installation and cost effective process.

The calabash, or African pot design, proposed by Boogertman Urban Edge + Partners was selected as being the most recognisable object to represent what would automatically be associated with Africa, the calabash representing a 'melting pot of African cultures'.

The pot's façade is made up of laminated fibre reinforced concrete panels, in a selection of eight colours and two textures that make reference to the shades and textures of the calabash. The pot is punctured by open or glazed panels which create a suggestion of pattern when the inside volumes are illuminated.

The roof and the façade steel structures were studied, re-projected and realised in Italy by Cimolai SpA in their workshops.

The global form of the perimeter bowl structure, doubly symmetrical to the axes north-south and west-east, is a torus while the plane of the roof follows the rectangular form of the game field. This conferred a complex double bending that varies both in height and width of the supporting perimetric ring and the cantilevered roof beams.

The roof and façade structure primarily consists of A-frame support structures, an 800m long spatial ring truss, cantilever roof trusses and the façade shell structure, all of structural steel.

The supporting perimetric structure around the game field is a reticular construction with a triangular section composed of three longitudinal pipes with variable diameter between 710mm and 910mm and a thickness between 20 and 40mm and a series of wall pipes. The pipes were entirely produced in the shop of Cimolai using a press of 6000 tonnes.

The whole ring is constituted of 32 sections, each assembled on the ground and then lifted into position with a crane of 600 tonnes and connected to one another by bolted joints.

Sixty of the roof beams cover the galleries and the structures were assembled on the ground in panels and subsequently lifted into final position using cranes from 300 to 600 tonnes.

The façade is organised in 120 axes and consists of vertical HEA 400 and HEB 400 profiles bent with three different bending radii and of transversal RHS profiles. The erection activities onsite necessitated the use of a fixed topographical station to control both the exact position in space as well as the general appearance of the preceding sections so that the resulting geometry of the roof complied with the project.

Cimolai SpA won the South Africa Prize 2009 for the best structure in steel due to the complexity of the structure, the quality of the supply and the beauty of the realised work.

PD Naidoo & Associates (PDNA) as the principal structural engineer for the upgrading appointed German company, Schlaich Bergermann und Partner as specialist roof sub-consultant to assist with the detail analysis and design.

The roof is supported by 12 large, 40m-high rectangular concrete shafts, each of which is designed to withstand large horizontal and vertical loads. The shafts vary in plan from 3.5m x 5.0m to 3.5m x 14.0m, with an average wall thickness of 600mm.

A huge reinforcing steel content of 460kg per cubic metre of concrete (approximately three times more than normal reinforced concrete) made the placing and compaction of the concrete extremely difficult. The stiffness of the shafts under varying load combinations had to be determined accurately, as this could affect the member forces in the structural steel roof structure.

The A-frame support structures transmit all the horizontal forces into the 12 concrete shafts surrounding the stadium. The vertical downward and upward forces are distributed between the 14 shafts and 16 one metre diameter circular columns.

The spatial ring truss as a large triangulated girder enveloping the seating bowl consists of three thick walled circular sections (up to 915mm) with intricate connections to its circular diagonal members. The top of the spatial ring truss is clad with translucent polycarbonate panels thus allowing natural light to cascade into the stadium during the day and transmitting artificial light at night.

An innovative spatial ring truss system able to withstand large bending moments, torsion and normal-forces allowed for differing spans and supporting points to suit the architecture and geometry of the oval stadium seating structure and circular façade structure.

Roof trusses that cantilever up to 38m over the upper seating tier have been fabricated from open sections and are fixed to the spatial ring truss with neatly detailed bolted connections. These connections facilitated efficient erection time frames during construction.

The cantilever roof trusses are clad with arch supported PTFE membrane on the top and a perforated membrane on the bottom. The slim shell structure of the façade is supported on the inclined concrete façade columns at the bottom and the spatial ring truss at the top.

The structural concept and design of the roof and façade structure and its statical behaviour in staying upright was developed by the structural engineers in close collaboration with the architects and contractors to ensure fast track erection.

This design allowed the structural steel sub contractor to optimise the specially developed details which facilitated the transportation and lifting of the heavy steel elements. Bolted and hinged joints were designed to adjust the structure with jacks during erection ensuring a speedy and fluent sequence.

Approximately 9000 tonnes of structural steel was used for the roof and pot façade support:

"Steel combines the advantages of light weight structures with high strength performance. Steel is therefore the most efficient and aesthetically pleasing construction material for the roof and façade structure," said PDNA Director, **Hans Koorn**.

PROJECT TEAM

Client: City of Johannesburg

Main Contractor: Grinaker LTA/Interbeton Joint Venture

Architects: Boogertman Urban Edge + Partners and HOK Sports Architecture

Engineers: PD Naidoo & Associates Consulting Engineers

Roof Consultants: Schlaich Bergermann und Partner

Structural Steel Erection: Cimolai SpA

Steel Fabrication: DSE

Coatings Supplier: International Paint

Images courtesy of: Boogertman & Partners Architects, Grinaker LTA and P.D. Naidoo & Associates Consulting Engineers.