Moses Mabhida Stadium

THE MOSES MABHIDA STADIUM has been designed as a symbol of the unification of a nation with a passion for sport. This is epitomised by the 106 metre high central arch – spanning the length of the stadium. The 360 m long arch supports a web of interlocking galvanised steel cables totalling over 36 km in length which add form to the tensile roof. The 30-storey high arch weighs 2 600 tonnes and consists of 56 sections, each measuring 10 m in length.

The iconic arch has become a world first tourist attraction featuring a high-tech cable car designed to take visitors up to a viewing platform, where they can disembark to enjoy panoramic views of the city and the stadium. The two southern legs incorporate a guided adventure walk of some 550 stairs to reach the top of the arch.

The stadium was designed to be a multi-purpose facility and has proved to be very popular with local and international tourists, due to the attractions and shopping area. To date it has successfully hosted 15 bowl events since its opening at the end of November 2009 with a total of 275 000 spectators. In addition, over 100 conferences and corporate functions have been hosted, 100 000 people have been up the SkyCar, almost 3 000 have walked up the arch and 35 000 people have been on a stadium tour.

MOSES MABHIDA STADIUM

COMMENDATION – Technical Excellence category

KEY PLAYERS

Client Strategic Projects Unit, Ethekwini Municipality
Professional Team Ibola Lethu Consortium (Pty) Ltd
Main Contractors Group 5, WBHO, PANDEV Joint Venture

PROJECT OVERVIEW

Ibhola Lethu Consortium was awarded the design and project management of the new stadium in mid-2006. The major challenges and highlights of this unique project include:

- Stringent requirements for concrete quality, durability and aesthetics were specified and achieved
- Procurement of 57 contracts, 3 direct and 54 sub-contracts, to the main building contract
- Installation of 1 901 no of CFA piles, ranging from 450 – 700 mm in diameter, to an average depth of 20 m
- A world first in the design of the roof arch foundations, involving diaphragm walling to bedrock, massive cappings and springer plinths
- Innovative design and a South African first for pre-cast design and installation in stadiums
- Construction of saw-toothed raking beams to stringent tolerances for the support of pre-cast concrete seating panels

- Design, manufacture and erection of 1 832 pre-cast seating panels varying in weight from 4,5 – 6,5 tonne
- 102 pre-cast façade columns in 25 progressively raked shapes weighing up to 60 tonne
- 16 Shear-cores providing lateral stability to both the bowl and roof structures
- 84 000m^2 of post-tensioned suspended slabs
- Construction of 800 m of reinforced concrete retaining walls varying in height between 4 m and 8 m
- 18 pre-cast 'Tilt Up' panels for architectural cladding of the arch's springer plinths
- 100 pre-cast U-shaped illumination beams
- Precision planning for the operation of 14 tower cranes with 60 – 70 m overlapping jibs, 450 and 650 t crawler-cranes with 115 m jibs, as well as numerous mobile-cranes often working simultaneously
- A workforce of over 2 800 on site at peak time.

STADIUM DESIGN

The stadium bowl provides a structural concrete frame for the support of the spectators seating arena and also acts together with the arch foundations as support for the roof structure. Normal seating capacity is 56 000, which was extended to 70 000 for the FIFA World Cup with additional seating installed on Level 6.

The main structural member of the roof consists of a 106 m high arch spanning 360 m onto the arch foundations. Fifty main ridge cables are supported from the arch which defines the shape for the 46 000 m^2 of roof coverage. These ridge cables, as well as the valley cables, are connected to the compression ring that in turn is supported on steel façade columns

The roof cables are pre-manufactured to exact lengths required for the precise geometry of the cable net structure that spans between the arch and the compression ring. Any deviation from the tight geometrical tolerances would induce forces in the pre-stress cable net that would potentially have serious structural implications. This necessitated very stringent specifications with respect to the setting out tolerances for all support points at the interface between the concrete and roof structure. In addition, the stiffness of the concrete support structure had to be precisely determined, as accurate stiffness values at the interface to the roof were required for the structural analysis model of the roof.

The required stiffness parameters of the concrete support structure were obtained through Finite Element Modelling (using Robobat software) of each segment (expansion joint to expansion joint) of the bowl.

1 and 2 The Moses Mabhida Stadium in Durban – impressive by day and by night

These models incorporated all structural concrete components that contributed to the overall vertical and lateral stiffness of the stadium bowl. The output of the FEM modelling was also used for the foundation and shear core design.

The shear cores provide lateral stability for each section of the stadium bowl (expansion joint to expansion joint). The thickness of the walls varies from 250 mm to 300 mm. The main reason for this variation in wall thickness is to obtain compatible deflections in the concrete structure at the interfaces with the roof structure at Level 6.

The loads transferred from the steel roof columns onto the concrete structure at Level 6 vary vastly around the circumference of the bowl. The concrete structure provides lateral support to the arch at the north and south sides, whereas the reactions on the east and west sides are mainly axial loads.

The main forces transferred through the arch onto the reinforced concrete foundations are in excess of 100 MN applied at an inclination of approximately 38° to the horizontal. A number of

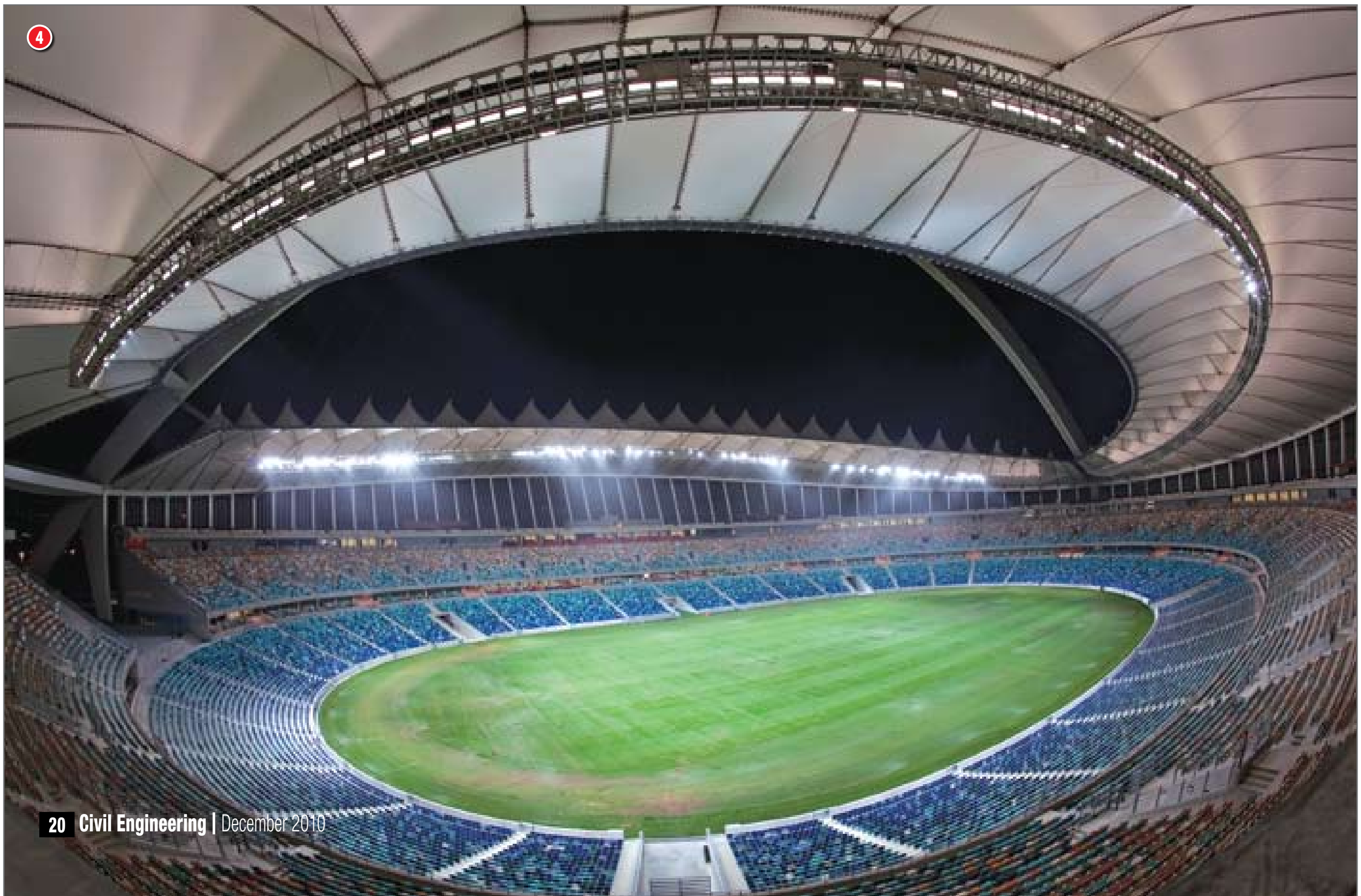
options were investigated to resist these astronomical forces, with the main challenge to limit lateral deflection of the arch foundations.

Options considered ranged from pile solutions, pile and anchor solutions, tie-back to the main bowl structure and diaphragm walls acting as shear walls. It was eventually determined that diaphragm walls were not only the most practical and least time consuming, but also the most cost-effective solution.

The foundations are elongated rectangular boxes with 800 mm thick reinforced concrete walls. The northern foundation is 44 m x 7 m in plan, and the two southern foundations are 30 m x 4 m in plan. The walls were excavated and cast under bentonite slurry (drilling mud) in panel lengths of up to 7 m to a depth of 20 m. Each wall panel is embedded at least 0,5 m into siltstone with a compressive strength of 2 MPa or stronger.

Only limited bond could be relied on between adjacent concreted panels since no transverse shear reinforcement is provided across the vertical joints due to the construction methods. In order for the wall panels to structurally act together, the individual wall panels were connected

3 and 4 The roof of the Moses Mabhida Stadium – attractive in its intricate complexity. The main structural member of the roof consists of a majestic 106 m high arch spanning 360 m onto the arch foundations



at the top with deep heavily reinforced capping beams (3 m on the south foundations, 5 m on the north).

In addition to vertical and horizontal reinforcement, each wall panel contains four or more vertical multi-strand post-tensioning cables. The vertical reinforcing is fully bonded into, and the strands extend through, the deep capping beams which are also post-tensioned. The high-strength post-tensioning cables were introduced not only to reduce the amount of conventional reinforcing in order to provide enough free space for the placing and compaction of the concrete, but also to enhance the stiffness of the foundation structure.

The structural design of the arch requires that the maximum initial horizontal deflection has to be limited to 25 mm while the maximum long-term deflection is limited to 50 mm. The load deflection behaviour of the foundations was analysed using PLAXIS 3D which applies Finite Element Elasto-Plastic techniques for the calculation of soil-structure interactions.

The connection of the arch to its foundation is facilitated through the introduction of a reinforced concrete springer plinth on top of the capping beam. The stringent geometrical tolerances with respect to the positioning of the arch, coupled with the transfer of the enormous forces onto the foundations, necessitated the introduction of a very complicated but precisely detailed steel cast-in element at the top of the concrete plinth.

The arch plinths have a trapezoidal shape similar to that of the arch and are in excess of 10 m high and 16 m long. A total of 275 m^3 of concrete was used in each of the southern plinths, and 420 m^3 in the northern plinth. Each of these plinths was constructed in a single pour, except for the top 1,2 m which contain the embedded cast-in elements. Appropriate additional measures were implemented to control the high heat of hydration to ensure optimal curing of these massive plinths. This was achieved through the introduction of 100 mm thick polystyrene cladding applied externally for temperature insulation.

The final architectural shapes of these plinths were achieved by the introduction of pre-cast cladding panels that were erected using tilt-up technology. These panels weigh up to 20 tonne each and are in excess of 12 m high.

SUSTAINABLE MEASURES

Several sustainable measures have been incorporated into the construction of the precinct. Masts, control gear, topsoil, pre-cast seating, steel (400 tons) and bricks (40 000) removed from the old Kings Park Stadium on the site were recycled and utilised for the new stadium, as well as for other projects in the city. Although the stadium has a huge visual impact, all the stadium lights are contained in a catwalk below the roof, so there are no light masts protruding above the stadium roof. Another sustainable measure has been the incorporation of a harvest tank which collects rainwater from the roof to irrigate landscaping in the precinct. Energy-saving light fittings and regulated water flow devices have also been incorporated, as well as double glazing and sun-control features on all windows. □