ASH RESOURCES

MATERIALS FOR TODAY AND THE FUTURE

In one bold move the skyline of Johannesburg has changed. Symbolising hope and inspiration for the future of the city, the magnificent new Nelson Mandela Bridge fittingly commemorates the person who has the unique charisma to uplift us all.

The dramatic Nelson Mandela Bridge is 284m long, making it the longest cable stayed bridge in South Africa. It reaches out from the slopes of Braamfontein across 42 railway lines to link up with the struggling cultural precinct of Newtown. At one stage the initiatives of two decades ago to transform Newtown into a vibrant cultural entertainment area appeared to be lost to the malaise of urban decay. The determination of the city planners to bring it back to life is showing praiseworthy results. Nearby, the imposing banking blocks with their pedestrian precincts and smart shops, look on approvingly.

The new bridge alone has cost R56million and together with the associated infrastructure and approach roads, the bill will be in excess of R80million. The project has been funded and developed by the Gauteng Provincial Government (through their implementing agency, Blue IQ), working in partnership with the Johannesburg Development Agency (an initiative of the City of Johannesburg), the South African National Roads Agency (represented by their engineers, Goba Moahloli Keeve Steyn) and the National Department of Transport.

The tender was awarded to the LBA Consortium made up of South African companies, Grinaker-LTA-Bafokeng Civil Works Joint Venture and the Nelson Mandela Bridge Consultants Consortium (NMBCC). NMBCC was formed between BKS and ARQ. International bridge design expertise was provided by the appointment of two Danish firms as specialist subconsultants: structural engineers, COWI A/S and architects, Dissing & Weitling A/S. Service relocation and site supervision was awarded to local company, PD Naidoo & Associates. The tender was awarded in July 2001 and allowed a three month period for the design. Piling for the substructures began in the following September. ARQ was responsible for the geotechnical aspects and the substructure, which had to deal with the challenging soil variations that are often a feature of the Johannesburg terrain. On the southern side, the bridge structure is supported on 30m long piles and the northern side 20m.

The dominant visual features of the bridge and a key engineering aspect, are four tubular steel, concrete filled pylons. The pylons are mounted on large concrete support cones designed not only to cope with the high bursting stresses generated by the bridge design, but also designed to withstand the impact of a train derailment. The pylon supports, which were the most difficult aspect of the concrete works in design, specification and construction, are in the form of truncated cones, approximately 6m in height, with a base diameter of 6m and a top diameter of 2,85m. Each cone required almost 100m^3 of concrete and some 12ton of reinforcing steel. BKS detailed each cone to be poured in three lifts, using three different grades of high strength concrete. The bottom section was specified to be 30MPa concrete, the middle 40MPa and the top section 50MPa.

The critical nature of the concrete cones in the bridge structure and the large pours involved emphasized the importance of minimizing thermal defects during construction. With this objective, LBA evaluated various concrete mix options and building procedures. They predicted that if CEM I cement was used for the three high strength concretes, peak curing temperatures of 55ºC above ambient would be reached. Assuming a typical ambient of 20ºC this would have meant a concrete temperature of 75ºC. The differential temperature between the inside and outside would have been such that immediately shuttering was removed, or, a sudden lowering of temperature by a thunderstorm occurred, massive thermal cracking throughout the pylon would have happened. No amount of steel in the design would have been able to prevent it. "In conjunction with the concrete supplier, Holcim Readymix, we arrived at the solution to incorporate 50% of the cementitious content as the high quality Dura-Pozz ® fly ash from Ash Resources," said Alan Parrock of ARQ. "This appeared much higher than the 30% fly ash commonly used but we were able to call on our extensive experience in dam construction, where we often incorporate up to 70% fly ash. Using 50% Dura-Pozz ®, we calculated a peak temperature of 55℃, around which we then developed the building procedure. Although we considered this would give potential temperature differentials of less than 20ºC that were workable, we still had to guard against the possibility of a hailstorm wreaking havoc! This we achieved by stipulating that the lower sections of the pylons should only be poured at night and no activity should take place with thunderstorms in the vicinity. We also designed an insulation system for the outside of the shutters and positioned thermistors in the cones to monitor the temperature gradients. In practice, with the influence of the insulation, the temperature rose very quickly to peak at just under 60ºC at the centre of the pour, within four hours of casting. The external portions of the cones rose to about 45ºC. The shutters were kept in place for four weeks and when removed to start on another pylon, the insulation blanket was put back around the pylon."

"Other points of note about the design and construction of the pylon support cones," adds Parrock, "were the quality assurance procedures that we adopted and the optimisation of the concrete mix. Curing at elevated temperatures causes rapid hydration and consequently rapid strength gain. This is not always taken into consideration on a construction site. We arranged for the quality control test cubes to be done at the same elevated temperatures profile. We experienced no problems at all with achieving the predicted strengths. With regard to the mix design, we specified a slump limit of 75mm, which was fairly low in order to minimise the water content of the mix and consequently enhance the final strength. On the other hand, the pylon support design was very congested with reinforcing and we needed a concrete mix with good workability to prevent pour voids. Using 50% Dura-Pozz ® gave us the flexibility to design an excellent mix that easily accommodated the seemingly conflicting requirements. The final proof of this was seen on removal of the shutters, when an absolutely perfect non-cracked surface was revealed!"

All concrete for the project was supplied in readymix form by Holcim Readymix. "Due to the choice of materials and the excellent teamwork between Grinaker-LTA and ourselves," said Rajen Naidoo, Product Technical Manager at Holcim Readymix, "all the concrete work on the project went extremely well."

An interesting first for South Africa was the use of Flowcrete concrete for the 30m piling which had to be placed in difficult ground exacerbated by the vibration from the trains. This was achieved by first filling the augured piling holes with a polymer slurry to maintain a slight positive pressure to prevent collapse. A self-compacting fly ash concrete mix (80/20 Holcim's CEM II 42,5 A-M/Dura-Pozz®) was then pumped from the bottom up using tremie pipes. The pumping went well with no problems at all. The displaced polymer slurry was recovered and reused.

The expertise embodied in the team that has created Johannesburg's new landmark is impressive. For example, the Danish consulting engineers, COWI A/S, who designed the superstructure and stay cable system, also designed the Øresund Link Bridge that connects Denmark to Sweden. When it was built three years ago, it was the largest civil engineering project in Europe.

Local company, ARQ (Pty) Ltd who handled the tricky geotechnical engineering together with the detailed design of the piled foundations and substructures, is part of a group that operates in thirty countries worldwide with a branch office in the UK. The five divisions of the group are involved in dam design and construction, commercial structures (e.g. the new executive hangar at

Lanseria), heavy structures (major chemical plant e.g for Sasol and bridges), water services and geotechnicsal.

The technique used to cast the pylons is believed to have achieved a world record for a single lift column. Holcim Readymix's Self Compacting Concrete was pumped into each permanent steel shutter, the highest pair being 47m, using Holcim's Schwing pump.

The largest challenge to the construction work on the bridge was building over the continually active main Braamfontein railway lines and marshalling yards. This required intensive cooperation and coordination with Transnet and Metro Rail to ensure that all safety aspects were addressed while keeping the project on track. Grinaker-LTA, wisely and successfully, employed an experienced ex-railway employee as operations manager to handle the coordination.

Completed in May 2003, the creativity and techniques used for the Nelson Mandela Bridge will be discussed and admired for a long time in engineering circles. The bridge has fulfilled the visionary requirements of the Johannesburg Development Agency, that it should be of exceptional architectural merit and be a high class, original, notable structure. Created to focus attention today on the upliftment of the city, the bridge is a worthy gift to posterity. The official opening by Nelson Mandela on his 85th birthday on 20 July will be a memorable day.