Innovative structural steel tied arch footbridge

This project forms part of the prestigious development of the Knightsbridge complex at Century City. The structure provides pedestrian and golf cart access and carries services to Knightsbridge Island. Several challenges had to be innovatively overcome during design and construction. Not least of these involved the structural steel arches, which were to be constructed from a bent 457 mm tubular section. The final solution saw the tubular sections rolled and bent in Gauteng, transported to the DLE yard in sections where they were sandblasted, galvanised and welded. After this they were transported to site where they were erected adjacent to the bridge location before being moved into the final position. The structure incorporated existing piers, which had not been designed to withstand significant lateral load. This required the arch to be 'tied' so as not to induce lateral loads onto the pierheads

THE PRESTIGIOUS KNIGHTSBRIDGE development in Century City required numerous canal crossings, both vehicular and pedestrian, to provide access to the Knightsbridge Island. At this particular location, three existing piers were located on the site, a result of previous unfinished development in the area, and it was decided to incorporate these into the new structure. It was required that the structure carry a trough containing services in the form of five 11 kV cables to the island. These cables need to be inspected and serviced periodically, and so the deck surfacing needs to be able to be removed in sections. Sufficient clearance was required beneath the structure to allow canal traffic to pass underneath, but the approaches to the bridges were limited in terms of gradient as the bridge needed to be suitable for wheelchair and golf cart usage.

The initial proposal carried over the architecture of the early stages of the Canal Walk development. This comprised a two-span arch bridge with a reinforced concrete deck. The client's decision to opt for a more eye-catching design resulted in a proposal from architects Boogertman and Partners in Pretoria. This proposal required considerable space to found the arch bases and also presented some serious construction challenges, including a tapering tubular arch section! The proposal was modified to be more symmetrical and fit in with the adjacent proposed developments. The central pier was to be demolished and the bridge would span the

STRUCTURAL STEEL TIED ARCH FOOTBRIDGE, CENTURY CITY

Western Cape Branch Award for Technical Excellence

KEY PLAYERS

Client Century City Property Developers
Architect Boogertman and Partners
Landscape architect Planning Partners
Structural engineers HHO Africa
Main contractor Peak Projects
Specialist steel contractor DLE Engineering

full canal, and have two jack spans on either side. This proposal was accepted.

STRUCTURAL DESIGN

The structural modelling and analysis of the bridge superstructure made use of the Prokon suite of structural analysis programs. A three-dimensional linear elastic frame analysis was performed on the full structure, checking for maximum deflections as well as for maximum moments and axial forces in the individual members. The deck live loading was taken as a standard uniformly distributed load for pedestrian loading, with additional point loads for golf cart traffic incorporated into certain load cases. The dynamic effects of pedestrian loading were also considered, and it was found that the mass of the cable trough in combination with the cross bracing minimised the dynamic response induced by pedestrian loading.

Upon investigation it was discovered that the existing piers were not capable of withstanding any significant lateral loads, especially not the type of load that would be induced by a purely arched system. Thus it was deemed necessary to use a 'tied' arch system, incorporating the axial strength of the deck's longitudinal members to counter the induced horizontal force. The resultant force on the existing pier would then only be a vertical reaction. It was also necessary then to allow movement at one support so that any temperature effect (such as the thermal expansion of the deck) would not induce lateral forces into the pier heads. This was achieved by using a Teflon sliding plate under the western baseplates to the arches. Slotted bolt holes allowed for a limited range of expansion and contraction.

FABRICATION

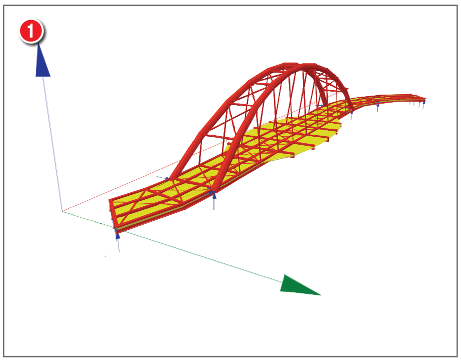
Possibly the most challenging aspect of this project was the fabrication of the two main arch members. These were to be constructed from heavy 457 mm tubular steel sections bent to a radius of 20,78 m. During the preliminary design phase, the difficulty with which such a section could be sourced was underestimated. Several alternatives were investigated, including using straight chords to create the arch shape as well as a trussed arch, but none matched the elegance and simplicity of the curved tubular section. It was perhaps only the assistance of the executive director of the Southern African Institute of Steel Construction, Dr Hennie de Clercq, that finally led to the location of a willing supplier. Mining Pressure Systems in Gauteng bent the section to the required radius in 6 m lengths, which were then cut down to 5 m lengths as the last 0,5 m of section could not be bent.

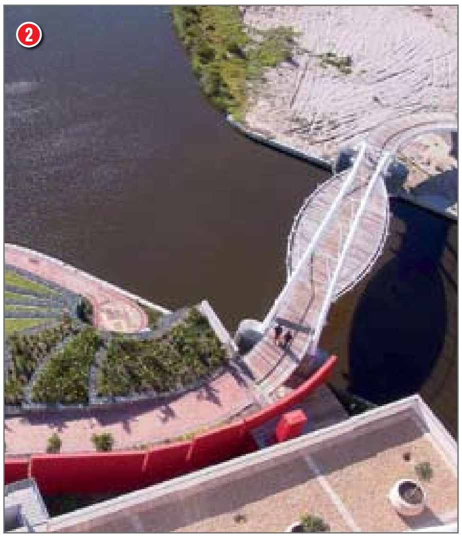
These lengths were transported to the DLE Engineering yard in Cape Town where they were sandblasted to remove a crust formed in the bending process, galvanised and welded together.

ERECTION

Two earth berms were created across the canal on either side in order to drain the bridge site, and the existing central pier was demolished to the level of the canal floor. The remaining pier heads required modification and the closed type reinforced concrete abutments were constructed on either side of the structure.

It was decided that the deck would be erected in situ on props while the arches would be assembled and erected adjacent to the bridge site. This allowed for the two tasks to be performed simultaneously, thereby reducing the length of time required. The arches had been fabricated in segments and had been transported to site in three pieces per arch (15 m, 3 m, 15 m). Four 'dummy' bases were cast to the correct dimensions approximately 30 m away from the bridge piers in order to erect the arch superstructure. Before raising the arches at the trial site, the three segments were welded together and given galvanic protection in the form of zinc-based 'Coldgalv' paint.





The welds were ground flat to minimise the visual interference with the smooth lines of the arch. The welds were also coated on the inside of the arch through holes left in the sections for lighting purposes. Once the two arches were raised, the cross bracing could then be attached, and the final 'brilliant white' finishes could be applied to the structure.

The deck sections were assembled on temporary props until such time as they could be suspended from the arch. After the deck had been assembled, the two arches with their connected bracing were moved into position using a mobile crane. The deck was suspended from the arches and the deck surfacing could continue.

CONCLUDING REMARKS

While it is acknowledged that this project may perhaps not have been the cheapest option for providing access and services to Knightsbridge Island, the client sought to create a feature of the structure and make it an eye-catching element of the surrounding development. The use of a tied arch structure provided an elegant solution and the efforts that were made by the engineers in overcoming various design and construction challenges have proved worthwhile. □

1 Preliminary design model for bridge superstructure
2 Overhead view
3 Arch assembly adjacent to bridge site
4 Placing of arch superstructure

Source:
http://www.saice.org.za/downloads/monthly_publications/2007/CivilEngNovDec2007/#/0