Blackburn Pedestrian Bridge and Walkway: technical aspects

IN THE FEW months following the completion of the Blackburn Pedestrian Bridge, the structure has become a landmark feature of the Durban area, showcasing the technical capabilities of civil engineering design and construction companies in South Africa. Conceptualised by SANRAL, designed by SSI Engineers and Environmental Consultants and constructed by the JT Ross / Devru Construction Joint Venture, the project achieved all the planned objectives, having been designed and constructed within an extremely tight time frame, as a safe and pleasing structure, within SANRAL's budget.

Originally conceived as part of the envisaged Cornubia development, increasing traffic volumes and completion of the new King Shaka International Airport forced the hand of SANRAL to proceed with the construction of a pedestrian bridge and walkway that would allow safe pedestrian access along the N2-26 from Blackburn to the Umhlanga area. A survey revealed that over 500 pedestrians were crossing the N2-26 every morning and evening. Vehicular and pedestrian incidents were recorded as very high for the area and the numbers showed that increased future incidents and deaths were inevitable unless a solution was provided.

Identified as a SANRAL Community Development project intended to provide long-term socio-economic upliftment, the project began at community level by meeting with community leaders to identify the location preferred by those who would be using it. The location chosen was a high-level crossing over the N2 adjacent to the community, with the aim to create a walkway with the mildest possible gradient for its entire 2 km length.

The location, at the widest median of the N2-26, was an 80 m wide valley

1 The completed Blackburn Pedestrian Bridge

BLACKBURN PEDESTRIAN BRIDGE AND WALKWAY: technical aspects

Technical Excellence category
Submitted by the SAICE Pietermaritzburg Branch

KEY PLAYERS

Client South African National Roads Agency Limited (SANRAL)
Professional Team SSI Engineers and Environmental Consultants
Main Contractors JT Ross (Pty) Ltd – pedestrian bridge
Devru Construction – roadworks and walkway
Major Subcontractors and Suppliers
Structural Systems Africa – deck post-tensioning and cable stays
Métier Mixed Concrete, Empower Reinforcing

between the busy northbound and southbound carriageways. In order to satisfy the community's request for a mild gradient, the deck level would have to be 9 m above the N2.

Conceptual designs were greatly influenced by the deck height, median terrain and soil profiles identified from the geotechnical investigation. Design options such as a six-span continuous beam and column structure and a two-span stressed-ribbon bridge were explored, along with more innovative and technical solutions such as a cable-stay option and a double arch. It was the aforementioned factors, in particular the difficult founding conditions at the selected location, which dictated the costs of each option.

The significant depth to adequate founding along half of the bridge length favoured fewer footings. Utilitarian options offered almost no cost savings over the more challenging long span solutions, and in early 2009 SANRAL's technical team approved the cable-stay pedestrian bridge in the form in which it now stands.

The height and location of the structure required that provision for lightning protection, as well as a protective light beacon, be provided to prevent damage to the structure from extreme weather and to alert aircraft. For these purposes, electric ducts were enclosed within the legs of the pylon to maintain the sleek aesthetics of the structure.

The aesthetic appeal of the structure was intended to be derived from its slenderness and the configuration of its components rather than by unnecessary adornments, and was conceived in-house without architectural input.

Technical challenges in the design of the bridge deck included:

- Post-tensioning to accommodate TMH7 requirements, as well as international cable-stay standards (fib), which mandate the loss or removal of any single stay. This required that at the cable-stay connections, the bridge deck edge beams were required to accommodate both positive and negative bending moments arising from either 8 m or 16 m spans. These requirements favoured the use of concentric pre-stressing for the entire stayed deck length.
- In order to satisfy the same international standards with which the cable stays complied, the cable-stay connections at the bridge deck and pylon were required to meet 100 year life-cycle parameters.

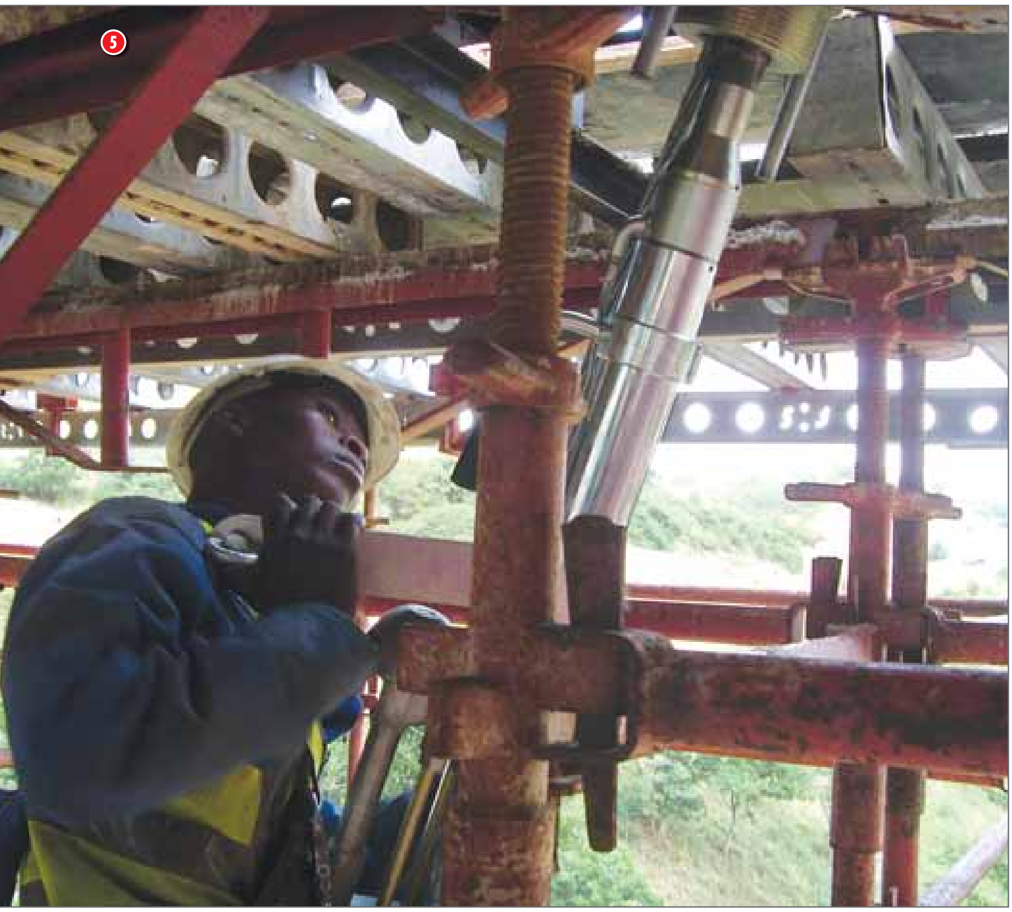
This meant that corrosion (including electrolytic decay between unlike metals) and fatigue design (to eliminate the risk of brittle fracture) due to cyclical load cycles from cable-stay vibrations required careful consideration.

- Splitting in the thin deck slab warranted a 3-D finite element analysis of the deck section as post-tensioning effects could result in tensile forces away from the compressive stress flow in the edge beams. Significant additional reinforcing was required in the slab to prevent longitudinal cracks from forming at the stressing points.

In addition to the challenges listed above, a wind expert, Dr Adam Golliger, was consulted on the wind forces expected in the area and the potential for associated dynamic effects. The engineering team and Dr Golliger determined that the proposed deck shape, mesh screen and cables would not contribute or succumb to wind induced excitation, such as swaying, vibration or galloping. Dynamic models had suggested that the TMH7's alternative wind loading Method B was applicable to the Blackburn Pedestrian Bridge and Dr Golliger's report served to provide an external check of the wind-loading forces determined from this method.

Slenderness of the structure required a careful investigation into potential effects of footfall-induced vibrations. Because the TMH7 does not provide guidance on dynamic behaviour of cable-stayed structures (such as the Blackburn Pedestrian Bridge), specialist literature was consulted. A computer model was created to determine the modal excitations of the structure. Whilst special attention was paid to the bridge deck (in vertical, lateral and torsional movements), the entire structure was analysed for dynamic behaviour. The preliminary investigation revealed that several structural modes existed within the frequency range shared by pedestrian footfalls. Although

2 Aerial view of construction site between the north- and southbound carriageways of the busy N2
3 Prepping stays for installation
4 Installation of stays (prior to tensioning)



this raised alarm bells, the design team used customised design tests and experience in dynamics (from past design experience in earthquake-prone California) to rule out footfall-induced vibrations.

Originally envisaged as balanced cantilever construction of the deck, the contractor's proposed construction method utilised scaffolding to continuously support the entire bridge deck, which required several kilometres of support tubing. The balanced cantilever method of construction was intended to minimise the impact on N2 traffic and the environmentally sensitive wetlands in the median. Using scaffolding to support the bridge deck required that truss beams be used to span over the wetland area in order to have little or no impact on the area.

The alternative construction method also required a quick re-design of the deck post-tensioning. The bridge deck comprises two edge beams sized

5 Tensioning of stays from below the deck
6 View along deck of the completed bridge

to accommodate the deck-stressing ducts and the coupling anchors. Detailing the couplers, their uniquely shaped bursting reinforcement and the cable-stay ducts with their own system of bursting reinforcement required excellent attention to detail and three-dimensional thinking from SSI's technical team. The level of detailing required to accommodate the electrical conduits for lighting and lightning protection in the pylon legs at the intersection with the bridge deck also proved a technical achievement.

The cable stays and their installation required SSI to provide a 'stage-by-stage' analysis of the structure, outlining the behaviour of the structure as each stay was progressively stressed. Not only time consuming, this process required that the cable would be loaded to the correct final stresses (bearing in mind that each additional cable being stressed impacted the cables around it) and attainment of the deck at correct fi nal levels. Complicated by elastic behaviour of the scaffolding and the lateral flexibility of the pylon, the looming FIFA World Cup deadline meant that additional re-stressing would result in unacceptable delays. Prior complications and challenges had reduced the time window allowed for installing the stays but the final deck profile was achieved ahead of the required deadlines and by late May 2010 the Blackburn Pedestrian Bridge was standing on its own. The impact and benefit to the community was evident early on when community members began crossing the N2 using the Blackburn Pedestrian Bridge before it was fully completed. A follow-up pedestrian survey is under way and findings are showing that today those hundreds of Blackburn Community members who previously risked their lives every day crossing the N2 now walk and bike to their work using the bridge and its walkway. This project has clearly achieved its goal of providing its intended value to the Blackburn community, while also successfully overcoming the numerous design, detailing and construction challenges inherent in such a technical project.

Originally envisaged as balanced cantilever construction of the deck, the contractor's proposed construction method utilized scaffolding to continuously support the entire bridge deck, which required several kilometres of support tubing. The balanced cantilever method of construction was intended to minimise the impact on N2 traffic and the environmentally sensitive wetlands in the median. Using scaffolding to support the bridge deck required that truss beams be used to span over the wetland area in order to have little or no impact on the area