Rebuilding a historic Stellenbosch bridge with precast concrete beams

The old bridge over the Plankenbrug River (formerly Dwars River) in Stellenbosch was rebuilt by Martin & East with nine precast concrete beams supplied by Concrete Manufacturers Association member, Cape Concrete. Designed by infrastructure consultancy, AECOM, the first phase was completed in August 2022 and the second and final one during the first quarter of 2023.

The second beam in Phase 1 is lowered into position onto the first abutment lift

The new bridge provides improved access to Bosman's Crossing, a burgeoning residential, commercial and light-industrial precinct situated in the old KWV Industrial Park immediately east of the bridge.

The site's first bridge appeared in 1691 on what was the old wagon road "Highway", the earliest formal route into Stellenbosch, and one of the first, if not the first, bridges to have been built in South Africa. The site is considered an integral and authentic piece of Stellenbosch and indeed Cape history, and over the years the bridge was either upgraded or rebuilt.

The area's known historical links can be traced well beyond the 17th Century, in fact to the early Stone Age period some two million years ago. A monument just off the western approach to the bridge marks the point where stone implements, including a Palaeolithic quartzite axe, were discovered in 1899.

The new bridge replaced the one which was erected in stone and in-situ concrete during the early part of the 20th Century. It was upgraded to a narrow double-lane thoroughfare in the 1950s when its abutments and central stone pier were enlarged and strengthened. During the 1960s the structure gradually fell out of use as one of the main routes into Stellenbosch after the construction of the Adam Tas Road Bridge over the Plankenbrug River, which provided more direct and faster access. And from the first decade of the new millennium onwards Distillery Road was closed as a route into town and only served Bosman's Crossing, which it still does today.

However, the growth of the Bosman's Crossing precinct during the second decade of the 2020s; an increase in traffic and the deteriorating condition of the bridge, prompted the Stellenbosch Municipality to investigate widening and strengthening options.

Design proposals and heritage factors

AECOM was appointed to inspect the bridge in 2020 and found the structure to be neither safe nor practical for existing and anticipated traffic volumes. Based on this finding AECOM was commissioned to evaluate alternatives which compared repair, rehabilitation and upgrading options. And because of the site's possible historic significance, the council also appointed a heritage architect to compile a report to be used as a guideline for the rebuild.

Prepared by Rennie Scurr Adendorff Architects and CTS Heritage in consultation with Heritage Western Cape, the report was submitted together with the permit application to upgrade the bridge. Covering the heritage, archaeological, landscape and contextual significance of the site, the report recommended that the new design should respond to the semi-rural character of its immediate surroundings rather than the commercial and residential aspects of Bosman's Crossing.

PROJECT TEAM

Client: Stellenbosch Municipality

Consulting engineers: AECOM

Main contractor: Martin & East

Precast beams: Cape Concrete

Support work: Formscaff

Heritage architects:
Rennie Scurr Adendorff Architects

Heritage consultants: CTS Heritage

Several design proposals were considered in the report. In each case, the improvements required to improve traffic flow and safety were assessed in terms of the bridge's alignment and positioning; its component features; load bearing capacity of the old elements; river through-flow and flooding; and the need to limit any potential damage to the surrounding landscape and environment.

The engineering team tabled six design proposals that were workshopped with the heritage team. Two options which adhered to both heritage and functional requirements were adopted and developed further by the engineering team. One proposed retaining the central stone pier as a non-structural component in a single-span bridge and the other advanced a two-span structure with a functional central pier.

Bearing capacity

AECOM's analysis confirmed that the bearing capacity of the existing central pier would be significantly exceeded if it were incorporated structurally in the proposed two-span design and would require another row of piles and further structural modifications. By contrast, in a single-span design – using prestressed precast concrete beams supported by new abutments – the central pier could be retained in a non-structural capacity, and it was this solution which was finally chosen.

The retention of the pier was recommended because, as with the old abutments, it predates the existing upper structure and could therefore serve as a visual link to the old stone bridge. An additional heritage aspect was the reinstatement of four existing handrail bollards, which serve as entry markers at either end of the bridge.

Workers insert rebar through sleeves situated in the beams' lower web sections

Eight metres wide, kerb-to-kerb, and 22,5 m long (2 m longer than the old bridge), the new bridge accommodates two lanes of traffic. In addition, cantilevered sections on either side of the vehicle deck were built for pedestrians and cyclists. Besides their functional purpose, the sections enhance the visibility of the central pier and reflect the character of the old bridge.

The new bridge was designed by AECOM bridge engineer, Heinrich van Wijk, who proposed a precast beam design primarily because it saved time, reduced the risk of flood damage to formwork staging, and limited construction debris falling into the riverbed.

"In a cast in-situ bridge option, there is an element of flood risk when staging formwork above a riverbed. Instead, we chose to specify

The edge beam in Phase 1 is lowered into position

The soffit sides of Phase 1 beams and the old central pier

T-shaped suspension bracketing at the Phase 1 walkway mounted on pivot-point jacks

The underside girders and Econoform panelling

a precast construction technique, which limits disturbance in the riverbed and enhanced our application to the Department of Water and Sanitation for a water-use license," said van Wijk.

Van Wijk's design adheres to the South African bridge design code of TMH7 for NA and NB loads. One of the design constraints was the need to keep the bridge open during construction, which is why it was built in two phases. Apart from 1,5 m wide edging – which was demolished – the old bridge was left intact during the construction of Phase 1 and was only fully demolished once Phase 1 was opened to traffic.

Integral monolithic design

"The abutments and deck were built in an integral monolithic design, unlike conventional bridges which are mounted on bearings with expansions joints at either end. The integral design approach allows the free articulation of the deck without imposing significant stresses on the abutments. Thermal expansion and contraction are the primary source of movement (elongation and shortening) and the magnitude of this movement is directly related to the length of the deck," Van Wijk continued.

"For shorter decks, conventional expansion joints are not needed. Instead, thermal expansion and contraction can be accommodated by buried joints located at either end of the bridge, which allows for the small movement of the flexible abutments.

"Bank pad abutments were cast onto a single row of piles in two lifts. The first abutments were cast above new piles, which varied in depth between 13 m and 19 m, at either abutment end. The pile diameters were designed with sufficient flexibility to accommodate deck movement, and the back-ends of the abutments were backfilled with rounded aggregate, which allows for ratcheting movement within the fill and prevents the build-up of stresses behind the abutment."

Precast installation and piling

Cape Concrete cast nine 22,8 m prestressed beams for the new structure: seven internal beams weighing 25 tonnes apiece; and two edge beams at 35 tonnes each. The edge beams are non-symmetrical with thicker sides and flat face finishes. Four beams were used in the construction of Phase 1 on the southern side of the bridge and five were used for Phase 2 on the northern section. Both edge beams were designed to support the cantilevered walkways with protruding transverse pull-out bars.

Martin & East construction manager, Ricardo De Sa said that a temporary barrier was placed on the old bridge during construction of Phase 1. "Once the piles had been sunk, seven in Phase 1 and six in Phase 2, they were trimmed to the bottom of the foundation level before the first-lift abutments were cast. The second lifts act as diaphragm beams, tying all the precast beams together at either end of the bridge. Moreover, we cast concrete jockey slabs between the second abutments and the feeder road sections at each end to act as an interface between the solid concrete of the bridge deck and the more flexible road surface," said De Sa.

When the first-lift abutments had reached the requisite seven-day strength, the precast beams were lowered onto temporary steel bearings which had been cast into the first abutment lifts of both phases. In addition, matching bearing steel plates were cast into the beams' soffit sides. After being lowered into position, the beams were tied together at the bottom of the lower beam flanges with transverse reinforcing, which was covered with a 150 mm layer of in-situ concrete.

The installed beams were capped with a permanent Nutec formwork and reinforcing for the 175-250 mm cast in-situ bridge deck. The deck was cast with protruding rebar to tie into and support the walkways' cantilevered reinforcing.

"Apart from some minor staging at each end of the bridge, the walkways were constructed without ground supported staging due to environmental concerns. This meant we had to come up with an alternative method of supporting and constructing the cantilevered platform," De Sa continued.

"We opted for inverted steel-girder T-shaped suspension brackets, designed and manufactured by Formscaff, from which the support-work and formwork could be hung. The brackets, which extended 2,4 m off the edge of the deck, were mounted on two pivot-point jacks."

In addition, the brackets' horizontal sections were secured to the underside of the deck with dywidag bars, and once all 24 T-brackets had been attached to the deck they were linked together with steel girders and poles to form an integrated support unit. Girder sections were also attached to the underside of the deck to support the Econoform panels used for casting the walkways' sloped soffit surface.

Transverse cantilever support

Six transverse cantilever beams support each walkway slab. They include voids in the concrete to save weight and make provision for future service pipes. The cantilever beam reinforcing was spliced together with the Y20 rebar rods which had been cast into the top deck. They were also spliced with R20 inclined pull-out rebar, which extended from the bottom of the edge beams.

Additional formwork support was provided by tension cabling, which were attached to the top of the vertical bracket sections and the lower support girders on the one side, and from the top of the bracket sections and the

Perspectives of the completed bridge

end of horizontal girders on the deck side. Once the walkway concrete attained an early strength of 60% of the required 40 MPa rating, the cabling was de-tensioned.

After all the support work had been removed, a further 20 mm of concrete was added to the top surfaces of the walkways, rendering them flush with the 40 mm premix layer on the bridge deck. This additional layer includes several service ducts and slopes at 1,5% for stormwater drainage. The bridge itself slopes at 1% from west to east for drainage.

M-type beams

The M-type beams were cast at Cape Concrete's yard in Cape Town as a portal framework based on a bending schedule and rebar drawings supplied by AECOM. They comprise a wide bottom flange, a narrow web portion and a flared upper flange section.

"We used a W50 mix with a super plasticiser in a 100 slump flowable concrete, which complied with three durability criteria: oxygen permeability, water sorptivity, and chloride conductivity," said Cape Concrete director Johan Nel. "The plasticiser reduced water consumption and gave us better workability. What's more, we achieved a transfer strength of 40 MPa which was reached in 18 hours using the high-strength mix design and steam curing."

After de-tensioning, the beams assumed a vertical positive camber of between 15-20 mm, but once they were positioned on the bridge and the in-situ deck slab had been cast, they assumed a neutral camber.

"Reinforcing is congested when using prestressed strands, which is why we used a 13 mm stone in the mix. It is vital for the concrete to flow through the rebar and fill the entire structure without air pockets, and smaller stones facilitate this process. We used external vibrators and pokers to remove all the air, but we only used pokers on the top flange sections," Nel continued.

"One of the plusses in M-type beam casting is that the bottom flange dimensions remain constant. If larger spans are required, one simply adjusts the web or top flange depths," Nel concluded. ■