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Warwick Triangle Viaduct

BACKGROUND

The Warwick Triangle precinct is the busiest transport hub in Durban. The major access to the CBD from the west passes through the precinct and the precinct is the location for the main rail terminal, as well as bus and taxi ranks. To mitigate against the conflicting traffic movements it was necessary to separate, as far as possible, traffic within the precinct and traffic that was passing through. The best way to achieve this was to build a viaduct that would carry outbound traffic over the existing Eilat Viaducts, Market Road and Warwick Avenue before merging with the Western Freeway.

National government made funds available to the host cities to improve transport-related infrastructure in the lead up to the 2010 FIFA World Cup. A condition of the funding was that the improvements had to be in place before the start of the tournament in June 2010. To procure the viaduct in the shortest possible time it was necessary to proceed with the project on a design-and-construct basis. Tender documents were made available on 26 November 2008 after four tenderers had been shortlisted following a prequalification process. Distinguishing features of the tender included the following:

- Beneficial occupation of two of the three lanes of the viaduct was required by 28 May 2010. Thereafter a temporary suspension of the work would take place during the World Cup, with final completion mooted for September 2010. Assuming a starting date at the beginning of February, this left the contractor with only 16 months to the first milestone.
- An onerous allowance of 110 days for adverse climatic conditions had to be allowed for. This was far in excess of the normal provision of approximately 40 days for a similar length contract and again highlighted the importance the client had attached to meeting the first milestone date.
- The contractor was responsible for all service relocations and would be paid on a dayworks / proven cost basis for all work involved in moving and reinstating these services.
- A preliminary layout of a viaduct was included. The tenderers were, however, encouraged to consider alternatives that would still meet the basic requirements.

SITE CONSTRAINTS

The proposed viaduct was required to be three lanes wide and approximately 370 m in length, commencing just west of the Russel Street and Leopold Street intersection before rising steeply over the inbound Eilat Viaduct. The viaduct then had to cross over an office block, the outbound Eilat Viaduct, Market Road, the Victoria Bus Station, Warwick Avenue and a taxi rank before joining with Canongate Road and the Western Freeway.

CONCEPTUAL DESIGN

The primary challenge that had to be addressed at tender stage was to develop a concept that would meet the difficult geometric constraints and that could be built within the extremely short construction

1 The completed bridge
2 The Warwick Triangle Precinct
3 Construction at western end
4 Formwork to pier head

period. An unusual design concept was developed that had a variable depth superstructure comprising a balanced cantilever-type pier head together with an infill deck of precast concrete U-beams. This novel structural configuration had the following critical advantages:

- The variable depth of the superstructure, which was achieved by having a greater structural depth at the supports and the thinnest possible depth at mid-span, meant that it would be possible to provide the necessary clearance over the Eilat Viaduct and limit the grade from the Russell Street intersection to not more than 10%.
- The construction of the pier heads would in general not interfere greatly with infrastructure below.
- Construction could progress at any of the pier locations in any order, subject only to the limitations of the contractor's resources.
- Construction of the precast U-beams could be carried out simultaneously with the pier heads.

Following submission of the tenders on 28 January 2009 and a short adjudication period, the contract was awarded to the Group Five Pandev JV on 6 February 2009.

5 Pier head awaiting placement of beams

6 Placing beams over Market Road

FOUNDATIONS

The construction of the foundations invariably is one of the riskiest activities during construction, as unforeseen obstacles or ground conditions can cause serious delays to the project. The Warwick Triangle project was no different, as a number of challenges arose during the installation of the piles. Chief among these was the massive obstruction encountered 6 m underground at the east abutment. Attempts were made initially to chisel through the obstruction. However, it soon became apparent that the obstruction was just too large, and it was decided to excavate and remove the obstruction. The excavation was promptly carried out and revealed a massive 3 m thick concrete slab. A search through the municipality's archives revealed that the slab probably formed part of a workshop for the city's tram station dating back to the early part of the last century. Once the foundation had been demolished, the excavation was backfilled and piling recommenced. Over 4,8 km of precast concrete piles were required for the nine piers and two abutments, with an average pile length of 23 m.

PIERS

The nine piers were spaced uniformly at 39 m centres. Pier heights ranged from 9 m to 19 m. The column section of the pier comprised a hollow box, 2 m wide in the longitudinal axis of the bridge and 6 m wide in the transverse direction, with 300 mm thick walls. The pier head has a variable radius bottom slab with 600 mm wide webs and a hollow box cantilever section to match the profile of the U-beams in mid span. A three-dimensional model was created by the supplier of the formwork and this assisted greatly in visualising the completed pier head. The complex geometry resulting from the vertical and horizontal curvature of the road was dealt with by keeping the bottom slab geometry constant at each pier and manipulating the arc length and slope of the initial radius at the root of the pier head.

The fast-track nature of the project, together with the desire to limit differential shrinkage cracking between subsequent concrete pours, led to a somewhat unconventional process for bridge construction. This involved casting the bottom slab of the pier head together with the lower portion of the webs. Polystyrene void formers, together with hardboard sheets, were then installed to create the internal formwork. This enabled the contractor to create the intricate formwork in only three days, with the net result that the top slab and upper portion of the webs could be cast within a week of the bottom slab. Whilst this was expensive, the decision contributed significantly to accelerating progress on site and virtually eliminating differential shrinkage cracking. After the concrete had gained a strength of 35 MPa the pier head was prestressed in the longitudinal direction.

Seven of the piers were constructed on conventional falsework. The pier heads for Piers 4 and 5 extended over the existing Eilat Viaduct and a different formwork arrangement was required. This took the form of a substantial structural steel gantry with a maximum depth of 4 m that cantilevered 10 m off the pier. The gantry weighed 65 tons and was constructed from plate girders and heavy-rolled sections. The steel gantry was supported by leaving a hole through the front wall of the pier and thickening the side walls. The concentrated load applied by the gantry required a large quantity of bursting reinforcing to distribute the stresses throughout the pier.

An important feature of the pier head was the connectivity between the precast beams and the pier head. To reduce future maintenance requirements, joints and bearings were eliminated as far as possible. The resulting structural system was a series of portal frames with only three internal joints required in the 372 m long bridge. Two end conditions were therefore required at the ends of the pier head. In most cases a monolithic connection was made between the pier head and the U-beams. This required careful detailing of the heavy reinforcing present to prevent a clash between the reinforcing projecting from the end of the U-beam and that projecting from the diaphragm at the end of the pier head. Allowance also had to be made for the jacks required to stress the post-tensioning tendons.

At the free end of the deck a halving joint was created to accommodate the pot bearings and a single gland and claw type expansion joint. The surface of the halving joint was treated with a silane-siloxane water repellent as a precaution against water leaking through the joint. The halving joint is easily accessible for inspection and maintenance due to the gaps between the U-beams. The lower portions of the piers were constructed from 30 MPa concrete, with the head itself constructed from 40 MPa concrete.

U-BEAMS

A total of 80 precast concrete U-beams were required for the bridge. The average beam length was 20 m, with minor differences in length required to suit the horizontal curvature of the bridge. A small side cantilever of varying length was used to match the horizontal alignment of the road. Beams were 1,1 m high and were normally reinforced. The beams were constructed in a precast yard adjacent to the site camp while the piers were being constructed. The beams were constructed from 40 MPa concrete, and retarding agents and high-pressure washing were used to create a sandpaper-like surface for all surfaces that were subsequently cast. Beams weighed up to 35 tons and were transported from the precast yard into position on Sundays during road closures. A 275-ton mobile crane, the largest available in Durban, was required to lift the beams into position. The team fine-tuned the logistics to such an extent that the road closures were reduced to just three hours in which time all eight beams for a span were loaded at the yard, transported to site and placed in position. The beams were supported on small nibs at the ends of the pier heads until the diaphragms had been cast.

CONSTRUCTION SEQUENCE

One of the primary benefits of the structural scheme that was adopted was the relative flexibility in working areas during the early stages of construction. The piers and abutments could be constructed in any order and simultaneously with the construction of the precast beams. This meant that the challenges encountered during the relocation of services and installation of piles had very little impact on the critical path.

There was far less flexibility during the final stages of construction, because stresses could be locked into the structure once the connecting diaphragms had been cast. This required careful consideration of the construction sequence. A number of detailed analyses were carried out in Strand 7 finite element software to determine which sequences of construction could be accommodated. These sequences were then verified by carrying out independent checks using RM2000 bridge analysis software.

PROGRAMME

The programme of just 16 months to complete a large viaduct over the busiest transport node in Durban was extremely challenging. The condition of the funding meant that the completion date of 18 May 2010 was non-negotiable. Detailed programming and continuous monitoring of progress, together with experience gained on previous fast-track industrial projects, meant that the site team could quickly identify when additional resources would be required. The teamwork from all role-players that characterised the project, together with the skill and dedication of the construction staff, were instrumental in the practical completion of the project one month ahead of schedule at the end of April 2010 – a fantastic achievement.

SUMMARY

The completion of this technically complex project over the busiest transport node in Durban is a noteworthy achievement. The design-and-build approach adopted by the eThekwini Municipality was fundamental to constructing the bridge in such a short period. The project was completed safely, with minimal disruption to traffic, ahead of schedule, achieving the highest quality and well within budget. The municipality has realized an asset that is aesthetically pleasing, functional and low-maintenance, and the passage of commuters through this congested area has improved dramatically. ◻

PROJECT TEAM

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eThekwini Municipality, Roads Provision Department
Project Manager
SSI
Designer
Goba (Pty) Ltd
Contractor
Group Five / Pandev JV

Source:
http://www.saice.org.za/downloads/monthly_publications/2011/2011-Civil-Engineering-march/#/0