Warwick Triangle Viaduct: Outbound

INTRODUCTION

The Warwick Triangle Precinct in Durban is one of the busiest trading and transport hubs in Africa. Major traffic conflict resulted from the movement of the estimated 460 000 people passing through every day. Funding made available by the government for transport-related improvement for the 2010 World Cup gave the eThekwini Municipality the opportunity to fast-track the construction of the viaduct that would be necessary to remove the at-grade intersections for vehicles travelling from the CBD. A condition of the funding (that the improvement be completed before the World Cup) necessitated a departure from normal procurement, design and construction processes. Faced with a highly congested work environment and many physical constraints, the project team overcame all challenges to successfully deliver the project safely, and with minimal disruption to traffic, four weeks ahead of the demanding schedule.

DESCRIPTION OF THE PROJECT

To procure the viaduct in the shortest possible time the eThekwini Municipality Roads Provision Department elected to proceed with the project on a design and construct basis, a decision which proved pivotal to the success of the project.

1 The Warwick Triangle precinct

WARWICK TRIANGLE VIADUCT: OUTBOUND

COMMENDATION – Technical Excellence category
Submitted by the SAICE Durban Branch

KEY PLAYERS

Client eThekwini Municipality Roads Provision Department
Professional Team SSI Engineers and Environmental Consultants (project manager), Goba (Pty) Ltd (design engineer)
Main contractors Group Five Pandev Joint Venture

SSI developed a conceptual design and facilitated the procurement process. Following a prequalification period, four tenderers were invited to submit bids. Distinguishing features of the tender were the following:

- Adjudication of the tenders was based not only on price and BEE, but also on programme, aesthetics and innovation. This indicated the client's willingness to reward schemes that could be built quickly, were harmonious with the environment and that offered a unique solution to the site constraints.
- Beneficial occupation of two of the three lanes over the viaduct was required by 20 May 2010, with final completion required by September 2010.

DESIGN APPROACH

The primary challenge that had to be addressed at the tendering stage was to develop a concept that met the difficult geometric constraints and that could be built within the extremely short construction period. An unusual design concept was developed by Goba (Pty) Ltd and the Group Five Pandev JV – 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 midspan, 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.

2 Pier 5 awaiting placement of beams
3 Placing beams over Market Road; note congested work area
4 Different formwork arrangements
5 The massive scale of the project is even more impressive when seen from below

CONSTRUCTION

Immediately after award the contractor created three distinct working zones that were fully boarded to provide a safe working area. The first challenge on site was to deal with the myriad of service relocations necessary to enable construction of the foundations. Excellent communication with the various service owners was instrumental in effectively and quickly completing this vital component of the work. The next phase was the installation of the foundations. The Warwick Triangle area has a fairly complex geology as a result of the area having been the Durban bay shoreline approximately 4 000 years ago. Berea formation sands overlay shale bedrock at the western end. Further east estuarine silts and clays overlay siltstone with dolerite intrusions. Depth to bedrock varies from 20 to 30 m. Layers of mixed fill cover the natural ground in many places, and the water table is shallow and tends to be perched on clay layers.

Precast piles offered the optimum piling solution in terms of economy and speed of construction. The piles were all equipped with rock shoes to aid penetration and to provide some fixity into the bedrock. Couplers were required, as two or three lengths of piles were required from the pile cap to the founding level. The piers were typically supported on 16 piles spaced at 1,5 m centres with rakes of 1:5 in the longitudinal direction. Over 4,8 km of piles were required for the nine piers and two abutments, with an average pile length of 23 m.

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 which 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 and 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 it was expensive, this 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 formwork. The pier heads for Piers 4 and 5 extended over the existing Eilat Viaduct and a different formwork arrangement was required. This took

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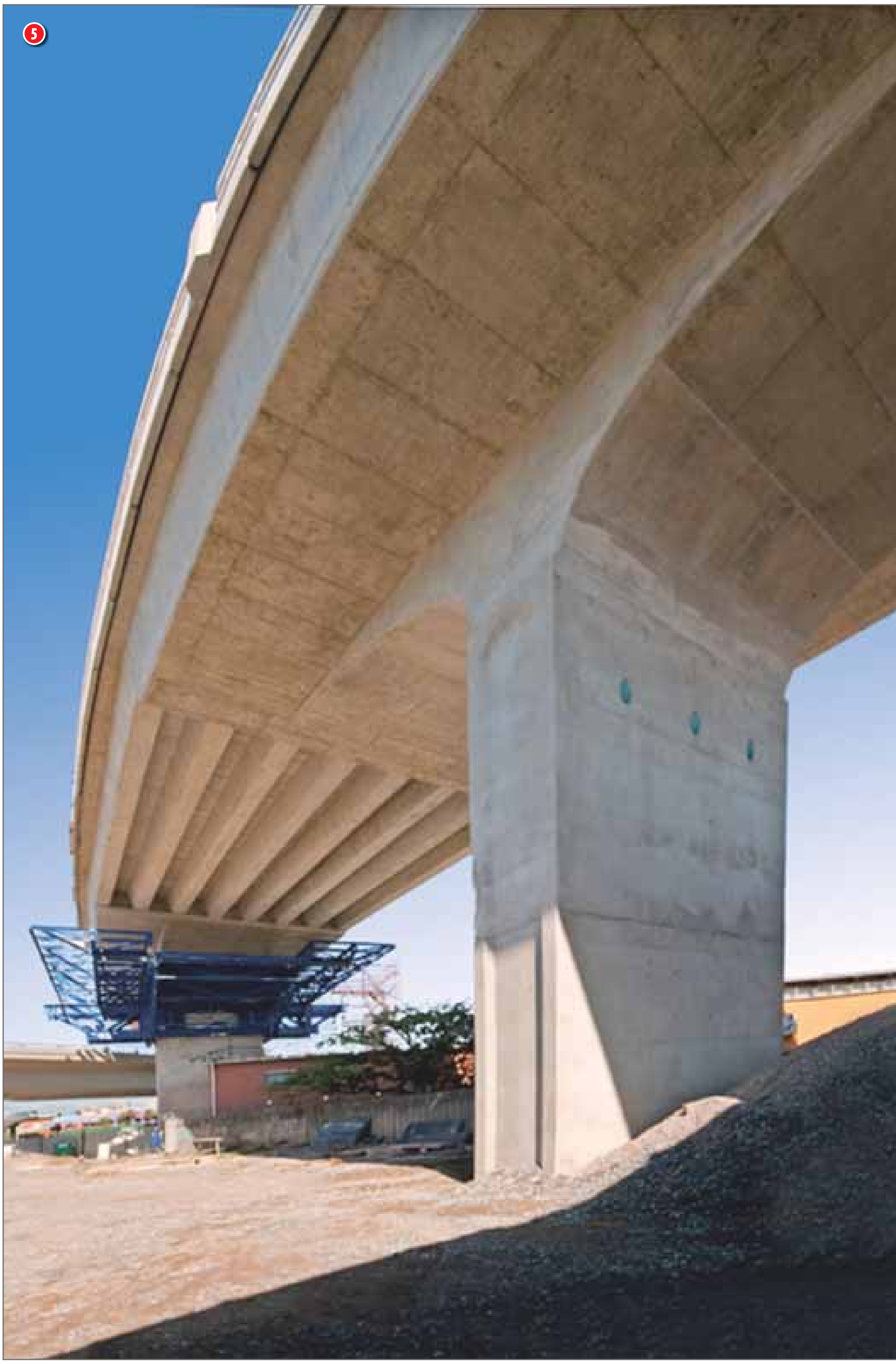

6 The completed bridge

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.

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. The beams were constructed in a precast yard adjacent to the site camp while the piers were being constructed. 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, during 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.

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.

CONCLUSION

Funds made available for infrastructural improvements leading up to the 2010 World Cup gave the eThekwini Municipality the opportunity to improve the lives of thousands of commuters travelling through the Warwick Triangle Precinct. Excellent communication and engagement between all role-players, together with the adoption of fast-track procurement and construction methods, delivered the project in record time. The innovative design and high quality of construction have showcased the role of engineers to society at large, and have left a legacy of a greatly improved urban landscape and safer environment for all. □

What the judges had to say

The construction of the outbound viaduct over the Warrick Triangle precinct had all the ingredients of an exciting project – congested work environment, difficult geometric constraints, complex geotechnical conditions and an extremely tight programme. The solution adopted for this 372 m long viaduct involved a combination of cast in situ, balanced cantilever-type pier heads combined with an infill deck consisting of precast concrete U-beams averaging 20 m long. The project demanded an innovative, yet practical solution and a team effort between designer and contractor. In commending this project, the awards adjudication panel took cognisance of the technical complexity of the project, the many innovations involved, its timely completion and the effect the project will have on the lives of the estimated 460 000 people who pass through this busy trading and transport hub every day.

Warwick Triangle Viaduct: Inbound

PROJECT OVERVIEW

The location of the Warwick Triangle in Durban, with its historic market for the informal economy, caused tremendous conflict between pedestrians and vehicles. It is a transportation hub and a major gateway to the Durban central area. Every day hundreds of thousands of pedestrians and traders, and more than a 100 000 vehicles entered and left the Warwick area, resulting in serious congestion and an alarming accident rate (of which more than 70% were pedestrian related). The 2010 FIFA World Cup provided an opportunity for the city to transform the Warwick Junction into a world-class transfer facility.

The solution was to separate commuter traffic from the Warwick Triangle through the construction of an inbound and outbound viaduct (see article on page 17 on the outbound viaduct). The main element of this project was the construction of a 1 000 m long inbound viaduct (which would serve as an extension of the Western Freeway on the inbound carriageway into the Durban CBD). This would remove the through traffic and create space where people could engage in economic activities and access public transport in safety.

1 Completed inbound Warwick Triangle Viaduct

WARWICK TRIANGLE VIADUCT: INBOUND

Technical Excellence category
Submitted by the SAICE Durban Branch

KEY PLAYERS

Client eThekwini Municipality Roads Provision Department
Professional Team eThekwini Municipality Roads Provision Department
Main Contractor Rumdel Construction Cape (Pty) Ltd
Major Subcontractors and Suppliers VNA Piling, National Asphalt, Beatus Civils, Afrisam, Amsteele

This 1 000 m link from the Western Freeway to Johannes Nkosi Street (ending just before Joseph Nduli Street) effectively by-passes the highly congested Warwick Junction precinct, thereby improving traffic flow through the area in a safe and efficient manner. The elevated section of this link is approximately 300 m long and consists of three lanes.

INVOLVEMENT OF MUNICIPAL ENGINEERS

The Ethekwini Transport Authority received funds for the reorganisation of the Warwick precinct from the National Department of Transport. The Ethekwini Roads Provision Department was then appointed to implement the project, which Department then decided to utilise in-house municipal engineering expertise.

RELOCATION OF SERVICES

A multitude of services located within the construction zone had to be relocated in the most efficient and least disruptive manner. This included the relocation of a 300 mm diameter steel water main and 400 mm diameter sewer along Johannes Nkosi Street. The 400 mm diameter sewer was located below the water table level and involved well-point drainage to lower the water table. Other services that needed to be relocated included major electrical cable relocations, CCTV infrastructure relocation, TELKOM infrastructure and traffic signals.

2 Inbound viaduct under construction
3 Warwick Triangle: a transport hub and informal trading area
4 A multitude of existing services within the construction zone had to be relocated
5 Warwick Triangle taxi bays

FOUNDING CONDITIONS AND WATER TABLE

The bridge was constructed across a zone of fairly complex geology. The water table is very shallow and tends to be perched on clay layers. Layers of mixed fill cover the natural ground surface in many places. Pietermaritzburg Shale bedrock occurs at depths of about 21 m in the west in Old Dutch Road and falls away eastwards to 27 m near Grey Street. Designers determined that piled foundations relying on end bearing onto bedrock were necessary. Strong water flows into open excavations below the water table were experienced during construction.

STRUCTURAL DESIGN

The inbound viaduct was designed to carry three lanes of traffic over the Warwick Triangle. It consists of a pre-stressed concrete box-girder 2,5 m deep, constructed in stages from the middle span outwards. Made up of six spans, the longest (60 m) are designed to allow for the acute angle of the traffic lanes intersecting beneath the deck between the main piers. The piers are also offset from the centre line of the deck to maximise the horizontal traffic clearance of the roadway below.

The slenderness ratio of 1:24 of the two longest spans required 75 000 kN of pre-stress to obtain an extreme fibre stress within the Class 2 envelope for a pre-stressed concrete structure under NA and NB36 loading conditions, and can accommodate an NC load in the ultimate limit state. A reasonably high-strength concrete of 45 MPa was used. The contractor elected to place the concrete by pumping, which required careful consideration of the placing sequence so as not to cause slumping of the concrete from the webs into the bottom slab before the latter had become suitably set. General frustration came in the form of early shrinkage cracks in the top of the deck, especially when placing in warm and windy conditions. Working around this problem involved careful and thorough compaction and re-vibrating of the surface concrete, along with careful floating and accurate timing of the application of the curing compound.

The design of the bridge deck was carried out by the municipality's in-house structural branch of the Roads Provision Department, with the computer-aided design software package "Bentley RM-Bridge", which specialises in the time-dependency aspects of staged bridge design.

TRAFFIC MANAGEMENT PLAN AND RELOCATION

Prior to implementation of the road detour, the various stakeholders were consulted regarding the affected public transport facilities, such as the loss of parking bays along ML Sultan and Cross Streets.

Once agreement had been reached regarding the intended detour, the affected parties and the general public were informed about the road closures/ detours through advertising, the distribution of pamphlets, and other communication methods.

On-site traffic monitoring was carried out by the Metro Police throughout the construction period. The Metro Police also attended technical meetings and assisted with the implementation of deviations and road closures.

Due to the construction of both the inbound and outbound viaducts, some informal traders were perrmanently relocated to alternative trading positions that would not hamper their trading activities. In addition, certain on-street taxi ranks also had to be permanently relocated. This was done as seamlessly as possible after extensive consultation with all the stakeholders.

CONCLUSION

Construction of this R152 million project commenced in March 2008. The inbound viaduct was opened to the public in February 2010, well ahead of the 2010 World Cup event, and since then people have been engaging in informal economic activities and accessing public transport in safety. ◻

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