BRIDGE OVER VAAL RIVER AT VILJOENSDRIFT, DESIGNED FOR FUTURE WIDENING

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SUMMARY

A pair of identical bridges constructed over the Vaal River have been designed in such a way that future widening can be carried out simply and inexpensively. The method involves splitting each deck down the middle by sawing, jacking one half sideways by 3,7 m, and then casting a top slab to join the two halves together. By using this technique, well-proportioned cantilevers are possible for both stages of construction and the balustrades need not be demolished and re-built. Sheet piles were used for the construction of the four piers nearest the banks and a floating caisson was used for the construction of the remaining four piers. This latter aspect is discussed in detail in another paper at this convention.

OPSOMMING

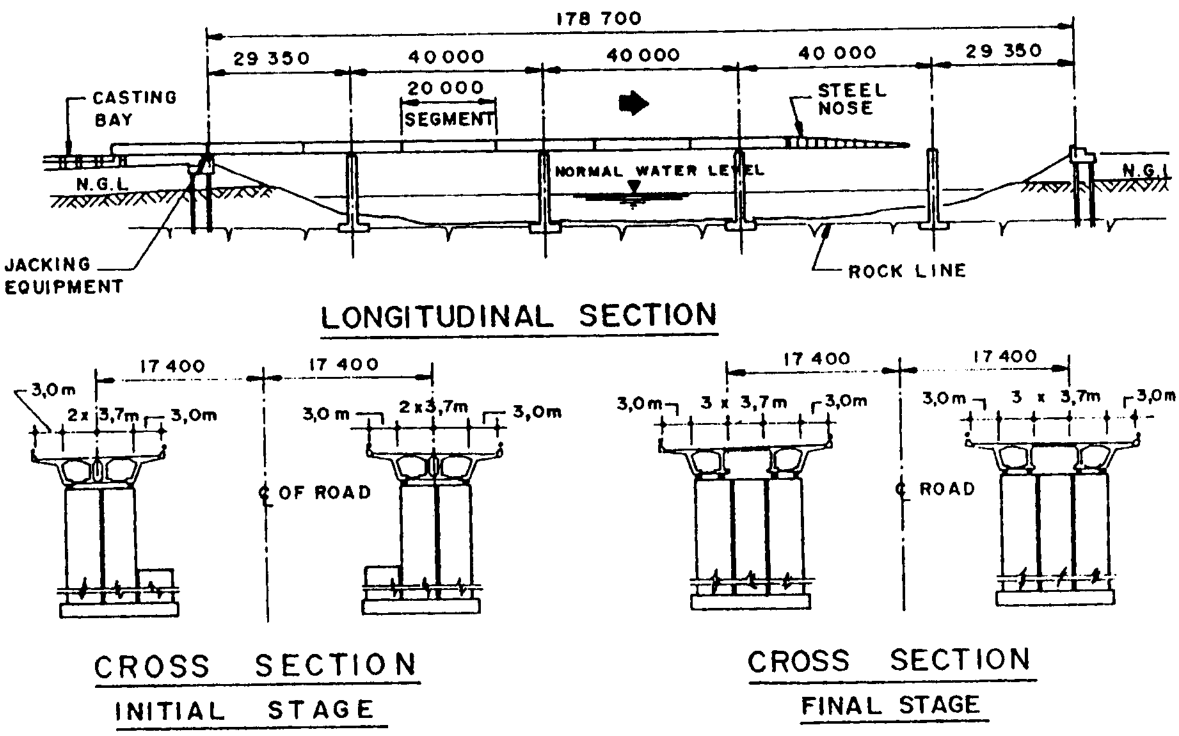
Twee identiese brue oor die Vaalrivier is ontwerp om te verseker dat die toekomstige verbreding maklik en teen lae koste uitgevoer kan word. Die brugdekke sal langs die middellyne oor die volle lengte in twee gesny word waarna die een helfte van elke dek 3,7 m sywaards gedomkrag word. 'n In situ boblad sal die twee helftes van elke brug finaal koppel. Hierdie tegniek laat toe vir kantelbalke met goeie estetiese afmetings vir beide stadiums van konstruksie en skakel die afbreek en herbou van die balustrades uit. Heiplate is gebruik vir die konstruksie van die vier pilare naaste aan die oewers en 'n drywende caisson is gebruik vir die konstruksie van die ander vier pilare. Laasgenoemde aspek is in 'n ander referaat by hierdie konvensie verhandel.

INTRODUCTION

The Vaal River at the site is about 140 m wide and the bedrock on which the bridges are founded lies about 7 m below water level. A particular initial design requirement was that the bridges should be designed to carry two lanes each with provision for widening to accommodate a third lane on each deck in the future. The approaches to the bridges are on a long straight necessitating a further requirement that the bridges be aligned with the initial two lanes and be widened in the future on the median side only to accommodate the future lanes.

Figure 1 shows the general arrangement of the bridge. Incrementally launched, precast beams with an in-situ slab and balanced cantilever decks were considered at the design stage. The latter technique does not lend itself to widening on one side and the beam and slab configuration was ruled out due to high initial cost and aesthetics.

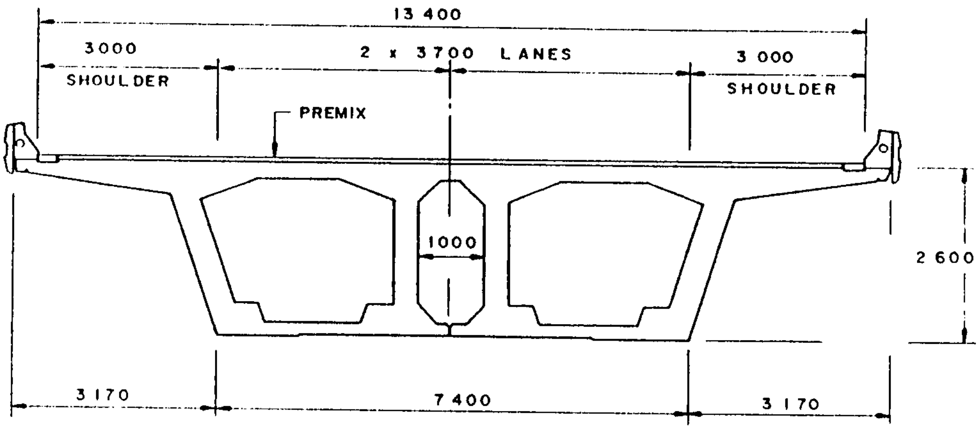
The cost of the substructures was to be kept as low as possible for the initial stage whilst ensuring ease of construction for the future lanes.



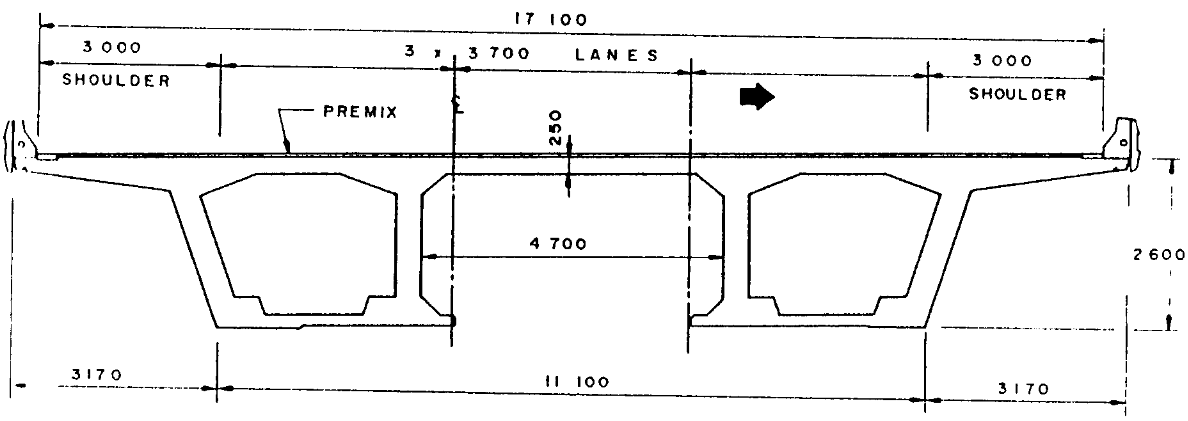
GENERAL ARRANGEMENT FIG. 1.

DESIGN CONSIDERATIONS

Although the actual widening of the bridge will be relatively quick and simple, the design of the decks had to be given careful consideration. On the one hand, the two centre webs of the deck have to be as close together as possible during the first stage so that when the deck is widened the span of the connecting top slab will be kept to a minimum. On the other hand, the gap between the two centre webs must be sufficient to allow removal of falsework between the two webs during the first construction stage. Refer figures 1 and 2.



INITIAL DECK CONFIGURATION FIG. 2.



FINAL DECK CONFIGURATION FIG. 3

During the launch the decks were supported at the piers and abutments on sliding bearings under the outer two webs only as impractically close tolerances ruled out the option of a third support beneath the centre webs. As a consequence of the deck being supported under only the outer two webs during the incremental launch, a detailed finite element analysis was required to determine how the shear forces in the central webs would be transferred through the top and bottom slabs to the bearings under the outer webs.

Special care had to be taken in locating the prestress in the deck to ensure that the prestress does not cause the separated halves to bow sideways when the deck is split.

The separated halves have had to be designed to carry the mass of the freshly cast connecting slab together with construction loads. The completed widened deck has been designed to carry the additional traffic loads due to the additional lane with due account taken of shrinkage in the connecting slab. An interesting feature is that no additional prestressing is required for the widened bridge.

The pier width provided was for the ultimate deck width up to 1,5 m above normal water level in order that the additional pier width could be provided without resorting to underwater work.

The perched abutments were constructed up to pile cap level for the ultimate deck width.

CONSTRUCTION DETAILS

The construction of the bridges began in February 1988 and was completed recently at a cost, including earthworks, of R9,3 million.

Embankments up to 9 m high were constructed at the abutments and allowed to settle for three months before 900 mm diameter continuous flight augered grouted piles were bored through the embankments and down to Ecca shales lying 11 m below the pilecaps. The piles have an ultimate load capacity of 4 500 kN.

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The river works formed an interesting and very important part of the construction work. In the early stages of the contract, this work lay on the "critical path" and because of the difficulties and uncertainties which are normally associated with construction work in deep water, it was realised that the key to the eventual financial success of the contract was the speed and efficiency with which these river works could be constructed.

The geology of the river bed is fairly straightforward, - carbonaceous shales, silts and mudstones of the Ecca series, overlain by silty clays, which varied in depth from zero up to over 3 m. Pre-tender borehole surveys, carried out in 1983 and 1987, had shown the rock surface to be reasonably flat and level, the rock classification at foundation depth to vary between "soft" and "medium" and joints and bedding planes to be generally "closely jointed". The borehole surveys also revealed a fluctuating depth of silt overlying the rock which could vary with time by as much as 3,5 m near the river banks.

The river water level at the bridge site is regulated by means of the downstream Vaal barrage, resulting in a constant 6 m to 7 m water depth over virtually the whole width of the river.

At the tender stage, the contractor stated his intention of using two floating, re-useable concrete caissons to construct the eight piers in the river. After further investigations, however, he concluded that the very thick silt deposits close to the river banks made the use of sheet piled coffer dams a more practical method to adopt for pier construction at these locations. Accordingly the contractor decided to use the sheet pile method for building the four piers closest to the river banks and to use the concrete caisson for constructing the four mid-stream piers.

Construction of the two Orange Free State river bank piers was begun by tipping fine sand into the water, so as to slightly project the banks into the river and form a level piling platform. Frodingham 2N sheet piles were then driven down through the sand and silt onto rock so as to form a completely enclosed rectangular coffer dam, which was 1 m longer and 1 m wider than the proposed pier foundation.

Thirty six sheet piles of up to 9 m long were used to form each coffer dam. Driving to the intitial set was by means of a 5 ton drop hammer suspended from a 22 R.B. crawler crane. An electrically driven pile vibrator was then used to complete the drive down to the top of the rock.

Excavation within the coffer dams was begun by using a P.C. 300 back-hoe down to the limit of its reach and then completed by hand digging. Three steel frames were installed at various depths in each coffer dam to support the sheet piles as the excavation proceeded.

Problems were encountered during the excavation of the Orange Free State coffer dams due to the lack of guide frames during the initial driving of the sheet piles and flimsy bracing frames. The result of this was that some of the pile clutches were not properly engaged and consequently several delays occurred due to serious sand and water inflows through the gaps in the sheet piles.

For the Transvaal coffer dams, the material available for constructing the piling platforms was a silty clay. An excellent two tier guide frame was used to accurately position the sheet piles and hold them plumb during the intial driving. A larger 38 R.B. crane was used and the internal bracing frames were re-designed to give much more substantial support to the coffer dam. All the sheet piles were correctly clutched and the corner piles closed and the subsequent excavations were completely dry and trouble-free.

Construction of the caisson was started while the sheet piling was in progress. The design and construction of the caisson is the subject of another paper.

The sequence of operations which gave the best results for the installation of the caisson was as follows:-

1) Dredge the general area of the piers, using a floating dredger equipped with a water lift dredging unit.

2) Accurately position and sink the caisson at the chosen pier position.

3) Further excavate silt round the inner and outer perimeters of the caisson with the help of divers using suction pumps, to encourage the caisson to sink until impeded by bedrock.

4) Drill dowel bars into the rock and erect a rough shutter by means of sand bags and sheets of corrugated iron round the inner perimeter, using divers.

5) Clear remaining silt under caisson and along inner perimeter up to shutter.

6) Pump concrete under water using divers, under the hopper bottom and along inner face to form a seal.

On completion of the above sequence of operations the concrete seal was allowed to cure for two days and then the water was pumped out of the large central rectangular area of the caisson, so as to allow pier construction to begin. A power hoist mounted on a gantry, which ran on rails across the top of the caisson, was used to remove hand excavated rock and silt and load the material onto rafts for subsequent disposal.

The piers were completed to ± 1,5 m above water level and then the caisson was floated by pumping water out of the buoyancy compartments and repeating the procedure at the next pier position.

The use of the caisson was very successful. The cycle time on the first pier was 15 weeks; during which time procedures and techniques were perfected. The cycle time for each of the subsequent 3 piers varied between 5 and 7 weeks.

The decks were cast in 20 m segments on the OFS bank and incrementally launched into position using Eberspacher jacking equipment. Each of the deck's nine segments has a mass of about 550 t and the maximum launching force was 270 t (or 2 700 kN).

FUTURE WIDENING

The widening of the bridges will be carried out by splitting each deck by sawing it down the middle using a diamond saw to cut through the top and bottom slabs. After separation, the one half of the deck will be jacked sideways by 3,7 m. The jacking force required to separate the two halves of the deck is estimated at about 100 t. Thereafter a connecting top slab will be cast joining the two halves of the decks together.

Small diameter ducts were cast into the deck to facilitate rapid installation of reinforcing for the connecting slab. The travelling shutter which will be used for casting the connecting top slab will run along the nibs provided by the sawn-through bottom slab.

The main advantage of this solution is that very little demolition or concreting is required when compared with the conventional widening technique of demolishing the balustrades and ends of the cantilevers and reconstructing them with lengthened cantilevers. Further benefits include the ease of modifying the expansion joints and the relatively short time required to do the work.

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CONCLUSIONS

Bridges have been provided to cater for initial width requirements only, which, with relative ease, may be converted to cater for additional lanes.

The saving realised in providing for the initial two-lane requirements only amounts to about 10% of the cost of the bridges. The cost of widening the bridges in present-day terms is estimated as twice the saving. Based on a 5% real rate of return on capital, the decision not to build the bridges to their full width now will have been correct if the bridges are not widened within the next 15 years.

ACKNOWLEDGEMENTS

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2. Contractor: Grinaker Concrete Constructions (Pty) Ltd.

3. Consultant to the Contractor: van Niekerk, Kleyn and Edwards.

4. Use of material from the following is acknowledged:-

   (i) "Innovatons in jacking and moving bridges into position" by D.R. Forsyth and D. Peters, presented at "Concrete into the 90's" - National Convention of the Concrete Society of Southern Africa.

   (ii) "An innovative solution to future bridge widening" published in "South African Construction World", December 1989/January 1990.