Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 73/1/73/2 (1995)

Artikel: Rehabilitation of a historic bridge over the Sand River in South Africa

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DOI: https://doi.org/10.5169/seals-55165

Rehabilitation of a Historic Bridge over the Sand River in South Africa

Consolidation d'un pont historique sur le Sand River, en Afrique du Sud

Erneuerung einer historischen Brücke über den Sand River in Südafrika

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SUMMARY

The old Sand River arch bridge near Virginia in the Free State, which was built in 1926, was totally inundated during the floods in 1988 and, apart from the approaches which were washed away, the bridge superstructure was severely damaged. Future planning of roads in the immediate vicinity of the bridge made provision for a new bridge over the Sand River, thus replacing the existing bridge. Closer investigation revealed that the bridge exhibited far greater inherent strength than previously believed. Through innovative design, a solution was found which obviated the construction of a new bridge and led to substantial cost savings to the client.

RÉSUMÉ

Un pont construit en 1926 sur le Sand River près de Virginia fut entièrement submergé par les inondations de 1988 qui emportèrent non seulement les voies d'accès, mais endommagèrent également le tablier. La planification des routes dans les alentours du pont prévoyait déjà un nouveau pont sur le Sand River, remplaçant ainsi l'ouvrage existant. Les études révélèrent que le pont possédait une résistance beaucoup plus grande qu'on ne croyait. Une solution innovatrice fut trouvée qui évita la construction d'un nouveau pont et réalisa d'importantes économies pour le client.

ZUSAMMENFASSUNG

Die Freistaat Provinz von Südafrika wurde 1988 von verheerenden Überschwemmungen heimgesucht. Die alte Bogenbrücke über dem Sand River in der Nähe von Virginia, 1926 gebaut, wurde ganz überschwemmt. Die Auffahrten wurden weggespült, und der Oberbau der Brücke wurde schwer beschädigt. Die Planung von Strassen in der unmittelbaren Nähe der Brücke sieht eine neue Konstruktion über dem Sand River vor, also eine Ersetzung der alten Brücke. Eingehende Untersuchungen zeigten, dass die Brücke mehr Tragfähigkeit, als früher vermutet, besass. Eine innovative Lösung wurde gefunden, die den Bau einer neuen Brücke vermied und zu erheblichen Kosteneinsparungen für den Kunden führte.

1. INTRODUCTION

During February and March 1988 the Free State province of the Republic of South Africa was hit by devastating floods. The provincial road network was disrupted to such an extent that Bloemfontein, the provincial capital, was cut off from the rest of the country for several days. Although several bridges were completely washed away, the approaches of 20 other bridges were also washed away. The biggest problem was the reconstruction of the bridge approaches to re-establish road links.

One of the bridges which was damaged during these floods was the historic Sand River Bridge No.96 near Virginia which was built in 1926. The importance of this bridge lies in the fact that it forms part of the link between the Gold Fields of the Free State and Lesotho which provides labour for the mines. Owing to a sharp increase in traffic volumes, the route was to have been upgraded as a matter of course. The planned new road alignment also made provision for the construction of a new bridge which would have made the existing bridge obsolete.

The prohibitive cost of a new bridge resulted in a closer investigation into the feasibility of repairing and untilising the existing structure rather than building a new bridge at a greater cost.

2. EXISTING BRIDGE

2.1 General

The existing structure was built in 1926 and consequently very little as-built information was available. No structural drawings could be located and the only drawing found was a location plan which did not even show the bridge position. The bridge is of an arch-type construction and due to its age is deemed to be historic.

2.2 Founding conditions

A visual inspection of the bridge site revealed that the bridge piers were founded on sandstone rock. Sandstone was also found at various locations in the river bed in the vicinity of the bridge. Based on the visual assessment and the absence of any scour in the river bed, it could be assumed with reasonable certainty that the bridge was firmly founded on rock and further geotechnical investigations were deemed unnecessary. The estimated safe bearing pressure of the sandstone is 1000 kPa.

2.3 Structure

The sub-structure consists of mass concrete piers, abutments and wingwalls. The total length of structure is approximately 90 metres, made up of nine arch spans of reinforced concrete. Mass concrete walls constructed on the sides of the arches kept the rubble infill placed on the arches in place. The single roadway was provided by placing premix on the infill and constructing sidewalks on the walls. Steel handrailings were added. The total height of the structure above the river bed was 11 metres and the bridge width was 4.6 meters with an effective roadway width of 3 metres.

An interesting feature of the bridge was the fact that the two outside openings between the abutments and the piers were closed up by means of concrete walls. The reason for this is unknown. It is presumed that the abutments needed structural support but the closure of the openings would definitely have had a negative influence on the hydraulic capacity of the structure.

3. FLOODS OF 1988

3.1 Extent of floods

The flood in the Sand River was not investigated by the Department of Water Affairs as it was not deemed to be as severe as the flooding in the rest of the province. Hence it is dificult to give accurate figures. However some calculations were made and are summarised :

Hydrological data:

Catchment area:	6113 km^2
Average slope :	,57 m/km
Average rainfall:	615 mm / year

In order to determine the magnitude of the flood in the Sand River all available data was analysed including the level of water during the floods which could accurately be determined from eye witness accounts and debris. It was determined that the floodwater overtopped the bridge by approximately one metre.

The hydraulic and hydrological investigations revealed that the flood which overtopped the bridge was in the order of 2650 cumecs, which constitutes a flood with recurrence interval of more than 50 years. Recurrence intervals of more than 200 years were recorded in the rest of the province.

3.2 Damage to bridge

The bridge was overtopped by the floods and consequently the approaches were washed away, allowing water to flow around the structure as well. Furthermore the water removed large portions of rubble infill on the arches which effectively made the bridge impassable. Apart from the damage described, tonnes of debris, including large trees, were left on the bridge.

An inspection of the bridge after the floods showed that the sub-structure, in contrast to the super-structure, showed no signs of damage or structural distress. Although cracks were found in the wingwalls and arches it could not be proven to have been caused by the floods.

The fact that the bridge withstood the flood forces indicated that the structure posessed far greater inherent strength than the visual appraisal indicated. The existence of large cracks in the arches and wingwalls also indicated that the existing structure should not be subjected to any additional loads.

4. REHABILITATION OF THE EXISTING BRIDGE

4.1 General background

Due to severe cuts in financial budgets for roads in the province, the possibility of utilising the existing structure in order to obviate the construction of a totally new bridge downstream had to be investigated. The cost of a new bridge was estimated at $ 800 000. The client was willing to accept recommendations regarding speed restrictions and lower geometrical standards if necessary.

4.2 Design criteria

The rehabilitated structure had to comply with the following :

- The structure had to accommodate two-way traffic.
- Pedestrian traffic had to be accommodated.
- Minimum costs were to be incurred on the demolition of the existing structure.
- The existing sub-structure had to be used and no additional loading onto super-structure was allowed.
- The cost of strengthening the existing structure had to be minimised.
- The existing wingwalls were not to be built higher.
- The structure had to be designed to withstand a 50 year flood as well as NA & NB24 loadings.

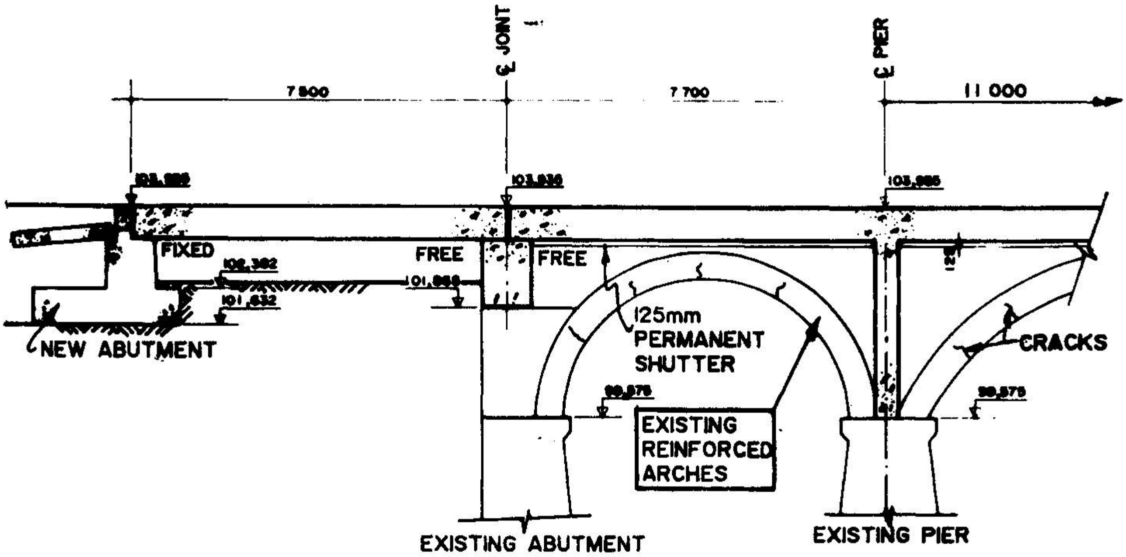
- The minimum cross-section of the deck was :
  - 2 x 3.1 metre lanes.
  - 2 x 0.3 metre shoulders.
  - 2 x 0.425 metre New Jersey balustrades.
  - 1 x 1.2 metre walkway for pedestrians.
  - Total width = 8.85 metres.

4.3 Final structure

In order to comply with the abovementioned criteria a structural solution was proposed and subsequently built which made optimal use of the existing structure while still providing a functional and economical alternative to a new bridge.

The solution will now be discussed briefly with reference to Figure 1.

The existing sub-structure was kept intact while a new continuous reinforced concrete deckslab, supported by piers on the existing piers, was added. All rubble was removed from the existing arches leaving the side walls intact. The new piers were designed to be cast composite with the deckslab forming a portal structure which rested on the old piers. A continuous structure was needed to ensure the stability of the new super-structure due to the relatively large cantilevers needed to provide for the total deck cross section.



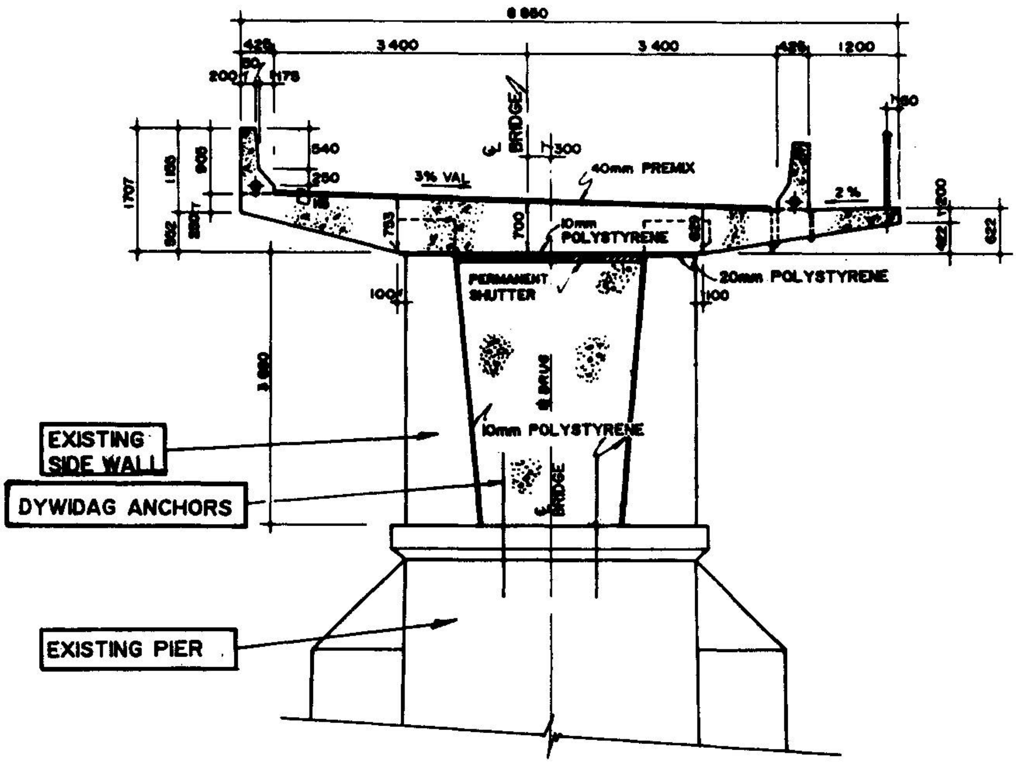


FIGURE I

TYPICAL SECTION

The new piers were designed as pinned joints resting on the existing piers and fixed by means of unstressed Dywidag bars grouted into the existing concrete. To ensure a minimum load transfer onto the existing structure, care was taken in providing for movement gaps between the old and new structure.

In order not to extend the existing wingwalls vertically, it was decided to rather build two additional short spans on either side of the bridge. These spans are simply supported and rest on the existing abutments and new abutments founded on the reconstructed approach fill. Expansion joints were provided at the ends of the portal structure.

Before construction commenced and after the rubble was removed from the structure, cores were taken at all the existing pier positions to determine the in situ strength of the supporting material for the new piers. Results obtained showed the existing concrete to have a minimum strength of 20 MPa.

4.4 Construction

Numerous problems were experienced during construction. The biggest problem was contending with the flow of water and necessary stagework needed to shutter the large cantilevers. Due to the lack of as-built data the actual dimensions of the structure once cleared of rubble and debris differed from the design assumptions to such a degree that it was necessary to re-analyse and adapt certain dimensions and reinforcing. A special support system for the cantilever shuttering had to be designed to ensure that no additional loads were placed on the arch walls. The formwork had to be precambered to compensate for deflections during concreting.
It was however the team work from all parties involved which ensured that the project was successfully completed on time and within budget with no claims from the contractor.

The final cost of rehabilitating the structure was $125 000 and was completed within six months and within the original estimates and tender price.

5. CONCLUSION

South Africa, like many other countries in the world, is experiencing a lack of funding for road construction and maintenance. This means that innovative solutions will have to be found to provide the much needed infrastructure to ensure a growing economy. This project, even though it does not classify as a major engineering achievement, does however show that through innovative engineering large savings or greater return on investment is possible.
This solution not only saved money but also provided an aesthetically and functional alternative. The principles adopted can be used in many other larger projects and could provide for substantial savings.