PAPER 16

WIDENING AND STRENGTHENING OF THE EXISTING CERES VAN BREDA BRIDGE

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ABSTRACT

The Van Breda Bridge is located in Ceres within the Witzenberg Municipality, Western Cape. It is on the main provincial R46 route through the town, and crosses the picturesque Dwars River. It is a strategically important route in the region, that carries major traffic, in particular large transport vehicles for the fruit industry which is a major employment provider in the area. The present concrete bridge with piers and simply supported beams was originally constructed in 1928, replacing an old wooden bridge, and therefore has heritage value.

The current upgrading project was initiated in December 2021, and was co-funded by the Transport Directorate of the Provincial Government of the Western Cape and Witzenberg Municipality. The objective was firstly to address maintenance and safety issues including the deteriorated riding quality of the surface, secondly to widen the bridge to accommodate two lanes plus a shoulder, and thirdly to strengthen the bridge to accommodate current loading code requirements.

The objectives were achieved by means of widening the existing piers to support new precast tee-beams on each side of the bridge. The pier footings did not need to be enlarged, however, for the widened abutment and wing wall supports, the use of end-bearing piles was required. The new cross-section now accommodates sidewalks on the widened bridge, separated from the vehicle carriageway by concrete balustrades. For heritage purposes, light poles to the exact shape of the originals are mounted thereon.

Structural strengthening of existing beams and deck structure was carried out by means of fastening steel plates and strips onto the bottom and sides of the beams, and by dowelling an additional concrete layer into the existing deck slab.

Outside of the bridge structure, the geometry of the approach roads was improved, and new accesses and parking facilities were created for adjacent businesses that were affected.

One of the challenges of the project was the precise dimensioning of each individual precast beam to enable placement within tolerance and to match the original curved deck and horizontal angle of the diagonal river crossing, at the same time accommodating the original bridge's inconsistencies. Traffic management posed another challenge, necessitating complex sequencing of construction to always keep two lanes open, as there was no suitable alternative route.

Ultimately this heritage landmark bridge in Ceres has been successfully upgraded in 2024 to current standards, and to operate efficiently and safely and promote the economy of the region.

1. INTRODUCTION

This paper provides a history of the Van Breda bridge in Ceres, along with previous upgrades leading up to the recent project. It outlines the project's objectives and the development of concepts into the selected option. The detailed structural design of the new widening elements and the strengthening of the existing elements are covered, including construction aspects that played a role. Additionally, other associated improvements outside of the bridge structure to enhance overall traffic flow are mentioned. It concludes with photographs of the completed project and acknowledgments.

2. BACKGROUND AND HISTORY

The Van Breda Bridge is located on the R46 main route through the town of Ceres otherwise known as Voortrekker Street and crosses the Dwars River. Refer to the location as shown in Figure 1 below.

FIGURE 1: *Van Breda Bridge Locality Plan in the Town of Ceres, Western Cape*

The first bridge over the river was a wooden bridge built by Thomas Bain in 1885. This was replaced by the present concrete bridge in 1928, comprising seven simply supported spans, each 13.3m long at a 20° skew angle to align with the direction of the river. In 1950, it underwent widening the roadway width to 7.9m to accommodate increasing traffic, enough for two 3.9m wide lanes. Steel sidewalks, 1.65m wide, were added on both sides of the bridge. In 1993 structural rehabilitation was undertaken, including repairs of concrete deterioration and spalling, and the repair of timber planks on the walkways and the asphalting thereof.

Photographs of the bridge at various stages are in Figure 2.

In 2013, concerns about maintenance and structural deterioration prompted an initiative to assess the situation and propose solutions. This effort, supported by various experts, including heritage and urban planning specialists, as well as a certified bridge inspection engineer, culminated in a comprehensive basic planning report in 2016, which is covered in the next section.

Based on that report and the detailed design that followed, the recent upgrading project began in December 2021. This project was co-funded by the Transport Directorate of the Provincial Government of the Western Cape and the Witzenberg Municipality.

FIGURE 2: *Historic Photographic Images of van Breda Bridge*

3. OBJECTIVES AND EVOLVEMENT OF DESIGN CONCEPT

The main objectives of the recent upgrading project, as outlined in the above-mentioned basic planning report, were:

- To repair and enhance the riding quality of the surface, which had deteriorated over time. It was identified that the concrete topping slab was delaminating from the underlying beam structure.
- To widen the cross-section geometry of the bridge and accommodate two lanes with shoulders, and to provide space for cyclists and pedestrians.
- To increase the load capacity of the bridge to meet current standards. A 2013 investigation revealed that the structural capacity might have been as low as 66% of the TMH7 code requirement.

The above had to be addressed in conjunction with, and to the approval of the Transport Directorate of the PGWC and the Witzenberg Municipality. The planning also had to take into account heritage considerations, for which specialist heritage architects were appointed to provide a report and recommendations.

Figures 3 and 4 below depict photographs of the existing bridge before the upgrade, and its cross-section, respectively.

FIGURE 3: *Van Breda Bridge (June 2016)*

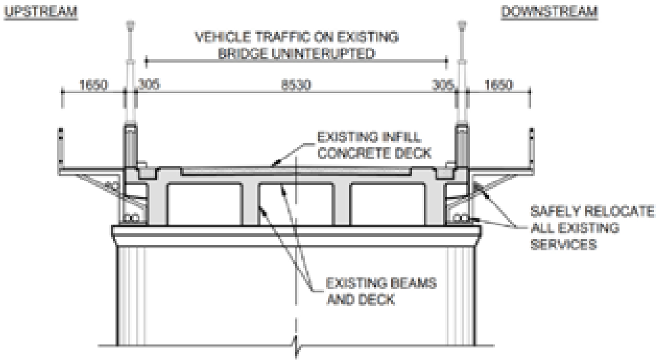

FIGURE 4: *Typical section of existing van Breda Bridge*

A number of options for widening the cross-section were considered to achieve the objectives. The primary consideration was to retain the existing balustrades for heritage reasons. However, because they were found to be structurally inadequate and posed a safety risk, it was agreed to remove them and replace them with robust concrete barriers in the appropriate position. The sole heritage requirement was that the shape of the existing light poles needed to be replicated on the new bridge.

Ultimately, the selected cross-section for implementation evolved into the option depicted in Figure 5 below. This entailed removing the previously added timber walkways and their steel supports, and installing edge beams to support the widened traffic lanes and pedestrian walkways. These beams would be supported on a widened section of the existing piers.

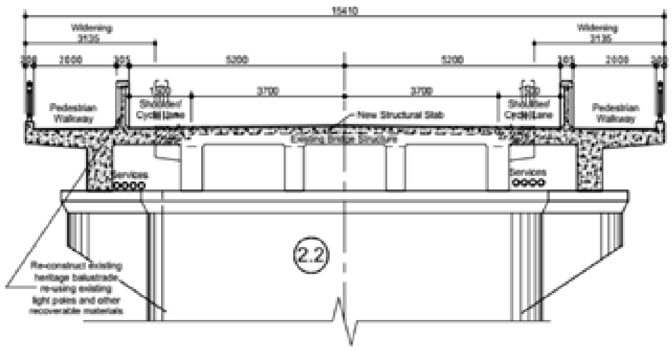

FIGURE 5: *Selected cross-section for upgraded Van Breda Bridge*

This cross-section achieved the objectives of accommodating the significant volume of pedestrians in a protected and safe manner, with the shoulders serving as cycling lanes. The overall width allows for potential future expansion to two traffic lanes in each direction by adjusting the balustrades and adding outer sidewalks. According to the traffic engineering investigation included in the basic planning report, such expansion is unlikely to be necessary for at least the next 25 years.

4. STRUCTURAL DESIGN AND CONSTRUCTION ASPECTS

4.1 Original concrete structure

The original drawings of the bridge contained extensive information, enabling the designer to evaluate the capacities of the existing structure. Missing detail was supplemented through on-site investigations.

The original structure features a reinforced concrete beam and slab deck with discontinuous transverse diaphragms at quarter points. These diaphragms are designed primarily to provide torsional restraint to the beams rather than distribute transverse moments.

The bridge piers are normally reinforced at the bearing seat to withstand concentrated loads, such as bursting forces and spalling. The remainder of the pier is unreinforced. Abutments and wing walls are constructed with mass concrete in steps on the earth face.

Foundations for both the piers and the abutments and wing walls shown were detailed on the drawings as mass concrete on shale bedrock, and verified by a geotechnical engineer during investigation.

4.2 Pier substructure

The bearing capacities of the bedrock under the existing piers were verified and confirmed by the geotechnical engineer to be sufficient to withstand both the current and additional loads imposed by the new design. Consequently, widening the base of the existing piers was unnecessary. Instead, the piers were only widened at the top to support the new edge beams. This was achieved by means of widened corbels tied to the existing piers using dowels and post-tensioning. The corbels were reinforced and standardized across all piers to streamline the construction process, and minimizing the need for extensive river work and excavation.

Details of the pier widening are shown in Figures 6 and 7 below.

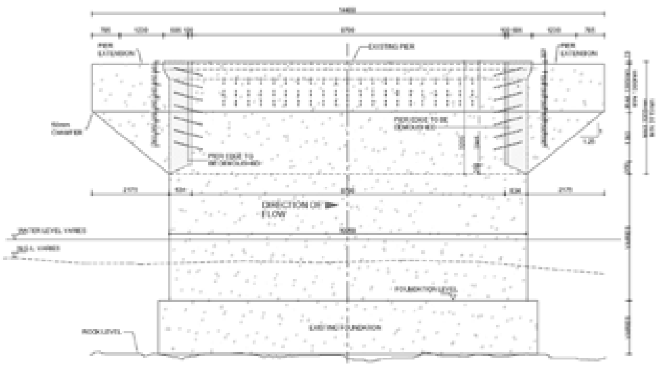

FIGURE 6: *Side view of widened piers by means corbels tied to existing piers*

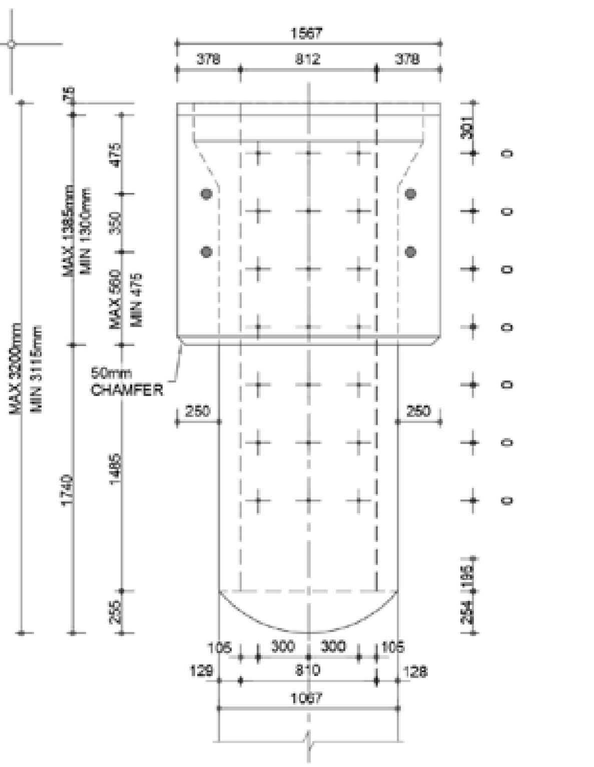

FIGURE 7: *Cross-section through pier widening, showing post-tensioning*

4.3 Abutment and wingwall substructure

The original intention was to extend the widened abutments down to the bedrock for foundation support. However, geotechnical investigations revealed that the bedrock was deeper than expected at both abutment ends. Excavating to these depths in the constrained areas, especially considering potential groundwater, was deemed impractical and unsafe, even with a caisson method. Consequently, the decision was made to use end-bearing pile foundations.

These piles were designed and constructed by a specialist piling sub-contractor, and were configured in sets of four at each abutment extension to carry the specified loads and plans. ODEX/Rota piles were selected for their suitability in riverine environments and their quicker establishment. Figure 8 illustrates the installation of one of these piles in close proximity to the existing bridge.

FIGURE 8: *ODEX/Rota piles at abutment extensions.*

Pile-caps were constructed at each corner just below the natural ground level, along with abutment extensions. Wingwalls were designed as independent substructure elements, supported on a 1.5m deep engineered fill mattress below the founding level.

Transition slabs were also installed at both the existing and widened abutments.

4.4 Final superstructure cross-section

A cross-section of the final superstructure is shown in Figure 9 below, and the design and construction of the various elements are described in the sections that follow.

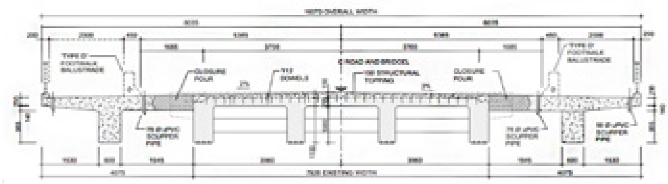

FIGURE 9: *Typical section of the upgraded Van Breda Bridge superstructure*

4.5 New edge-beams and infill slabs

Instead of casting the new edge-beam elements in-situ, the contractor opted to use precast edge-beams manufactured at the supplier's yard. These beams were then transported to the site and positioned using mobile cranes. This method was chosen for its practicality and

FIGURE 10: *Precast beam manufacture*

environmental friendliness, minimizing disruption to the river area below. It also eliminated the need for extensive shoring, shuttering, or scaffolding, thereby simplifying the construction process.

The primary challenge in manufacturing and installing the precast beams arose from the unique dimensions of each of the 14 required beams. This complexity stemmed from several factors:

- The existing curvature of the bridge deck, which peaks near the midpoint of the bridge.
- Varying heights of the pier supports that did not precisely match the curvature of the beams.
- The diagonal alignment of the bridge relative to the piers, which follow the direction of the river flow.
- Discrepancies between the as-built bridge dimensions and the original drawings.

Consequently, a detailed survey of the structure was essential to enable precise detailing of each beam, such that accurate placement could take place to achieve the 30mm expansion gap within tolerance. Figure 10 below shows a photograph of one of the beams being manufactured at the supplier's yard.

After delivery of the precast beams to the site, they were lowered onto the bearing plinths using two mobile cranes. The angles and levels of the bearing plinths were carefully determined relative to the pier level and the required beam angles to achieve the necessary slopes. Malthoid

FIGURE 11: *Precast T-beam being lowered into position by two mobile cranes*

sheeting was placed between the beams and plinths. Each beam spanned approximately 13.5m and featured a T-shaped cross-sectional design, with a 1.35m deep beam section and a 3m wide top flange section tapering from end to end. The beams weighed 65 tons each. A photograph depicting one of the beams being lowered into position can be seen in Figure 11.

After positioning the beams, the gap between them and the existing deck needed to be closed using an in-situ cast infill slab. Where there was insufficient space for lapping reinforcement, couplers had to be used.

4.6 Strengthening of existing beams and deck

While the new edge-beams could be designed and manufactured to withstand current loading code requirements, the existing beams and deck had to be strengthened in place to do the same.

This was achieved by bolting on steel plates to the soffit of the beam to act as additional tensile reinforcement, and to the sides to act as shear reinforcement. The effective depth of the beam and slab combination was then increased by means of first removing the original concrete skin that had delaminated, and constructing a thicker and more durable reinforced concrete slab which was dowelled into the existing deck slab with steel bars at a close spacing to act as shear connectors. A photograph of the steel plate reinforced original beams and conventional new edge beams is in Figure 12 below. The new supports to the existing and new services can also be seen.

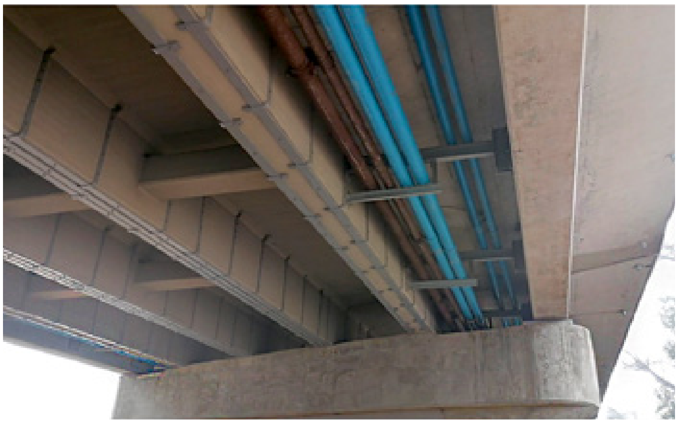

FIGURE 12: *Steel plates to the bridge soffits for strengthening*

A decision was made to forego the installation of new bridge bearing material under the existing beams, after an assessment of the operational performance in the present condition.

4.7 New balustrades and other finishing

The remaining structural elements on the cross-section of the upgraded bridge include new robust New Jersey-shaped reinforced concrete barriers separating the traffic and pedestrian ways. These barriers also support the streetlights and the polycrete handrails on the outside of the pedestrian sidewalk, all to meet contemporary safety standards.

The finished surface on top of the new concrete deck slab is overlaid with an asphalt layer. Asphaltic plug-type expansion joints were installed under the traffic roadway side. Underneath the bridge, the existing piers and beams were cleaned, and coated with a protective paint to seal hairline cracks and ensure long-term durability.

5. TRAFFIC ACCOMMODATION DURING CONSTRUCTION

Due to the significant industrial and commercial traffic and its importance to the local economy, accommodating traffic during construction was a critical aspect and challenge during this project. The municipality mandated that traffic in both directions had to be maintained throughout the construction phase. Various alternative routes were considered, including a detour via a nearby low-water bridge, but safety concerns and the risk of flooding rendered this option unsuitable.

Instead, the cross-section of the bridge was marginally widened, and construction was carefully planned in phases to ensure continuous traffic flow in both directions. These phases had to be integrated into the structural design. Figure 13 below illustrates three out of a total of ten construction phases. Each phase had a designated vehicular traffic zone, a work zone, and a pedestrian zone to accommodate the substantial pedestrian traffic using the bridge.

There were only a few instances when the bridge had to be temporarily closed necessitating the use of the alternative detour route, primarily during activities such as the beam placement, and these closures were often scheduled for night-time to minimize disruption to traffic flow. Compliance with standard traffic accommodation signage and markings was strictly observed throughout the construction period.

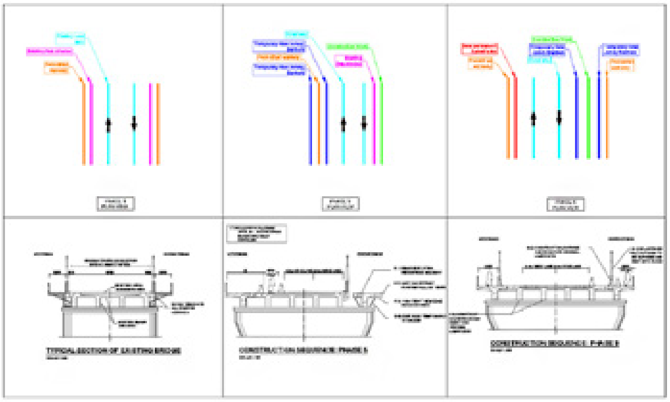

FIGURE 13: *Selected construction phases for traffic accommodation*

6. OTHER ASSOCIATED IMPROVEMENTS

A number of associated improvements to the approaches were made in addition to the bridge widening itself. The traffic engineering report identified that many existing accesses and on-street parking were substandard or unsuitable for safe traffic operation, given the geometry of the bridge and its approaches. Consequently, several proposals were put forward, including the closure of existing accesses or their conversion into left-in left-outs, along with relocating parking to alternative off-road locations. These changes were implemented after consultation with affected parties.

The vertical curvature of the approaches to the bridge and the horizontal layout were also improved, including the addition of turning lanes, all aimed at enhancing traffic flow. At the provincial bridge department's request, the centreline of the western approach was adjusted to align with the bridge centreline. This adjustment required slight road widening and a southward shift of parallel parking bays, which encroached on some sidewalk width but maintained more than the minimum required sidewalk width. Figure 14 shows the associated improvements.

FIGURE 15: *Completed bridge (side view)*

FIGURE 16: *Completed bridge and approach road from east*

Various existing services on the underside of the bridge deck had to be re-supported in their original position on new steel brackets attached to the modified structure. Additionally, new ducts and sleeves were installed to accommodate anticipated future electrical and communication cables, as illustrated in Figure 12. These modifications as well as the widened abutment structures, necessitated adjustments and relocation of existing underground services at the approaches to the bridge.

7. CONCLUSION

The project was successfully completed in June 2024. Photographs of the completed project are shown below. The bridge has been upgraded to current standards, and operates efficiently to the economic benefit of the town and wider region, while still maintaining its landmark status.

ACKNOWLEDGEMENTS

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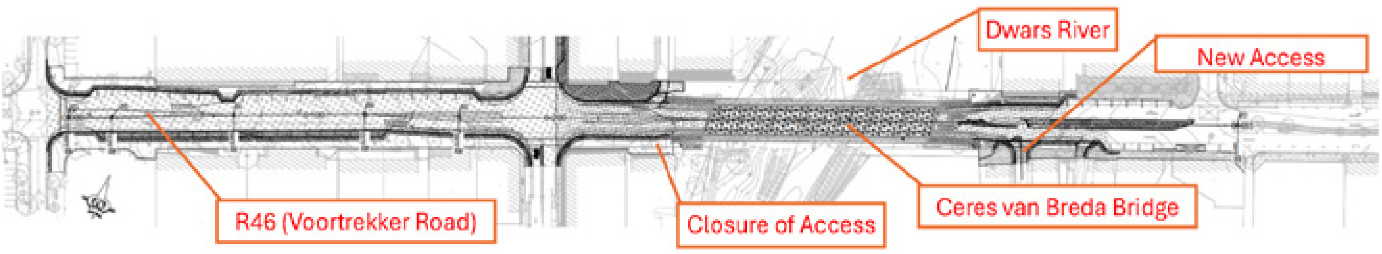

FIGURE 14: *Plan view of Closure of Accesses/ New Accesses*