# Design and Construction of Black River Bridge, Tasmania

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**SYNOPSIS**

A $1.9 million design, construct and demolish project to replace a significantly deteriorated 45-year old bridge over the Black River on Tasmania's northwest coast recently won a national Case Earth Award. The bridge is located on the Bass Highway approximately 20km east of Smithton and 1.5km from Bass Strait.

Van Ek Contracting carried out the construction of the new bridge and its approaches downstream from and adjacent to the old bridge, before demolishing the old structure. The concept design was developed by Graeme P. Walter Pty Ltd in conjunction with Van Ek Contracting with Sinclair Knight Merz responsible for the detailed structural design of the new bridge. Graeme P Walter Pty Ltd was responsible for proof engineering and for the design of the temporary works.

The design and construction processes were integrated in the conceptual planning of the project, with the co-operative input and involvement of the construction contractor, the designer and the proof engineer. An exemplary synergistic outcome was achieved, satisfying all project requirements specified by the owner and the local community, which has resulted in an attractive, durable concrete replacement structure.

## 1 INTRODUCTION

Tasmania's Department of Infrastructure, Energy and Resources awarded a contract to Van Ek Contracting in early 2002 for the design and construction of a replacement bridge over Black River, including associated road approaches and the demolition of the existing structure. The catalysts for the project included the deterioration of the existing bridge, with increasing potential for reduced load carrying capacity, and the general need to provide for increased permissible vehicle mass limits.

The bridge site is located within a recognised high quality estuarine environment inhabited by a range of native plant and animal species, including a threatened fish species, the Australian Grayling. The Department's project brief incorporated many structural and environmental objectives including the provision of:

- a durable concrete bridge approximately 60m long with minimal maintenance requirements during its service life
- an aesthetic structure blending with the local environment and obtaining community acceptance
- blade type piers with rounded ends
- specific durability measures in the design and construction phases to ensure that the service life objectives could be met by passive means, with the use of stainless steel reinforcement a "deemed to comply" option

- minimal change to the existing environmental conditions of the estuary and surrounding area, and the hydrodynamics of the waterway
- no change to the existing waterway aperture and no piers in the centre of the channel
- removal of the existing bridge to provide a clear channel and a clear estuary bed
- provision for the movement of terrestrial fauna beneath the bridge
- construction processes resulting in minimal environmental impact, and
- minimal disruption to all bridge users during construction

## 2 BRIDGE SITE

The bridge spans the tidal estuary of Black River immediately south of Bass Strait where the mouth of the river adjoins Sawyer Bay. The river at the bridge site is 38m wide at high water level (28m at low water) and flows through a steep sided rocky gully approximately 50m wide and 10m deep at the river invert. The tidal range at the site is approximately 2.5m.

The geology at the site comprises Precambrian conglomerate overlying Precambrian siltstone. The moderate to high strength rock has in the past been folded, intruded by dolerite dykes and faulted. Boreholes for the geotechnical investigation showed a distinct difference in rock type from one side of the river to the other, and a seismic investigation confirmed the existence of an inactive fault zone under the centre of the river and parallel to it.

## 3 GENERAL DESCRIPTION

The bridge has three spans, 13.9m, 30.8m and 15.05m long, and an overall length of 59.75m, excluding 3m long approach slabs at each end. It is straight, has a width between parapets of 9.1m and a 3% one way crossfall. The bridge elevation is shown in Figure 1.

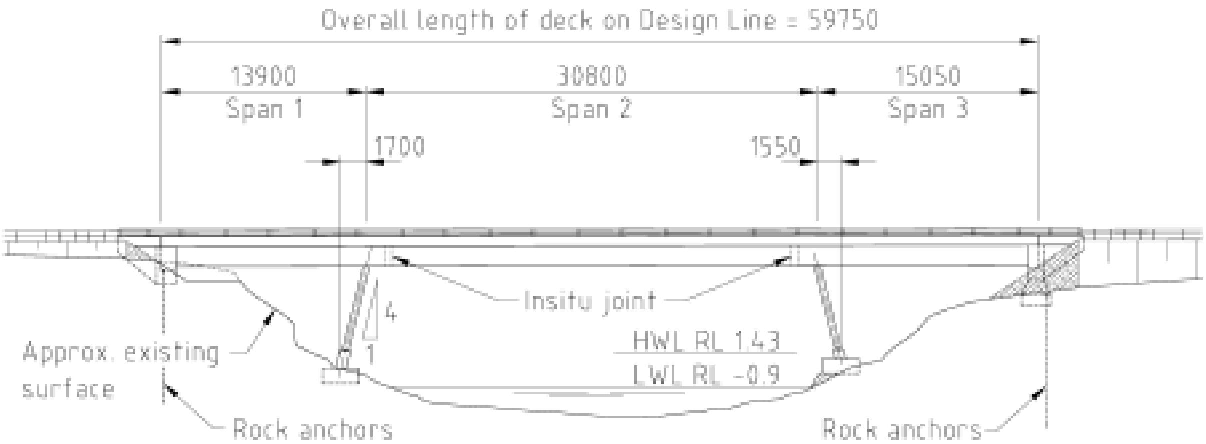


***Figure 1: Bridge Elevation***

The superstructure comprises four 1510mm deep pretensioned T-Roffs, a compositely acting in-situ concrete deck and is fully continuous for live load. The piers are transversely tapered blade walls with rounded ends. The piers are integral with the superstructure at the top and hinged at the base and are also inclined at a 1 to 4 slope in elevation. The abutments and piers are founded on spread footings on rock. A cross section of the bridge at the pier is shown in Figure 2.

The project brief included the following design criteria:

- design life of 100 years
- 2 lane structure integrated into the existing road network
- SM1600 design vehicle loading
- thermal gradient with a maximum differential temperature of $24^0$C
- maximum differential settlement between adjacent supports of 10mm

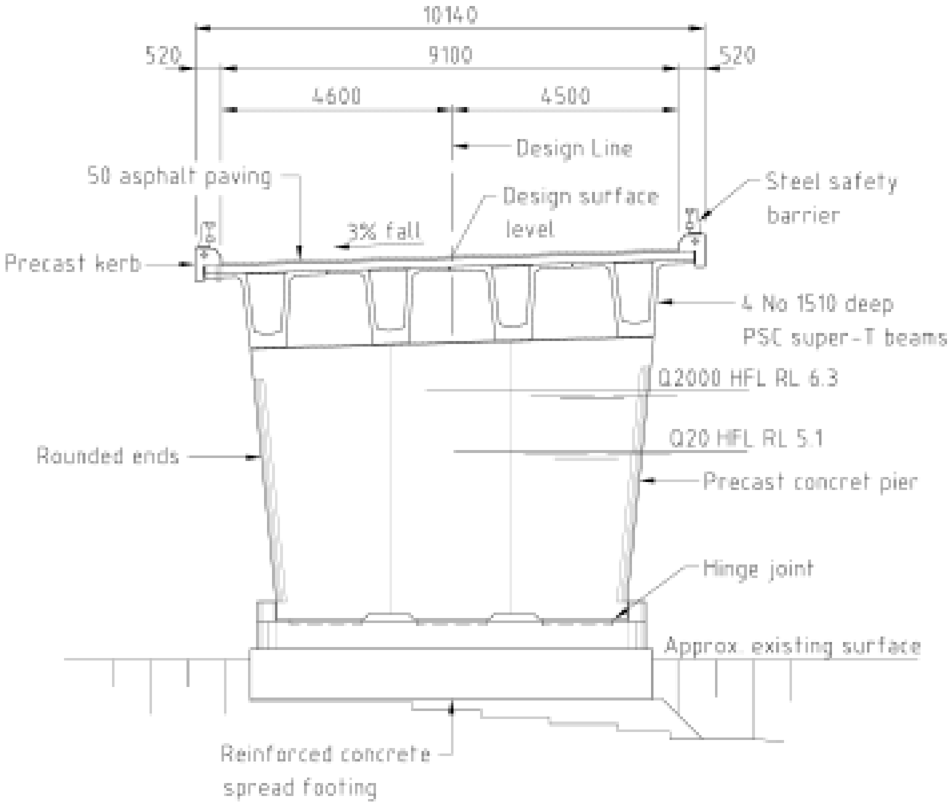


***Figure 2: Bridge Cross Section***

## 4 BRIDGE CONCEPT

### 4.1 Tender Design

During the tender period for the design and construct contract, a concept design was developed by the Contractor and the proof engineer. The concept was shaped by the need to provide an economical structure while at the same time satisfying all of the criteria in the project brief.

A three span bridge gave economical span lengths and the use of high strength blended cement concrete components, including a superstructure with precast prestressed concrete beams to be manufactured at the Contractor’s casting yard, satisfied the requirement to provide a durable concrete structure.

A key element of the concept was to locate the pier footings clear of the water. With good rock at these locations, it was envisaged that spread footings could readily be constructed between high tides. While this feature had an economic basis, it also meant that no excavation or construction would occur in the water, thereby avoiding contamination and possible degradation of the marine environment.

This placed the footings at approximately 34m centres, and with vertical piers, would have resulted in a large central span and two small side spans. In order to capitalise on the opportunity that this presented, inclined reinforced concrete piers were proposed, thereby shortening the central span to 30.8m, and resulting in an aesthetically pleasing structural form.

With constraints imposed by the available bearing capacity of the foundation and the limited bearing area under the footing, a pier articulation was selected with a hinge joint at the base and a fixed connection to the superstructure at the top. The hinge is shown in Figure 3. Various options, including a conventional concrete hinge, were considered for the lower hinge joint. As the joint will be subject to intermittent salt water exposure throughout its service life, a reinforced concrete hinge cast against a cylindrical stainless steel sliding surface on one side and a concentric teflon-coated stainless steel surface on the other was adopted.

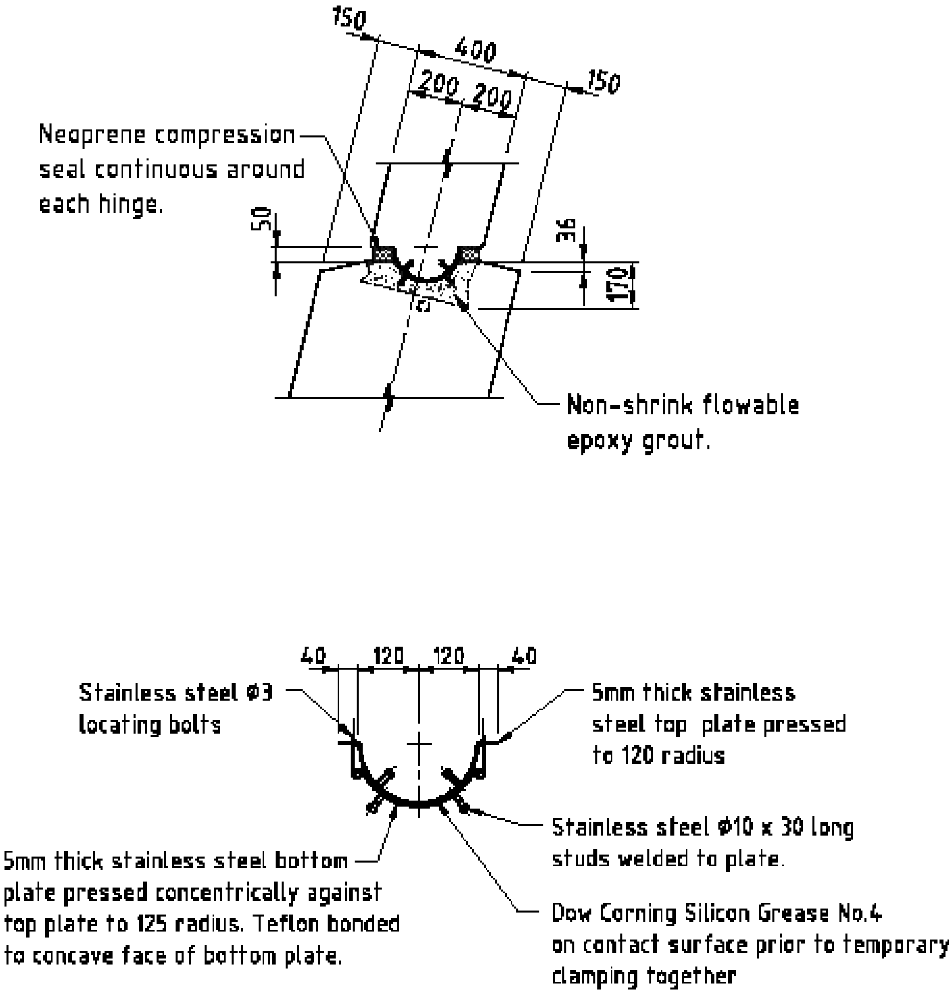


*Figure 3: Hinge Joint at Base of Pier*

Precast concrete was adopted for the piers and axial prestress, with anchorages in the pier diaphragm, in combination with projecting reinforcement was proposed to effect the moment connection to the superstructure. Three match-cast segments per column were adopted in order to limit the maximum segment mass to 15.7t, dictated by the capacity of the erection crane. Horizontal high tensile bars, subsequently grouted, were used to stitch the segments together.

The abutments were founded on rock and high tensile bar rock anchors were incorporated to resist sliding and overturning. Stainless steel pot type bearings were required at the abutments to resist a small uplift at the serviceability and ultimate limit states.

The proposed construction sequence included the following:

- construct abutments and pier footings
- erect and temporarily brace precast inclined pier segments
- complete transverse stressing of piers
- erect end span girders cantilevered beyond piers to receive centre span girders on temporary steel bearings at the ends of the beams
- construct diaphragms at tops of piers providing integral connection between pier columns and superstructure
- construct insitu deck in end spans
- erect centre span girders
- concrete joints and construct remaining insitu deck

### 4.2 Detailed Design

The bridge articulation was reviewed as the detailed design progressed because of the expected congestion in the pier diaphragms, with reinforcement and prestressing anchorages protruding from the precast girders, reinforcement, prestressing tendons, ducts and anchorages from the inclined precast pier segments and diaphragm reinforcement protruding transversely through the ends of the girders. The Contractor reviewed the construction sequence in detail and assessed the difficulty of achieving the required construction tolerances and the possibility of not being able to accommodate all of the required reinforcement and prestress in the diaphragms. It was agreed that there was an unacceptable risk of a problem arising at this critical construction stage.

Various factors contributed to this issue and the preferred solution was not immediately obvious. Specifically:

- the relationship between pier thickness and associated bending moment differed significantly for the vehicle braking and the deck shortening load cases
- a thicker pier, better able to resist braking forces but attracting larger bending moments from deck shortening, allowed a larger moment capacity with a combination of reinforcement and prestress but resulted in congestion in the pier diaphragm
- a smaller pier was subject to relatively larger braking effects, smaller deck shortening effects, but had significantly reduced flexural capacity

Alternative articulations were considered, including the provision of a hinge at the top as well as at the base of each pier. Stability of the structure in this case was to be achieved by fixing the superstructure to one of the abutments. This option was structurally feasible, but the expected difficulty of accessing or replacing the hinge joints at the tops of the piers made it unacceptable.

The eventual solution incorporated an interesting innovation that proved ideal for this situation. The structure was analysed for a range of pier blade thicknesses. An optimal solution emerged, and the thickness of each pier was reduced from 800mm to 400mm, giving a significantly reduced bending moment at the top of the pier. The column was provided with a quantity of reinforcement which could readily be accommodated in the pier diaphragm. With the problem of congestion solved, the remaining difficulty was that the flexural capacity of the pier was not sufficient to resist the entire design loading. With the bridge fixed at one abutment, excessive bending moments were generated in the more distant pier from deck shortening caused by creep, shrinkage and thermal effects. With the bridge free at each abutment, excessive bending moments were generated by braking loads in combination with other design effects. This problem was solved by incorporating “lock-up” devices at each end of the bridge.

A “lock-up” device consists of an enclosed steel cylinder containing a loose-fitting piston fixed to a transmission rod. The cylinder is filled with an unpressurised silicon-based compound that can flow around the piston to accommodate slow movements, such as concrete creep, shrinkage and thermal movements. However sudden impact loads, such as arise from earthquakes and live load braking forces, give insufficient time for the compound to migrate, and the device “locks up”, transmitting the force as a rigid link. Two proprietary 200kN capacity lock-up devices were provided at each end of the bridge and were rigidly attached to the girders and to the abutments. The use of lock-up devices in this case caused braking loads to be transmitted directly to the abutments, thereby eliminating longitudinal sway of the bridge and the resulting flexure of the piers.

## 5 DESIGN OF TEMPORARY WORKS

A range of site constraints necessitated close liaison between all parties associated with the project to ensure that the final construction drawings adequately provided for all of the associated constructability issues. The most significant issues relating to temporary works were:

- crane access and availability
- access to the pier footings
- the influence of tidal movements on footing constructability
- placement and support of the precast pier segments
- stability of the bridge until continuity was achieved
- placement of the drop in central span beams

Each item required close co-operation and communication between all the project partners.

### 5.1 Pier Footings

Access and durability requirements resulting from the large tidal range necessitated the base of the footings being located on rock marginally above the low tide level. Permanent concrete formwork was constructed for the footings to minimise the ingress of salt water, and the footing construction was programmed to coincide with periods of low tidal variation.

## 5.2 Pier Brace

The overall stability of the bridge during erection was dependent on the rigid support of the inclined piers, which were hinged at the base. This stability was achieved by providing a pair of 600mm diameter steel tubes (see Figure 4) as a rigid link between each pier and abutment, and by stressing the pier to the abutment using prestressing strand passing through the steel tubes. Sufficient load was applied to ensure rigid frame action for the remainder of the construction. Stability of the abutment headstocks was achieved using rock anchors stressed vertically to the underlying rock.

***Figure 4: Temporary Support for Pier***

## 5.3 Launching Truss

The lack of availability of a suitable sized crane and the difficulty in positioning any cranes led to innovation in the erection and placing of the central span beams. Van Ek Contracting proposed to fabricate a lightweight launching truss to facilitate this operation. The truss was designed to launch across the opening, and then with the assistance of light cranes at each end, was positioned to optimize beam placement.

Beams were transported to the site by prime mover and were placed using this purpose-made launching truss as shown in Figure 5.

***Figure 5: Launching Truss supporting Beam***

## 6 DURABILITY

The Brief called for the reinforced and prestressed concrete components of the bridge to be designed for a service life of 100 years. It was recognised that the provisions of the Australian Bridge Design Code alone would not achieve the required service life in this environment, and that the Contractor should undertake specific durability measures in the design and construction phases to ensure that the service life objectives would be met. The durability design, which is the subject of another paper at this Conference, was carried out under the direction of Dr Frank Collins of Maunsell, and was an integral component of the detailed design of the bridge. The durability considerations for the bridge elements included consideration of soil tests, tests of concrete samples taken from the existing bridge, concrete mix design details, chloride ion diffusion tests, clear cover to reinforcement and an assessment of the risk of thermal cracking in the pier footings. Durability reviews of the design drawings were undertaken at each stage of the design.

Although the pot bearings, longitudinal deck restraints and hinges at the bases of the piers were designed for long term maintenance-free performance, consideration was also given to access for maintenance. A detailed methodology was accordingly provided on the bridge construction drawings for the future removal and replacement of these items, should this ever be required.

## 7 CONSTRUCTION

The construction process involved close liaison and communication between all parties during the design and construction phases.

The construction process involved:

- placement of silt traps and other environmental site management devices prior to the commencement of the bridge construction to protect the river from site contaminated runoff
- excavation of the abutment foundations to rock, construction of the abutment headstocks and installation of stressed rock anchors
- construction of the pier footings and pier stubs with a recess for the stainless steel hinge
- placement of the central individual precast plate element of the three that formed the pier on temporary supports, attachment of a strong-back to the plate and stressing this back to the abutment through the pier brace
- placement of the remaining two pier plate elements and transverse stressing of these plates together to form the integral pier.
- casting the stainless steel hinges in the pier stubs to match those cast into the individual pier plate elements
- erection of the end span beams, which cantilevered over the pier, with the pot bearings attached and casting the bottom attachment plate into the abutment
- casting the end span decks to within 1.5m of the inclined piers
- placement of the launching truss over the gap between the piers
- placement of the central span beams
- casting the deck on the central span beams including the temporary cantilever joints to form continuity of the beams

- casting the remaining beam and pier diaphragm sections giving full continuity of the superstructure
- removing the temporary pier brace
- installing the lock-up devices at the abutments
- completing the barrier rails, approach slabs and asphalt surfacing

The processes were both technically and logistically complex.

To protect the Australian Grayling, turbidity monitoring of the River was carried out regularly, first to establish baseline levels and then to determine the impact of the construction works on the water quality.

After the new bridge was completed, the old bridge was demolished by cutting it into sections, which were removed from the centre out by a crane located on the existing bridge. During the demolition, environmental protection was maintained by using an under-bridge collection system that piped the cutting water to the riverbanks where it was filtered prior to being discharged back into the River.

## 8 CONCLUSION

This award winning bridge with inclined piers is aesthetically pleasing, highly durable and satisfies the requirements of the owner and the Bridge Design Code through innovative design and construction techniques and through excellent liaison between the construction contractor, the bridge designer and the temporary works designer. These processes arose from the difficult site conditions, the corrosive effects of seawater, the limitations of the available construction equipment and the complexity of the structural form of the bridge. Innovations included the provision of:

- stainless steel hinge bearings at the bases of the piers
- longitudinal deck restraints (lock-up devices) to transfer braking forces to the abutments in order to relieve the loading on the piers
- significant falsework to support the inclined piers during the erection of the superstructure
- a purpose-made erection truss to launch the centre span superstructure girders, and
- an extensive analysis of all bridge elements based on tests of local materials to confirm the required durability provisions