SORELL CAUSEWAY CHANNEL BRIDGE, TASMANIA

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ABSTRACT

One of Australia's first post-tensioned beam and slab bridges was constructed in 1957 in a maritime environment north-east of Hobart, Tasmania. A feature of this bridge is that the voids for the tendons were created using inflated rubber tubes which were withdrawn after the concrete had hardened.

In light of serious deterioration of this bridge caused by the ingress of chlorides, the Owner awarded a design/build contract for its removal and replacement in 2001.

The $18.7m (AUD) replacement Sorell Causeway bridge is thought to be the only match-cast precast-segmental channel-type road bridge outside of France or the USA. This paper describes the successful use of this rare bridge form, which provides for a very small depth of structure below roadway level. The Authors recommend the channel form for widespread use. Conclusions are drawn with the aim that others can more easily adopt and develop the concept further.

Keywords: channel girder, trough girder, through girder, finite element model, age adjusted, linking slab, segmental precast, post tensioned, long line method, epoxy joint, durability, crack control

INTRODUCTION

Description Of Channel Bridge Concept

A channel-type bridge is essentially a large box girder with one of its flanges removed in entirety. The longitudinal stiffness and strength are therefore obtained from significantly proportioned parapets, while the roadway slab spans between opposing parapets as a one-way slab.

The resulting 'apparent' depth of section below roadway level is very much less than is usually required for conventional beam-and-slab type designs. In addition, precasting makes the channel section faster and cheaper to construct than flat-slab type designs cast insitu.

Previous Examples Of Type

The concept of the channel road bridge was developed in France by Mr. Jean Muller and several examples have been built for that country's highway administration. In the United States, and in conjunction with Highway Innovative Technology Evaluation Centre (HITEC), the New York State Department of Transportation has built and monitored a number of channel bridges by diagnostic load testing.[1]

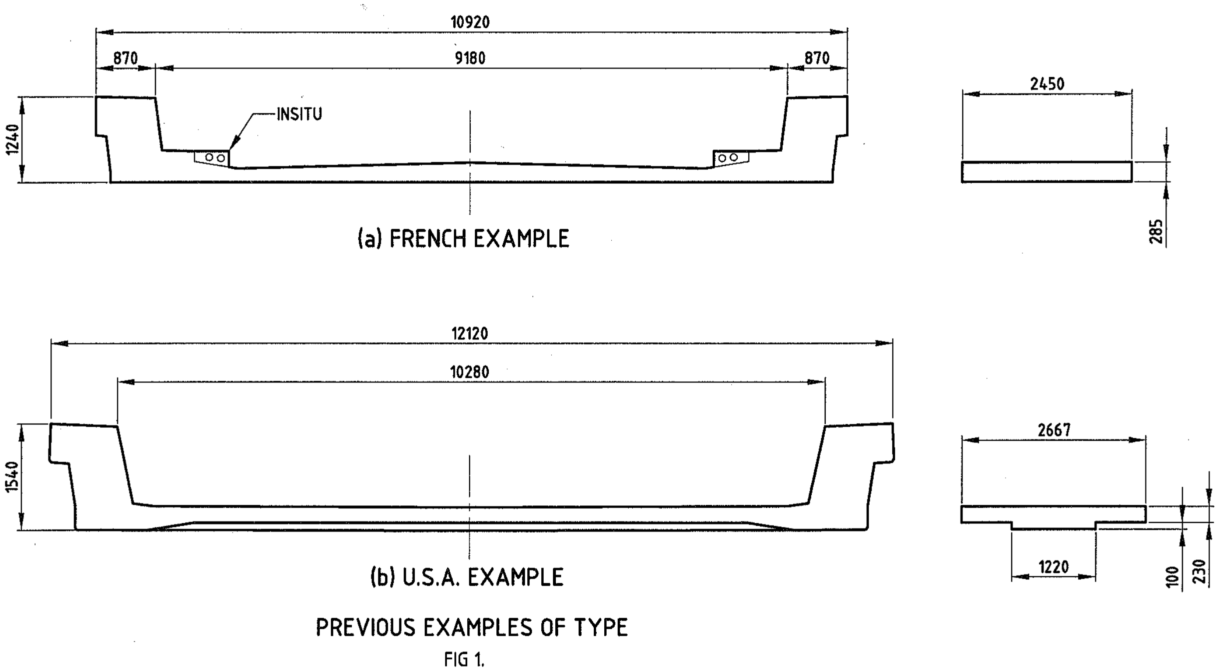

Fig. 1 Previous Examples

Figure 1 shows examples of bridges built to date. The bridge '(a)' does not have transverse ribs, and is stressed transversely using monostrand tendons whereas the bridge '(b)' utilises a prismatic section with transverse ribs and the transverse prestress is draped.

Another example has been constructed in the U.S.A. with individually-manufactured deck planks and box beams stressed together (not shown). In all instances, parapet separation has been sufficient only for dual lane.

Proprietary nature of design - Jean Muller International (JMI) and the specialist prestressing contractor Freyssinet jointly hold the patent for the channel bridge concept in the United States and most of Europe. In the USA, the licensee Bridgetek offers the system as a proprietary product, and JMI prepares design documentation.

THE NEW SORELL CAUSEWAY BRIDGE

General Arrangement

The existing Sorell Causeway consists of over 3280 ft (1000 m) of reclaimed armoured embankment and 1510 ft (460 m) of low-level bridge structure. The channel concept was offered during tender stage as an 'alternative' design. Figure 2 shows the concept as originally advertised by the Owner.

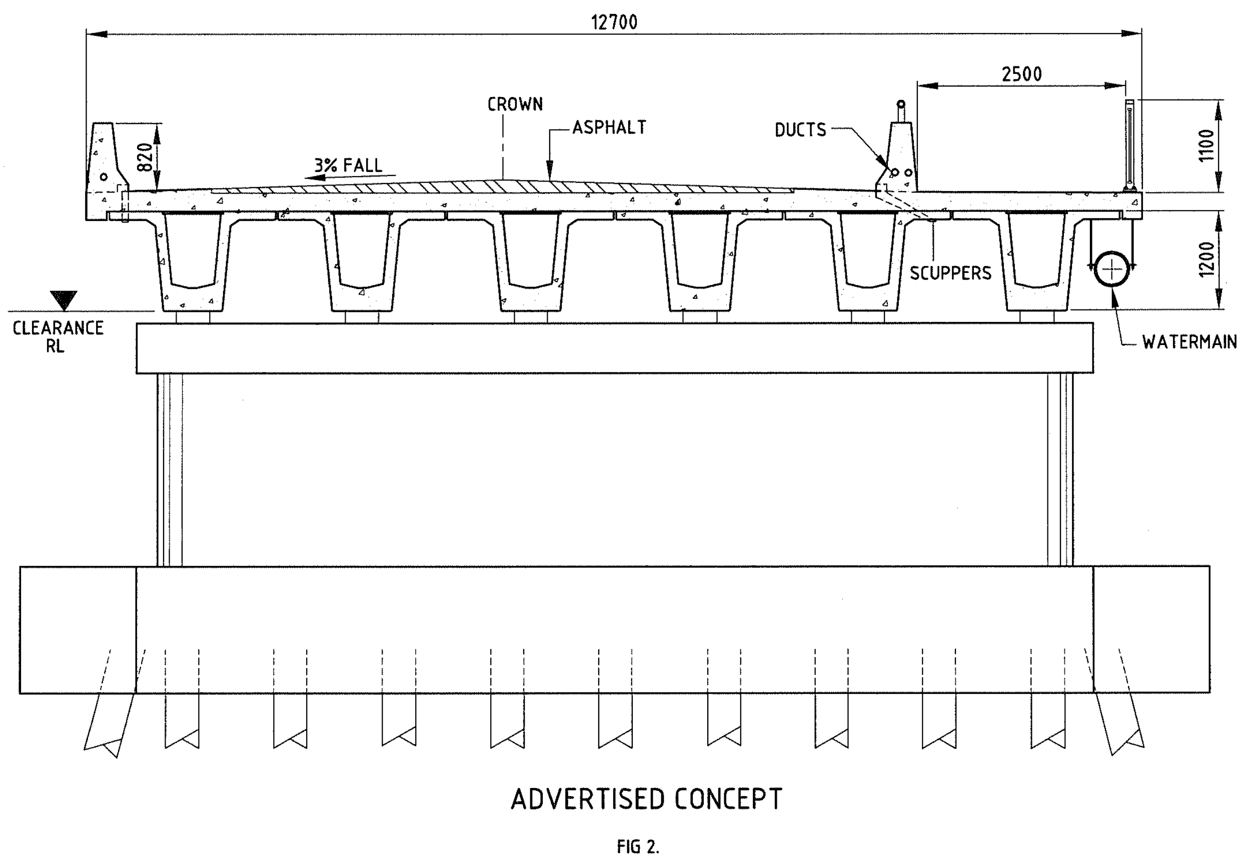

Fig. 2 Advertised Concept

The replacement channel-section version consists of 18 nearly identical 83.7 ft (25.5 m) simple spans with no net cross fall or horizontal curve. The vertical alignment is a constant grade and supports are not skewed. Consistent with Australian conditions and practice, 2 in (50 mm) of asphalt was specified for the road surfacing, with no allowance for sacrificial concrete.

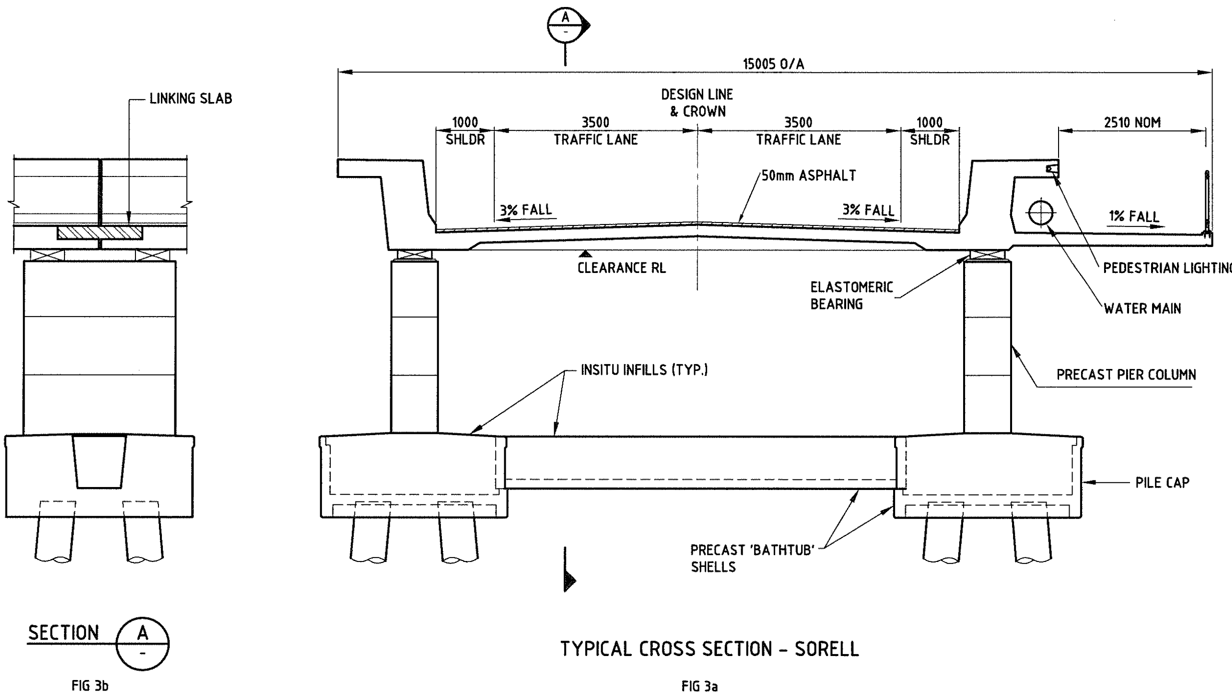

Fig. 3 Design as Built

Figures 3 shows a typical cross section from the new Sorell bridge which provides for two marked traffic lanes, a water main, and a combined pedestrian and cycleway. The depth of the 'flanges' was constant, however the rib depth varied across the width of the bridge.

The soffit clearance adopted was the minimum specified by the Owner (refer 'clearance R.L.' in figures 2 and 3). The road level adopted was therefore considerably lower than was required for the advertised design.

The replacement structure was built adjacent to the old one which was retained in-service during the construction works. The armoured approaches were therefore widened. Significant reduction of off-structure earthworks resulted from the lowering of the roadway surface.

Comparison Of Properties

The Table 1, below, compares directly the channel design built to that concept advertised at tender after deleting the pedestrian cantilever and for an assumed common kerb to kerb dimension of 29.5 ft (9.0 m) for both section types. Values are determined on the basis of the transformed cross-section.

TABLE 1 Comparison of properties

	referenced modulus of elasticity ksi (MPa)	second moment of area ft^4 (m^4)	stiffness EI kip.ft^2 (kNm^2)	gross section area ft^2 (m^2)	surface area per unit length ft^2/ft (m^2/m)	% precast by weight	apparent structural depth (not inc. asphalt) in. (mm)	average effective prestress at transfer ksi (MPa)
advertised ‘beam and slab’ design	5176 (35700)	133.1 (1.15)	9.67e7 (4.1E7)	52.9 (4.92)	110.7 (33.75)	65	54.1 (1375) inc 6.5 (165) deck	1.45 (10)
adopted ‘channel-type’ design	5669 (39100)	121.5 (1.05)	9.67e7 (4.1E7)	58.6 (5.45)	97.4 (29.7)	100	11.8 (300) min 17.1 (435) max	1.16 (8)
ratio channel / advertised	1.09	0.91	1.00	1.10	0.88	N/A	0.31 at max depth	0.8

Durability Requirements

The specified serviceable life of concrete elements was 100 years. In addition, maximum design crack width was restricted to 0.0079 in. (0.2 mm).

Careful consideration of concrete mix, work methods, and structural design was made to conform to durability requirements. High performance concrete with a low w/c ratio and high slag and silica flume content was used to minimise shrinkage and reduce the ability of surface chlorides to diffuse. For the small amount of deck concrete cast insitu (linking slabs and expansion joint blockouts) calcium nitrite corrosion inhibitor was also used.

The channel section was chosen, in-part, because of an anticipated reduction in life-cycle cost associated with its relatively low surface area. While the deck units were partially prestressed in the transverse direction, the epoxy joints between segments were designed in the longitudinal direction to remain fully compressed under service and construction loadings.

The crack width limitation was especially onerous, and restricted the increment in steel stress past decompression to within the range 17.4 to 23.2 ksi (120-160 MPa) depending on bar size and spacing. Various methods of calculation were compared to guard against an unnecessarily conservative outcome, however each gave similar results.

While the allowed steel stresses under service loads were low, full advantage of the available 72.5 ksi (500 MPa) minimum yield of reinforcing steel was made at the strength limit state. The efficiency of the design was therefore not skewed by the consideration of durability and crack widths. For the spans considered, the design live loading M1600 (Reference 3) produces, at the ultimate limit state, a load effect approximately equal to that from the self weight of the structure.

Construction loading

Differing from previously demonstrated erection methodology, spans were erected by lowering precast units using a 150 ton capacity crane from the span just completed (photo 1).

Photo 1 View from Above (courtesy John Holland P/L)

Units were suspended by the underside of their flanges, and placed onto temporary steel girders launched between piers. This procedure required the crane to rotate in plan and load the deck significantly. The construction loading governed the transverse design and detailed negotiation between the Designer and the Contractor was required.

Substructure

Substantial use of precast elements was made in the substructure. Each pier has two small circular pier pilecaps tied to each other via a compact beam. These both utilise precast 'bathtub' shells, the walls integral with the floor. The pilecaps were inserted over the tops of the piles (see Photo 2) , tie-beams inserted, and insitu concrete poured into all.

Photo 2 View from underside pilecap shell (courtesy John Holland P/L)

Two round pilecaps per pier are each supported on four 24 in. (610 mm) diameter driven steel tubes. The length of tube estimated to corrode significantly was filled with reinforced concrete.

Match-cast column sections were stressed vertically to the pilecap using greased and sheathed bar. Elastomeric bearings supporting the spans were positioned directly above the stressing bar block-outs, to improve durability further. Sufficient space was allocated between the two bearings on each column to provide for jacking to replace bearings.

The advantages of precasting units in factory conditions were identified as follows:

- improved durability at exposed surfaces
- superior and consistent finish quality
- better level of inspection
- improved site safety when working over water
- reduction in formwork and temporary falsework.
- compression of the construction programme

The tie beam has the advantage of increasing the robustness of the substructure, and served to support eccentrically-located temporary works. This increased robustness also reduced the design's sensitivity to mis-driven piles.

The bridge is in a region of low seismicity, and crosses shallow water. Earthquake and ship-impact loading were not estimated to be appreciable. It was recognised, however, that under more demanding conditions, the tie beam arrangement between pilecaps could be developed further to achieve an energy-absorbing structure to resist loads in the plane of the pier, a similar detail having been developed elsewhere.[2]

Superstructure

Unit details - Although the articulation of the structure varies along its length, only two types of concrete segment shapes were used; eight number 'standard' units, and two number 'end' units per span. Unit lengths were chosen to minimise weights. Reinforcement was varied slightly in end units to produce two variations on the theme.

All end units include a rebate to achieve either linking slab or expansion joint details.

Linking slab design – The simply-supported spans were connected together except at necessary expansion joints using 'linking' slabs cast insitu. These slabs reduced the number of expansion joints required, therefore reducing maintenance costs and improving the riding surface.

Linking slabs were debonded from the precast concrete over their bottom and side surfaces, and were designed to be sufficiently flexible to accommodate differential rotations between adjacent spans. Limitation to the maximum differential displacement across the linking slabs during possible remedial jacking of bearings was nominated on the drawings.

Prestressing -Longitudinal prestress was applied in three stages. Once the number of spans between expansion joints was completed, and intermediate linking slabs cast, their entire length was stressed together using 'flat-slab' type cables. The resulting benefit was twofold:

- The number of anchorages per span was significantly reduced.
- The linking slabs were prestressed, increasing their durability.

Parapet design - The parapets resist crash loads, and provide longitudinal strength. They are also non-redundant, and therefore were designed to resist the vehicle crash loading elastically. Reference 1 infers that parapet design should be assessed assuming some damage to the concrete.

Transverse Features

Because the deck is suspended from the parapets, it was necessary to include 'hanger' reinforcement at the kerbs. In addition the transverse prestress was draped to help resist this effect. Similarly, steel detailed to resist hanger action was included in the top flanges of deck units so they could be lifted at those locations.

CONSTRUCTION

Match-cast superstructure segments were cast horizontally in a long-line procedure. Match-cast pier column units were cast vertically.

Cycle times of approximately two weeks per span were achieved.

Problems reported on other projects[1] were not observed at Sorell, and deck geometry, and cambers values were close to those predicted.

APPLICATION OF STRUCTURE

The depth of structure below roadway level can be considered to be a function of the transverse design only, and need not increase with increasing span. An increase in parapet size and the establishment of structural continuity may allow increases in span.

Application of the channel bridge concept is especially well suited to the following situations:

- road overpasses
    - reduces extent of approach embankments and ancillary works
        - approach vertical curves reduced and sight distances improved.
        - reduced earthwork volumes and heights
        - reduced preloading of embankments may be achieved
        - reduction in right of way / impact on adjacent properties
    - increased under clearance

These points are illustrated schematically in Figure 4.

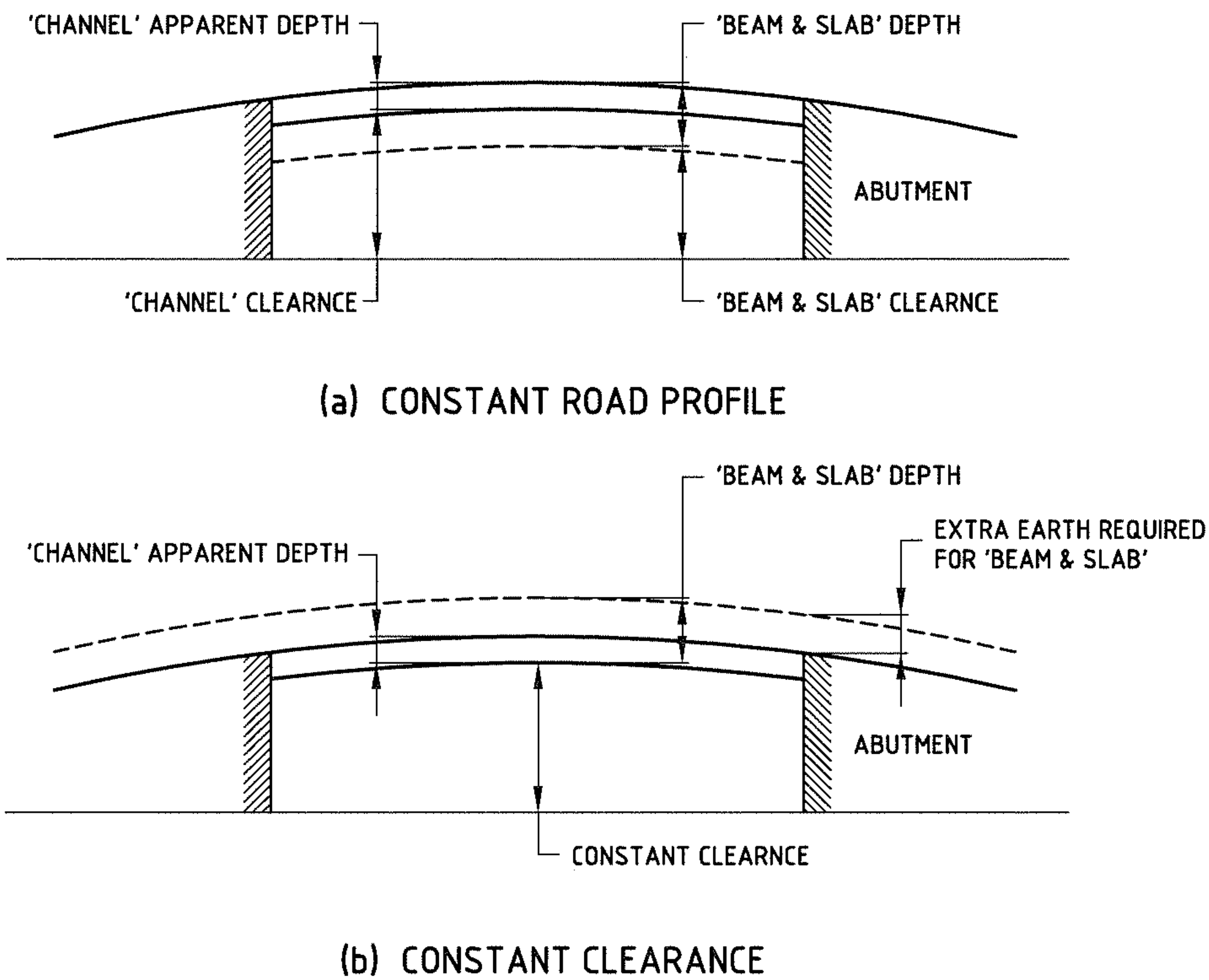

Figure 4. Relative advantages of channel design.

RECOMMENDATIONS

The channel design is well suited to design/build contracts, and the following points are recommended.

- spans up to 115 ft (35 m) may be possible if structurally continuous.
- end units suffer reduced longitudinal distribution of load and should be made deeper than internal units.
- non-redundant parapets must be designed so that safety of the bridge is ensured after the design impact has occurred.
- draped transverse stressing is recommended in order to resist shear. This is especially helpful when variable depth transverse ribs are used and the depth of slab at kerbs is small.

CONCLUSIONS

The precast segmental channel bridge has been demonstrated to have several important advantages for highway bridges.

- minimal effective depth beneath the roadway improves clearances and reduces the heights of approach embankments.
- pedestrians and utilities can be fully protected from traffic on external walkways.
- precast units reduce construction time and cost
- precast units increase durability and reduce life cycle costs
- smaller surface area and lesser number of bearings reduces life cycle costs
- use of linking slabs reduces the number of expansion joints
- the lateral and longitudinal designs are essentially independent as long as parapets are parallel. The effect of skewed supports is therefore minimal, and can be easily accommodated. Indeed it may be possible to support continuous bridges on staggered bearings yielding massive skews. The design of prestress in opposing parapets can therefore be similar but arranged ‘out of phase’.
- support piers for continuous bridges can be made to be very slender and open in appearance.

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Owner	Department of Infrastructure, Energy, and Resources, - Government of Tasmania
Builder	John Holland Pty Ltd
Designer of bridge and roadworks	GHD Pty Ltd
Durability consultant	GHD Pty Ltd (formerly Taywood Engineering)
Designer of temporary works	Dr Russell Keays

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RECOMMENDED FURTHER READING

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