Terragong Swamp Bridge, North Kiama Bypass - Innovative Design

I. Sloane, BE (Hons), MIEAust, CPEng
Associate, Connell Wagner Pty Ltd, Auckland, New Zealand

K. Srivelan, BSc (Hons), MIEAust, CPEng
Project Engineer, Connell Wagner Pty Ltd, Melbourne, Australia

P.T. Sheasby, BSc (Hons), MIEAust, CPEng
Senior Project Engineer, Connell Wagner Pty Ltd, Sydney, Australia

SYNOPSIS

The design and construction of the Terragong Swamp bridge incorporates a number of innovative features which allowed Baulderstone Hornibrook and Connell Wagner to secure this project in a fiercely competitive market. The significant economic benefits of the alternate design in terms of material cost and constructability ensured the success of the project for all parties, particularly the facility owner, the Roads and Traffic Authority of NSW (RTA).

This has been recognised in the Excellence Awards awarded to the project team by The Institution of Engineers and the Concrete Institute of Australia.

1. INTRODUCTION

Tenders were called for the construction of the Terragong Swamp Bridge in mid 2000. Baulderstone Hornibrook won the tender by offering an alternate design produced by Connell Wagner. The innovations introduced in the alternate design produced a saving of around $8M on the conforming design. These features included; special concrete V-Piers integral with the superstructure to allow precast I girders construction to span the 70m over an environmentally sensitive billabong, the use of precast soffit panels containing the main reinforcement to span between precast girders, and the deletion of shear restraints.

Additional savings were introduced by Connell Wagner during the detail design phase, including the deletion of diaphragms for the deck girder spans, reduction in the extent of piling, and abutment stabilisation by reinforced soil.

Some of these innovations are described in Section 4 below.

2. PROJECT CONSTRAINTS

Key project objectives were as follows;

- An overall bridge length of 942 metres
- Crossings over Minnamurra River, associated minor streams, Minnamurra flood plain and a major crossing over the billabong.
- A 21 metre roadway width comprising design loading for 3 lanes in each direction separated by a median barrier
- A provision for SM1600 design traffic loading
- Accommodation for variable geological site conditions over the bridge length, including the presence of acid sulphate soils
- Consideration of the environmental sensitivity of the area, much of which is classified as SEPP 14 Wetland into the design of the structure.

3. PROJECT DESCRIPTION

The total length of the bridge is 942m passing over the Minnamurra River and associated Billabong and swamp land to the north of Kiama on the New South Wales south coast, refer Figures 1 & 2. In all, the structure comprises of 30 spans. Twenty-six of these are general viaduct maximum 29m spans consisting of precast pre-tensioned I-girders simply supported on elastomeric bearings. The deck consists of reinforced concrete precast panels which are supported by the girders and act both as formwork for the overlying cast in-situ deck concrete and in composite action with both the girders and cast in-situ deck for support of live load and superimposed dead load.

The substructure for the viaduct spans consists of reinforced concrete headstocks supported by 1200mm diameter columns. The columns sit on individual square pile-caps that are in turn supported by 4 composite raked driven piles founded on rock.

The geological profile of the bridge route identified the region as an ancient riverbed with varying depths and types of sedimentary deposits throughout. Where sediments overlay the deepest section of the bedrock a layer of dense gravels exist overlying less dense silts and ultimately latite bedrock. Elsewhere, the deposits were generally less dense and in these locations full-length 550mm octagonal precast prestressed concrete piles are provided. Where the piles were required to be driven through the dense gravels the 550mm octagonal pile was cast composite with a 250UC89 steel section. This enabled the pile to be driven through the gravels and onto the bedrock. Dynamic modelling showed high tensile stresses could be developed as the pile breaks through the dense layers. The concrete section was pre-stressed to account for this tension. All piles were driven to refusal in the latite bedrock. Only two of the 324 driven piles required strengthening due to deficiencies in strength exhibited by a dynamic analysis during driving.

The V pier spans consisted of a main 70-metre span over the Billabong with end spans of 50 metres, refer to Figure 6. The superstructure consisted of precast girders cast integrally with a V-pier substructure and cantilevering over the V-piers by about 10 metres with step joints at the end of the girder, refer to Figures 3 and 6. In the adjacent span, precast prestressed I-girders were fabricated to be placed on the step joints of the V-pier girders. The 3 spans were subsequently post tensioned after construction of the cast in-situ portion of the deck slab to provide the continuity for the superimposed dead and live loads. Figures 4, 5 and 6 show the stages of construction adopted for assembling the main span elements. The substructure was founded on 1050 diameter bored piles socketed 3 metres into the strong latite rock layer.

Deck drainage was accommodated through deck scuppers that discharged into longitudinal drainage pipes located between the outer two lower girders as well as two central girders. These drainage pipes discharge water to collection points located behind the abutments.

4. INNOVATIONS

Innovative design solutions included;

4.1 Elimination of Diaphragm Beams between I-girders

Traditionally, the design approach to I-girder construction included the use of end and intermediate diaphragms to assist the deck slab in distributing live loading between the girders. The diaphragm also acted to provide torsional restraint, edge stiffening to the transverse spanning deck slab at the ends, and also a convenient mechanism for jacking up the superstructure to replace the bearings.

Developments in structural analysis software have allowed lateral distribution loads within the structure to be more accurately determined. As a result intermediate diaphragms have generally been found to be superfluous. The length of the Terragong Swamp Bridge encouraged the investigation and additional analysis required justifying the elimination of end diaphragms as well. They are traditionally very costly and time consuming to construct.

Part of this investigation included a site visit to several bridges in South East Asia including an inspection of the bridges in service and discussions with the bridge owners.

Designs were undertaken using plane grillage and down stand grillage modelling to analyse the deck with and without the end diaphragms and under lateral and vertical loading. A number of sensitivity analyses were also done on the behaviour of the deck.

Following these investigations it was concluded that the end diaphragms could be deleted provided end blocks were incorporated to strengthen the girder ends. The end blocks adopted included web thickening so the extent webs were as wide as the girder top flange. It is important to note that this analysis in no way implies, recommends or validates removal of end diaphragms to precast I girder bridges in general. Each bridge must clearly be assessed and analysed on its merits, noting the significant effect of girder size and spacing, span length, span aspect ratio, nature and extent of vertical and lateral loading, bearing restraint and deck thickness.

4.2 Pre-Cast Concrete Deck Panels and In-situ Deck Reinforcement

In the design of precast I-girder bridges in the past, the use of relatively thin reinforced concrete deck panels have generally been used as permanent formwork for the cast in-situ deck concrete above.

For this project the deck panels also incorporate the main transverse reinforcement and act compositely with the cast in-situ concrete above. The discontinuity provided by the abutting deck panels was modelled using finite element techniques.

Shear restraint between the pre-cast deck panel and the cast in-situ deck was not achieved through reinforcement placed across this interface, but rather through the shear resistance developed by roughening the upper layer of the pre-cast panel.

The concrete panels were designed as 85mm thick panels with a 145mm cast in-situ deck above, totalling a 225mm concrete deck required to accommodate the new SM1600 vehicle loading.

4.3 V-Pier Design

The most challenging component of the design was the main 70-metre span over the Billabong. Several options were considered at time of tender including steel and launch bridge options. The key constraints were construction in the time frame required for the project and aesthetic compatibility with the remainder of the structure. The development of the V-pier structure enabled all of these criteria to be satisfied.

The arms of the V-pier have been designed as cast in-situ elements of traditional reinforced concrete design. The innovations are realised with the design of the 40-metre long precast girder which was transported to site, post tensioned and lifted onto the V-piers, cast integrally with the pier and post tensioned transversely. Each girder maintains the same profile of the "typical" I-girders used for the viaduct spans although they vary in depth up to 2400mm to accommodate the higher forces for this longer span. This ensures that there is no visual change to this section of the bridge and allows the contractor to modify its existing forms to build the larger girders.

Once each V-pier table has been constructed on each side of the Billabong, 30 metre precast pre-tensioned girders are lifted and supported at half joints at the ends of the main girders over the piers. Sequential staged post tensioning of the whole 3 span structure is then undertaken to provide continuity for superimposed dead and live load conditions.

In the detailed design a three dimensional grillage/frame model was developed to analyse the entire three spans including substructure and piles. Analysis included the effects of creep, shrinkage and temperature gradients on these three continuous spans.

5. ENDORSEMENT

In a letter to Connell Wagner dated 12 June 2003 RTA advised, "The alternative design of the 942 metre long, $40 million bridge provided an innovative design which met our requirements. Not only did the structure minimise the impact on the environmentally sensitive wetlands, the V piers provide a visually elegant and effective solution to providing a clear span over the Billabong."

ACKNOWLEDGEMENT

The authors acknowledge the Roads and Traffic Authority of NSW and Baulderstone Hornibrook Pty Ltd for permission to publish this paper.

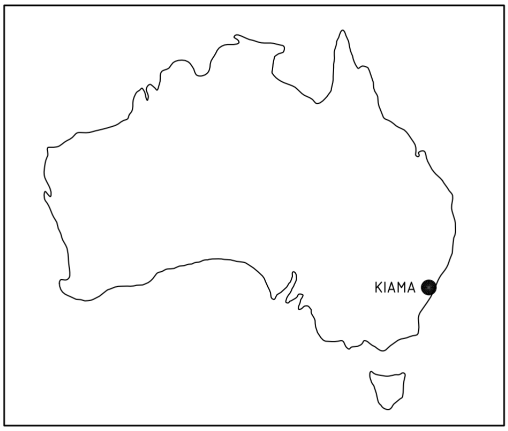

Figure 1: Location, General

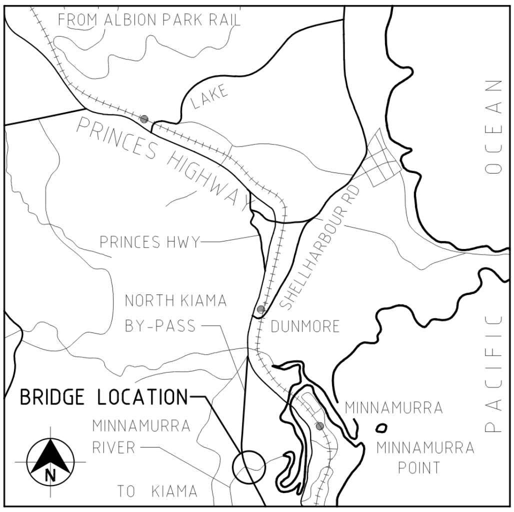

Figure 2: Location, Detailed

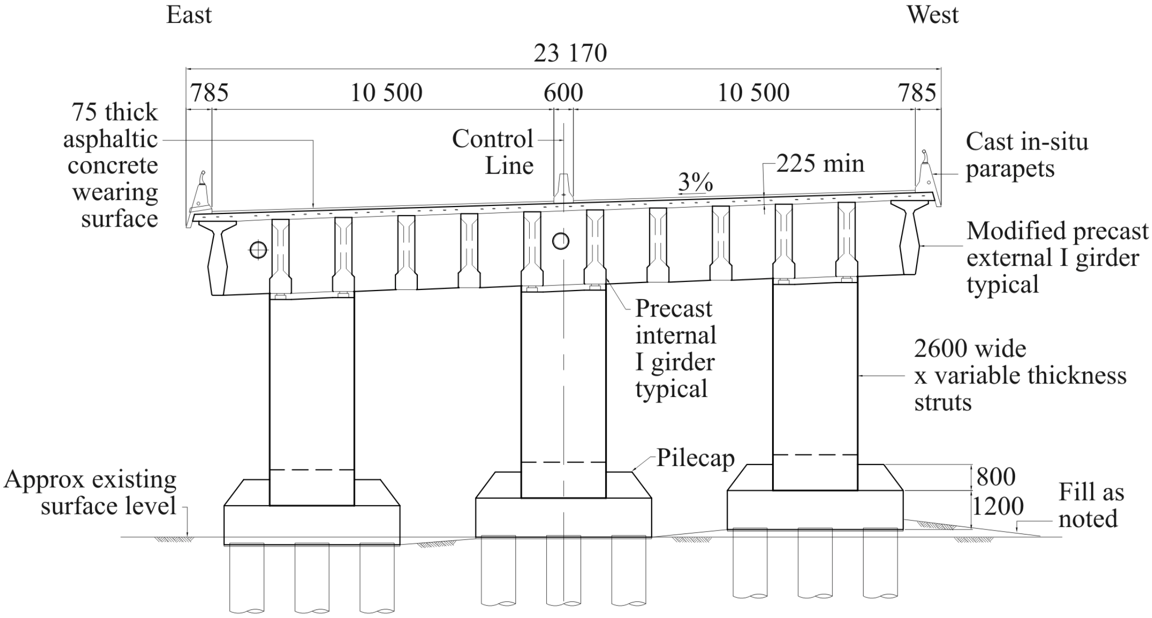

Figure 3: Main Span, Cross Section

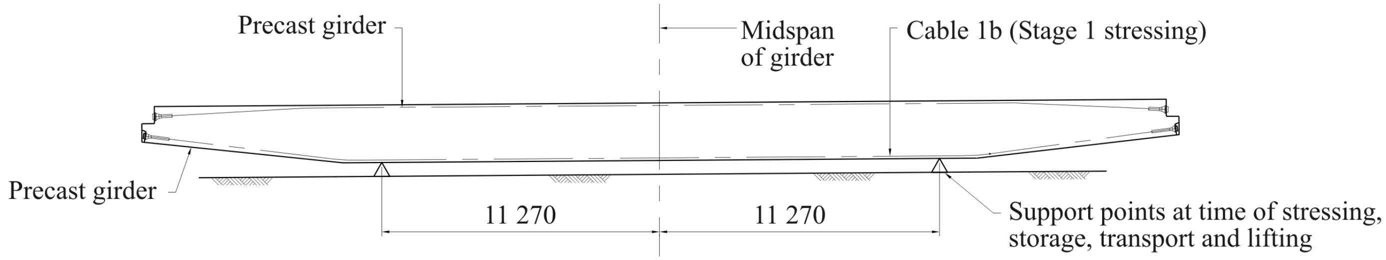

Figure 4: Main Span Girders

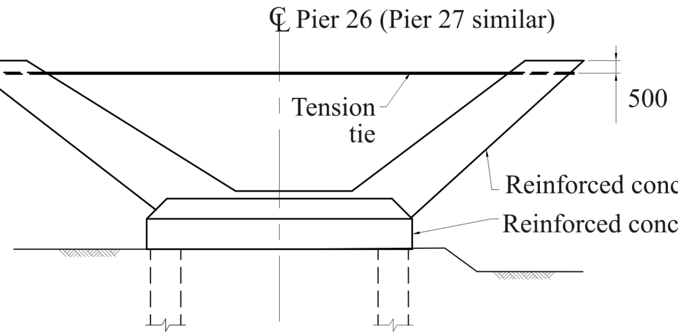

Figure 5: V-Piers

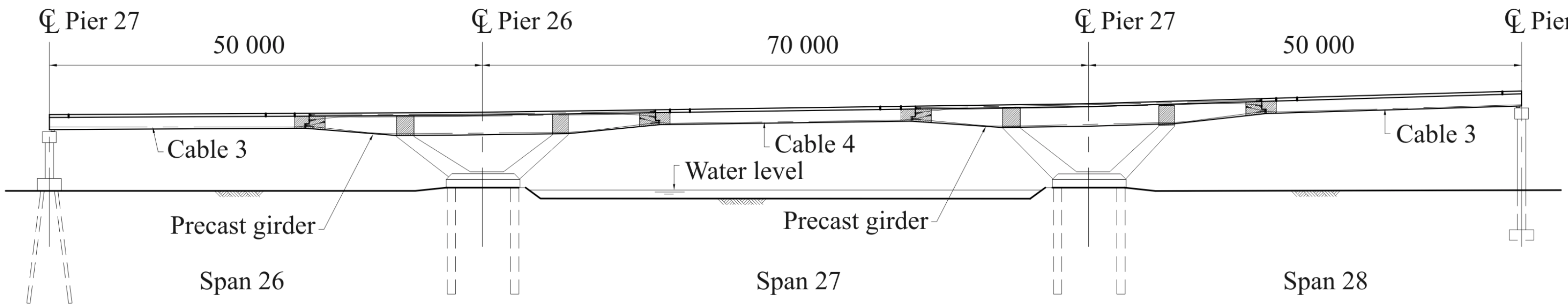

Figure 6: Main Span Elevation