Porters Creek Wetland Bridge – Design of a unique incrementally launched bridge

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Synopsis

The need to link two urban areas while providing for its future development, as well as supporting a critical water main support structure across a wetland was the key aim for Wyong Council’s proposed road works project. Ensuring that minimal impact was imposed on the protected wetland while complying with significant site constraints resulted in the adoption of a 444 m long bridge structure.

The superstructure of this bridge comprises an 11 m wide roadway, a 3 m footway and in addition carries two large diameter water mains on either deck edge. A design development process considered various bridge types with the most cost effective solution determined as being an unusual bridge superstructure suitable for incremental launching. This construction methodology was selected to minimise impact on the wetland by limiting disturbance to natural ground for superstructure works and proved to be optimal in comparative cost estimates.

This paper covers the design development of the superstructure and substructures for construction by the incremental launching technique. The deck section is unique in that it comprises twin solid beams linked by a top slab that also serves as the edge cantilevers.

The deck edge cantilevers incorporate supports for large diameter water mains. A key design feature was the accommodation of the concentric post-tensioned tendons within the deck section and the innovative placement of the second stage or draped tendons. These required particular attention for development of a workable solution.

There being no conforming alternative solutions offered at tender stage, the design was through an open tender process, confirmed the design to be the optimal solution.
Project Summary

Porters Creek Wetland Bridge is an integral part of the Watanobbi to Warnervale Link Road and Water Main project within the Wyong Local Government area. Wyong Shire Council is proposing to construct a new Link Road between the Pacific Highway at Watanobbi and Sparks Road at Warnervale. The Link Road, approximately 3.1 km long, serves to connect several communities at existing junctions, thereby supplementing existing roads, cycle ways and future water supply.

A 444 m long bridge structure was selected based on criteria including minimising disruption to the environmentally sensitive wetlands, cost and constructability.

The design takes into consideration the local fauna and provides improved access to education facilities and linking communities. Bridge foundation design accounts for the poor foundation soils at surface level.

The bridge design fulfilled the following criteria:

- To provide a roadway width of 11 m carrying SM1600 vehicle loads, and a 3 m footway and cycleway.
- Be constructed on a curved horizontal and vertical alignment.
- To be above the calculated 1 in 100 year flood level whilst providing a 100 year design life.

Tenders were called for the construction of the Porters Creek Wetland Bridge in late 2007.
Project goals

The Link Road provides an important and efficient link between Wyong and Warnervale, allowing for increased connectivity between Wyong and the planned Warnervale District Centre.

It provides an important addition to the local road network, ensuring that the road network is capable of handling both the existing and 20 year forecast traffic levels. The project provides for a shared off road facility for pedestrian and cyclists as well as on-road cyclists travelling in both directions.

The bridge provides elevated support of two proposed 900mm diameter water mains above the Porters Creek wetland, connecting Mardi Water Treatment Plant and existing pipelines at Sparks Road, Warnervale. Placing the water mains below the ground was considered environmentally unacceptable. The proposed Water Main has been identified as being necessary to improve the existing water supply services in the Warnervale area and support the planned future development of the Warnervale area.

Another key objective of the project is to provide access to the Lakes Anglican Grammar School at Warnervale.

Figure 2: Elevation view of Bridge
Benefits to the community transport network
Wyong Shire Council’s consideration of future development and transport requirements identifies the demand for both commuter, on road cyclists and shared off road facility for pedestrian and recreational cyclists.

With expected growth of the Central Coast and surrounding areas, there is a need to increase transport links and existing road capacity. Incorporated into this are provisions for links to current and future water supply via the proposed Hunter Pipe line.

The proposed Warnervale to Watanobbi Link Road enhances the existing transportation network and links community access to educational facilities

Project challenges
This link road site presented several design challenges, including:

• Environmental considerations –
  Impact on the wetland was a major consideration in the design of the bridge. When selecting the optimal bridge structural form and its method of construction environmental impact of temporary and permanent works were a critical consideration.

  The protection and limited effects to endangered ecological communities, such as the Swamp Sclerophyll Forest and Freshwater Wetlands, was of high importance within this project.

  The design of barriers and location of light poles were selected to limit the impact on local fauna.

• Soft ground conditions –
  Geotechnical investigations indicated deep soft soils existing throughout the wetland overlying competent sandstone bedrock. A road embankment required extensive ground improvement to reduce settlement.
An options analysis was completed with consideration given to key criteria in a weighted average assessment of road embankment and bridge structure. This assessment indicated that a bridge structure was optimal with major advantages being the reduced environmental impact to the wetland and cost of construction.

Following identification that a bridge structure was preferable over the wetland crossing, further assessment regarding structure form was undertaken. Two main forms of bridge superstructure were considered;

1. Precast prestressed concrete super T girders with cast in-situ deck slab erected by crane from ground level or with overhead gantry.
2. Cast in-situ prestressed concrete twin beam monolithic with deck slab incrementally jacked into position.

A comparison of the two forms of bridge superstructure and their associated construction method indicated that an incremental launched bridge was optimal based on construction programme and cost. An additional advantage with a cast in-situ deck is that a continuous superstructure can be constructed, offering a reduction in maintenance costs required over segmental precast girders.

- Geometrical constraints –
  A bridge length was selected for a section of the Link Road which spans wetland and where a road embankment with spill batters would impact the adjacent SEPP 14 wetland. A span configuration with piers positioned at typically 24 m was selected so as to not impede existing cross drainage culverts on the adjacent railway. The road alignment in preliminary design comprised composite horizontal curves and a parabolic vertical curve. The alignment was optimised in detailed design to a constant radius spatial curve for the length of the bridge suitable for construction by incremental launching.

- Water table level –
  Foundations comprise driven precast concrete piles with pilecaps located at natural surface level. This level was chosen to minimise impact on the wetland and simplify construction by avoiding expensive excavation and temporary works for construction below the water table.
Bridge structural form
The incrementally launched bridge consists of 17 internal spans of 24 m and 16 m end spans, with a slender prestressed superstructure supported on pot bearings. Abutments support the main bridge structure and approach slabs which bear onto reinforced earth.

The overall bridge width of 15.2 m provides 11 m between road side barriers and 3 m wide separated shared path for off-road cyclists and pedestrians.

Superstructure
The bridge superstructure is a monolithic constant 1600 mm deep cast in-situ prestressed twin solid beams composite with varying depth top flange. The bridge has a modular deck joint at each abutment and sliding pot bearings at each pier, except at Piers 7 and 8, where longitudinal restraint is provided by fixed pot bearings to minimise movements where the watermain diverts from the bridge superstructure to an in-ground trench. The deck is designed to be cast in segments equal in length to the span, behind Abutment B.
Segments are designed to be stressed a segment at a time and incrementally launched. The girders are structurally continuous between piers with prestressing applied in two stages, concentric tendons for the launching sequence and draped tendons for service loads.

Two sets of tendons are housed within the deck section; concentric tendons running at deck level and bottom of web for the launching conditions, and draped tendons for final in service condition.

**Figure 4: Leading end view deck segment**

Whereas box type decks can accommodate stressing points at internally located nibs, adoption of a solid deck section required an alternative arrangement with stressing points exiting the beam section itself, proposed at the deck surface.

Careful assessment of stresses was carried out at several stages of the launching sequence in order to design the concentric cable layout. The design of draped tendons, to provide additional capacity for actions from the SM1600 live load, takes into consideration the prestress of the concentric tendons.

Two draped multi-strand tendons are provided in each beam varying by 1400 mm in their vertical position along a parabolic profile. To limit frictional and loss effects on the prestress force over the draped tendons, anchorages were located evenly at 24 m intervals, to match segment lengths with an overlap between each set of tendons.

**Figure 5: Draped tendon profile**
The narrow beam width restricted the possible arrangement of tendons. Tendons are typically located within the beam, except when anchored where they deviate laterally to facilitate anchorage. Resultant out of plane effects were calculated and translated into additional reinforcement within the section. The profiles were adjusted to achieve a reasonable balance in secondary induced actions.

An alternative anchorage arrangement was required for the secondary prestress tendons as it was not possible to use internal anchorages at the ends of the segments, which are typically used in box girder superstructures. An anchorage arrangement at deck level was chosen to permit easier access for stressing operations to be undertaken. Several iterations within the design were undertaken to achieve an anchorage point with acceptable geometry. Tendons were returned back to the deck surface with a blockout created perpendicular to the tendon exit angle.

Figure 6: Draped tendon stressing pocket and tendon overlap

At the leading end of the deck, eight high tensile stress bars are proposed to support the launching nose, as shown. Careful design of the anchorages to the concentric and draped tendons had to be made to fit within the beam section.

Figure 7: Leading segment with launching nose connection details

Diaphragms are only provided at each end of the span. A constant section is maintained throughout the length of the superstructure, with reinforcement continuous across match cast joints.
**Substructure**
The bridge substructure typically comprises twin 900 mm diameter columns supported off a 2.6 m circular pile cap founded on driven precast piles. The two columns are located directly below the solid beams obviating the need for pier headstocks.

The two central piers are blade walls with an elongated circular pilecap with fixed bearings to resist longitudinal braking loads. Longitudinal restraint of the bridge superstructure coincides with the water main exiting the bridge and changing from an elevated support to an underground trenched pipeline. The blade pier and foundation provide restraint for the thrust imposed by the water main. The remaining piers have sliding bearings.

**Figure 8: Elevation view of typical Bridge substructure**

**Approach embankments**
The approach embankments comprise of vertical reinforced soil structures where spill through embankments are situated along wetland and rail corridors. Ground improvement in the form of a pile raft foundation is provided for road embankments approaching the bridge at Abutment B.

**Maintenance considerations**
A key consideration of the bridge was the support of proposed twin 900 mm diameter fully welded steel water harvesting pipes. Pipes are aligned either side of the bridge and are supported on discrete concrete cantilevers monolithic with the bridge deck. A
structural steel bracing frame is provided at Pier 7 to resist thrust loads where the pipes transition into ground. The pipe is accessible from the bridge deck for future inspection and maintenance.

**Construction method**

The bridge is designed to be constructed by incremental launching from the Warnervale bridge abutment where ground conditions are more favourable to establish the casting bed and launching temporary works.

Establishment of the casting bed requires ground improvement to provide a rigid foundation to limit settlement.

A temporary pier is used in the beginning and final stages of construction to reduce design actions in the leading and end spans to a level where they are not critical.

A 15 m long launching nose comprising varying depth welded beams is proposed to be attached to the lead end of the launched deck. The nose is connected with high tensile stressed bars to each beam. The deck segments are cast in a single pour using rigid forms, a segment at a time. Following casting of the first segment the next segment is match cast in the bed and stressed with Stage 1 concentric multistrand prestressing tendons to provide a monolithic continuous bridge deck. Joints are positioned such that they are located away from regions of maximum moments. Tendons at the lead end of segment 1 are anchored using dead end anchors 4 m behind the end of the segment to avoid clashing with the launching nose connection bars. The geometry of the modular expansion joint provided at each abutment required a seating recess be provided in the end segments once incremental launching operations are complete. A temporary concrete infill is provided during launching which is required to be removed once the deck is in its final position.

Half of the prestress is continuous though the segment joint and half anchored with tendon couplers connected to the next segment. The location of couplers is staggered for alternate segments. Stage 2 draped tendons are provided in the segments prior to launching and stressed once the superstructure is in its final position. Draped tendons are stressed and anchored in the top surface of the deck at 1.5 m from the joint location, which is approximately span/4 from pier locations.

Temporary reinforced concrete bearings are to be used during launching operations with teflon coated strips used to reduce thrust loads being imposed on the piers as the deck passes. Once the deck is in its ultimate location the temporary bearings are replaced with permanent pot bearings.
Consideration was given to loading conditions during launching. Differential settlement of the beams and 0.5 kPa construction live loading (with restrictions placed on the lead 3 spans) were included.

Key advantages identified for construction by incrementally launching over alternate methods include:

- Construction equipment is relatively simple with formwork supported directly on the ground
- High level of quality control resulting in a durable structure
- Minimal falsework is required
- Construction joints are reduced when compared with other forms of construction

**Project status**

Wyong Shire Council tendered the Warnervale Link Road project which included Porters Creek Wetland Bridge in October 2007. There were no conforming tenders for alternate structures proposed by bridge contractor submissions received by Council thus proving the bridge structural form and method of construction selected in detailed design to be optimal.

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