Bridge Structures on the Western Highway Anthonys Cutting Realignment Project.

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Abstract  The $200 million realignment of the Western Highway in Victoria between Melton and Bacchus Marsh involves the construction of approximately five kilometres of dual carriageway freeway on a new alignment which avoids the existing steep hills and dangerous curves of Anthonys Cutting. As well as five kilometres of dual freeway, the project also involves a new interchange at Bacchus Marsh, a smaller half diamond interchange at Hopetoun Park Road, a new overpass at Bulmans Road, and two bridge structure crossings of Djerriwarth Creek and Pyrites Creek – 165m and 98m long respectively. These two creek crossings include bridge piers built using prestressed matchcast concrete segments, which at up to 30m in height are some of the tallest piers of their type in Australia. Along with the significant bridge structures, the project also involves the construction of cuttings and fill embankments of up to 25m in height which involved moving approximately 1.3M cubic metres of material. The project is being delivered under an alliance project delivery framework comprising of VicRoads, AECOM and John Holland and is programmed for completion in early 2012. The paper describes the selection of the various bridge forms used on the project, the use of precast segmental construction for the tall piers and some of the challenges faced in the design and construction of the bridges, particularly those built adjacent to high fill embankments and in steep terrain.

Introduction

The Western Highway – Anthonys Cutting Realignment Project involves upgrading a five kilometre stretch of highway known as Anthonys Cutting, from Harkness Road, Melton West to Bacchus Marsh Road, Bacchus Marsh through a Greenfield site. Once complete, the new freeway will carry upwards of 30,000 vehicles per day and avoid the steep inclines and tight corners through the existing Anthonys Cutting. This will improve motorist safety, reduce travel times by
enabling a 110km/h speed limit, and increase freight efficiency. As a vital route to western Victoria and South Australia, the Western Highway – Anthonys Cutting Realignment Project will also reduce expenditure for the road transport and freight industry.

The project is of national significance and funding has been provided by both the Australian Government, as part of the Australian Government Nation Building Program and the Victorian Government.

The new road alignment provides:

- Full freeway conditions with two lanes each way for approximately 5km from Harkness Road Melton West to Bacchus Marsh Road, Bacchus Marsh.
- Melbourne bound access ramps at Hopetoun Park Road.
- A new interchange into Bacchus Marsh.
- Provision for future widening to three lanes in each direction within the central median.

The Project involves the construction of six road bridges in varying terrain and ground conditions across the site. The bridges vary in size and form from conventional two span precast girder bridges such as the new interchange bridge at Woolpack Rd to the 165m long and 32m high bridge over Djerriwarrah Creek which is the largest bridge on the Project and also one that utilises precast segmental pier construction. A summary of the bridges on the Project is included in Table I.

**Table I. Bridges Summary**

<table>
<thead>
<tr>
<th>Bridge Location</th>
<th>Number of Spans</th>
<th>Overall Length (m)</th>
<th>Deck Type</th>
<th>Pier Type</th>
<th>Abutment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulmans Road Overpass</td>
<td>2</td>
<td>64.6</td>
<td>Precast Tee-Roof Girders</td>
<td>Cast in situ</td>
<td>Semi-integral</td>
</tr>
<tr>
<td>Djerriwarrah Creek Bridges¹</td>
<td>5</td>
<td>165</td>
<td>Precast Tee-Roof Girders</td>
<td>Precast Concrete</td>
<td>Jointed deck</td>
</tr>
<tr>
<td>Hopetoun Park Road Overpass</td>
<td>1</td>
<td>51</td>
<td>Cast in situ post tensioned box girder</td>
<td>N/A</td>
<td>Semi-integral</td>
</tr>
<tr>
<td>Pyrites Creek Bridges²</td>
<td>3</td>
<td>98</td>
<td>Precast Tee-Roof Girders</td>
<td>Precast Concrete</td>
<td>Jointed deck</td>
</tr>
<tr>
<td>Woolpack Road Overpass</td>
<td>2</td>
<td>64.8</td>
<td>Precast Tee-Roof Girders</td>
<td>Cast in situ concrete</td>
<td>Semi-integral</td>
</tr>
<tr>
<td>Lederderg River Bridge</td>
<td>2</td>
<td>56.5</td>
<td>Precast Tee-Roof Girders</td>
<td>Cast in situ concrete</td>
<td>Semi-integral</td>
</tr>
</tbody>
</table>

¹Bridges at Djerriwarrah Creek and Pyrites Creek are twin bridges
Concept Development

The design of the bridge structures evolved from the Target Outturn Cost (TOC), or options assessment phase, of the Project through to the detailed design which formed the basis for construction. A range of bridge options were considered in the development phase, including some “non-bridge” options. Each of these was assessed using a triple bottom line approach with weightings of 60%, 22% and 18% assigned to the criteria of cost, social impact and environmental impact respectively. The latter two criteria also had 3 separate criteria each with their own ratings. For example, social impact was further subdivided into visual, traffic and heritage/legacy. A ranking (or rating) was applied to each criteria with zero being the base case, 4 being “very much better” and -4 being “very large disadvantage”.

A description of the developed designs of some of the bridges on the Project is included in the following sections.

Bulmans Road Bridge

The Bulmans Road Bridge extends Bulmans Road over the existing freeway and is located at the eastern end of the Project. The bridge accommodates two 3.5m lanes and a shared path located along its eastern side. The structural form is of conventional precast Tee-Roof girder deck construction with the central pier and abutments supported on precast concrete piles driven to refusal on basalt which is located at approximately 10m below freeway level.

One of the highly visible features of this project are the twin towers which extend approximately 18m above the Bulmans Road Bridge deck. Early on in the options assessment phase the client (Vicroads) identified Urban Design as an important element of the Project and specifically requested that some form of Urban Design treatment be developed for the Bulmans Road Bridge.

The concept developed is a twin tower arrangement with each tower comprising a galvanized steel lattice clad on three sides with randomly shaped weathering steel panels and with aluminium composite panels fixed to the side facing the bridge. Weathering steel was chosen for the cladding due to its low maintenance requirements. Feature lighting is also included and comprises of LED flood lights (also chosen for their low maintenance requirements) located within the towers which illuminate the towers at night through gaps in the weathering steel cladding. External flood lights (also LED) are also provided within the freeway median. Refer to Fig. 1.
Other Urban Design elements on the project include motifs, also in weathering steel, fixed to the side faces and soffit of the Hopetoun Park Road Bridge and also along the rock cutting each side of the Hopetoun Park Road bridge.

![Bulmans Road Bridge](image)

**Hopetoun Park Road Bridge**

The Hopetoun Park Road Bridge carries the existing Hopetoun Park Road over the realigned freeway and forms part of a new half diamond interchange at this location. The bridge accommodates two 3.5m through lanes, a 3.5m right hand turn lane for the Melbourne bound freeway on-ramp and a 1.5m wide footpath. Refer to Fig. 2. The freeway alignment goes through a cutting in basalt at this location, is located on a horizontal curve and is slightly skewed to Hopetoun Park Road.

A number of options were considered during concept development for this bridge including several single span as well as two span and three span bridge options. The introduction of a pier within the central freeway median would have resulted in an overall widening of the freeway alignment over a significant length in order to provide adequate site lines around the pier. This would have resulted in a significant increase in the volume of excavated material, which at this location was primarily basalt. Consequently, the overall costs associated with options that
included a pier in the median were greater than for the single span option ultimately chosen.

The selected option was a single span three cell cast in situ post tensioned box girder bridge approximately 2.7m deep and spanning 51m between abutments that are located each side of the freeway. The bridge deck is supported on elastomeric bearings at the abutments and these in turn are founded at a high level directly on basalt. The bridge is built using a “top down” approach with the box girder cast directly on existing ground and the freeway cutting excavated upon completion of stressing. This approach eliminates the need for a central pier and also avoids the need for expensive falsework.

![Fig. 2. Hopetoun Park Road Bridge Cross Section](image)

**Djerriwarrh Creek Bridges**

The twin bridges at Djerriwarrh Creek take the re-aligned freeway through a steep valley over the Djerriwarrh Creek. The bridges are on a straight horizontal alignment with maximum vertical grades of approximately 4%. Each carriageway accommodates two 3.5m lanes, a 3m outside shoulder and 1m inside shoulder.

The design of this structure posed a number of challenges for the project. The surrounding environment was highly challenging and required the team to work within a sensitive waterway and flood prone valley in very steep terrain. The project team needed to develop a design and construction methodology that would minimise the impact on the surrounding environment while achieving an ambitious construction program.
A substantial amount of planning was undertaken by the project team prior to finalising the design and approach. A large number of options were considered for the bridge ranging from arch culverts to bridges varying from approximately 100m to 250m in length built using a variety of construction methods. These included incrementally launched super structures, the use of launching gantries to erect precast beams as well as crane erected precast and steel beams. After having considered these options and applying a triple bottom line assessment the preferred solution was a 165m long, five span structure. Refer to Fig. 3.

The chosen solution comprised precast concrete girders supported on precast segmental concrete piers. The girders are supported on elastomeric bearings at each end which are in turn supported on a cast in situ crosshead at the tops of the piers. Foundations comprise four No. 1050mm diameter cast in place bored piles at each pier socketed into the underlying siltstone and 750mm diameter cast in place bored piles at each abutment.

The resulting bridge required the construction of a high fill embankment up to 25m in height at the eastern abutment. This had program implications as bridge construction had to be staged in such a way to allow the majority of the embankment to be completed prior to construction of pier 1 and the eastern abutment.

Crane erection methods were used to erect the precast pier segments as well as to lift the precast deck girders in place. This required the construction of hardstand areas located at piers 1 and 4 and also a temporary hardstand located in the creek between piers 2 and 3. Due to the high loads developed under crane outriggers, particularly during girder erection the hardstands at piers 1 and 4 required particular attention to ensure they performed adequately during all stages of construction. This included developing an engineered solution for the hardstands, load testing the hardstands prior to girder lifting and monitoring the performance of the hardstands during lifting operations.

On completion of construction the hardstands at piers 1 and 4 will be used to provide permanent maintenance access to these piers.

![Fig. 3. Djerriwarrh Creek Bridge Elevation](image-url)
**Pyrites Creek Bridges**

The twin bridges at Pyrites Creek take the freeway over the creek and an existing local road (Cowans Road) along a section of alignment located on high fill embankments up to 20m in height. The bridge cross section is identical to that at Djerriwarrh Creek.

During the options assessment phase consideration was given to a number of bridge forms and also arch culvert solutions with Cowans Road re-aligned so that only the creek had to be crossed. The implementation of a triple bottom line assessment resulted in the preferred solution being of similar structural form to that adopted at Djerriwarrh Creek. The added benefit of this result was the standardisation of structural forms and details which had advantages both from a design perspective and also construction.

The resulting bridge is a 98m long three span structure comprising precast deck girders and precast concrete piers. Refer to Fig. 4. Ground conditions at this site comprise deep alluvial deposits which were expected to settle during embankment construction. As for the Djerriwarrh Creek bridge staging of construction activities needed to allow embankment construction to be largely completed prior to bridge construction commencing in order to minimise the effects that ground movements may have on the structure.

Foundations included cast in place bored piles built under polymer slurry at piers 1 and 2 and precast driven piles at each abutment.

Temporary hardstands required for construction activities were provided at pier 1 and between piers 1 and 2 within the creek. Pier segment and precast beam erection were carried out using cranes.

![Fig. 4. Pyrites Creek Bridge Elevation](image-url)
Semi-Integral Abutments

Maintenance was a Key Result Area for the alliance and something that is critical to the long term success of the project. The client (VicRoads) had identified maintenance as a key performance area at the project inception phase, well before the alliance was formed. Whole of life costs, of which maintenance is a part, were considered throughout the design development phase and selection of durable and low maintenance materials and construction forms was of key importance.

Along with initiatives such as the extensive use of precast concrete in bridge decks and piers and weathering steel for Urban Design elements, another initiative identified during the options assessment phase was to minimise high maintenance elements on the bridge structures. A number of the bridges on the project had overall lengths of under 70m and with skew angles of less than 30 degrees. For such bridges the elimination of deck joints to reduce long term maintenance was considered not only feasible but desirable. After having considered a number of options including fully integral construction, whereby bearings are also eliminated, and semi-integral abutments where only the joints are eliminated, semi-integral abutments were ultimately chosen as they achieved the objective to eliminate deck joints and were considered easier to construct than fully integral construction. Refer to Fig. 5.

![Fig. 5. Typical Detail of Semi-Integral Abutment](image-url)
Precast Segmental Piers

The use of precast segmental construction for the pier columns at Djerriwarrah and Pyrites Creek bridges was identified early in the detailed design phase as a potential innovation with significant benefits over conventional cast-in-place techniques. The use of precast concrete offered a number of advantages for these bridges including:

- The precast piers provided program advantages as segments were cast off site, not exposed to inclement weather, and could be delivered upon the request of the site construction team.
- By producing the precast columns in a controlled environment a more consistent finish was achieved with the added benefit of higher quality controls in concrete placement over conventional in-situ construction. This resulted in a high quality finish that not only looks good but is durable.
- The ability to build components off-site minimises the materials and working space needed on site. This also minimises the amount of in situ concrete pours which can lead to problems in sensitive environmental areas such as waterways.
- During the planning stages it was identified that a single crane set up between columns could service a number of columns and thus several work fronts could progress in parallel resulting in increased workforce efficiency. To achieve the same flexibility with in situ pier construction would have required additional form systems operating in parallel.
- Improved on site safety as it reduces the number of personnel on site and the time required working at heights.

One of the key objectives of the design was to standardise the precast units and associated detailing as much as possible. By standardising the structural details, economic and visual benefits could be realised.

Column Details

The construction of the columns utilised precast concrete voided segments constructed using a “short line” match-casting procedure which ensured a perfect match at segment joints. The specialist precast yard was located in Thomastown which is approximately 40-50km from site. Each column segment was identical in size being 6m long, 1.8m wide and 2.1m high. A small recess was introduced at each segment joint which provided a neater joint appearance as well as minimising the extent of any additional joint treatment required post segment installation.
The first segment at each column was installed on a variable height in situ concrete plinth cast above the pile cap with the joint between the segment and plinth grouted in place once the segment had been correctly aligned. Subsequent segments were erected with dry joints and prestressed together using up to thirty 40mm diameter stress bars arranged around the perimeter of the column. Dry joints were chosen in preference to epoxy grouted joints due to the greater speed of construction that could be achieved using dry joints and the safety and environmental hazards associated with the use of epoxy on site.

The stress bars were installed in oversized (96mm diameter) galvanized ducts cast into the segments which facilitated segment installation and also ensured better grout coverage around the bars to provide the required corrosion protection. Bar lengths were chosen to ensure that couplers were located above segment joints and each coupler was at a slightly different height to ease insertion during segment lowering. A minimum of four stress bars were stressed at intermediate levels up the height of the columns to ensure the columns remained stable during all stages of construction. Some bars were curtailed up the height of the columns where the design forces permitted a reduction in prestress with a total of 12 bars extending into the in situ concrete cross head at the tops of the columns.

During concept development consideration was given to the use of strand prestressing instead of stress bar. However it was consideration that stress bar offered greater flexibility in providing intermediate stage stressing to maintain pier stability during construction and also lowered the overall risk during construction.

A key aspect of the design of the columns was the development of suitable details to ensure the structure meets the required 100 year design life. Particular attention was paid to the prestressing details to ensure that the bars are adequately protected against corrosion. This included:

- Designing the prestressing system to ensure a residual compression exists at segment joints under all serviceability limit state loading conditions.
- Detailing of prestressing anchorages and ducts to ensure the free flow of grout.
- Attention to grouting procedures including air pressure testing of all ducts to 400kPa and the development of appropriate details at segment joints. Refer Fig. 7.
Fig. 6. Precast Segment Details

Fig. 7. Precast Segment Stressing Details
Construction Tolerances

Owing to the height of the piers (up to 30m in some cases) considerable effort went into developing an appropriate design methodology for dealing with the potential for misalignment during construction. To this end the effects of column misalignment was an important consideration in the design of the columns and bridge structure. An example of this was the use of in situ cross heads at the tops of the precast columns. These provided greater flexibility in adjusting support locations for the precast deck girders in the event the columns are built outside of the specified construction tolerance. A project specific construction specification was also developed which defined construction tolerances for the manufacture and erection of the segments. This specification was loosely based on the AASHTO specification for construction of segmental bridges but modified to suit pier construction. The specification so developed provided a means of checking segment manufacture and erection at each construction stage.

The essential requirements of the developed specification are summarised below:

Tolerances on Manufacture of Segments:
- Length, height, width, thickness = 5mm.
- Position of tendon ducts and shear keys = 5mm.
- Grade of formed or matchcast surfaces = 1mm in 1m.
- Maximum angular deviation about a vertical line measured between two successive segment joints = 0.001 radians.

Tolerances on Erection of Segments:
- Maximum overall deviation from the vertical measured in any direction = 1mm in 1m of height of pier.
- Maximum horizontal deviation from the vertical measured at the top of the pier = 30mm.
- Base segment to be installed within 10mm of plan position.
- Maximum angular deviation measured from a vertical line = 0.002 radians.
- Maximum differential between outside faces of adjacent segments in erected position = 5mm.

During construction two of the piers at the Djerriwarrh Creek Bridge were built significantly outside the specified tolerances. However due to the contingencies made in the design to cater for such a possibility the piers had adequate structural capacity to cater for the as-built profile. Minor adjustments to the detailing of the in situ cross heads were made on site to ensure correct seating of the precast girders.
Summary

The Western Highway Anthonys Cutting Realignment Project involves the construction of approximately 5km of dual carriageway freeway and six bridges of varying form through a Greenfields site with large variations in geology and topography. The variability of the site posed significant challenges to both the design and construction teams.

The use of precast prestressed concrete piers up to 30m in height required specific attention to be paid to alignment control and to details to ensure the long term durability of these structures.

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