CityLink Tulla Widening - Existing Bulla Road Bridge North Abutment Modification

Dr. Kabir Patoary, BScEng(Hon) MEng PhD MIEAust CPEng NER RPEQ
Principal Bridge Engineer, GHD

An Nguyen, B.Eng CPEng, Aurecon Pty Ltd

ABSTRACT

CityLink Tulla Widening-Bulla Road to Power Street project incorporates additional lanes and other measures to improve the flow of traffic across approximately 19 kilometres of freeway. As part of the project, existing Bulla Road Bridge north abutment require modification to accommodate two additional traffic lanes between Pier No. 1 and North Abutment. The modification involves removing the existing spill through batter in front of the north abutment and removing a section of the spread footing and buttress wall.

In order to provide the vertical support for the existing bridge abutment, new 550 mm thick reinforced concrete blade wall and 150 mm soil nail wall are proposed between the existing footing and abutment sill beam. To provide lateral retention against soil pressures and surcharge, ground retention is achieved using a combination of soil nails and rock bolts. Construction sequence analysis, excavation staging and continuous monitoring during excavation was critical to develop a safe construction methodology to maintain the integrity and functionality of the existing bridge under live traffic.

This paper presents the design and construction challenges encountered by the project team for modification of the existing Bulla Road North Abutment under the live traffic. The method of excavation of the existing batter slope, demolition part of the existing abutment footing, abutment movement monitoring and response measures, and construction of new abutment wall, soil nail and rock bolt walls are also presented.

INTRODUCTION

The City Link Tulla Widening project covers a 24 km section of three of Melbourne’s busiest road corridors including the western section of the City Link tollway, Tullamarine and Westgate Freeways. The project aims to increase capacity by up to 30 percent, reduce travel times and improve safety. The project is delivered under two separate Design and Construct contracts as shown in Table 1 and Figure 1; the VicRoads managed section from Melbourne Airport to Bulla Road and the Transurban managed section from Bulla Road to Power Street.

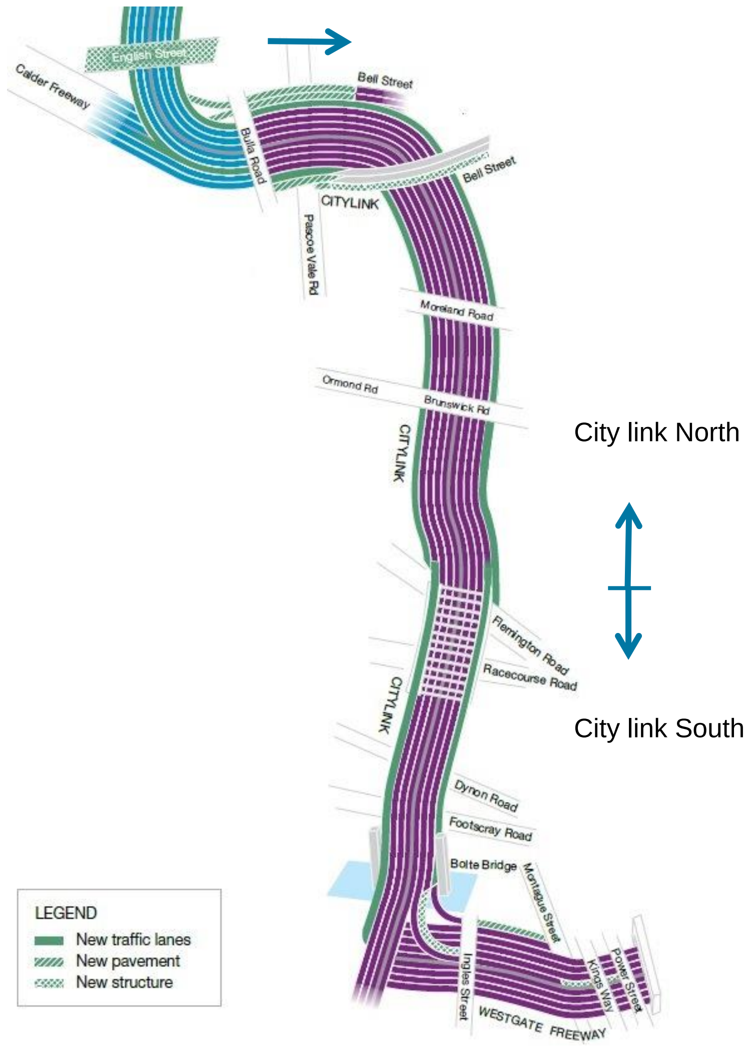

Figure 1 – Schematic CTW Sections

Table 1: Project Sections

Section	Scope	Nature of works	Delivered by
State works	From Bulla Rd north to Melrose Dr (non-CityLink concession area)	Widening – extra lane north and south	VicRoads
CityLink northern works	Between Bulla Rd and Flemington Rd	Widening – extra lane(s) north and south	Transurban

Section	Scope	Nature of works	Delivered by
CityLink southern works	Between Flemington Rd and West Gate Freeway on WesternLink and on the West Gate Freeway between Bolte Bridge and the Burnley Tunnel east bound	Widening on WesternLink – extra lane north and south. Bolte Bridge exit ramp to Burnley Tunnel widening and reconfiguration of traffic flows on the West Gate Freeway to the Burnley Tunnel	Transurban

In early 2015, CPB Contractors were awarded the design and construct contract to deliver the Bulla Road to Power Street section of the project delivered by Transurban with Aurecon GHD Joint Venture engaged as design consultants. Construction works for the project commenced in October 2015 and will be complete by the end of 2017. The overall scope of Bridge and Structural works include:

- Structural design of three new bridges:
  - Pascoe Vale Road over Western Link
  - Bulla Road southbound entry ramp over the Collector Distributor
  - Mt Alexander Road over Moonee Ponds Creek
- Structural design of the widening of 7 existing bridges:
  - West Gate Freeway eastbound elevated structure
  - Widening of existing Citylink southbound ramp to power street and Burnley tunnel (Ramp Z)
  - Moonee Ponds Creek Bridges, 1,2,4 and 6
  - Western Link over Pascoe Vale Road
- Modifications to the abutment of the existing Bulla Road Bridge and Pier protection works
- Structural design of the extension of the Wheeler Street Underpass
- Pier and/or abutment protection works on 15 existing bridges:
- Structural design of new gantries and modifications to existing gantries
- Design of retaining walls including soil nail walls, soldier pile walls and post and panel walls
- Design of new noise walls and adjustments to existing noise walls

This paper will discuss the various engineering and construction challenges for modification of existing Bulla Road Bridge north Abutment to accommodate two additional traffic lanes under the bridge.

EXISTING STRUCTURE DETAILS

The existing Bulla Road Bridge crosses the Tullamarine Freeway in a north/ south alignment, as shown in Figure 2. The structure is a four span (11350 mm, 25900 mm, 25900 mm, 9150 mm from south to north) bridge that crosses the Tullamarine Freeway at a 13 degree skew. The superstructure consists of 13 pre-tensioned I-girders, acting compositely with a cast-in-situ concrete deck, that are continuous over the piers via cast in-situ post tensioned concrete diaphragms. The superstructure is supported by 5 columns at each pier. Each column is on a pad footing that founded onto basalt. Each abutment sill beam is supported by 7 counterfort walls. Each wall is on a pad footing sits on top of basalt. Expansion joints are located at the abutments only.

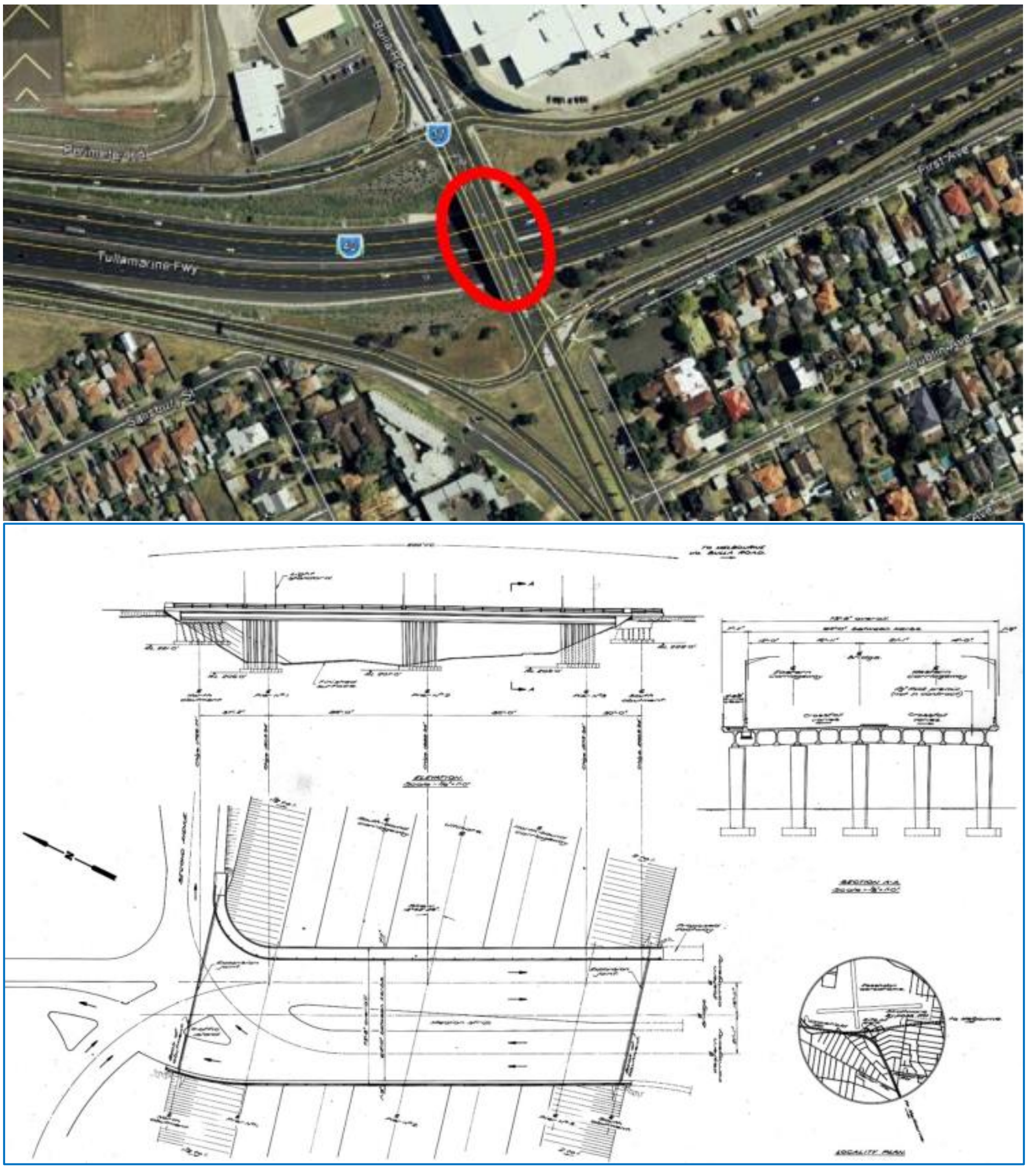

Figure 2 – Locality Plan and Existing Bridge Arrangement

PROPOSED UPGRADE WORKS

CityLink Tulla Widening incorporates two additional lanes at the existing Bulla Road Bridge. It is proposed to incorporate these two additional lanes between Pier No. 1 and North Abutment under the existing Bulla Road Bridge. To do this, the existing spill through batter in front of the north abutment and a section of the spread footing and buttress wall required modification.

In order to provide the vertical support for the existing bridge abutment, new 550 mm thick reinforced concrete blade wall and 150 mm soil nail wall are proposed between the existing footing and abutment sill beam. To provide lateral retention against soil pressures and surcharge, ground retention is achieved using a combination of soil nails and rock bolts. The new blade wall above footing and shotcrete walls above

and below footing also provide lateral retention by using soil nails and rock bolts respectively.
The design also incorporated cast in situ and precast reinforced concrete protection barriers at both the central median for pier 1 and at shoulder. Pier protection barriers have been designed for High Performance level with 1500 mm high concrete barrier above finished surface level, thus achieving the minimum 1400 mm effective height required for High Performance level.

Generally, the construction process is:

- Excavate the north abutment embankment down to the existing pad footings;
- Drill existing buttress walls and pad footings and fix reinforcement starter bars;
- Cast concrete walls with soil nails between the existing buttress walls and pad footings;
- New concrete walls to be stitched to existing buttress walls and pad footings;
- Break back existing and now exposed buttress walls and pad footings to create a vertical wall;
- Excavate, shotcrete and soil nail remainder of embankment down to design finished surface level;
- Construct a high containment level barrier at face of shotcrete wall; and
- Construct pier protection barriers at all piers.

All of the above work to be undertaken without any traffic restriction or road closure at bridge deck level. Figure 3, 4 and 5 below shows the details of existing abutment modification.

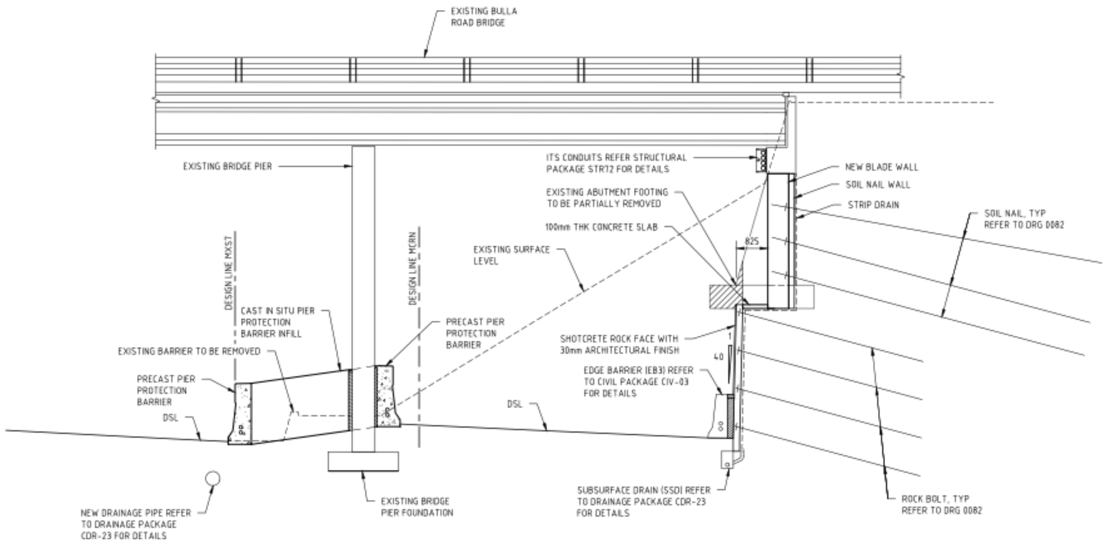

Figure 3 – Elevation-Abutment Modification

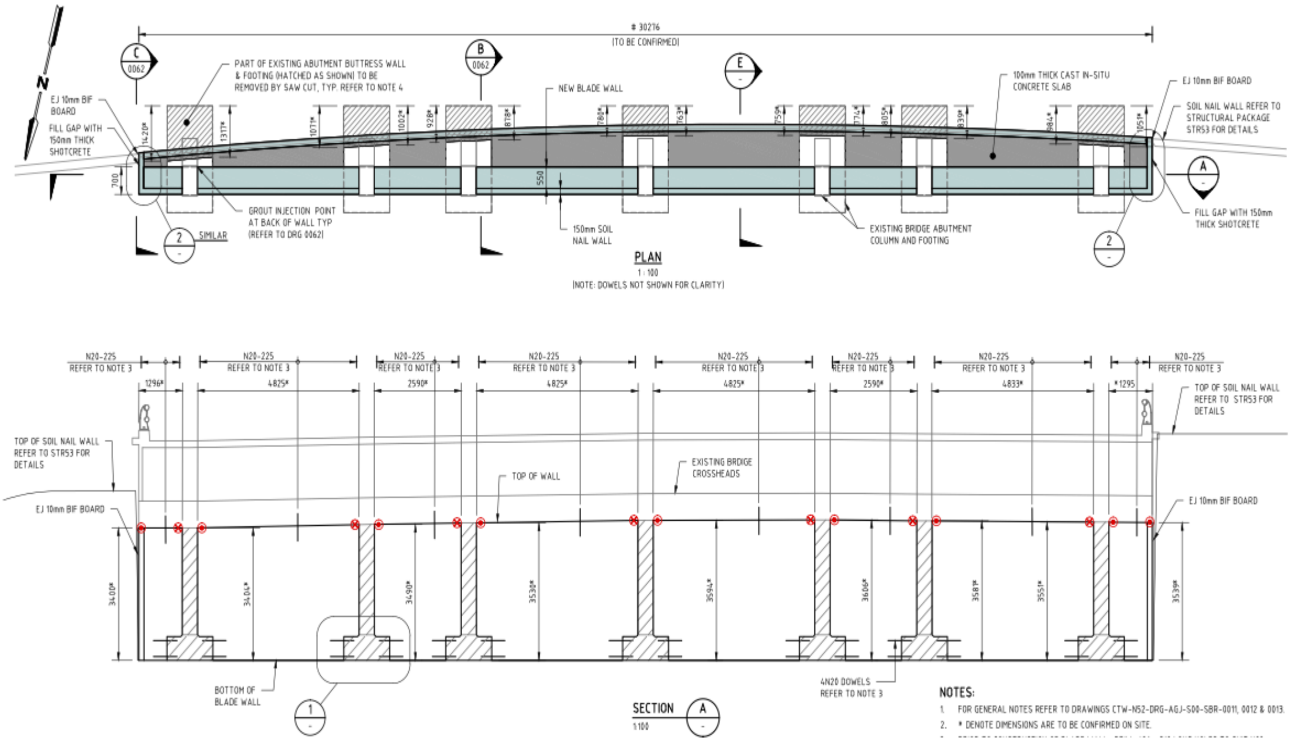

Figure 4 – Detail of Existing Footing Demolition and New Wall

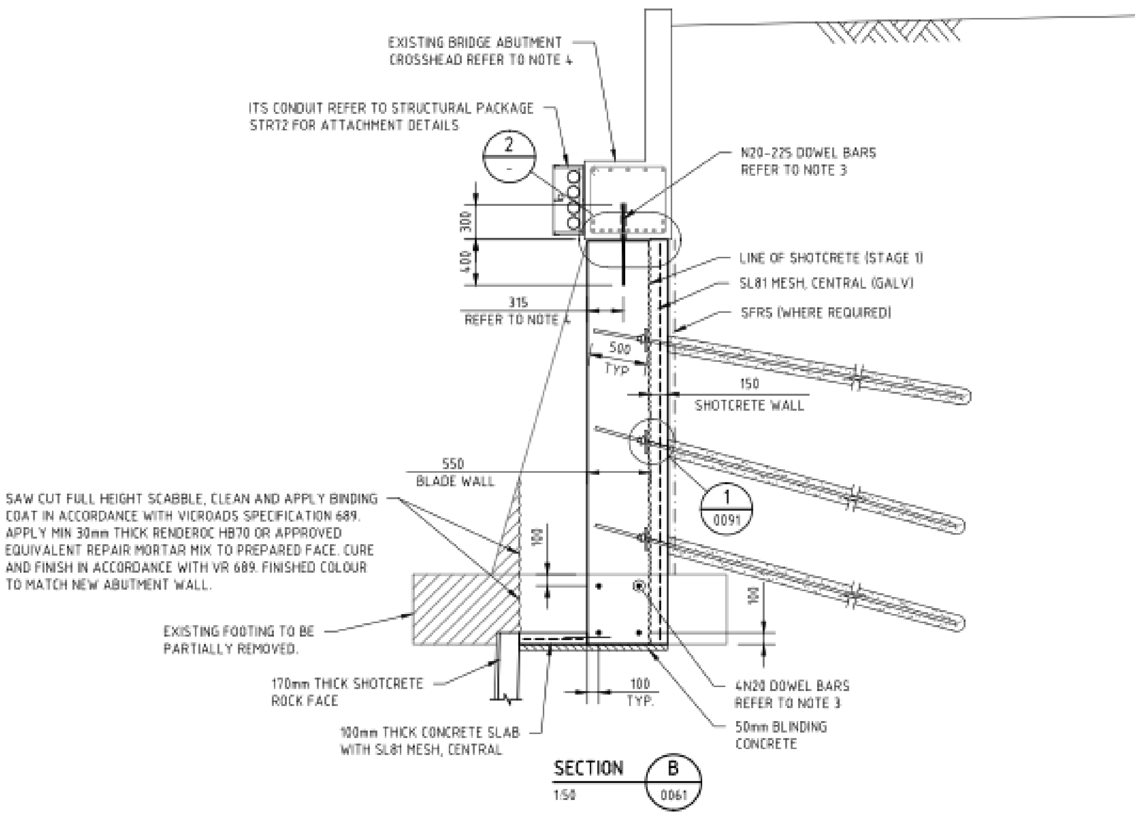

Figure 5 – Detail of New Wall and Soil Retention System

GEOTECHNICAL AND STRUCTURAL DESIGN

Slope stability analyses were carried out using the STARES software package which assumes circular type failure surfaces through the internally reinforced slope to calculate factors of safety against instability.

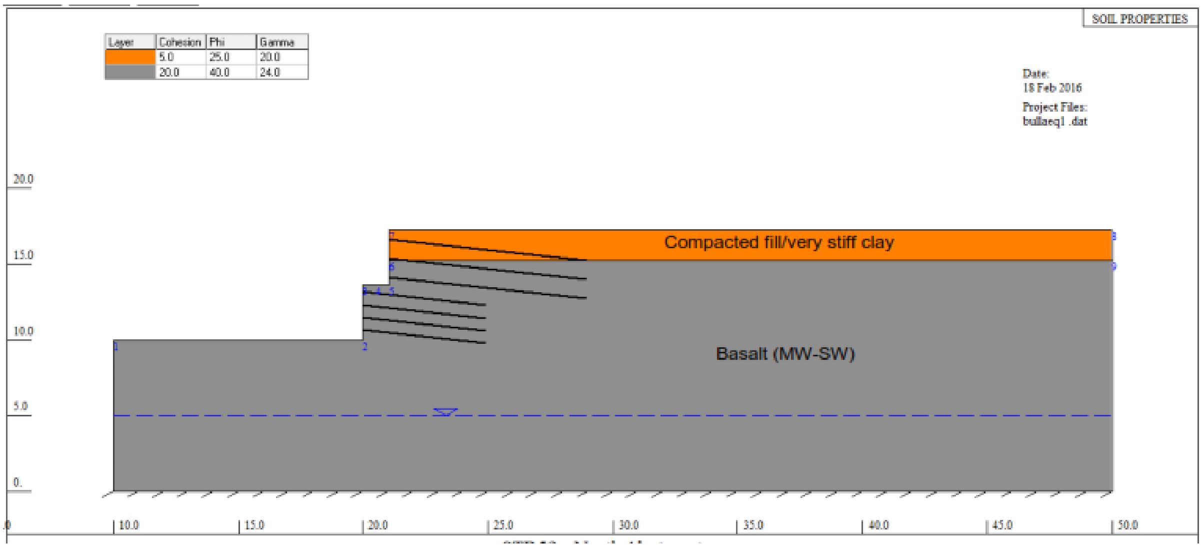

Figure 6 – STARES Model for Stability Analysis

For the permanent condition (i.e. pavement at final level) the factor of safety based on the proposed nail / bolt layout was calculated as 1.67. The analysis included a surface surcharge pressure of 60 kPa to simulate loads from the backfill behind the abutment plus a factored up live load (1.5 x 20 kPa). The calculated factor of safety is greater than the minimum design requirement of 1.50 for the permanent condition.

A target design factor of safety = 1.5 for global stability is customarily selected for design of permanent nailed retention when utilising Bishop's Simplified Method of Slices. A factor of safety of 2 has been adopted for the internal design of the wall (nail pullout/failure) to minimise the risk of excessive creep movements of the nails. For short term stability (e.g. for temporary staging works and under construction conditions) a factor of safety = 1.3 is considered satisfactory. A sensitivity analysis was also undertaken adopting seismic coefficient of 0.08 and a FOS was 1.65.

Since the superstructure is fixed at pier and simply supported on sliding bearing at abutment, it is reasonable to assume that bridge longitudinal loads are not transferred to the abutments but are applied on the pier foundations. Therefore, no lateral loads from the bridge are included in the STARES analysis model. In addition, the action of anchor elements installed into the basalt is to lock the rock-mass together so that it behaves monolithically.

New infill blade walls with continuous strip footings connecting the existing footings are proposed to carry axial load of the abutment. The width of the new walls is to be similar to the thickness of the existing abutment columns i.e. about 700 mm and the overall length would run the length of the abutment. An average applied bearing pressure was calculated as 437 kPa. The available borehole information indicates that the column footings are expected to be founded on competent basalt, of medium to high strength and moderately to slightly weathered. A minimum allowable bearing pressure of 2000 kPa would be available for spread footings founded on such material. Hence, the available bearing resistance is well in excess of requirements.

The new infill blade wall has been modelled and analysed using Space Gass structural analysis computer software with vertical loads from the existing Bulla road bridge and lateral loads provided by Geotechnical Engineer. Shotcrete facing has been designed for punching shear for Nail head load and soil pressure behind.

MAJOR CONSTRAINTS

The major constraints that affect the design and construction of the north abutment soil nail and rock bolt wall and pier protection barriers include the following.

- Existing Bulla Road bridge structures and foundation.
  - The fill at the back of the existing north abutment requires careful assessment before the construction of soil nail wall due to no approach slab on bridge approach above.
  - Space constraint under the north abutment due to low headroom from existing I girder and the existing batter slope.
  - Part of the existing reinforced concrete buttress walls and footings must be cut off, removed and grouted.
  - Existing bridge pier and foundation can affect the pier protection foundation
- Existing and proposed utility services.
- Demolition of existing barrier too close to Pier 1.
- Existing Tullamarine Freeway carriageway in terms of traffic interface.
- Drainage pipes and pits around pier protection.
- ITS requirements along the abutment.

PROPOSED CONSTRUCTION SEQUENCE

Construction sequencing and staging is a critical element of the works. The issue of temporary works and constructability has been considered throughout the design process at formal and informal meetings with CPB and Douglus Partners (DP) and through the design review process. As discussed below a ‘hit and miss’ sequential approach has been adopted for excavation of the slots and subsequent installation of the soil nails rock bolts. This method is to ensure that soil buttresses remain in place to provide necessary stability to unsupported sections of the excavation faces until such time that all retention is installed. The indicative construction stages for the works are outlined below and in Figure 7.

Stage 1: Construction sequence adopted above base of footing for soil nails

- Excavate in 'hit one, miss two sequence' slots, in numerical sequence 1 to 9 to form horizontal benches for nail installation
- Bench levels > 0.3m below row of nails
- Apply one layer of steel fibre reinforced shotcrete (SRFS) (nominal 50mm thickness) where loose material is encountered in exposed/excavated face
- Drill holes for soil nails, install & grout within each sequential area
- Install all nails and load test nails along row 1 prior to excavation for subsequent bench lowering

- Fix reinforcing mesh on bar chairs to maintain correct cover under nail and bolt head plates. Spray shotcrete after soil nails, repeat sequence to row 2
- Drill into existing abutment sill beam and pad footings and install reinforcement starter bars and complete the blade wall.
- Excavation of basalt will require vibration free methods to minimise fracturing and loosening of rock mass under existing footings

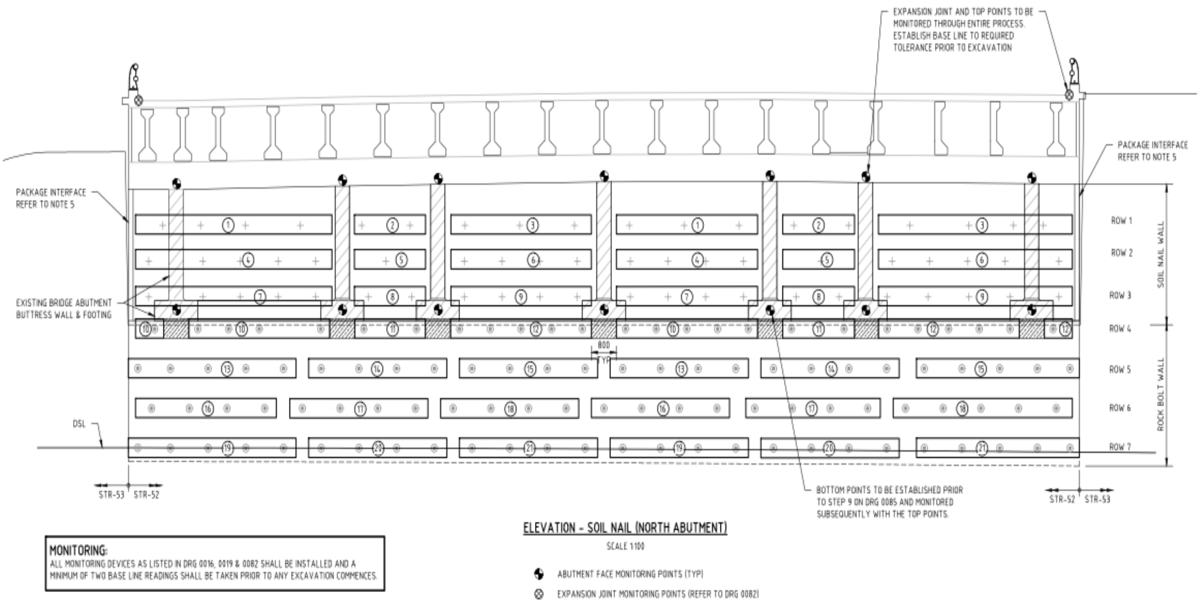

Figure 7 – Abutment monitoring and Excavation sequencing details

Stage 2: Construction sequence adopted below top of footing for rock bolts

- Saw cut existing footing and provide corrosion treatment.
- Excavate in 'hit one, miss two sequence' slots to base of footing in numerical sequence
- Excavate next bench below footing and install rock bolts and shotcrete as per above sequence
- Excavate lower benches over max. 10m horizontal length and install rock bolts and shotcrete
- Excavation at abutment to be undertaken under continuous geotechnical inspection.
- Install Abutment Protection Barrier

ABUTMENT MOVEMENTS AND MONITORING RESULTS

Based on construction sequence and the available soil/rock properties and geotechnical analysis, it is anticipated that the movement of the abutment during construction will be negligible. However, due to the critical nature of the works, extensive monitoring requirements are defined to limit the abutment movement to less than 10 mm and settlement of less than 5 mm. Figure 7 above shows the monitoring and sequencing details.

The bearings at the north abutment are sliding bearing, consisting of rocker plate, and sliding plate, pinned to the abutment pedestal. On each bearing, the two

25.4mm diameter dowel pins are positioned in two no. 28.5 mm wide x 76.2 mm long slotted holes on beam bearing plates. It is reasonable to assume that the dowels were placed centrally in the first place and they had approximately 25.4mm clear of the outer end and the inner end of the slot. The existing bridge is approximately 50 yrs old and due to long-term creep and shrinkage effects, the calculated shortening of bridge is more than 20 mm at each abutment. This gives minimum allowable expansion of the bridge at each abutment of 45 mm. If the abutment moves towards the span by 10 mm, there would still be a theoretical 35 mm expansion range before locking the bridge. Due to temperature effect, it is expected that the maximum bridge expansion will be only 11 mm and hence no adverse impact on the bearings. In fact, due to this abutment movement, the dowel will move closer to its original as constructed position.

The existing bridge founded on Basalt; hence, no meaningful settlement is expected to have occurred to date. Geotechnical engineer again confirmed this. Based on the design concept herein, predicted movement may be up to a maximum 5 mm settlement. Based on calculation it shows that 5 mm settlement at abutment will increase the hogging moment over the pier by 3% and as per as constructed drawings, the factored hogging moment capacity is sufficient to accommodate this additional hogging.

From these considerations/correlations, it is anticipated that the bridge can accommodate lateral movements of 10 mm and maximum settlement of 5 mm without compromising the overall structural integrity. A maximum lateral movement of 10 mm and maximum settlement of 5 mm are specified on drawing as limiting movement to ensure that the structural integrity is not compromised.

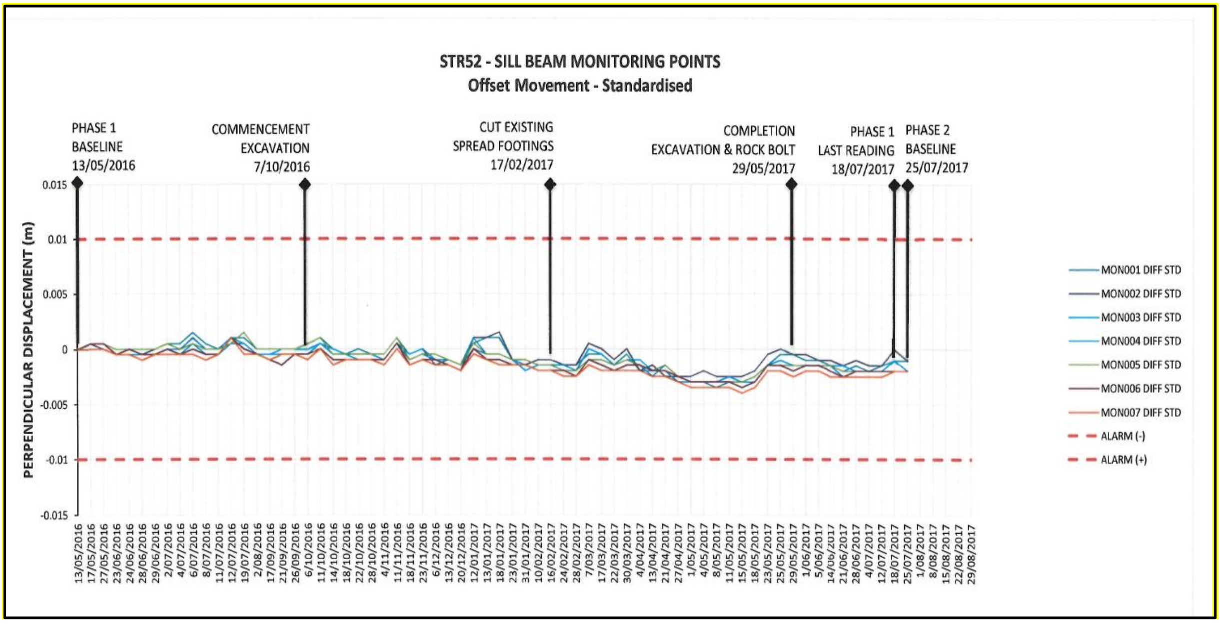

Figure 8 – Abutment Sill Monitoring Results

Figure 8 shows the graphical representation of the apparent off-set movement (perpendicular to the face of abutment) of the monitoring points along the abutment sill. A small trend in outward movement is apparent from the graph from the time the existing column foundation was cut until construction was completed. After applying the standardisation to these measurements, the quantum of the movement is a maximum of 4 mm and considered very small and within expectations for this type of construction and within the limits shown on the design drawings. From the time excavation and rock bolting has been completed, the movement appears to have stabilised with only very small fluctuations (+/- 1mm) and likely due to survey inaccuracy. These results indicate the wall has stopped moving as expected.

CONCLUSION

The proposed widening between the north abutment and the existing pier involved removal of the existing spill-through batter and partially cutting through the protruding section of the existing pad footings under the columns supporting the north abutment. By removing the existing spill through batter and the front part of the existing footing, the remaining part of the footing is found insufficient in terms of providing axial and lateral support to the abutment. Therefore, an alternative augmented footing and retention system is proposed.

New infill blade walls with continuous strip footings connecting the existing footings are proposed to carry axial load of the abutment. For the lateral support of the ground, the north abutment wall is to be reinforced with soil nails and rock bolts. Details of the stability analyses carried out to determine the configuration of the soil nails and rock bolts. The main geotechnical issue in relation to the proposed altered arrangement of abutment footing was to ensure the integrity of the basalt rock supporting the blade wall via the installation of the closely spaced tensioned rock bolts to effectively stitch up and tie together the rock mass within the zone of influence below the base of the column footings.

The construction was successfully completed and the road under is now open for traffic. Ongoing monitoring will also be undertaken for a period to confirm that the structure is in stable condition and further movement is not expected compromising structural integrity.

ACKNOWLEDGEMENT

The authors acknowledge the project team members, government organisations and subcontractors in contributing to the success of this project;

- Aurecon GHD Joint Venture
- CPB Contractors
- VicRoads
- Transurban
- Douglas Partners (DP)

The views expressed in this paper are those of the authors.

REFERENCES

(1) Standards Australia, “AS5100 Bridge design: Parts 1 -7”, Standards Australia International, 2004, Sydney, Australia.