A Bridge Abutment Solution for the Tullamarine-Calder Interchange Alliance

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Abstract

The Tullamarine Calder Interchange (TCI) reconstruction in Melbourne is Victoria's first public sector Alliance contract. The project involves reconfiguring an interchange between two major freeways, which had become one of Melbourne's worst accident blackspots. As part of the $150M works, an additional exit ramp needed to be constructed beneath two existing bridges. In order to achieve this, the northern abutments of both bridges required to be partially demolished and re-built to create approximately 10 m of additional road width beneath the bridge decks. These works were done while maintaining live traffic conditions on and beneath one of the bridges.

This paper describes the design and construction of the temporary and permanent retention systems that were employed; with an emphasis on the combination of soil nailing, ground anchoring, piling, underpinning and reinforced earth techniques utilised. An important feature of the paper is the novel way in which the Alliance delivery model facilitated innovation and flexibility throughout the design and construction phases.

1 INTRODUCTION

The Tullamarine Calder Freeway interchange is a key component of Melbourne's arterial road network providing access to Melbourne International and Essendon Airports; to Melbourne's north-west growth corridor as well as to Bendigo, Ballarat and beyond. The interchange is located approximately 10 km north-west of the Melbourne CBD. The upgrade of the interchange included a realignment of both the Tullamarine and Calder Freeways and reconstruction of the Bulla Road entry and exit ramps, all within tight boundary confines. The location and key features of the project are shown in Figure 1.

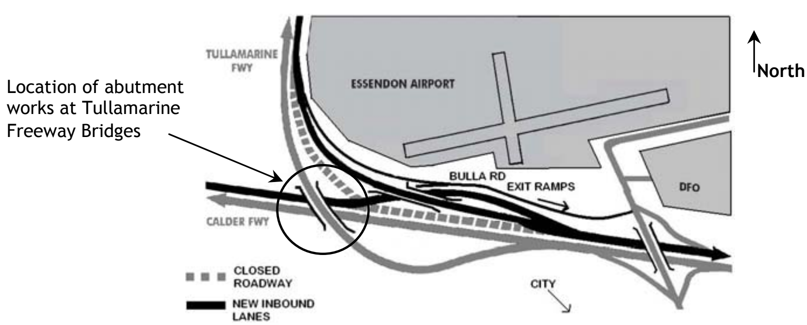

Figure 1: Location of TCI works

The new Bulla Rd exit ramp was required to be constructed beneath two existing bridge decks. There was no space for an additional lane unless the bridge abutments were partially demolished and re-configured to create the necessary additional width. The work was required to be carried out under live traffic conditions.

A combination of soil nailing, ground anchoring, piling, underpinning and reinforced earth walls were used in a top-down construction method to provide incremental lateral support to the abutments. This allowed the spill-through embankments to be excavated whilst preventing movements which would have damaged the deck expansion joints and fender walls. While the various elements of these works are considered common construction practices, it was their combination in the final solution, within an Alliance delivery environment, that makes these works unique.

Given the complexity of the project and its inherent risks, the project was managed and delivered under an Alliance agreement between VicRoads, Parsons Brinckerhoff (PB) and Baulderstone Hornibrook (BH). The Alliance delivery mechanism allowed the design to evolve with innovative thinking where both design and construction delivery teams worked closely together. The project commenced in October 2005 with an expected completion date in mid 2007, six months ahead of schedule and on budget.

Figure 2: The site prior to and after completion of works for the Bulla Road exit ramp

In other project delivery formats, such as design & construct, the level of risk involved with partial demolition and re-configuring an existing bridge abutment under live traffic would typically be considered unacceptable. This risk was mitigated through the presence of geotechnical and structural engineers working with the construction delivery team throughout design and construction, thereby allowing for modifications of design parameters and dimensions as construction progressed. This multi-disciplinary team format improved efficiency and allowed greater control of construction processes, thereby achieving the Alliance goals.

2 THE CHALLENGES

As part of the interchange upgrade it was necessary to provide a new single lane Bulla Road exit ramp beneath the existing Tullamarine Freeway bridges (see Figure 2). With no additional lane width available between the bridge piers, it was proposed that the spill-through embankment in front of the existing northern abutments could be removed to provide the necessary space for the new ramp.

The existing parallel bridges carry inbound and outbound Tullamarine Freeway traffic over the Calder Freeway and were constructed as part of the Calder/Lancefield project in 1968. The bridges allow the only convenient access between Melbourne CBD and the main airport, so closing this access was not considered to be feasible. The works were therefore required to be carried out under live traffic and this presented the first challenge.

Each of the bridges consist of a four span continuous post-tensioned voided slab. The abutments are formed of reinforced concrete crossheads each supported by two tapered rectangular concrete columns bearing on spread footings. The embankments in front of the abutments provided the necessary passive resistance to forward movement.

The abutments would need to be stabilised against overturning and sliding in both the temporary and permanent conditions. Calculations indicated that removal of even a small portion of the passive resistance from the abutments could result in forward movement which would damage the fender walls and expansion joints. The second challenge was to design temporary works to restrain the abutments prior to the start of excavations and an anchoring system for the final configuration. Both of these systems were required to be mutually compatible.

Limited access to the site meant that geotechnical investigations were restricted to locations at the sides of the abutments, and thus the quality of the backfill behind the abutments and within the spill through-embankments was not known until excavations had begun. During excavation it was discovered that the fill contained numerous voids around the many large basalt boulders and timber railway sleepers left in place from the original construction. The voids caused problems during the excavation and drilling stages as machinery vibrations caused the backfill to collapse locally. The third challenge was to adapt the design to meet the in-situ conditions, and find a way of stabilising voided fill behind the excavated faces.

As shown in Figure 3, Bridge 1 is staggered to the south-east of Bridge 2 with a 2.5 m high crib wall between the bridges to support the fill to the side of the Bridge 1 abutment. Removal of the spill-through embankment in front of the Bridge 1 abutment would require stabilizing vertical cutting faces at 90 degrees to each other and this represented the fourth challenge.

The bridge as-built record drawings indicated that the pad footing for the west column of the Bridge 1 abutment was much shallower than the others. The footing position conflicted with the new ramp alignment. The fifth challenge was to remove a large portion of the footing without compromising bridge stability.

Limited working area and headroom beneath the bridge decks required design and construction modifications throughout the works. The sixth challenge was to utilise appropriate methods and machinery in the correct sequence to overcome the access restrictions.

3 SOLUTIONS TO THE CHALLENGES

To accommodate the new Bulla Road exit ramp, the spill-through embankments located in front of the Tullamarine Bridge 1 & 2 abutments were to be removed and stabilization works were designed to provide the necessary lateral stability.

The solution needed to account for live traffic conditions at all times so each element of the abutments needed to be supported before any excavation of the spill-through embankments could commence. This requirement was provided for by utilizing a combination of geotechnical support systems, both in the temporary and permanent works solutions.

A method needed to be found that would restrain abutment movements without impeding the other works. The solution was to install three bored piles behind the abutments and use them as anchor points. The piles were then post-tensioned to a temporary waler beam installed on the abutment face, just below the deck soffit. This temporary restraint, supported from behind the abutments, allowed the permanent works to proceed in front of the abutments.

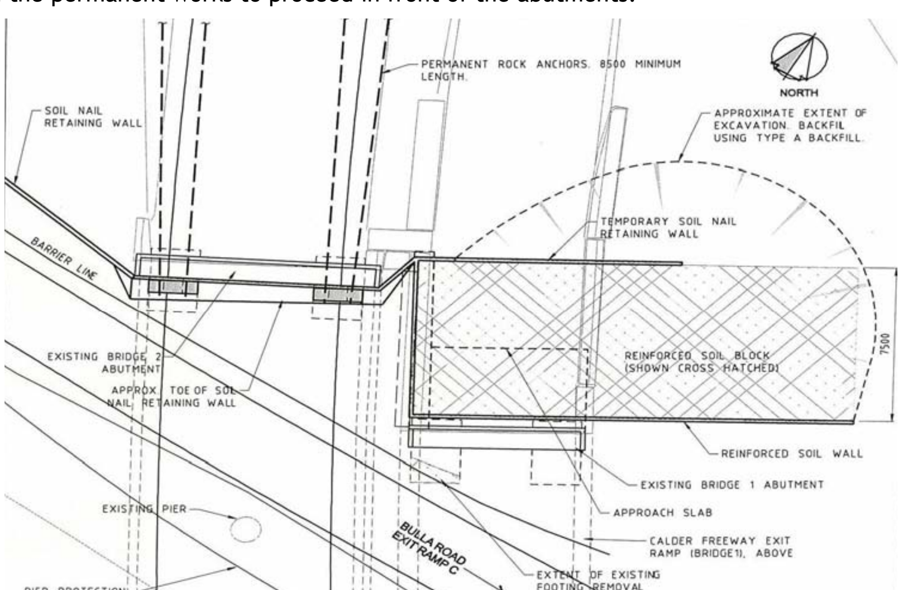

Figure 3: General arrangement of abutment works

Ground anchors and soil nails were essential elements of the preferred permanent works solution and, as the design progressed, the criticality of the ground/grout bond values was recognised. The geotechnical investigation was therefore expanded to include a series of destructive soil nail tests. One test was conducted for each dominant ground type encountered during the main ground investigation to quantify the ground/grout bond values for design of the permanent soil nails and anchors. These tests were conducted approximately 10 m to the east of the Bridge 1 abutment. The soil nails were installed, tested to failure and excavated to reveal the nature of the ground/grout interface.

As construction advanced, the poor quality of the abutment fill became apparent. It was determined that a reduction of the ground/grout bond values for some soil nails would be necessary to account for the variability of the fill material. This parameter change resulted in a requirement to extend the length of some soil nails. In addition, the open textured nature of the abutment fill caused local collapses of the fill and high grout volumes. This was solved by varying the location of the initially excavated face out from the final position to optimize the face conditions. The soil nails were installed from the temporary face, then the face was cut back to its permanent position.

Work procedure changes such as these were carried out with confidence since geotechnical engineers were present on site during construction and therefore had a working knowledge of the in-situ conditions. Considerable project savings were realised through monitoring of the abutment fill characteristics during construction, with this being one of the many examples of the tangible benefits of the Alliance delivery model.

The initial design for supporting the orthogonal vertical soil faces below the Bridge 1 abutment and crib wall was to use soil nails which were to be installed precisely to minimize interaction with each other. With some of the soil nails being lengthened, this directly impacted the design at the Bridge 1 abutment since there would be an increase in potential soil nail interaction around the 90 degree corner. More importantly was the possibility of interaction between the west face soil nails and the abutment ground anchors. With the limited geotechnical information available during the concept design phase, these issues were not fully understood at that time and their impact required a re-design of the solution.

Outside of an Alliance framework, these modifications would typically have resulted in contract claims and delays with a consequent strain on project team relationships. However, within the open-minded environment of the Alliance, the team immediately set about working on alternative solutions to accommodate the observed ground conditions. This involved extensive input from the construction delivery team, who provided rapid feedback on design concepts and their associated costs. One important Alliance principle that assisted with the efficient and timely production of the final design was a commitment to valuing innovation since this enabled a variety of 'outside of the square' concepts to be considered. The conceptual solutions to the nail and anchor interaction challenge included:

- Grouting of the entire block behind Bridge 1
- Extension of the existing bridge deck to span the crib wall
- Construction of a contiguous bored pile wall to support the west face of the Bridge 1 abutment and
- Removal and rebuilding of the approach to the Bridge 1 abutment using reinforced soil

The concept designs could take account of the fact that, as part of the project, Bridge 1 could be closed to traffic but would be available for vehicle access during construction. Conversely, the Bridge 2 works were to take place under live traffic conditions both over and beneath the bridge.

The concepts were ranked against the Alliance's eight Key Result Areas (KRAs): Safety, Quality, Cost, Traffic Operations after Construction, Traffic Operations for Public Transport, Stakeholder Relations, Environment and Legacy. Each element in the TCI upgrade had to meet minimum performance criteria whilst striving for exceptional performance.

Figure 4: Abutment works near completion

The final design solution consisted of excavations both in front of and behind the Bridge 1 abutment and the construction of a geosynthetic reinforced soil block with concrete panel walls, as seen in Figure 4. With this the original Bridge 1 abutment became a freestanding structure and a new reinforced concrete approach slab provided continuity between the roadway and the bridge deck.

The fifth challenge involved removing approximately a third of one of the bridge abutment footings to allow the necessary width for the new lane to be created. These works needed to be conducted without compromising bridge stability. This was achieved by first undertaking a structural analysis to the proposed abutment modifications. Once it was determined that the works were safe to proceed, detailed excavation around the footing was undertaken under the observation of a geotechnical engineer. The underpinning design was therefore conducted with comprehensive knowledge of the footing founding conditions. The final solution was to enclose the footing and the foundation material, within a reinforced concrete box. This effectively constrained the material below the footing and lowered the footing bearing level onto more competent material.

3.1 Description of construction sequence and final design elements

The requirement to undertake the construction works while maintaining live traffic conditions both on and beneath Bridge 2 meant that the design needed to maintain at all times the enhanced level of safety required for such circumstances. Temporary works were provided to prevent abutment movements during excavation, which could damage both the abutment fender walls and expansion joints. The temporary works consisted of an I-girder waler beam post-tensioned to bored piles positioned behind the Bridge 2 abutment. With the construction sequence being in a top-down format it was also necessary to ensure that the temporary works were effective at each stage of excavation using precise monitoring of any movement.

The construction stages were undertaken in the following sequence:

1. Install the anchor piles behind the bridge abutments
2. Install I-girder waler beam at front face of abutment crossheads and post-tension to the anchor piles
3. Excavate to first bench level in front of and between the abutments to allow vertical clearance beneath the bridge decks
4. Install 1st and 2nd row of soil nails and cast reinforced shotcrete face
5. Excavate to second bench level, drill and install upper-level ground anchors plus 3rd and 4th row of soil nails
6. Cast ground anchor saddle blocks around anchor heads and lock-off anchors
7. Cast reinforced shotcrete face for the second bench
8. De-stress temporary anchors and remove waler beam from abutment crossheads
9. Excavate third and final bench, drill and install lower-level ground anchors and final row of soil nails
10. Cast lower-level ground anchor saddle blocks and lock-off anchors
11. Cast reinforced shotcrete face for third bench
12. Prepare foundation for reinforced geosynthetic soil wall

13. Install first panels and continue reinforced soil wall to the height of the approach embankment for Bridge 1
14. Construct the remedial works to the pier footing at Bridge 1

4 SUMMARY BENEFITS OF THE ALLIANCE DELIVERY MODEL

Being the first public sector Alliance contract in Victoria there was a particular interest on the project. Both Parsons Brinckerhoff and Baulderstone Hornibrook brought previous Alliance experience to the project while VicRoads embraced the model with great enthusiasm.

The main defining features and benefits of the Alliance delivery model during the TCI project were shown to be:

- A rigorous development workshop process helping form early team relationships
- A Target Out-turn Cost process undertaken and approved at the project outset
- Emphasis on team member selection to provide synergies in relationships
- All Alliance partner personnel located at a single site throughout the project
- Continuous input from the construction delivery team throughout the design process
- No claims with the consequent reduction in paperwork and promotion of forward thinking
- A single project team allowing for quick and effective resolution to unexpected issues
- Fostering innovation and 'optioneering', all of which added to the project value
- Design specialists available during construction to assist with solutions to unexpected issues
- A no-blame culture promoting an atmosphere of teamwork towards the common goals

5 CONCLUSIONS

The Tullamarine/Calder Freeway Interchange, situated in the north-west of Melbourne, was reconstructed as an Alliance between VicRoads, Parsons Brinckerhoff and Baulderstone Hornibrook. The objective of this upgrade was to significantly improve traffic flow and safety through the interchange.

The fill embankments in front of the existing Tullamarine Freeway twin bridge abutments were excavated, thus providing space for an additional traffic lane underneath the bridges. The main component of the work was done under live traffic conditions, both over and beneath one of the bridges. The retention systems employed were a combination of temporary and permanent solutions and a variety of structural and geotechnical techniques were used.

As the project is located in a dense urban setting with a small works area and tight access restrictions, careful planning and integration across all project disciplines was critical to ensure an effective and successful delivery. The alliance delivery mechanism allowed the design to evolve with innovative thinking where both design and construction professionals worked closely together towards a common goal.

Many changes to the original concept design became necessary due to the conditions encountered during construction. The Alliance formed a framework in which many modifications to the design and construction techniques could take place causing minimum impact on the project, with the result being a highly successful outcome.

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