Challenges and Innovative Solutions for the Design and Construction of Blackburn Level Crossing Removal Project

Anthony Cheung - Senior Bridge Engineer, Awais Chaudry, Yanan Yang, Sleiman Mikhael, Arcadis Design and Consultancy, Melbourne Australia

ABSTRACT

The Victorian Government is committed to remove 50 level crossings by 2022, and at least 20 of them are to be completed by 2018. These level crossings are the most dangerous crossings around Melbourne area. The removal of these crossings is expected to deliver significant safety improvements to drivers and pedestrians and improve travelling time around Melbourne. This paper addresses the challenges and issues related the level crossing removal project at Blackburn.

The Blackburn site is situated in a densely-populated suburb and constrained by both residential housing and commercial buildings. The project involved the modification of existing Blackburn train station and lowering of the railway line resulted in retaining walls on either side and along the full length of the rail cutting. Furthermore, numerous utility services were required to be retained or diverted across the corridor with all the works to be completed in a short rail occupation period; which led to the use of various innovative techniques throughout the design and construction phase to meet to the program and construction challenges. This paper details the main issues and innovative techniques used in this project which could be an example for similar projects in the future.

KEYWORDS

Level crossing, constructability, safety in design, retaining walls, utilities, railway

INTRODUCTION

“Level Crossings” in this paper refer to intersection points of the Rail and Road traffic at the same level. These points exist on roads and necessarily comprise of automated boom gates to stop the flow of road traffic for passage of trains. With the growing number of population and vehicles over the years, these crossings have now become points of congestion causing significant traffic crowding affecting public safety, increasing travel time and environmental/noise pollution. The Victorian Government has decided to remove 50 level crossings by 2022 with a target of removing at least 20 level crossings across Melbourne by the end of 2018. Government of Victoria has allocated $2.4 billion in its 2015-16 budget for this purpose.

To achieve the target of removing and replacing first 20 level crossings by 2018, in 2015 the Victorian Government awarded four of the most dangerous level crossings in Melbourne to the consortium of Arcadis, Aurecon and CPB Constructors under design and construction contract. These four crossings were divided by the East and West packages with the East package comprising of the Blackburn Road and Heatherdale

Road crossings whereas the West package covered the Main Road and Furlong Road Level Crossings. As scheduled, all four level crossings were successfully removed by April 2017.

BLACKBURN LEVEL CROSSING REMOVAL PROJECT DESCRIPTION

During the tender period, the local community and stakeholders were consulted and it was decided that lowering of the railway line under Blackburn Road was the solution that met the criteria set up for the project. The existing dual rail tracks were required to be lowered in order to eliminate the significant traffic bottleneck caused by the presence of the existing rail level crossing at Blackburn Road and at a couple of pedestrian crossings at Cottage Street and Oliver Avenue as shown in Figure 1. As part of the project, the existing Blackburn Train station was also upgraded. Following are the objectives of this project:

- Improving safety for the drivers and pedestrian by eliminating major hazards
- Provide significant time savings to the local community
- Improve the amenity of the Blackburn township
- Improve traffic flow through the centre of Blackburn

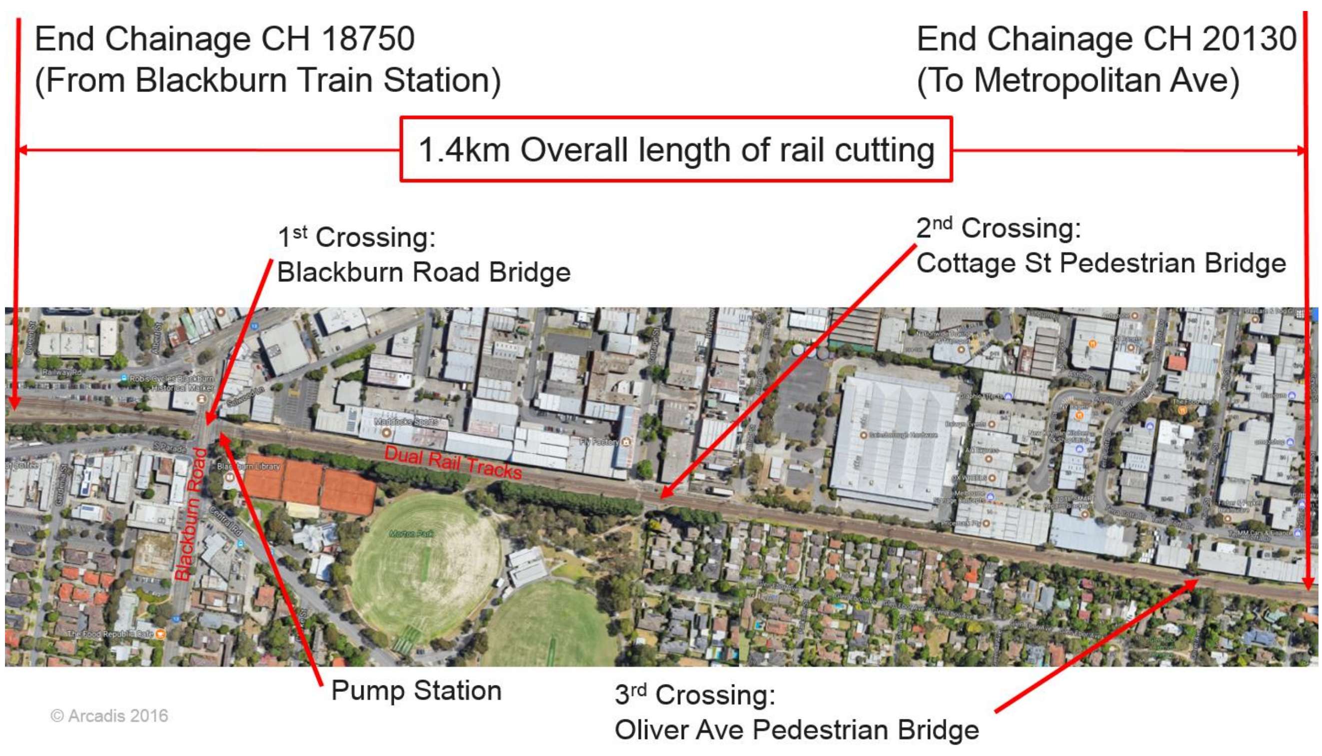

Figure 1. Level Crossing Removal Project at Blackburn – Location Plan

BLACKBURN RAIL CUTTING

The existing dual rail tracks were required to be lowered by up to 10m with the overall length of the rail cutting being 1.4km. Refer Figure 1 for the locality plan and location of vehicular crossing at Blackburn Road and the pedestrian crossings at Cottage Street and Oliver Avenue. The vertical alignment of the rail cutting was dictated by the rail envelope requirements and it was set as close as possible to the soffit of the Blackburn Road Bridge and the two pedestrian bridges to minimise the length and depth of the cutting and hence reduce the extent of the earth retaining structures and excavation. This was also marked by the realisation that timely construction of the retaining wall during the planned rail occupation was critical to the success of the project.

During the tender design, the retaining wall system consisted of 1050mm diameter bored piles with fibre reinforced shotcrete arches spanning between piles. This type of retaining wall system eliminates the requirement of any dowelling at the interface of piles and shotcrete arches. The arching articulation ensured that the shotcrete was always in compression. This system also eliminated the requirement on any flexure steel reinforcement in the shotcrete which could result in major time and cost savings to the project, refer Figure 2.

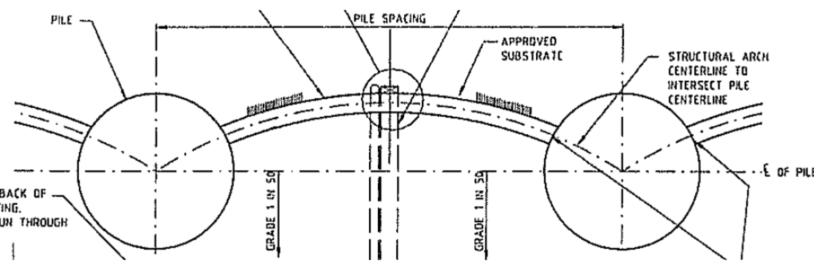

Figure 2. Tender Design of Retaining Wall with fibre reinforced shotcrete arches spaning between piles

However, at the start of the detailed design phase in May 2016, MTM released a Design Practice Note no. L1-CHE-INS-013 on Soil Retaining Structures adjacent to rail. This DPN stated the requirement that the faces of the retaining walls shall be continuous, free of abrupt changes in direction greater than 10 degrees and free of catch features greater than 25mm. The requirement in this DPN was to avoid the potential snagging hazard along the face of the piles during the train derailment event. The side of the piles in the original tender design concept was considered as a snagging hazard which was not complying with this newly released DPN. Therefore; after agreement with MTM, the shotcrete panel position was shifted to the rail face of piles to provide a smooth surface on the wall and complying with the DPN requirement. This change had huge impact on the design and construction requirements and now dowels were required at the interface of piles and shotcrete infill panels.

The shotcrete infill was re-designed as a slab restrained at each end by the galvanised dowels at the pile interface with SL81 galvanised steel mesh centrally placed in the shotcrete panel. To ensure there would be no significant cracks at the pile to shotcrete interface, the area of steel at the interface was detailed with N16-300mm CRS slightly higher than the area of steel in the shotcrete panel to force occurrence of small multiple cracks along the shotcrete panels instead of at the pile interface. The dowel diameter and spacing were worked out to resist the effects of soil pressure behind the infill panel along with resisting the short-term and long-term effects of shrinkage and contraction in the shotcrete infill panels. A 150x40mm strip drain was installed centrally behind each infill panel to minimise the hydrostatic pressure build-up behind the wall as shown in Figure 3. An additional operation to drill over 100,000 number of dowels was added which impacted the construction program significantly. Construction methodology and program were revised accordingly for the project.

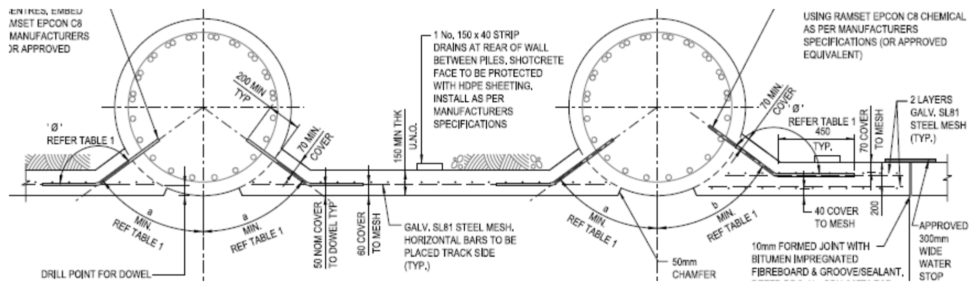

Figure 3. Revised retaining wall design adopted with reinforced shotcrete infill panels spaning between piles

A pump station was required at the lowest point along the rail cutting adjacent to the Blackburn Road Bridge to extract the stormwater from the 1.4km long cutting to connect to the local storm water system. The pump station consisted of a ring of 750mm diameter piles forming the pump well extending below the track level sufficiently to provide lateral stability. shotcrete infill panels were not considered practical to construct the pump station and it was decided to adopt secant pile construction as this method increased the construction alignment flexibility to enable piling to form the perimeter of the pump well. Two number 1200mm diameter oversize unreinforced soft piles were provided as shown in Figure 4 to enable the Constructors to core through the oversize piles from inside the pump well once they excavated to the bottom of the well level to install the required inlet pipes. The pump system consists of a main pump and a secondary pump to mitigate the risk of pump failure.

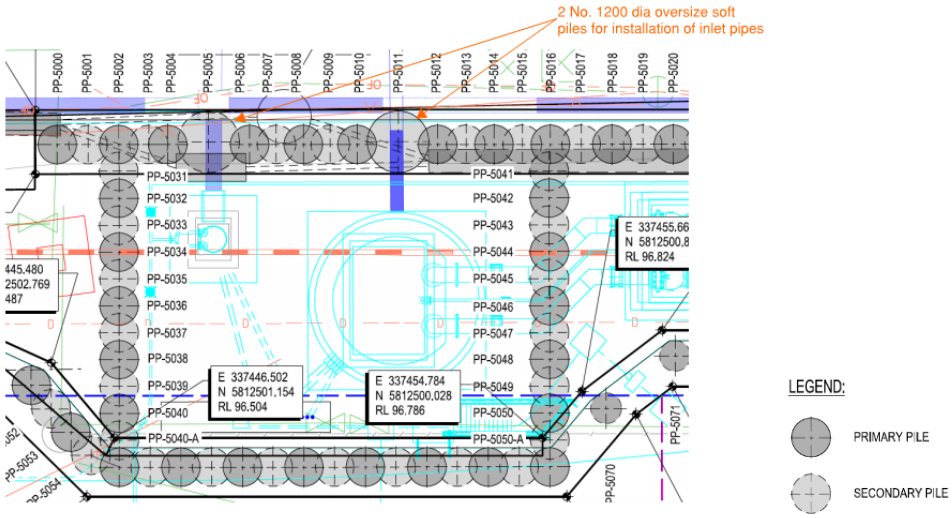

Figure 4. Pump Station - Plan

BLACKBURN BARRIER ASSESSMENT

It was recognised in early stage of the project that traffic impact, railway cuttings and other hazards, their consequences and safety conditions varied from site to site. Thus, implementing a uniform protection system across all project sites was deemed unreasonable and uneconomical. A Site-Specific Risk Assessment Method (SSRAM) was hence developed for barrier provision and design. The method followed the guidelines of AS5100.1, VicRoads Supplementary to Austroads Road Design Guide – Part 6 and QLD Rail/Main Roads Design and Selection Criteria for Road/Rail Interface Barrier (MCE-SR-007). Based on the outcomes of the assessment, minimum requirements for the roadside protection were adopted.

There were four steps involved in the risk assessment and determination of barrier performance levels; 1) Determine type of rail Interface and collect site specific information, 2) Verification of Clear Zone, 3) Evaluation and Section of Performance Levels in accordance with AS5100.1 & 1B; and 4) Evaluation and Selection of Protection Barrier in accordance with the Design and Selection Criteria for Road/Rail Interface Barrier (MCE-SR-007).

The SSRAM classified all rail interface sites into two types; Type 1-Road bridge over rail and Type 2-Road/Rail interfaces where roads run approximate parallel to and/or above the railway cuttings. For each specific site information, such as road geometry, traffic volume, commercial vehicles, hazard offset etc were collected. Based on the collected information, the clear zone requirements at the specific site was determined in accordance with VicRoads Supplement to AGRD Part 6. This was done to determine the likely requirements for protection against hazards for both vehicle occupants and third party, such as railway.

Specific barrier performance level was determined as part of barrier section process as indicated in AS5100.1 and 1B. The outcomes were then compared to the initial proposed barrier by the authority. For Type 2 site, QLD Rail/Main Roads Design and Selection Criteria (MCE-SR-007) was adopted to assess protection requirement for the barrier performance. It is an additional step compared to the bridge barrier selection procedure.

The QLD method required first to determine the offset from the edge-line of traffic road to the closet railway infrastructure (either 3m from centreline of nearest railway track or to the nearest significant QR network buildings/structure). The offset could be measured horizontal offset between road/rail interface adjusted by applying the slope adjustment factor and road curvature adjustment factor. Rail Status and Road Status of the railway and road concerned was then determined. Once we had all the parameters, a barrier performance level and the Test Vehicle (TL) could be determined by looking through Table 6 of document MCE-SR-007.

The adoption of SSRAM allowed us to reduce the barrier from High Performance Level to Medium Performance Level on Blackburn Road Bridge. Following Table 1 shows the assessment results for Blackburn Road Bridge.

Table 1. Barrier Performance Level Selection of Blackburn Road Bridge

	Location	Blackburn Road
	Site reference	Site 1
	Side of railway tracks	N/A
	Intersection control	N/A
Assessment against VicRoads Supplement to Austroads Guide to Road Design – Part 6		
	Operation Speed, km/h	60
	Average Annual Daily Traffic (one-way)	9,075
	Clear Zone on straight (m)	4.1
	Hazard offset to traffic lane, m	3.0
	Hazard offset within clear zone? (Yes/No)	Yes
Assessment against AS5100.1		
	Minimum Operation Speed/Design Speed, km/h	70
	Base Average Annual Daily Traffic (AADT)	18,150
	Commercial Vehicles Data (vpd)	737
	Commercial Vehicles Calculated from Data (%)	4.1%
Table B2	Commercial Vehicles AS5100 (%)	10%
	Car	63%
	Van/Pickups	27%
	Rigid Vehicles	4%
	Articulated Vehicles	6%
	No. of lanes	2
	Vehicles per lane per day	9,075
Table B4.2.1	Construction Year AADT	18,150
	Road Type	Two-way undiv
	Road Grade	+/-0%
	Road Curvature, (CU)	1000m
	Height above Under-structure condition (US)	7.0m
	Occupancy Land Use	High
	Rail offset	3.0m

Table B1	Adjustment factor for Road Type (RT)	1.5
Table B2	Adjustment factor for Road Type (RT)	1.0
Table B3	Adjustment factor for Road Type (RT)	1.3
Table B4	Adjustment factor for Road Type (RT)	1.5
Table B4.2.6	Adjustment Average Annual Daily Traffic (Adjusted AADT)	51,047
	Performance Level Section per AS5100.1	Regular
	Performance Level Section per (Test Level)	TL4
Risk Assessment Remark	VicRoads has initially proposed High Containment Performance Level Barrier for Blackburn Road Bridge. As per AS5100.1-2004, special performance level barriers should be assessed for high operational speed (100km/h) sites if commercial traffic level at the bridge site are greater than or equal to 3000 commercial vehicles per day per carriageway. Proposal: The actual site condition shows the post speed limit is 60 km/h and total commercial vehicles per day = 800 approx. Based on AS5100.1 and Site Risk Assessment, Medium Performance Level barrier is considered appropriate.	
Final Adopted Performance Level	Medium Level	

CONSTRUCTION OF BLACKBURN ROAD BRIDGE

Blackburn Road Bridge carries traffic over the lowered Belgrave/Lilydale rail tracks, located between Maroondah Highway and Canterbury Road. The bridge is approximately 17m long consisting of a single span 650mm deep prestressed concrete girders with a 180mm thick cast in-situ concrete deck slab. The superstructure is constructed on the abutment substructures with integral abutment diaphragms as per the Client's requirement to eliminate the need of elastomeric bridge bearings and expansion joints. The integral abutments are supported on 1050mm diameter bored piles with shotcrete infill panels between piles to also act as an earth retaining wall.

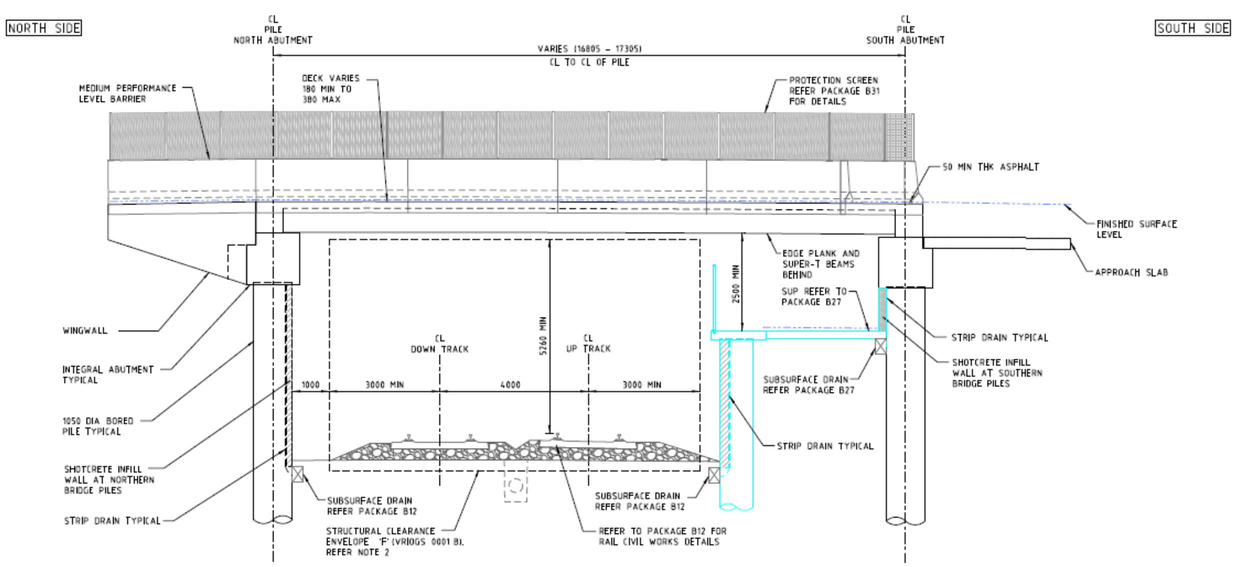

Figure 5. Typical Elevation of Blackburn Road Bridge

The existing Blackburn Road level crossing was a main road situated centrally between the residential and commercial areas, with a number of utilities installed along the road. These existing utilities were required to be re-located into the Blackburn Road Bridge to cross over the lowered rail tracks. They included:

- 12 No DN100 Telstra communication conduits
- 2 No DN100 Optus communication conduits
- 2 No DN100 pump station communication conduits
- 2 No DN150 United Energy electrical conduits
- 1 No DN300 gas main
- 1 No DN100 gas electrolysis conduit
- 1 No DN300 water main

The services were extremely important to the local community as they provided different type of services to the surrounding residents and business. It was critical that the period of temporary disconnection for these utilities was as short as possible. Also, the Construction Team had concerns about the time it would take to relocate the large number of utilities during the main occupation, and they requested to shift the utility relocation activity before the main rail occupation to reduce any project risks due to delays. We identified that diversion of utilities to the “final permanent location” before the bridge was fully constructed was a major challenge to the team. Also during this temporary condition, the diverted utilities would be subjecting to the railway loading until the main occupation.

To overcome these challenges, a new design concept was developed to split the construction of the bridge in stages over several closures starting six months prior to the main occupation. The remainder of the bridge construction and the associated excavation works to lower the rail tracks was completed in the main rail occupation.

In Stage 1 – Blackburn Road Bridge Construction, the bored piles for the bridge were installed over a series of night occupations with temporary closure of Blackburn Road with local traffic diversions. The rail speed limit was reduced as the trains approached the construction site. All bridge piles were designed and positioned to clear the existing utilities in the ground which resulted in the irregular pile spacing shown in Figure 6. 3D models of the existing utilities were produced from the survey information. The clash detection was performed during different stages of the project and the 3D utility model together with the 3D bridge model helped in early clash detection. The piles were positioned as per the utilities asset owners’ requirements.

The abutment crossheads were constructed during a weekend under full rail occupation as it involved excavation works in close proximity to the existing rail tracks formation due to the design level of the abutment crossheads required to be set minimum 1m below the existing surface level as per the vertical alignment of the new bridge.

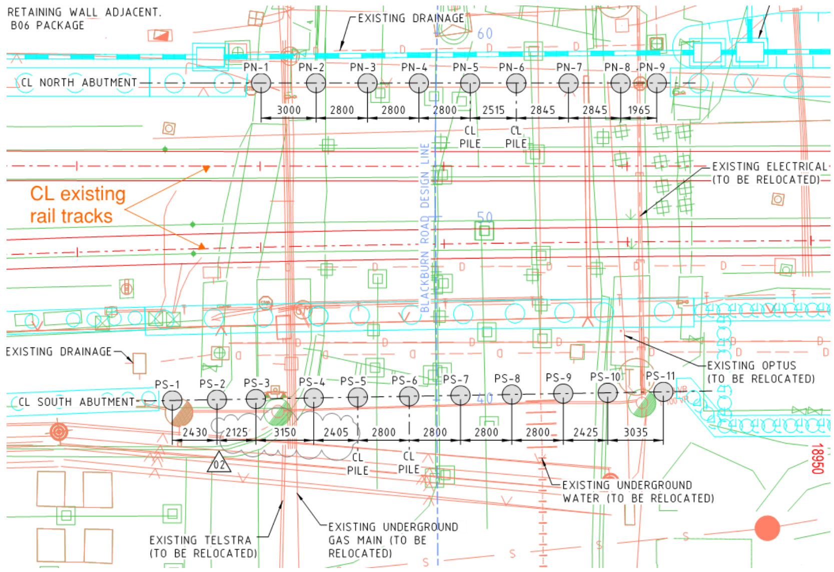

Figure 6. Blackburn Road Bridge Foundation Layout

Various options were considered and analysed with the most economical and suitable being changing the external girders along both edges of the bridge from super tee girders to prestressed planks with PVC pipes cast within the planks as sleeves for the utilities. These service planks are 650mm deep with plank widths varying between 2070mm to 1200mm to fit the required number of utilities as shown in Figure 7.

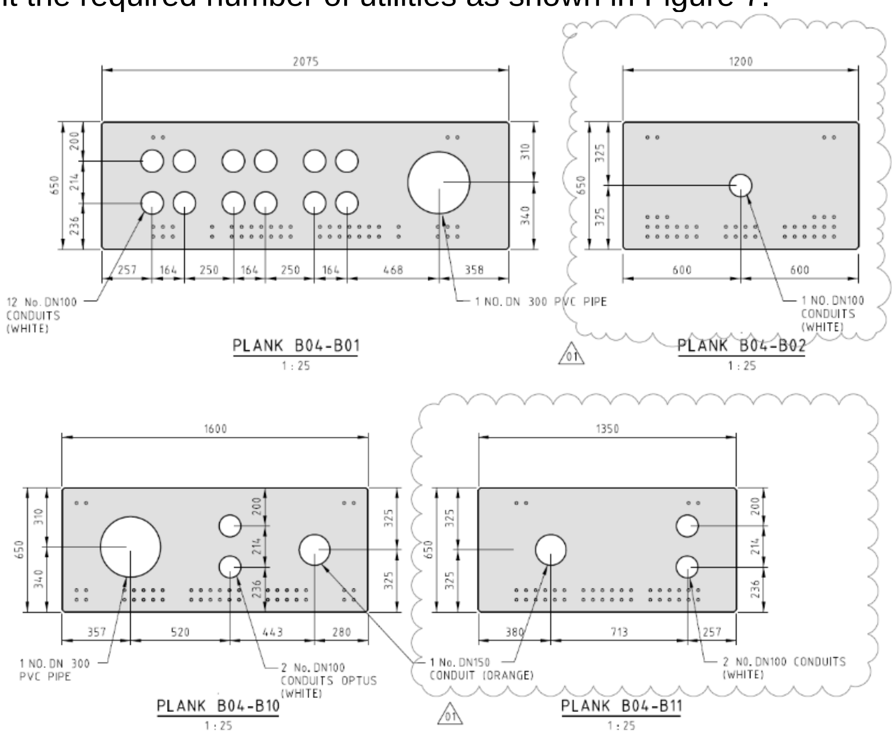

Figure 7. Typical Blackburn Road Bridge Services Plank Sections

During the temporary design in Stage 1 Construction, the service planks were designed to be fully supported on the founding material below to withstand the rail traffic in the transverse direction and road traffic in the longitudinal direction for six months until the bridge was fully constructed during the main occupation. A layer of cement stabilised sand was provided on founding material prior to lifting of the service planks to their final locations. This would ensure a uniform support to the underside of the planks. Sand jacks were provided at the top of the abutment crosshead to control and set the vertical levels on the service planks while the stabilised sand was still in its plastic state. These sand jacks were removed once the stabilised sand was hardened to ensure there was a 50mm nominal physical gap between the underside of the plank and the top of the abutment to eliminate any direct load transfer from the service planks onto the abutment sub-structure during this temporary stage as shown in Figure 8.

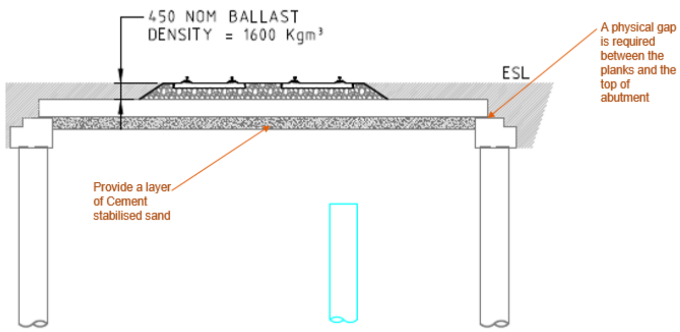

Figure 8. Typical Blackburn Road Bridge Elevation at Stage 1 - Construction

Since trains was planned to run transversely on the service planks with live services within the planks for six month until the main rail occupation, the planks were required to be wrapped with an HDPE wrapping to prevent electric current entering the planks and causing stray current corrosion to the planks and utilities. After the installation of the HDPE wrap, the excavated area was backfilled to the existing road and rail level to install the existing rail tracks; this would enable all traffic movements to the public to be reinstated for a period of 6 months before stage 2 - Construction to commence in the planned rail main occupation.

Figure 9. Typical Services Plank installation onto Sand Jacks on abutments

Stage 2 – Blackburn Road Bridge Construction occurred during the main rail occupation with all works adjacent to the bridge happened at the same time.

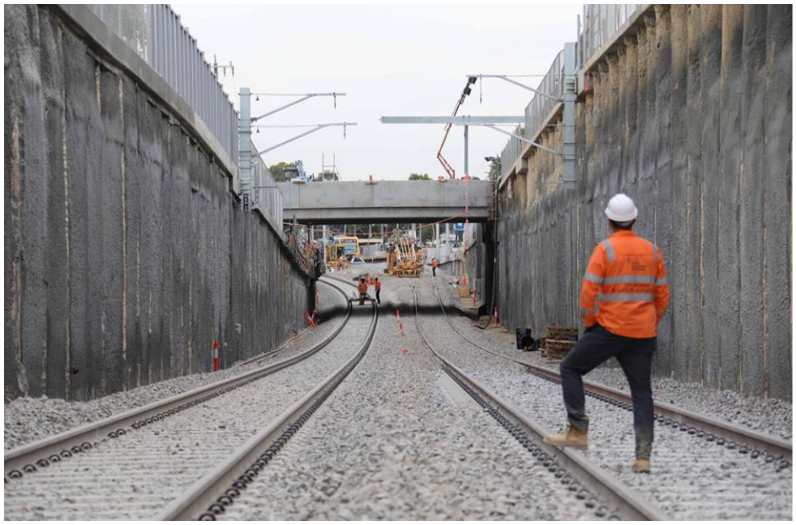

Figure 10. Typical Blackburn Road Bridge Elevation in Stage 2 Construction

Before the excavation works adjacent to the service planks, plastic packers were placed on top of the abutments to support the planks temporarily before gap was grouted. The top of abutment crosshead horizontal deflection due to the excavation in front of the abutment piles estimated by the Geotechnical Engineer was found to be excessive. We identified that the excessive movements could result in detrimental effects to the live services running within the services planks (ie. water main and gas main) and thus specified the use of temporary props along the length of the abutment crosshead to control and minimise the sub-structure deflection during excavation until the integral abutment diaphragm connections were established.

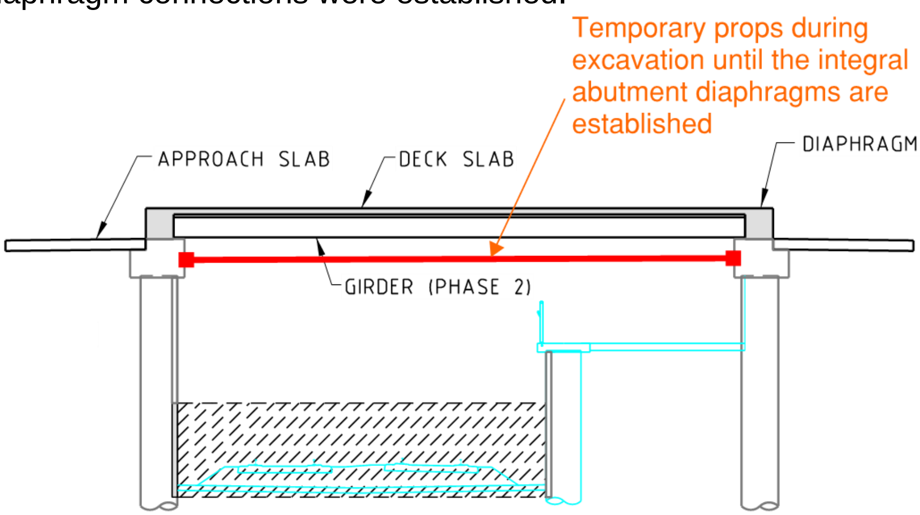

Figure 11. Typical Blackburn Road Bridge indicative prop location

CONCLUSION

Blackburn Road Grade Separation works is just one out of the fifty most dangerous and congested level crossings across Melbourne which are required to be removed by 2022. Most of these existing level crossings are located in densely populated suburbs where the project sites are closely constrained by residential housing and commercial buildings. The use of 3D CAD modelling and clash detection of existing utilities with bridge structures was a success and eliminating potential risk before construction. To overcome the challenges of this project, various construction methods and innovative techniques were used throughout the design and construction that can be a benchmark for similar projects in the future. The removal of these crossings is expected to deliver significant safety improvements to drivers and pedestrians to improve travelling time around Melbourne.

REFERENCES

1. Control of Restrained Shrinkage Cracking, Lecture 9. By R.I.Gilbert 2010, Concrete Institute of Australia
2. Level Crossing Removal Authority website
3. Level Crossing Removal Project – FMBH Barrier Risk Assessment Report no LAH-A00-CBA-RPT-GEN-0001
4. DMRB Volume 1 Section 3 Part 12 – BA 42/96 – The Design of Integral Bridges
5. Victorian Rail Industry Operators Group (VRIOG), 001 Structural Gauge Envelopes – Minimum clearances for Infrastructure adjacent to the Railway, Revision B – 4/6/12
6. MTM Design Practice Notes
7. VicRoads Bridge Technical Note No. 2012-002-V1.0 Bonded Anchors
8. VicRoads Bridge Technical Note No. 2012-003-V1.0 Design of Integral and Semi-Integral Bridges

ACKNOWLEDGEMENTS

The author would like to acknowledge the project team members, government organisations and subcontractors in contributing to the success of this project.

- Arcadis Aurecon CPB Contractors JV
- MTM
- VicRoads
- Golder Associates
- Hassell

AUTHOR BIOGRAPHY

Anthony Cheung is a Senior Structural Engineer joined Arcadis/Hyder Consultant in 2005. He has undertaken the design, assessment and proof engineering of various types of highway structures, including vehicular flyovers, railway bridges, and pedestrian bridges using steel, timber and reinforced prestressed concrete constructions. He has designed numerous civil structures for transport infrastructure projects in Victoria; these projects included the Princes Highway West Duplication, Western Highway Duplication, M80 Ring Road upgrade, M1 West Gate Freeway upgrade, EastLink Tollway Project, South Gippsland Highway upgrade, Hallam Road upgrade, Bayles Bridges upgrade. Anthony was also the Structural Design Lead responsible for the delivery of a number of elevated ramps and bridges required at four different major interchange junctions for the New Orbital Highway & Truck Route located in the North-West of Doha in Qatar.

Yanan Yang PhD, BEng (Hons), Senior Structural Engineer, MIEAust, Member of ASCE, Member of ACI and CIA. He has more than 17 years engineering experiences including researches in life cycles of reinforced concrete structures, detailed design, proof engineering, verification and structural assessment of bridges and other structures. His work also involves providing advisory recommendations to local authority bodies in terms of bridge assessment and strengthening. Some of the major projects he participated including M80 Ring Road Upgrade, Level Crossing Removal Project, Citylink – Tullamarine Freeway Upgrade Project, Regional Rail Extension Project, Westgate Bridge Strengthening, Western Hwy Duplication Project, Princes Highway West Duplication, Thompson Road Duplication etc.