

DESIGN AND CONSTRUCTION OF BR1449 VICTORIA PARK DRIVE MODIFICATIONS, BURSWOOD, WA

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ABSTRACT

Arup was lead designer for Lend Lease on the Victoria Park Drive Modifications project procured by Main Roads Western Australia on behalf of the Public Transport Authority. The upgrade project facilitates road, rail and pedestrian access to the new Perth Stadium. This paper outlines some of the key issues and considerations in both the design and construction of Bridge No. 1449 (BR1449). BR1449 required widening and lengthening of the existing single 19m span bridge to a three span bridge over an extended rail station and new rail lines. Rail services and road access along Victoria Park Drive were required throughout construction resulting in complex design and construction co-ordination. The northern abutment of BR1449 required widening immediately adjacent to a live electrified rail line. The existing southern abutment required temporary strengthening and complex construction staging to modify to a three column pier, located on a future rail platform. 4D BIM modelling was used to assist the construction staging and resulting design methodology. Earthing and bonding and allowance for rail collision loading and deflection walls were required for both the existing and new structure.

INTRODUCTION

The Victoria Park Drive Modifications project located in Burswood, Western Australia, refer to Figure 1 and 2, involved the design and construction of modifications to Victoria Park Drive and the adjacent rail, pedestrian and bridge infrastructure to accommodate the expanded rail infrastructure to service the New Perth stadium. The road and bridge expansion enables the new railway lines to be installed on the Armadale-Perth line to service the Stadium station and create an underpass to separate vehicles and pedestrians trying to access one of the station forecourts. The modifications accommodated the future expansion of the number of rail lines from two existing to six.

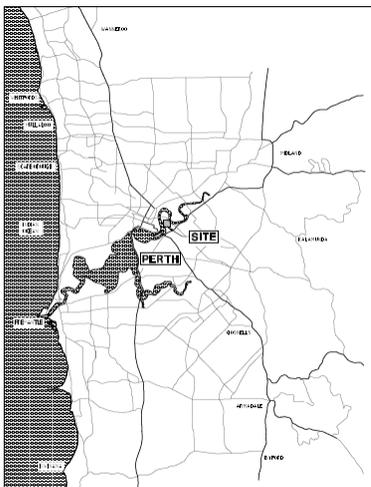


Figure 1: Site Location



Figure 2: Site Location

The project was procured by Main Roads Western Australia (MRWA) on behalf of the Public Transport Authority (PTA) under a design and construct contract. Arup were engaged by Lend Lease to undertake the design for the project. In total there were four bridge structures:

- BR1737: A new single span bridge over the new rail line 1.
- BR1449: A modified three span bridge over rail lines 2 to 6.
- BR9401: A new pedestrian underpass allowing access from the new Stadium to the new Stadium Station.
- BR9211: A modified pedestrian bridge from Belmont race course over rail lines 1 to 5.

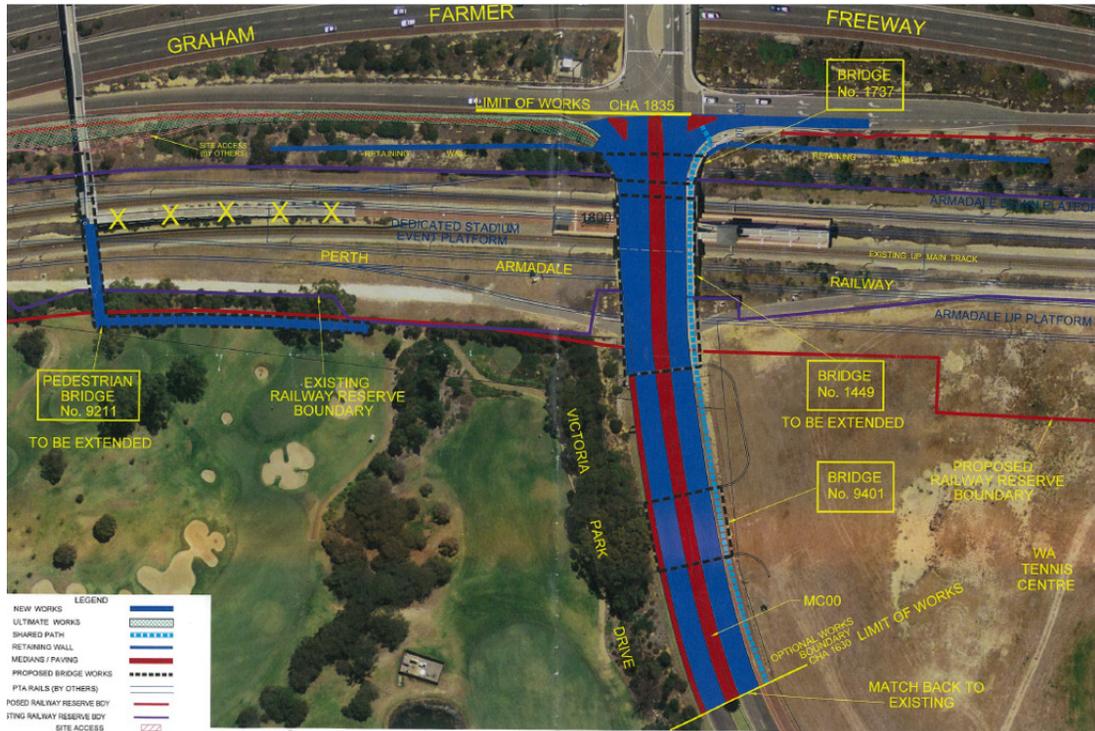


Figure 3: Project Limit of Works



Figure 4: View of Near Completed Project from BR9211 Looking East

Existing bridge

The existing bridge was constructed in 1999 as a single 19.256m span, 12 No. 850mm deep precast post tensioned beams composite with a 150mm deep deck slab. Refer to Figure 5 below for the typical beam geometry.

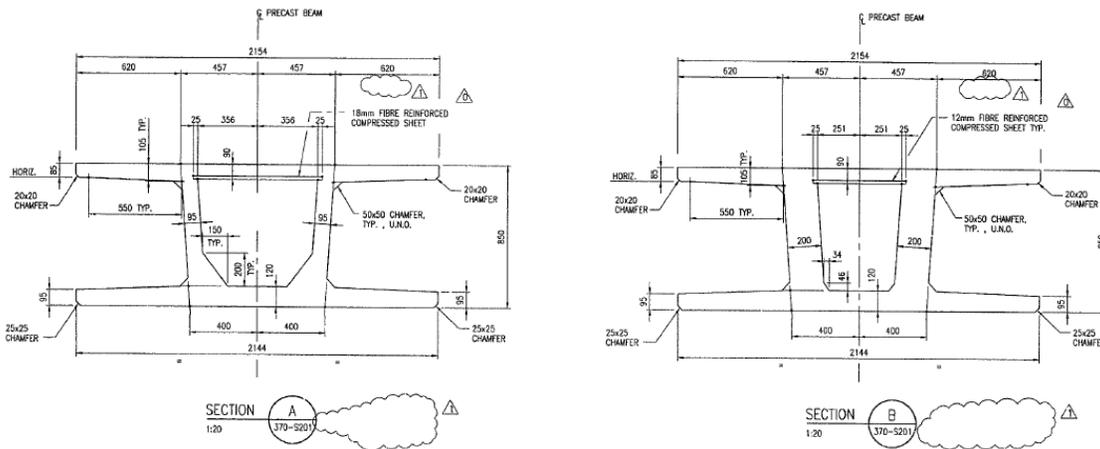


Figure 5: Geometry of Existing BR1449 Typical Beam

The bridge abutment walls were reinforced concrete 650mm thick typical and the bridge was founded on spread footings. Ground improvements works had been undertaken during construction via an excavate and compact and replace methodology for 2.8m depth below the underside of the northern abutment footing and 3.6m depth below the underside of the southern abutment footing. A walkway up from the Belmont Station platform was also attached to the bridge which was required to be demolished as part of the scope of works.

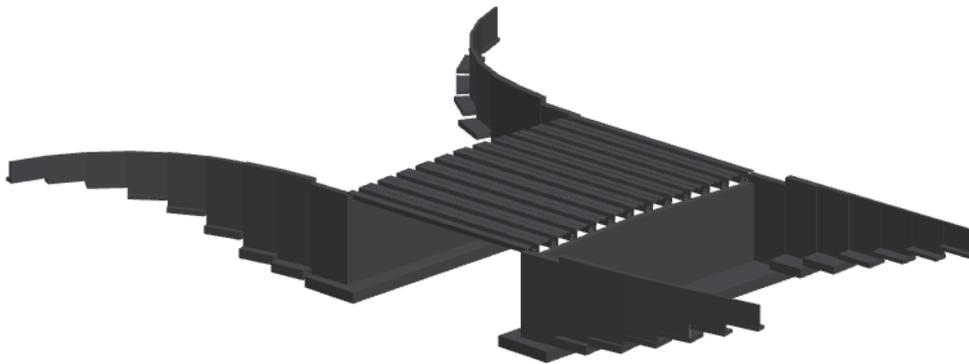


Figure 6: BR1449 3D Modelling of the Existing Bridge (Note deck slab and bridge furniture not shown for clarity)

New bridge

The new bridge consisted of reusing the existing deck, an approximately 3.7m widening of the existing deck with 13 No. beams in cross section and lengthening to three spans; Span 1 21.6m, Span 2 17.635m, Span 3 (existing span) 19.256m. T-Roff beams were adopted for the widening and lengthening sections of the bridge as the most economical solution. The 800mm deep T-Roff beams were made composite with a 200mm deep deck slab, giving an overall structural depth of 1.0m, the same as the existing deck structural depth.

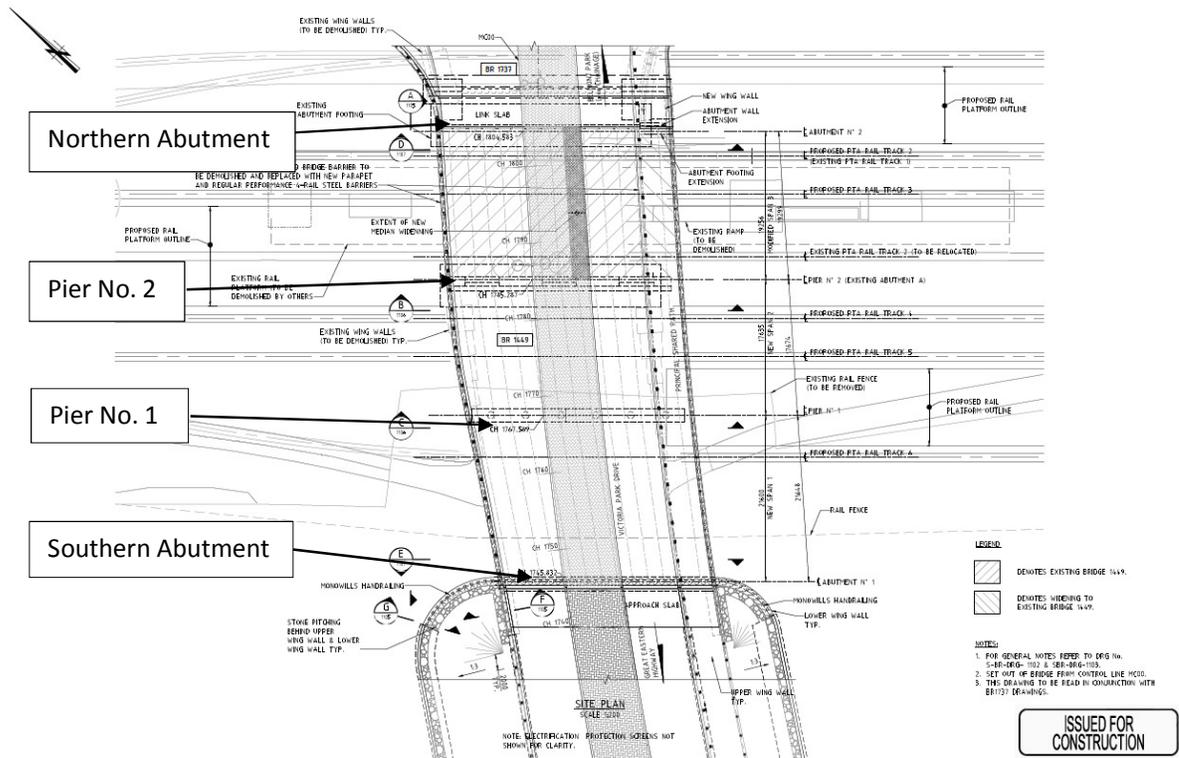


Figure 7: BR1449 Plan



Figure 8: Span 3 Beams

4D Building Information Modelling (BIM) was undertaken to assist the complex construction staging to assist in the design methodology. This is a powerful tool and has the benefit of not only assisting the design methodology but also the Contractor and their sub-contractors gain a clearer and enhanced understanding of what is required and the complexities involved in the construction of complicated projects in particular.

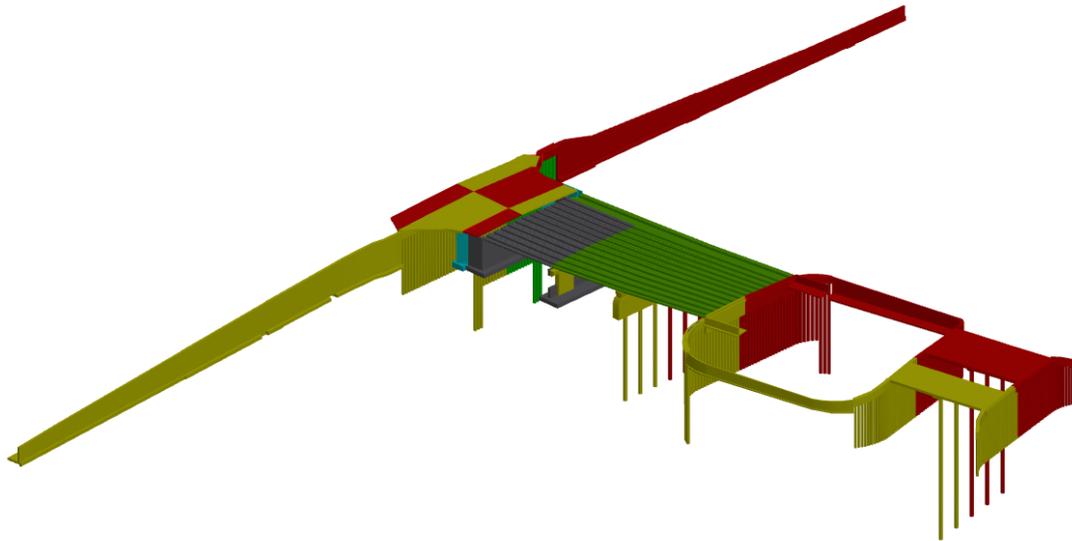


Figure 9: BR1449 4D Modelling (Also showing BR1737 and BR9401)

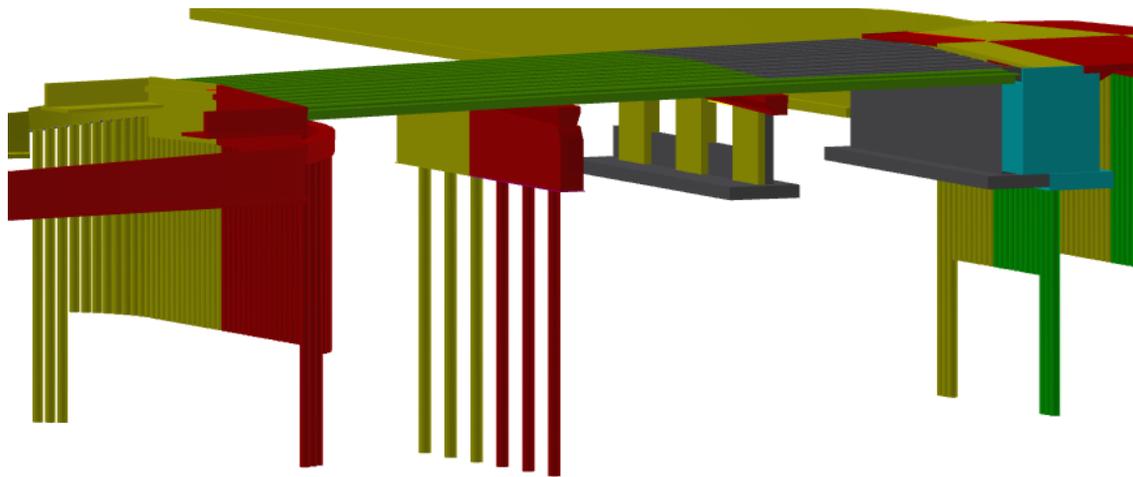


Figure 10: BR1449 4D Modelling (Also showing BR1737 and BR9401)

Design vehicles

The existing bridge was designed for T44 loading and the HLP320 vehicle. The new components of the bridge were to be designed for T44 loading, the HLP320 vehicle and also MRWA Group 1 vehicles.

Construction

The largest constraint on the project was the requirement that Victoria Park Drive remain open, one lane in each direction to traffic at all times throughout the project. Thus this was the key driver in the construction methodology adopted. Construction and earthworks staging was a significant determinant in the design methodology adopted for BR1449.

The construction staging adopted is outlined below:

1. Close the eastern side of Victoria Park Drive to traffic.
2. Staged excavation behind the northern abutment and southern abutment of BR1737.
3. Demolish the existing north-eastern wing walls off the existing abutment footing.
4. Temporarily relocate the overhead lines.
5. Excavate down immediately adjacent to rail line.
6. Construct wing wall footing (which joins BR1737 wing wall footing and BR1737 southern abutment footing).
7. Construct northern abutment wall extension and wing wall.



Figure 11: Construction of the Northern Abutment Widening of BR1449 and Wing Wall between BR1449 and BR1737 Looking North.



Figure 12: Construction of Northern Abutment Widening Looking South

8. Reinstall overhead lines.
9. Eastern side of Victoria Park Drive to remain closed to traffic.
10. Construct bored piles up to headstock at Pier No. 1 (southern pier) for eastern half of bridge.
11. Construct bored piles up to headstock at new southern abutment for eastern half of bridge including lower wing wall.
12. Excavate to top of pile level Span 2 side of Pier No. 1 through to underside of new headstock for Pier No. 2 and excavate to underside of new headstock for new southern abutment for eastern half of bridge and partially demolish the upper portion of existing wing walls.
13. Construct headstock at Pier No. 1 for eastern half of bridge.
14. Construct headstock at new southern abutment for eastern half of bridge and eastern lower wing wall.

15. Place bearings at Pier No. 1 and new southern abutment for eastern half of bridge.
16. Partially demolish existing skirt beam at existing southern abutment (Pier No. 2) for eastern half of bridge.
17. Existing southern abutment (Pier No. 2) at the upper level to be drilled and chemical anchors installed with end plates installed. Contractor to survey existing vertical bars before drilling. Note these bars will extend through the entire existing abutment wall into what will be the newly constructed Pier No. 2 headstock.
18. Existing southern abutment (Pier No. 2) wall and footing to be drilled and chemical anchors installed. Contractor to survey existing vertical bars before drilling.

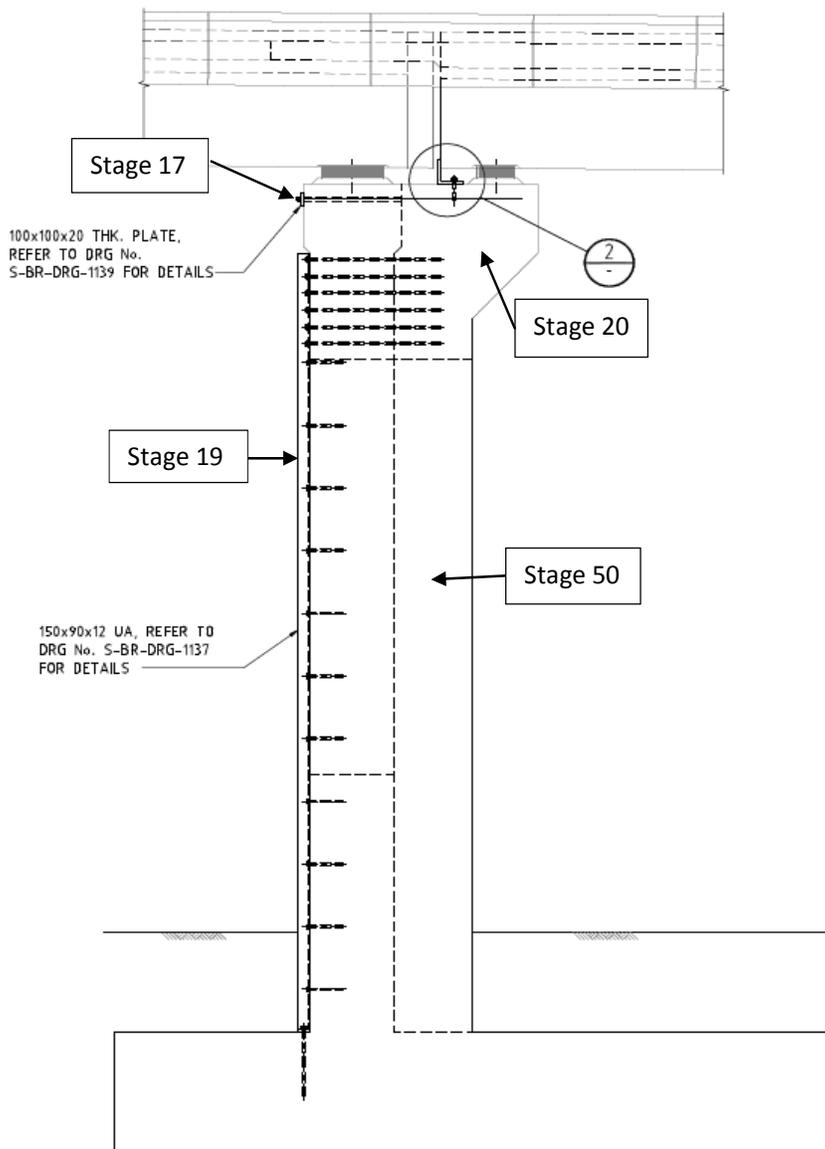


Figure 13: Temporary Strengthening to the Existing Southern Abutment (Pier No. 2)

- 19. Temporary steel unequal angles fixed to rail side of existing southern abutment (Pier No. 2) for full extent of bridge.



Figure 14: Temporary Steel Unequal Angles at Existing Southern Abutment (Pier No. 2)

- 20. Headstock thickening constructed at Pier No. 2 for eastern half of bridge. Note headstock to bear on partially demolished wing wall at eastern end.

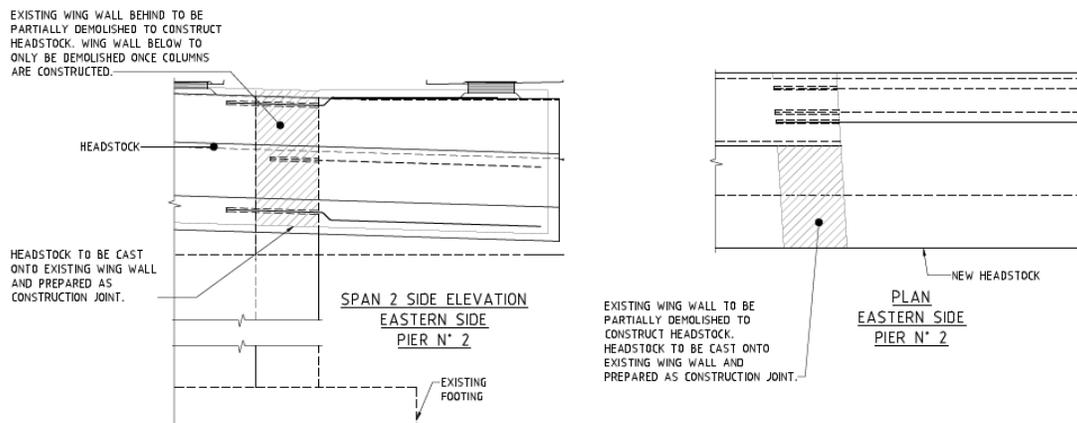


Figure 15: Headstock at Pier No. 2 Eastern End

21. Concrete to cure in accordance with project specification.
22. Place bearings at Pier No. 2 for eastern half of bridge.
23. T-Roff beams landed for Span 1, Span 2 and Span 3 for eastern half of bridge, after 14 days and headstock concrete has reached its full design strength.
24. Install equal angles on top of headstock at Pier No. 2 eastern half of bridge.



Figure 16: Equal Angle Behind T-Roff at Pier No. 2

25. Hydro-demolish existing deck slab at existing southern abutment (Pier No. 2) for eastern half of bridge.



Figure 17: Hydro-Demolition of Existing Slab to form Link Slab at Pier No. 2

26. Remainder of deck constructed for eastern half of bridge.



Figure 18: Eastern Deck Construction

27. Skirt beam and approach slab constructed for eastern half of bridge.

28. Close western side of Victoria Park Drive to traffic, open eastern side.

29. Excavate to top of pile level Span 2 side of Pier No. 1 through to underside of new headstock for Pier No. 2 and excavate to underside of new headstock for new southern abutment for western half of bridge and partially demolish the upper portion of existing wing walls.



Figure 19: Excavation at Western Side

30. Excavate on Eastern side battering down from western side.



Figure 20: Excavation at Eastern Side

31. Construct headstock at Pier No. 1 for western half of bridge.
32. Construct headstock at new southern abutment for western half of bridge and western lower wing wall.
33. Place bearings at Pier No. 1 and new southern abutment for western half of bridge.
34. Partially demolish existing skirt beam at existing southern abutment (Pier No. 2) for western half of bridge.
35. Existing southern abutment (Pier No. 2) at the upper level to be drilled and chemical anchors installed with end plates installed. Contractor to survey existing vertical bars before drilling. Note these bars will extend through the entire existing abutment wall into what will be the newly constructed Pier No. 2 headstock.
36. Headstock thickening constructed at Pier No. 2 for western half of bridge. Note headstock will be drilled and chemically anchored to the partially demolished wing wall at western end.
37. Concrete to cure in accordance with project specification.
38. Place bearings at Pier No. 2 for western half of bridge.
39. T-Roff beams landed for Span 1 and Span 2 for western half of bridge, after 14 days and headstock concrete has reached its full design strength.



Figure 21: T-Roff Beam Being Landed at Span 1 Western Side

40. Install equal angles on top of headstock at Pier No. 2 for western half of bridge.

41. Hydro-demolish existing deck slab at existing southern abutment (Pier No. 2) for western half of bridge.
42. Remainder of deck constructed for western half of bridge.
43. Skirt beam and approach slab constructed for western half of bridge.
44. Excavate to RL+2.6m underneath bridge for Span 1 and Span 2. Contractor to survey top of southern abutment wall and bearings prior to excavation in front of the wall. Contractor to monitor deflection of the top of the wall and bearings during excavation. If the deflection reaches 30mm, the Contractor shall stop the excavation, notify the design engineer and re-set the bearings individually one at a time.
45. Demolish remaining wing walls (note return wing walls on Pier No. 2 spread footing to remain).
46. Locally excavate to RL+2.25m at Pier No. 1.
47. Construct deflection wall.



Figure 22: Construction of Deflection Wall at Pier No. 1

48. Construct new southern abutment and lower wing walls facing in-situ wall.



Figure 23: In-situ Facing Wall at Southern Abutment

49. Locally excavate to RL+1.85m at Pier No. 2 (Span 2 side, top of existing footing).
50. Construct new pier columns.



Figure 24: New Columns at Pier No. 2

51. Cure concrete in accordance with project specification.
52. Remove temporary unequal angles and upper bearing plates.



Figure 25: Removal of Unequal Angles and Bearing Plates

- 53. Partially demolition of existing wall to create three pier columns and return wing walls on Pier No. 2 spread footing.
- 54. Install steel T-beams to underside of headstock at each stage of demolition.



Figure 26: Construction of steel T-Beams to Underside of Headstock

- 55. Construct bottom section below existing headstock and sides of columns.



Figure 27: Construction Edges to Columns

56. Repair faces to pier columns.



Figure 28: Repair Column Faces

57. Upgrading of barriers on western side of bridge.

58. Construct deck furniture such as electrification protection screens, barriers, kerbs, medians etc.



Figure 29: Construction Edges to Columns

59. Open western side to traffic also.

Design Issues

Cantilevering the north-east edge of the abutment wall

Removing the requirements to drive a temporary sheet pile between the widened abutment structure at the north-east corner and rail line resulted in cantilevering the corner of the abutment wall and the corner of the wing wall as per Figure 30 below. Refer also to Figure 11 above. This was a significant saving for the construction team and also avoided the need for ground improvement similar to the existing ground improvement under what would have been the widening abutment footing. Testing was undertaken further back from the abutment wall where the wing wall footing was to be constructed to ascertain there was sufficient bearing capacity available and no additional ground improvement was required for the wing wall footing.

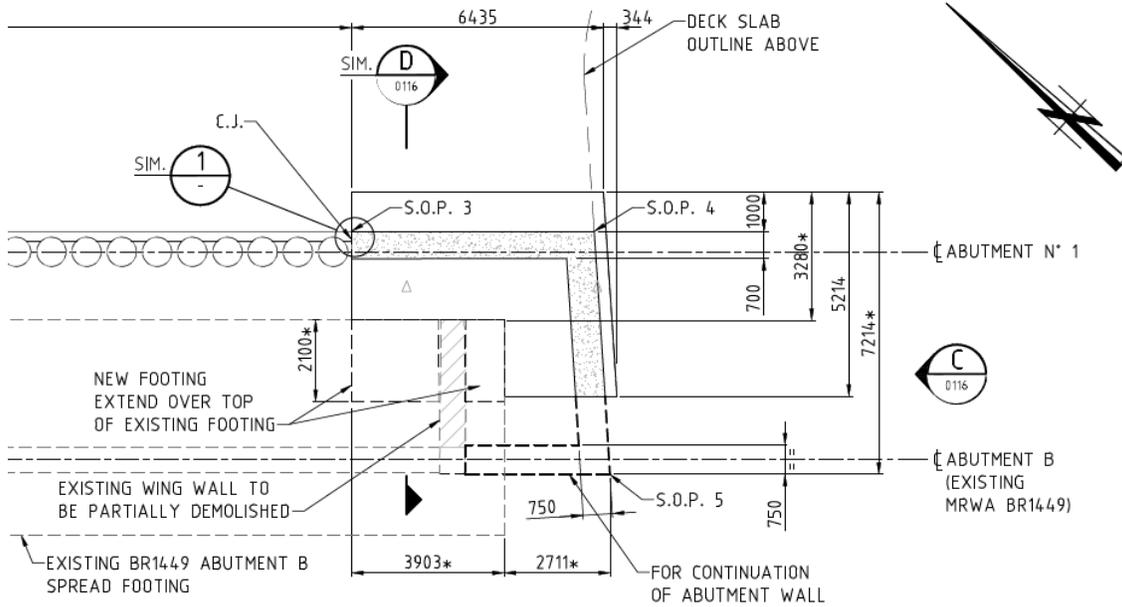


Figure 30: Plan Corner Cantilever of Abutment Wall and Wing Wall

Converting the existing southern abutment to a pier

The most significant aspect of the design of BR1449 was the conversion of the existing southern abutment into Pier No. 2. The existing abutment wall was 650mm thick. It was determined that due to the top down construction methodology that the vertical bars on the external face did not have sufficient capacity in the temporary case when the headstock had been constructed and the T-Roff beams have been landed and subjected to traffic loading. The external face also did not satisfy the minimum strength steel requirements in the temporary case, thus a non-ductile failure was possible and this was deemed to be unacceptable. Temporary strengthening of the external face and footing was thus adopted in the form of chemically anchored unequal angles and chemically anchored reinforcement bars with a bearing plate refer to Figures 13, 14 and 25. The unequal angles were removed along with the upper level bearing plates after the construction of the three pier columns. The upper chemically anchored reinforced bars were designed to take the full tension force from the 'push pull' action due to the Span 2 eccentric loads before new pier columns were constructed.

The three new pier columns are 1250mm thick by 4500mm wide, and are formed by two sections, being the existing abutment wall and the new column extension. The design of the columns has considered both the construction and in service cases. Interface shear between the new and existing sections of the columns was also considered, and hence a quality interface of the existing wall was required. Chemically anchored reinforcement bars were included for robustness and to laterally restrain the new longitudinal bars.

A prop in the form of an equal angle was adopted behind the T-Roff beams as a safety in design initiative, refer to Figure 16. This was implemented to mitigate the risk that should the pier wall begin to deflect excessively before the three columns were constructed then the equal angle would push against the T-Roff beam which would then engage the passive pressure pushing back against the skirt beam at the southern abutment.

Chemically anchored reinforcement bars were also designed to transmit the full loads from the existing top of wall section into new headstock section between columns. This was for robustness, as the extended portion of the headstock was designed to take the full loads from Span 2 and 3.

When considering shear and torsion, the headstock section was designed as a rectangular section of equal depth and approximately equivalent area and torsional modulus. Torsion was assumed through the new section only as once the section cracks the existing section has minimal torsion capacity, with no closed ligatures, or large corner bars. Torsion was designed considering steel contribution only, and considering combined bending, shear and torsion. The wing walls on the existing abutment footing were left in place until the columns were constructed as they allowed an alternative load path, through torsion in the headstock beam back to the return walls.

Cast in steel T-beam sections were required in the temporary case and were also considered for strength in the permanent case. The temporary section was designed for dead load only, whilst the in service case section was designed for the full loading, considering the contribution of the concrete/rebar cast around the section. The splice connection between T-beam sections was designed to transmit the full tension load, and required TF bolts to ensure there was no slippage, which would likely cause excessive cracking in the concrete. Interface shear capacity between concrete sections was not considered as the new concrete was cast below the existing and hence a good quality interface could not be ensured. Bolts were adopted to ensure longitudinal shear capacity over the construction joint.

Upgrading the existing barriers

As part of the scope the existing barriers were required to be upgraded to regular performance level barriers. The original barriers had been previously designed for a lateral outwards collision load of 90kN in accordance with '92 Austroads Bridge Design Code. The regular performance level barrier was required to be designed for a lateral outwards collision load of 250kN in accordance with AS 5100. This was complicated by the existing deck slab only being 150mm deep. The existing transverse reinforcement consisted of a layer of Y16-200 top and bottom. It was deemed the slab only should be considered in the capacity as it could not be guaranteed that composite action would be achieved with the top flange of the beam. The analyses determined that there was insufficient capacity. The Contractor expressed a desire to minimise the extent of hydro-demolition thus a design solution was determined to minimise the extent of hydro-demolition whilst providing a solution which was relatively easy to construct on site.

The design solution relied on a strut and tie model where the design compression was taken via the barrier into the L-shape plate and into the top flange of the beam. The design tension was taken via the barrier into the reinforcement through welded connecting plates. The connecting plates were welded on site at one end to the longitudinal 60mm thick main plate and at the other end to the existing reinforcement. This solution thus provided the Contractor the flexibility of locating the connecting plates relative to the existing reinforcement, whose location was not exactly known until the deck slab had been hydro-demolished.

Rail collision loading/Deflection walls

A deflection wall was designed at Pier No. 1 refer to Figure 22. The deflection wall was constructed from the ground up once the deck had been constructed above. AS5100 required the deflection wall to be a minimum 3.6m above top of rail level. Thus initially there was a gap proposed between the

top of the deflection wall and the underside of the headstock. After consultation with the independent project architect it was recommended that the gap between the deflection wall and headstock be filled with reinforced concrete for aesthetic purposes. Pier No. 2 was designed for a collision load of 500kN as per AS 5100 as the SWTC allowed the future platform that would surround the pier to be considered as a deflection wall.

The design methodology of the northern abutment was that the abutment was checked on either side such that a 2m length of wall is removed for a height of 3.6m above top of rail level for a head on collision and was found to be structurally adequate. Thus the first 2m length of wall for a height 3.6m above top of rail level was deemed to be acting as an integral deflection wall in accordance with AS 5100. The northern abutment was also designed for a 1500kN normal collision load in accordance with AS 5100 with passive resistance provided from the soil block behind the abutment wall.

Earthing and bonding

Earthing is the practice of connecting exposed metallic components to the earth, such that currents are diverted to the earth and dissipate. A correctly design earthing system will:

- Provide a safe return path for current in the event of an electrical fault and ensure that sufficient current flows to cause the protective devices to trip out;
- Prevent conductors and components from reaching potentials higher than the rated insulation voltage;
- Prevent a dangerous potential occurring between simultaneously accessible metallic components;
- Prevent the generation of excessive voltages around the earthing system itself during fault conditions;
- Provide a common reference potential that may be necessary for the correct functioning of data processing or communications equipment.

Bonding is the practice of connecting exposed metallic components such that dangerous potential differences do not occur between metallic components during a fault, even though these components may be independently connected to the protective earthing system.

The overhead contact line zone and pantograph zone are zones in which structures and trackside equipment could accidentally become live due to contact with broken overhead line equipment or pantograph. If the contact wire were to snap and hit the above bridge soffit, the electrical current would flow through to the bridge barriers and other metallic components, posing a high risk safety hazard.

The zone in which such contact is considered probable is defined in Figure 31, where:

- HP is the highest point of the overhead contact line
- $x = 4.0\text{m}$ (extended to 5.0m for tracks with curves less than 100m)
- $y = 2.0\text{m}$
- $S_H = 8.0\text{m}$ above top of the rails

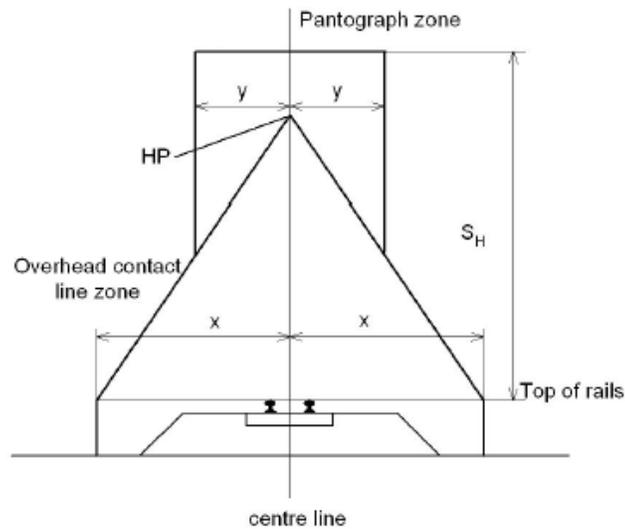


Figure 31: Overhead Contact Line and Pantograph Zone

BR1449 had additional complexities in that earthing and bonding was required of the existing structure and also of the new structure. The earthing and bonding system of the existing structure was achieved through external electrical conductors refer to Figure 8 as an example, connected to a copper insulated cable which then connected to exposed metallic components. Typically the earthing and bonding system of the new structure was achieved through welding internal reinforcement, connected to a copper insulated cable which was then connected to exposed metallic components.

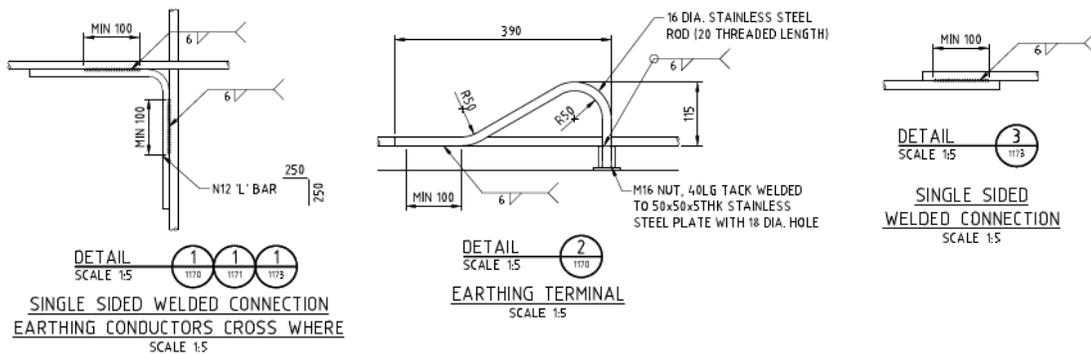


Figure 32: Earthing and Bonding Details

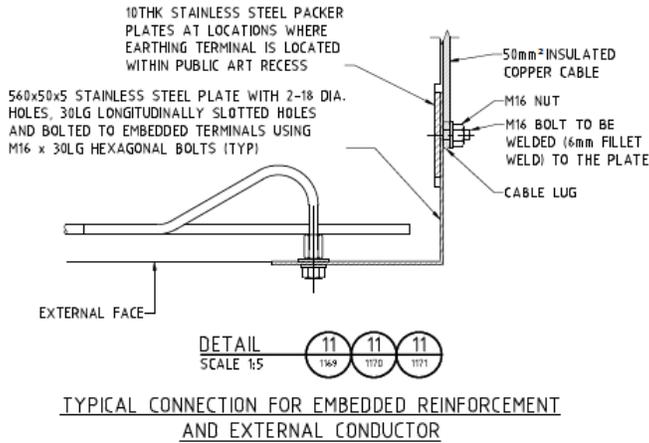
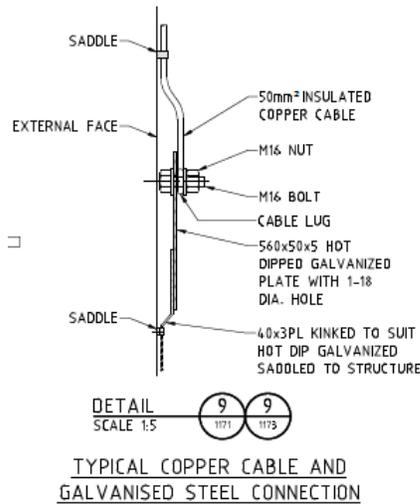


Figure 33: Copper Insulated Cable Earthing and Bonding Details

CONCLUSION

The design and construction of BR1449 as part of the Victoria Park Drive Modifications project was extremely complex. Close collaboration was required between the construction team and the design team and was a key catalyst for the successful completion of the bridge. Significant design and construction challenges included; staged excavations, cantilevering the north-eastern edge of the northern abutment due to close proximity to live rail, converting the existing southern abutment to a pier, upgrading the existing barriers to regular performance level barriers, rail collision loading and deflection walls and the earthing and bonding of existing and new structural components. This was made all the more complex by the requirement that Victoria Park Drive remain open for the duration of the project. 4D BIM modelling can be a powerful tool in aiding both the design methodology and the construction staging.

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5. *Technical Instruction 228E – Guidelines for Earthing and Bonding in the 25kV AC Electrified Areas*, Government of Western Australia, Public Transport Authority

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- PTA; Kym Hockley

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Brian Lord is a chartered Senior Civil Structural Engineer with an MBA in Arup's Transport and Resources team in Perth with approximately 11 years' experience. During this time Brian has worked on numerous road, rail and pedestrian bridges and a variety of maritime structures through concept stage through to construction. Brian was the Structural Lead and then later the Project Manager for the Victoria Park Drive Modifications project.