Removal of the Beatrice Bush Bridge for the Rozelle Interchange Project

Matt Hennessy, Structural Engineer, EIC Activities
Colin Edmonds, Technical Director - Structures, EIC Activities

ABSTRACT

The Rozelle Interchange is a new underground motorway interchange which provides connectivity to the M4-M5 Link Tunnels and the City West Link, and underground bypass of Victoria Road between Iron Cove Bridge and Anzac Bridge. The Rozelle Interchange also provides a connection to the future Western Harbour Tunnel. As part of the construction of the interchange, several existing structures required to be removed including the Beatrice Bush Bridge that provided an elevated pedestrian crossing of Victoria Road.

The existing bridge was constructed in 2005 and consists of a four span steel box girder with a non-composite concrete deck and reinforced concrete substructure. The northern approach consisted of 40.555m span and the southern approach consisted of 17.605m and 30.025m spans. The segment spanning Victoria Road was 40m in length. The bridge was given a vertical crest to meet the required vehicle envelope of Victoria Road and is horizontally curved in plan to meet the required grade specifications. The steel girder was integral in configuration and was stressed to each pier and abutment due to fabrication complications during construction.

Due to the location of the bridge, the time allowances for deconstruction were highly constrained and traffic management plans and safety were paramount. The removal sequence and associated analysis was centered around the planned closures of Victoria Road. The selected removal sequence was chosen to be an “inside out” approach where the span crossing Victoria Road was removed first and two workfronts removed the remaining three outer spans. This introduced complications in analysis as it differed from the original sequential construction sequence. This paper will focus on the selected deconstruction methodology of the bridge and associated staged analysis, studying the effects of girder removal including removal of the prestressing bars tying the girders to the piers and abutments. This paper also outlines the key constraints and considerations during the analysis and removal sequence and discusses the resulting deconstruction of the bridge that occurred in 2020.

1 INTRODUCTION

This paper concerns the removal of the existing Beatrice Bush Pedestrian Bridge that was located over Victoria Road as part of the Rozelle Interchange project. In order to construct the new intersection at Victoria Road (turning into the Western Distributor) and the Crescent and to facilitate the construction of the cut and cover structures the existing pedestrian bridge required to be removed.

1.1 Rozelle Interchange Project

The Rozelle Interchange project is the latest phase of WestConnex undertaken by John Holland CPB Joint Venture (JHCPBJV) and provides construction of the connections between the M4 and the new M5 link to the Anzac Bridge and Victoria Road in Sydney. The project provides the following key infrastructure:

- 23 km of tunnels providing the links of WestConnex to several arterial roads in Sydney
- 4 cut and cover structures providing access to the Westconnex motorway network
- 12 bridges providing vehicular and pedestrian access around the Rozelle area
- 2 ventilation facilities extending Westconnex’s existing ventilation network
- Upon completion, transformation of the previous railyard site into an extensive green parkland space

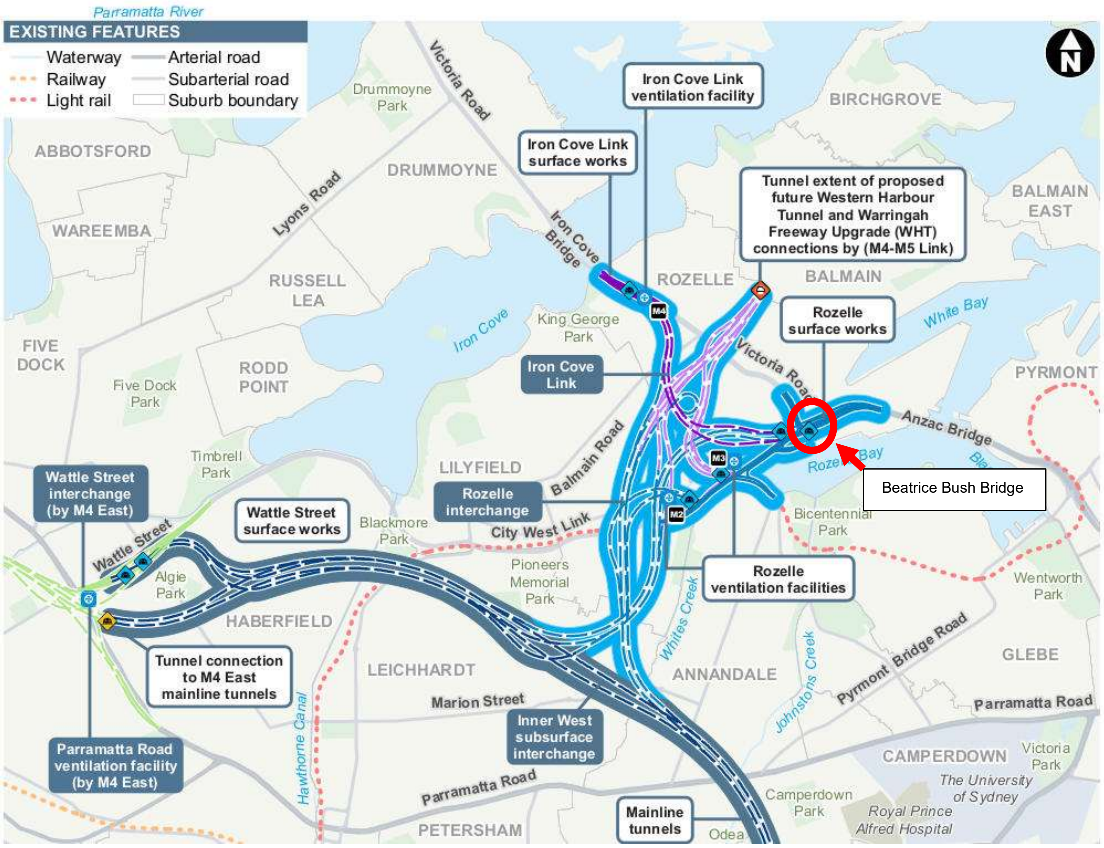

Figure 1- Rozelle Interchange Project

1.2 Beatrice Bush Bridge

Named after Beatrice Bush, who sold newspapers at the intersection which the bridge spans for over 25 years, the existing bridge was constructed in 2005 and consists of a four span steel box girder with a concrete deck and reinforced concrete substructure. The steel girder consisted of 4 spans, constructed in a span-by-span approach having lengths of 40.555m, 40m, 30.025m and 17.605m from north to south respectively. The bridge was horizontally curved in plan to meet the required grade specifications for pedestrian usage and was also provided with a vertical crest to meet the required vehicle clearance to Victoria Road. To resist torsion, the bridge utilised of several 32mm diameter stressing bars, tying the steel box girder to the pier with 8 no. provided at Abutment A, 8 no. provided at Pier 1 and 2 no. provided at Pier 2.

The steel box girder was 1.7m wide by 1.064m deep consisting of a 20mm thick bottom flange, 16m thick web plates and a 16mm thick top flange. The girder was stiffened both transversely and longitudinally. A minimum 170mm thick concrete decking was provided but was not made composite with the steel girder. To provide protection to pedestrians crossing the bridge and traffic passing below, the bridge was provided with a steel handrail and barrier complete with anti-throw mesh panels.

The bridge was founded on three reinforced concrete piers and two reinforced concrete abutments. An articulation was provided to the bridge through the use of guided and fixed pot bearings to reduce design actions resulting from longitudinal movements. The girders were connected by bolted splices provided on the web plates, providing an axial, shear and lateral bending moment connection to the girder.

As shown in Figure 3 below, bolted splices of the girders are located away from the pier locations, providing a continuous structure over each pier and consequently, hinges are located between the piers.

Figure 2- Beatrice Bush Bridge

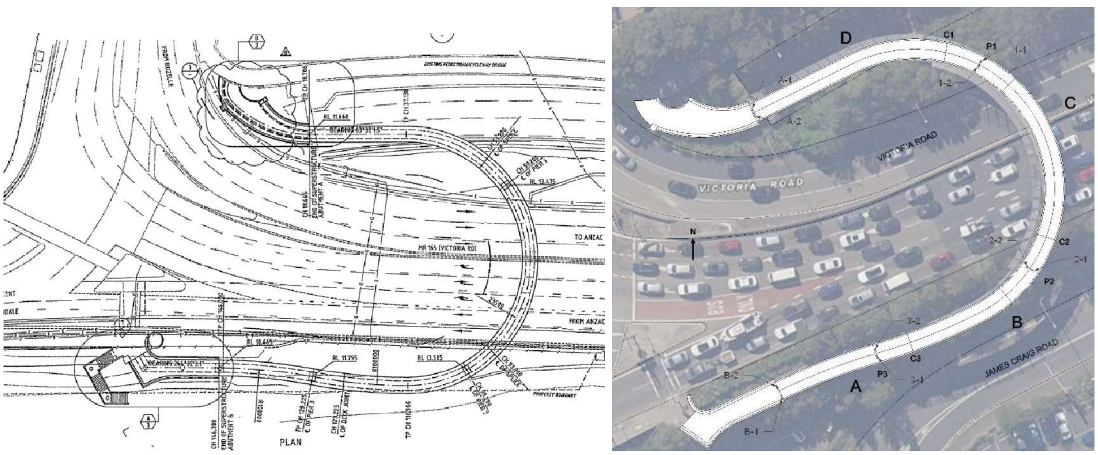

Figure 3- General arrangement and naming convention

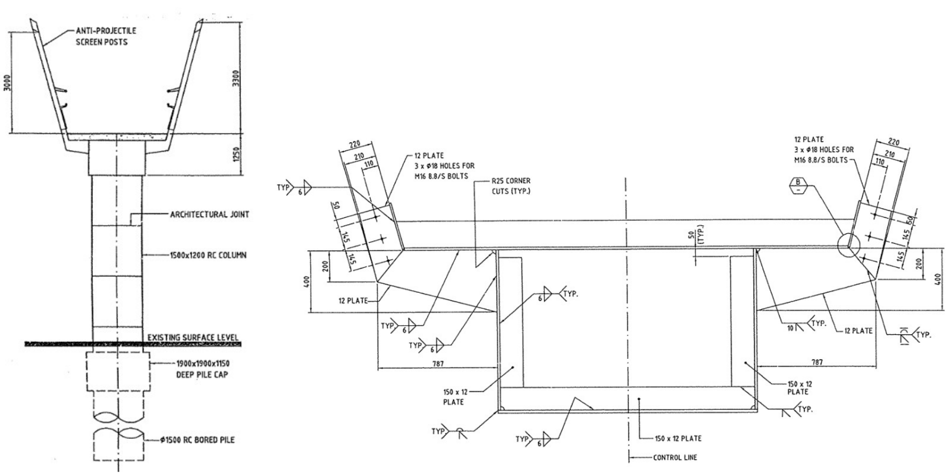

Figure 4- Girder and Pier general arrangements

2 CONSTRAINTS AND CONSIDERATIONS

As the bridge spanned Victoria Road, a main arterial road of Sydney, the removal of the bridge is prone to several constraints around access, time and safety. Ongoing meetings between the construction and design teams were made to discuss and mitigate the potential issues that could arise during the removal process.

Due to the location of the bridge, it was difficult to secure road closures of Victoria Road and limited opportunities were available to complete the removal. As such, it was critical that each component could be removed as quickly as possible with little disruption to the traffic flow. Procedures that could be completed away from Victoria Road were preferred.

As with all construction, safety is paramount to the successful removal of the bridge. Due to the nature of the works, careful consideration of the removal sequence was undertaken to ensure proper access and stability of the structure was accounted for with the expected works and loading. Additional precautions such as netting to prevent falling objects and additional handrails and guards were put in place to reduce risk onto the workers and passing traffic.

The presence of the post tensioned bars on the bridge, also presented a risk to the safety of the works and stability of the bridge during removal. Additional precautions had to be made as detailed below to ensure the safe removal of these bars. The concrete surrounding the PT bars was removed to investigate the top of the PT bars and it was found that the bars had been cut close to the deck at the end of construction, hence there was not enough length available for these bars to be destressed using jacks.

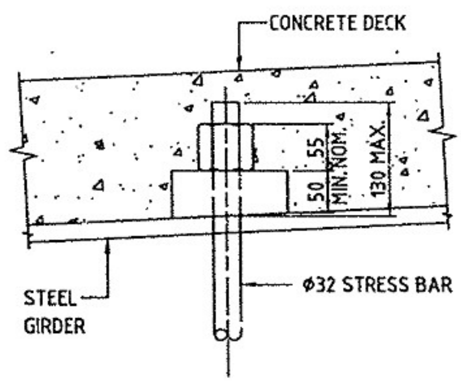

Figure 5- Stress bar connection to deck flange detail

Figure 6- Exposed PT bar locking nuts

As the bridge is curved, careful calculation of the bridge's weight and centre of gravity had to be considered to calculate the inbuilt torsion effects within the girder. Typically bridge removals follow the reverse order of the construction sequence, this ensures the bridge will not be subject to forces different to those imposed during construction. Any deviation from this sequence requires careful consideration to the stability of the bridge and overstressing of components.

3 REMOVAL METHODOLOGY AND STRUCTURAL ASSESSMENT

To analyse the structure, a model was created within Autodesk Structural Bridge Design (SBD), being split into two main phases; construction and deconstruction. The forces in the structure was dependent on the construction sequence as the "built-up" loads provided a basis for which the deconstruction sequence uses. Since both sequences are connected, the same structure was used throughout the modelling process.

The bridge was modelled as a line beam structure as illustrated below. As the analysis focuses on the behaviour of the steel girder, the piers and pilecaps were not considered in the model and were represented by fixed connections to the bearing members due to the relative high rigidity of the pier in comparison to the bridge deck since this was determined to not significantly affect the forces in the superstructure.

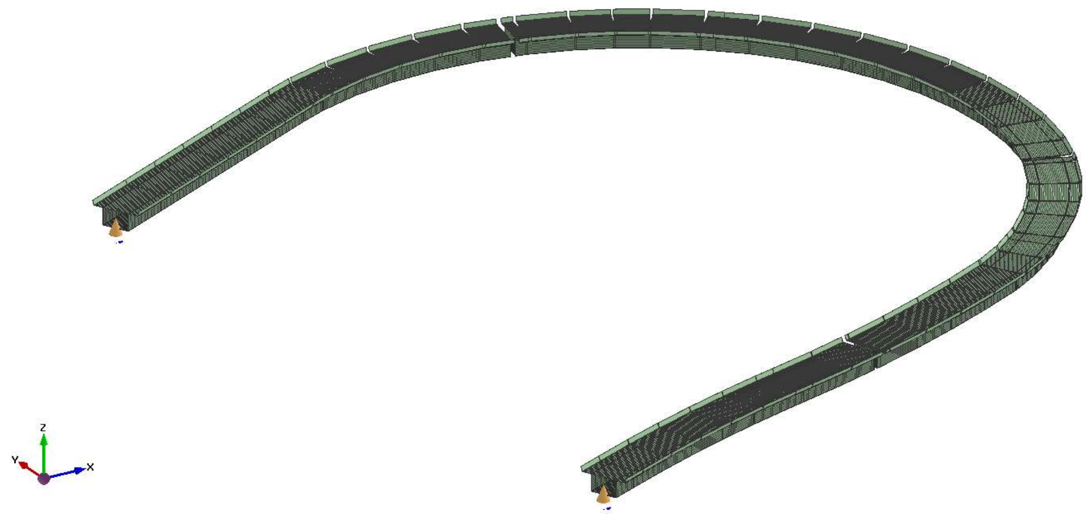

Figure 7- Structural Model

To model the bearings, rigid members were used to offset the bearings according to the dimensions given in the as built drawings. The bearing members themselves were also given rigid member properties due to the use of pot bearings. The bearings were either fixed, free or longitudinally guided depending on the pier location. Hence, member releases were defined in the model to replicate these bearings as shown in the following figure. Additionally, full rotational release was given to each bearing member to allow the girder to rotate freely over the bearings.

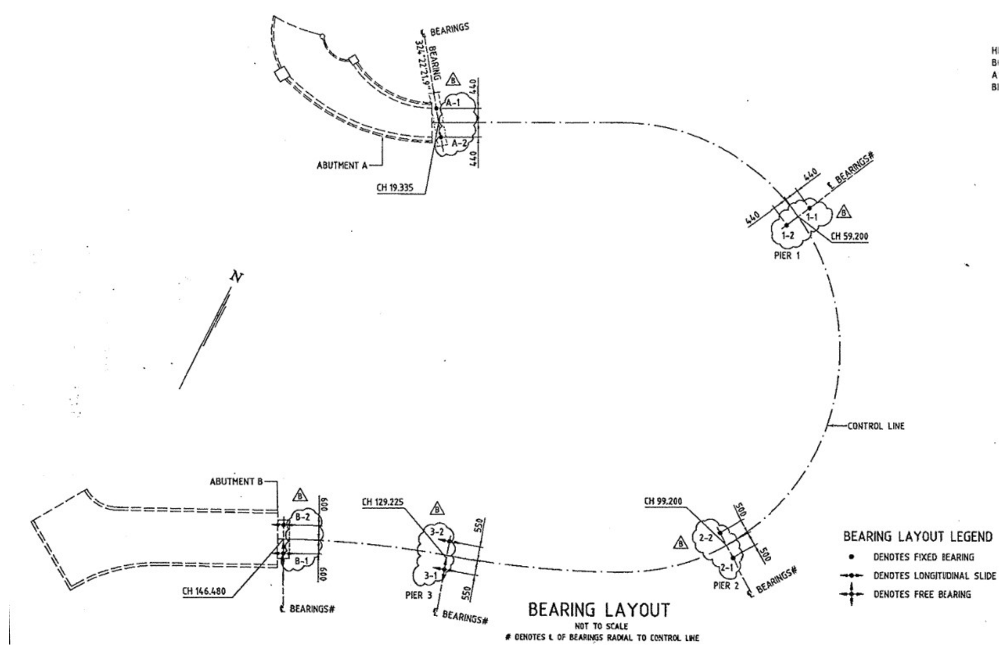

Figure 8- Bridge articulation

The splice connections that join each girder consist only of web splices. Hence these were modelled as pinned connections, which also reflected the original design.

3.1 Erection Sequence

To accurately model the forces during demolition, the erection loading had to be determined. The erection sequence in the model was designed to replicate the sequence defined by the as-built drawings. The table below outlines the construction sequence used in the model and the loads activated at each step. This loading produced the baseline for the deconstruction sequence.

Table 1: Erection sequence

SBD Stage	Load Added
Stage 1: Place Girder A	Girder A steel girder and diaphragm self-weight
Stage 2: Place Girder B	Girder B steel girder and diaphragm self-weight
Stage 3: Stress Pier 2	Stress force added to each bearing member after prestress losses
Stage 4: Place Girder C	Girder C steel girder and diaphragm self-weight
Stage 5: Stress Pier 1	Stress force added to each bearing member after stressing losses
Stage 6: Place Girder D	Girder D steel girder and diaphragm self-weight
Stage 7: Stress Abutment A	Stress forces added to north and south bearing members respectively after stressing losses
Stage 8: Place Concrete	Reinforced concrete self-weight added to entire bridge deck
Stage 9: Erect Barriers	Barrier self-weight and torque added to entire bridge deck

3.2 Removal Sequence

As discussed in the sections above, the removal sequence was constrained based off access to the bridge and in possession times of Victoria Road. Several removal sequences were considered including the reverse construction sequence, however, this limited activities that could be made concurrent restricting the programme. Eventually, the “inside out” approach was chosen as multiple workfronts were able to be created. The process went through several iterations with crane positioning and various lifting loads.

Removal of the stressing bars was a key challenge and whether these should be removed on or off the critical path. Ultimately, it was decided that the girders would be cut close to the piers leaving a “hammerhead” structure where the stressing bars and remaining girder could be removed off the critical path. These cutting locations were chosen based off required clearances to the various vehicle envelopes should the structure have to remain in a certain state with the road in operation.

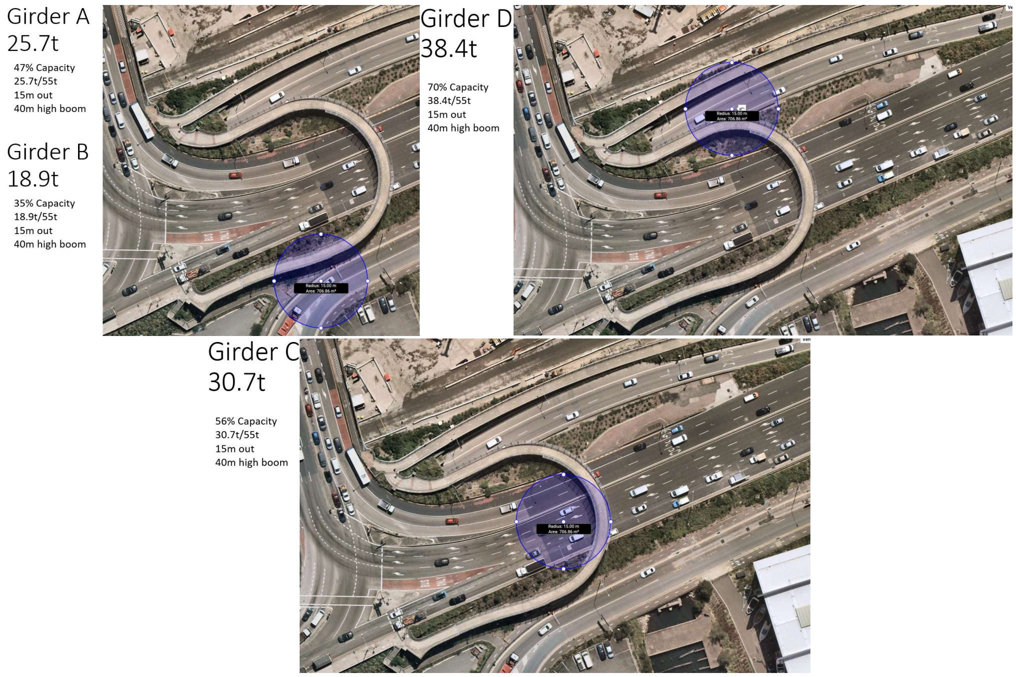

Figure 9- Examples of crane positions considered during development

The deconstruction sequence was finalised with Girder C removed first followed by Girder D, Girder B then Girder A. This required stability of the splice connections and leftover girder sections to be considered. The table below summarises the loads added/removed at each stage of the deconstruction.

Table 2: Removal sequence for Structural Analysis

SBD Stage	Description
Stage 10: Remove Girder C	Removal of Girder C self-weight, addition of construction and wind loads onto the model and manual load reversal
Stage 11: Remove Girder D	Removal of Girder D self-weight, addition of construction and wind loads onto the model and manual load reversal
Stage 13: Remove Girder B	Removal of Girder B self-weight, addition of construction and wind loads onto the model and manual load reversal
Stage 14: Removal of Remaining Girder Sections on Pier 1 and Pier 2	Removal of remaining leftover girder sections and piers. Had no impact on the structural analysis

Stage 10: Remove Girder C

The first stage of the removal was to remove Girder C as illustrated below. This was achieved by oxy-cutting Girder C at the Splice Joint C2 and then 6 metres from Pier 1 to retain stability after the removal of Girder D. However, Splice C1 is classified as a pin joint leaving a stability issue after the removal of Girder C. Hence, temporary splice plates were welded to the top and bottom flanges prevent rotation/collapse of the joint.

Temporary support brackets were added to the girder to prevent dynamic loading being transferred to the crane during the cutting operation. Additionally, an extended section of concrete above Splice C1 was also removed to reduce dead loading required for lifting.

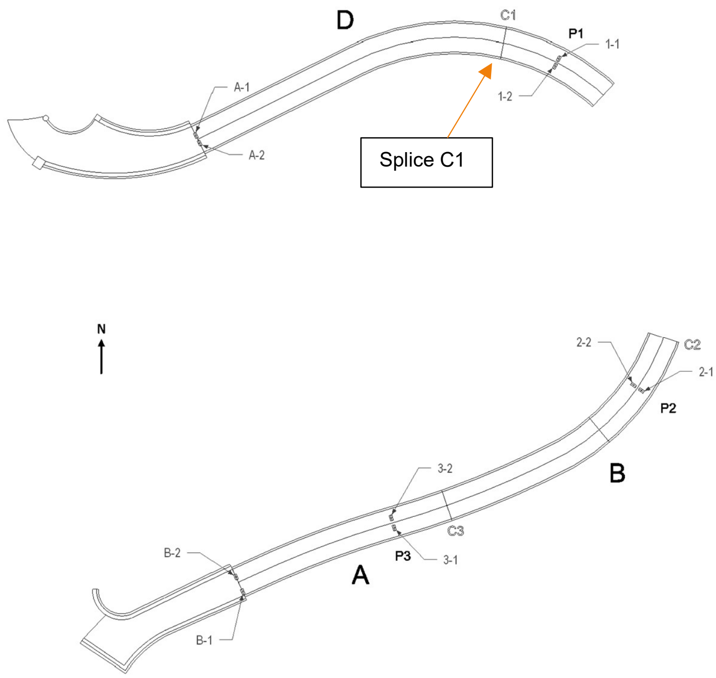

Figure 10- Stage 10

To represent this span removal in the model, the beam forces at each cut location were taken from the final stage of the construction sequence (Stage 9: Erect Barriers) and then reversed and reapplied in this stage to replicate the removal of Girder C. The construction and wind loads mentioned above were considered at this stage. This approach was adopted for all stages where the structure was removed.

To model the splice plates being added to Splice C1, the release was removed from this location during this stage creating a fixed connection.

<u>Stage 11: Remove Girder D</u>

Removal of Girder D was achieved by cutting the girder at Splice C1 and crane lifting the girder with the Abutment A spreader beam. The spreader beam located at Abutment A was decided to be removed with the girder to be able to remove the post tension bars between the girder and spreader beam off the critical path. As illustrated below, this left a cantilevered section of Girder over Pier 1 requiring measures to be carried out to ensure stability of the cantilever. Packers were inserted between the soffit of the girder and the top of the pier to provide stability.

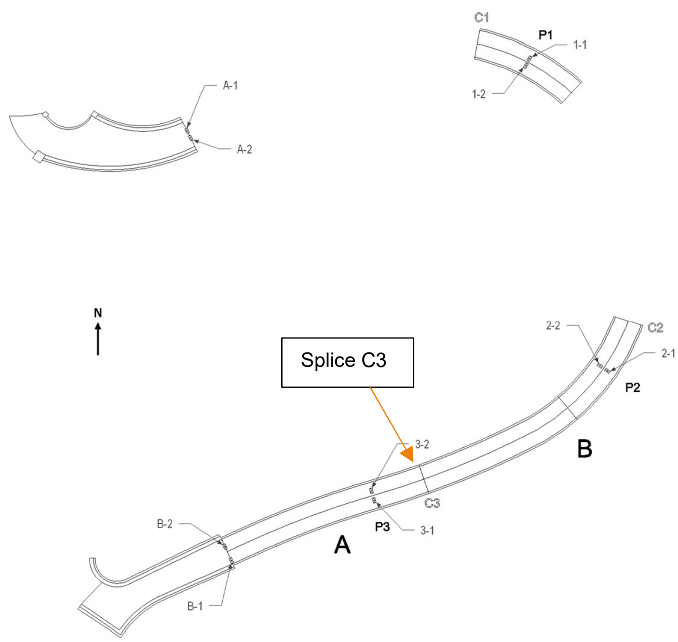

Figure 11- Stage 11

<u>Stage 12: Remove Girder B</u>

The last stage in the model is the removal of Girder B, since the removal of the leftover sections of Girder A, Pier 1 and Pier 2 had no significant effect on the structural analysis. Removing Girder B required the cutting the Girder at Splice C3 and 6 m from Pier 2 similar to removal of Girder C. As illustrated below, this left a cantilevered section of girder above Pier 2 also requiring temporary support ensure stability of this section. Prior to the removal of Girder B, longitudinal fixity was required to be installed on the connection of Girder A and Abutment B due to the free and longitudinally guided bearings that support Girder A allowing could longitudinal movement.

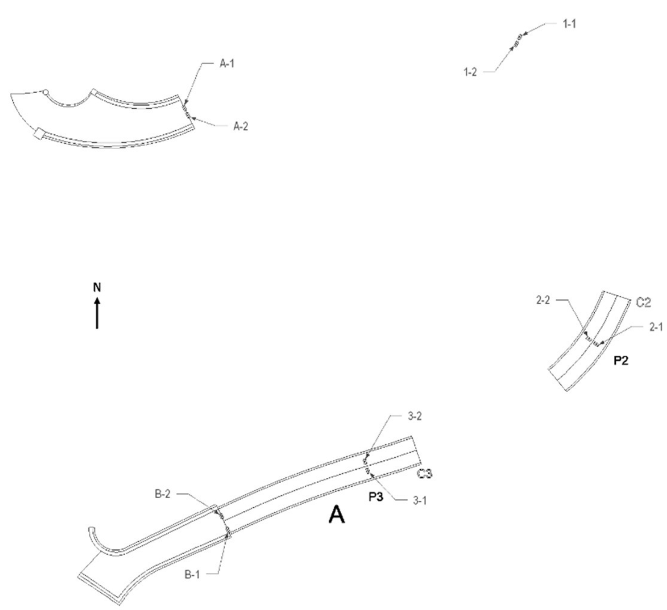

Figure 12- Stage 12

Stage 13: Removal of Girder A

The temporary longitudinal fixity at Girder A was removed prior to girder lifting.

Stage 14: Removal of Remaining Girder Sections on Pier 1 and Pier 2

To remove the remaining girder sections that were stressed onto the piers, required the removal of the post tensioned bars. Through discussions with the project, considering personnel access and safety, it was decided to cut the bars in the exposed section between the soffit of the girder and the top of the headstock. The risk of cutting stressed bars was investigated to assess the energy within the bars and potential safety concerns. Ultimately, an oversized welded bracket was designed to cover the top of the stressing bars since it was deemed a large amount of force would be released suddenly into these brackets. However, as the stressing bars were contained within the steel girder, risk of debris was considered low. To mitigate any other potential debris coming from the stressing bars, the brackets were then covered with several sand bags. Although the brackets were designed for the full potential force of the stressing bar being released, it was determined that a significant portion of the stress within the bar would be released during the oxy-cutting operation prior to full breakage of the bar.

4 BRIDGE REMOVAL

4.1 Removal

Physical removal of the bridge began first with installing the required temporary works to facilitate the expected actions that would occur during the removal process. The temporary longitudinal restraint between Abutment B and Girder A was installed just prior to the removal of Girder B as shown in Figure 13 below to restrain the bridge following the removal of Girder B.

Figure 13- Temporary longitudinal restraint

To prevent a mechanism forming following the removal of Girder C, the temporary splicing plates were required to be installed to Splice C1. These plates were installed to the top and bottom flanges as shown in Figure 14 creating a longitudinal bending moment couple.

Figure 14- Hinging Restraint

Packers were placed between the soffit of the girder and the top of the piers to provide stability following the removal of the main spans and the leftover girder portions remained on Piers P1 and P2. Lastly, the brackets covering the top of the PT bar locking nuts were welded to the deck.

Once all restraints were installed, the span removals were carried out over the course of two separate night closures of Victoria Road for the removal of Girders C and D and then for several weeks following for the removal of the remainder of the bridge. To aid the crane selection process, it was decided that the concrete deck would be removed prior to girder removal. The bridge was investigated for stability and strength without the concrete deck and it was found this did not produce any adverse effects on the bridge.

During the first closure, a mobile crane was chosen to remove Girder C as this crane did not require crane pad foundations to manage bearing pressures and was able to be setup and dismantled within the one overnight occupation. As shown in Figure 15 below, the crane was setup on the Westbound side of Victoria Road.

Figure 15- Mobile crane setting up on the Westbound side of Victoria Road

Once the rigging was attached and the project staff were ready, the contractor pre-loaded the crane with close to the theoretical girder weight to control the dynamic transfer of weight once cutting was complete. Oxy-cutting of the girders then completed and Girder C was lifted out of position. Cutting was completed at an angle to help remove the span. The girder was then transported to the project's storage yard where it was dismantled and taken off site.

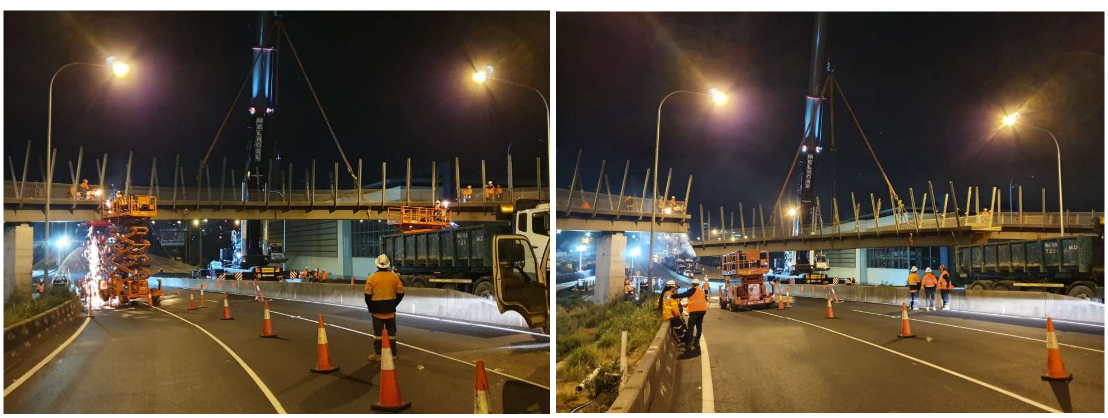

Figure 16- Oxy-cutting and removal of Girder C

Before the next night occupation of Victoria Road, Girders A and B were removed including the leftover section above Pier 2 involving the removal of the PT bars. The project did not experience significant set backs and the removal was completed successfully.

During the second closure, to avoid further disruption to Victoria Road, a larger crane was used for the removal of Girder D being set up in the storage yard adjacent to the bridge in the week prior to the closure. To reduce occupation time, it was decided that stressing bars located at the spreader beam at Abutment A would be lifted with the girder. This allowed removal of the girder through the process of just removing several bolts at the Abutment and oxy-cutting the girder close to Splice C1. The girder was then lifted to the storage yard where it was dismantled and taken off site. The stressing bars at the cross beam were cut within the storage yard. Stability of the leftover girder section at Pier 1 was provided with the remaining stressing bars and packers that were placed between the soffit of the girder and the top of the pier prior to removal.

Figure 17- Oxy-cutting and removal of Girder D

To remove the leftover girder portion located at Pier 1, cutting of the stress bars connecting the girder to Pier 1 was required. Firstly, the rigging to the crane was connected and the crane pre-loaded most of the girder weight. When the project staff were ready, the 8 no. stress bars were then cut underneath the soffit of girder. An audible popping noise was heard upon the cutting of each stressing bar and no visible debris was seen coming from the girder during cutting operations.

Figure 18- Leftover section above Pier 1

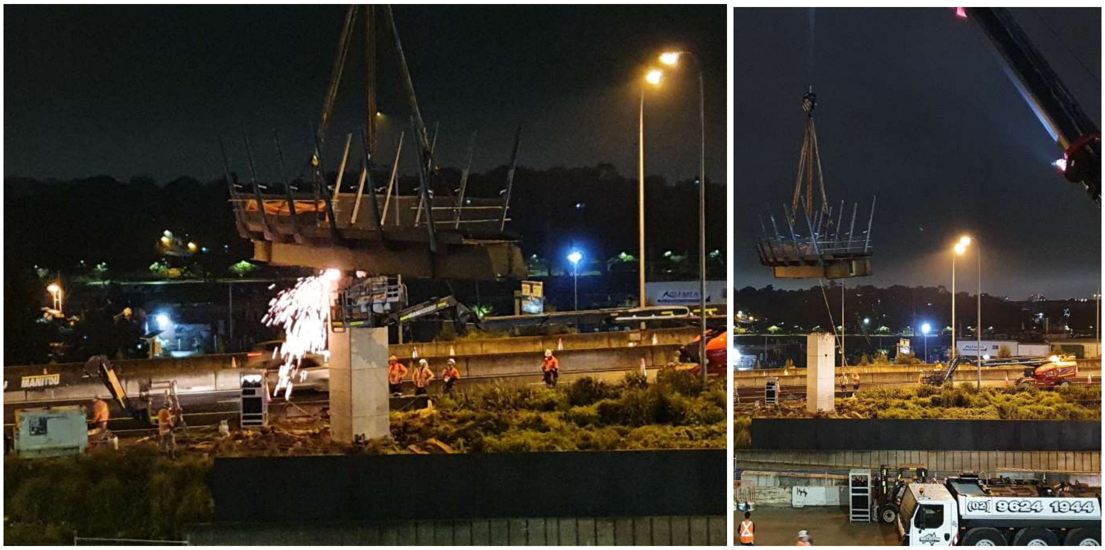

Figure 19- Cutting of the stress bars and removal of the leftover girder

Once the girders had both landed in the storage yard, the condition of the brackets covering the top of the stressing bars were inspected. No evidence of failure or damage to the brackets was observed. The girder was then dismantled and taken off site.

Figure 20- Inspection of stress bar brackets and cut stress bar

Whilst crane was still setup, Pier 1 was then also cut at the base of the Pier and removed via a predrilled corehole within the pier.

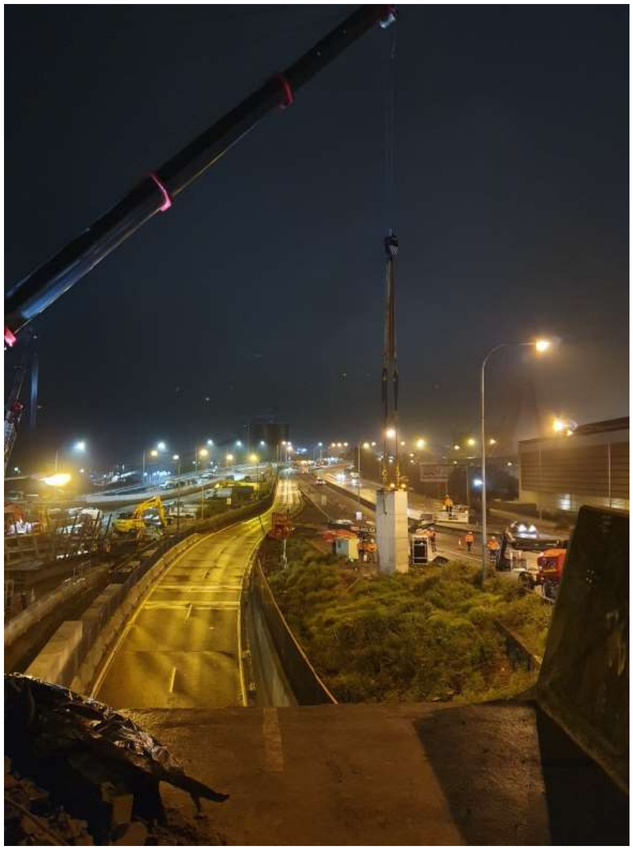

Figure 21- Removal of Pier 1

After the night closure, the remainder of the bridge being the Abutments were able to be removed without closures to the roads. No significant setbacks were observed and the removal of Beatrice Bush Bridge was completed successfully.

4.2 Comparison of Recorded and Theoretical Values

During the course of removal, the Girder weights were recorded and compared against the theoretical calculated weights. These were crucial to the design of the removal as a significant portion of design actions were driven by the self weight of the bridge. The differences between the weights was determined to be from slight variances in where the girders were cut and which barriers and mesh panels were in place at the time of removal.

As the recorded weights were found to be within +/-10% of the theoretical weight, it was deemed that the design actions on the bridge were accurate at the time of analysis. Due to the geometry of the bridge, it was found these weights drove the analysis and removal of the stressing bars.

Unfortunately, due to the time constraints of the removal, meaningful deflections were not able to be recorded. However, it was observed at the point of removal of Girder D that the deflections were relatively close to what was predicted.

Table 3: Recorded and theoretical girder weights

Lifted Section	Theoretical Weights (t)	Actual Recorded Weights (t)	Difference
Girder C	33.3	31.4	6%
Girder D	43.6	44.0	-1%
Girder B	19.7	19.3	2%
Girder A	26.8	28.0	-5%
Pier 1	16.1	16.5	-3%
Pier 2	14.0	13.7	2%

5 CONCLUSION

This paper discussed the removal methodology selected for the removal of the Beatrice Bush Bridge and described the justification for the particular method chosen. Key constraints involving access, safety and time were outlined and the key considerations involving potential behavior of the bridge behind the removal methodology were also outlined. The following removal process was explored and the key challenges were discussed. The author believes EIC Activities and the JHCPBJV provided a safe, cost-effective and efficient solution to the removal of Beatrice Bush Bridge and was completed without significant setbacks.

6 REFERENCES

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7 ACKNOWLEDGEMENTS

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8 AUTHOR BIOGRAPHIES

Matt Hennessy, Structural Engineer, EIC Activities (Proposed Speaker)

Matt has over 5 years' experience in the construction industry and currently provides design services within the EIC structures team based in Sydney. Matt has worked in a variety of project across Australia, New Zealand and South East Asia. His experience includes bridge and building design, construction engineering and project engineering.

Colin Edmonds, Technical Director – Structures, EIC Activities

Colin has over 25 years' experience as a Structural Design Engineer and currently leads EIC structures team based in Sydney. Colin has worked in a variety of countries including UK, Malaysia, Vietnam and Australia. His experience includes both civil and commercial projects with a focus on bridge design and cut and cover, especially in prestressed concrete including cast-in-situ, precast segmental, launched segmental viaducts and cable stay.