Botany Rail Duplication – Replacing a Bridge in 5 days

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Resumo

Botany Rail Duplication is a rail and bridge construction project in Sydney, Australia, commenced 2022 and due for completion end of 2023. The project involved duplication of the existing single track rail line next to Sydney Airport, operated by the freight company Australian Rail Track Corporation (ARTC), to provide a double track corridor.

The rail alignment crossed two busy roads leading to Sydney Airport, with two existing rail overroad bridges built circa 1920s through 1980s. To build the new tracks, the existing bridges had to be removed before the new bridges could be built. The new bridges also had to provide larger spans of up to 45 m to allow for more clear space below.

This paper discusses the various design and construction techniques used, with maximum use of precast concrete, to enable the Robey Bridge to be replaced during a 5 day shutdown window granted by the rail authorities and reopen the rail traffic on time.

Keywords: Precasting; temporary works; heavy lifting; railway

Introduction

To meet future demand, the Botany Rail Duplication (BRD) Project has been developed as a key initiative to improve road and freight transport through Sydney Airport and Port Botany, increasing capacity along the Botany Rail Line by providing bi-directional running on duplicated lines.

Within 3 km of new track built in the existing rail corridor, key features of the project include replacement of 2 rail bridges over the busy airport arterial routes of Robey Street and O'Riordan Street. The bridges are located in a constrained and high-traffic area situated next to Sydney Domestic Airport, making the works extremely challenging.

In February 2023, ARTC granted the first of 2 possessions to replace the first major bridge over Robey Street. Main Contractor, John Holland Group, removed the existing steel single-track rail bridge and constructed a new concrete double-track bridge in just five days, with Robey Street reopened to road traffic after three days.

The closure works included moving and installing two 36.5 m long main bridge girders over Robey Street, weighing 330 tonnes each. Twenty-four planks were also installed to form the bridge deck using a 600-tonne crawler crane and a 650-tonne mobile crane working simultaneously.

Bridge overall design

The bridge was designed in post-tensioned concrete, with two main girders on each side. The deck is made of precast concrete planks, connected to the main girders with transverse post-tensioning. Water proofing and ballast is then installed on top to allow rail tracks installation.

Substructure

To minimise the work to be done during the shutdown, the bulk of the substructure work was designed outside of the footprint of the existing bridge and prior to the possession, without requiring closing the rail traffic.

The piles were bored on either side of the existing bridge, with a cast in situ headstock on top, as per Figure 2 below.

The central headstock section was precast, with void to reduce weight to approx. 34t, and lifted into position during the rail possession period. It was connected to the previous sections using a short stitch and rebar couplers. Figures 3 and 4 below show the detail of the operation.

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Superstructure design

As with the substructure, the superstructure was designed to be built in parts to be connected to each other.

1 Two main longitudinal girders on the outside of the new bridge, each weighting over 305t, were designed to be cast next to the existing bridge. The girders are up to 4 m deep at midspan, with post-tensioning tendons stressed in stages.
2 The precast planks are landed in between the main girder on temporary outriggers. They are then stitched to the main girders with rebar couplers and are post-tensioned to form the deck of the bridge.
3 All stitches between precast elements performed during the rail possession were designed using Ultra High Performance Fibre Reinforced Concrete (UHPFRC) mixed on-site in a batching plant, to provide rapid curing and 130 MPa compressive strength. The high strength allowed to use very short rebar lap length as per the table below.

Table 1 – Rebar development length in UHPFRC

BAR SIZE	N16	N20	N24	N32	N36
DEVELOPMENT LENGTH / LAP LENGTH	160	200	240	320	360

Heat blankets were used to increase curing time of UHPFRC to attain 40 MPa strength in a matter of hours. This was critical to reduce the waiting time and start the final construction activities to be completed before opening of the new bridge.

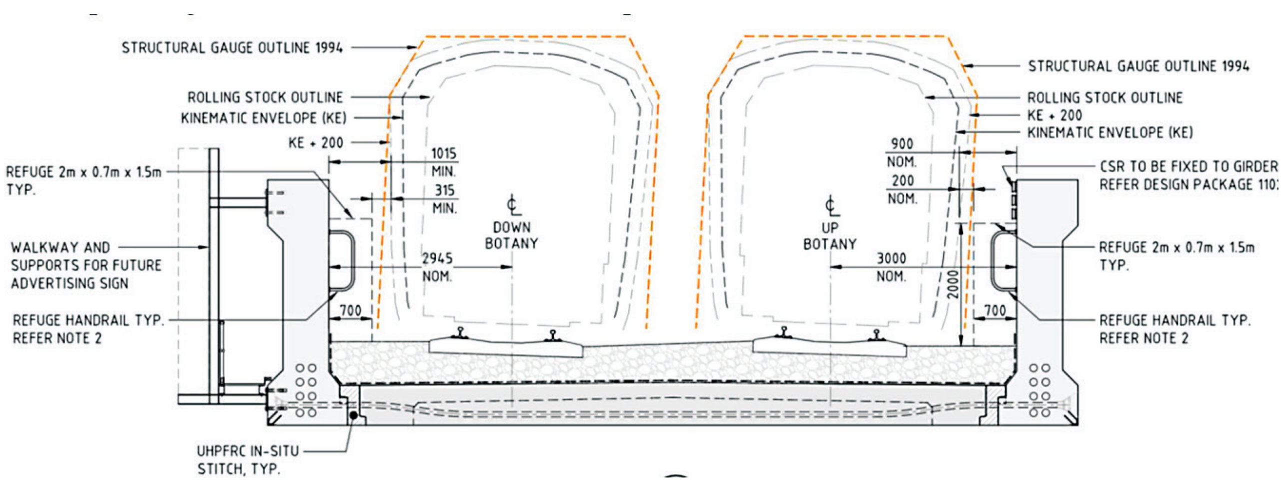

Figure 1 *– Typical cross section of new bridge.*

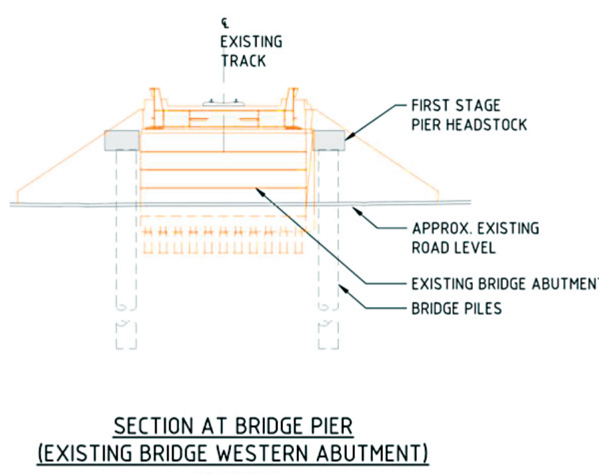

Figure 2 *– Substructure construction next to existing bridge.*

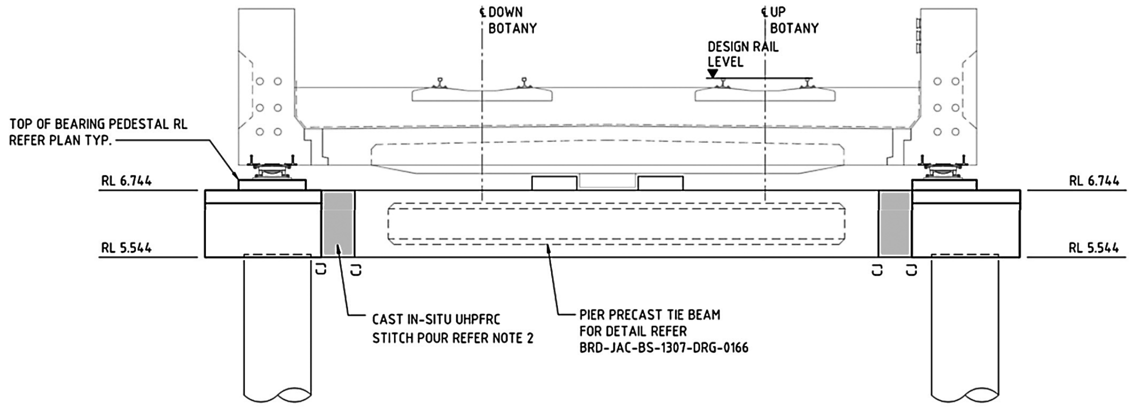

***Figure 3** – Elevation view of the precast tie beam stitched to the in situ headstocks.*

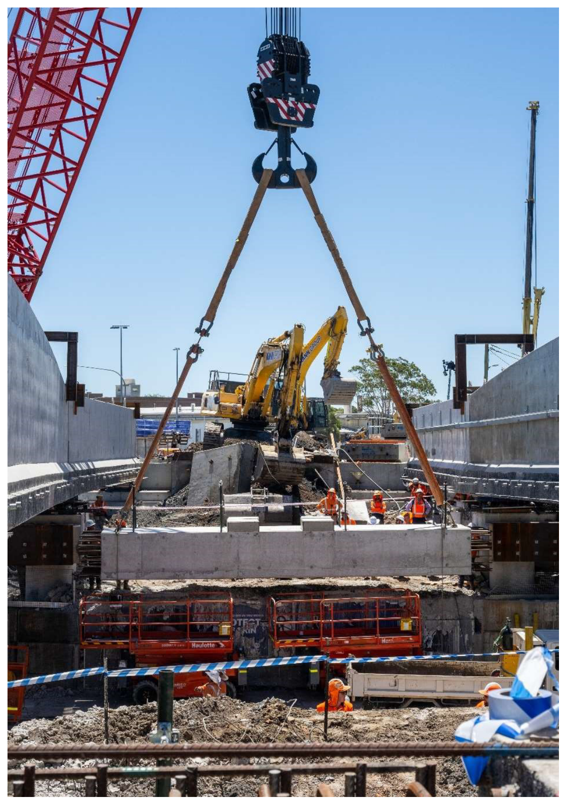

***Figure 4** – Lowering of precast crosshead tie-beam into position.*

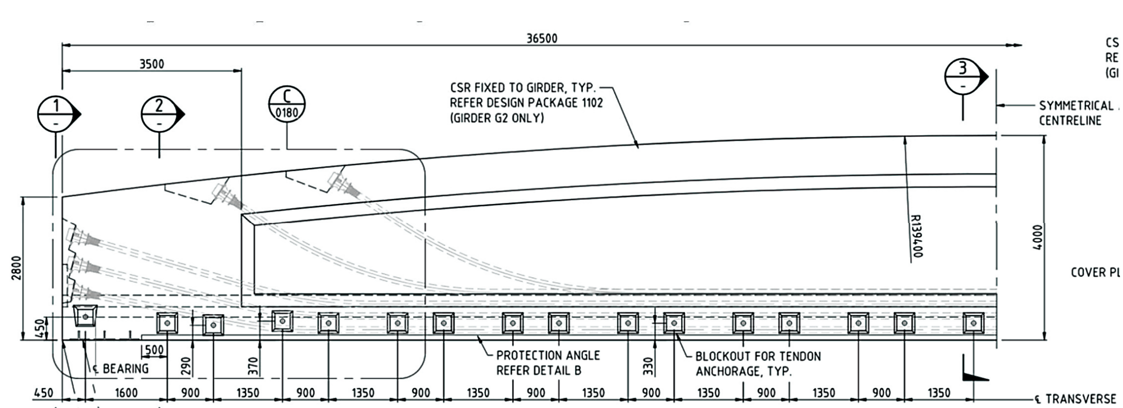

***Figure 5** – Main girder half elevation, showing longitudinal PT profiles and transverse PT anchorages*

Superstructure construction

Several innovative construction techniques were used to enable completion of the bridge assembly within the 5-day rail possession.

Before the rail shutdown, the following activities were performed:

1. A falsework structure, with a clear span over the road below, was installed connected to the already built substructure. The falsework was made of large steel welded beam to resist the weight of the concrete girders.
2. To avoid lifting the formwork over the road, the formwork was assembled with the reinforcement at the end of the falsework and slid longitudinally into position section by section. A sliding material was installed on the falsework and a pulling beam was used.
3. Because the falsework and formwork required clearance to be installed next to the existing bridge, the girders could not be cast in their final position. They had to be lowered by about 1.3 m, and then slid transversely by approximately 600mm.
   - The lowering system was made of 4 individual hydraulic jacks at each girder

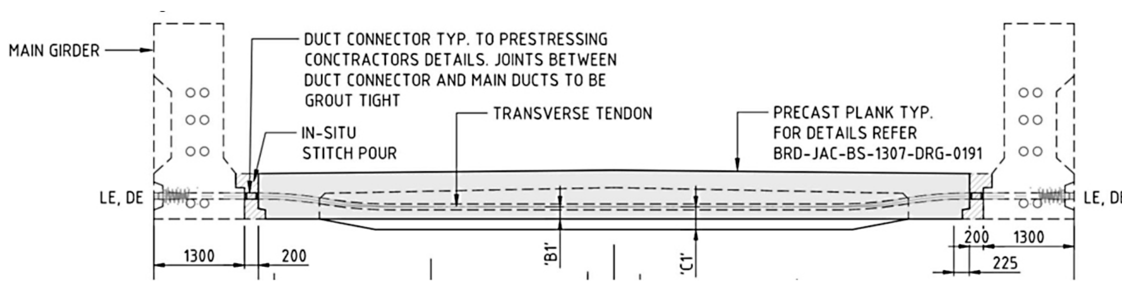

Figure 6 – *Deck section showing the transverse PT tendons.*

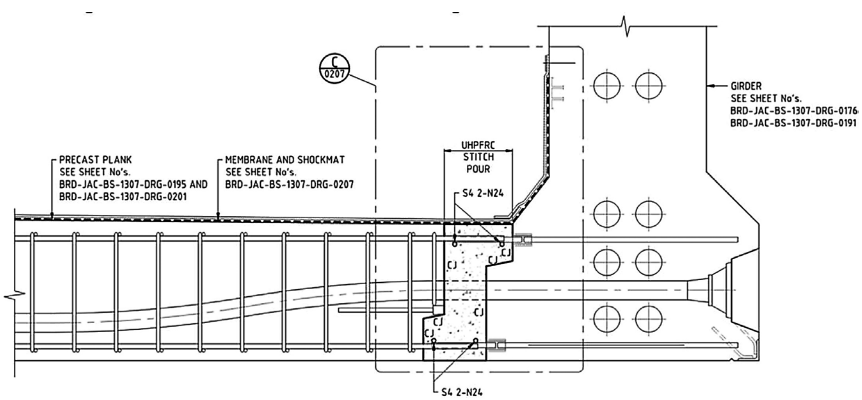

Figure 7 – *Plank to girder connection detail.*

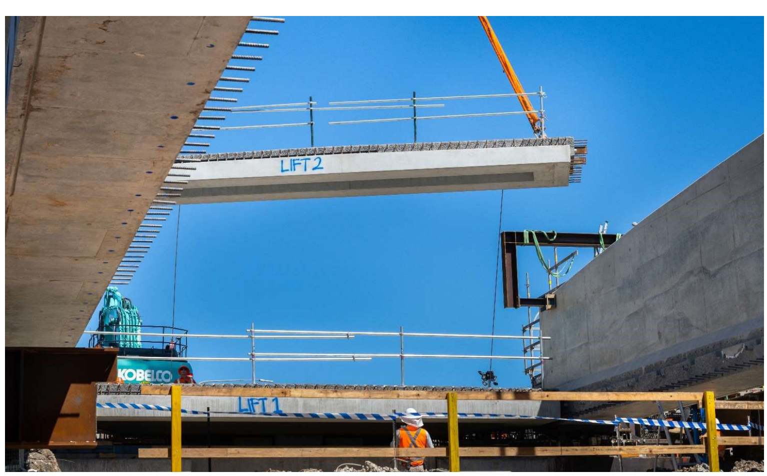

Figure 8 – *Lowering of 1st precast plank in position.*

end. The jacks are positioned on concrete packers installed in layers. They are activated using a synchro-lift system. Each double acting jack is connected separately to the synchro-lift control unit/pump on an individual channel. The jacks are controlled by stroke, so we set a maximum tolerance between each jack in the control unit & then the control unit ensures that all jacks lower together. This ensure stability of the girder being lowered.

- Once lowered, the girder is transferred to a sliding system, which is made of channel member laying on the abutment headstock acting as sliding track. Three 200 t jacks with locking nuts are placed on a spreader plate, which is pushed by a 100 t double acting jack pushing against a reaction shoe bolted to the sliding track. The sliding plate is guided inside the channel using rollers.

4 The girders are tall (up to 4m) and narrow (1.3 m wide) and therefore are at risk of overturning under unexpected wind load or accidental impact load of heavy objects being lifted hitting the girders. Therefore, a restraint system was designed to be installed until the girder reaches its final support configuration. During planks installation,

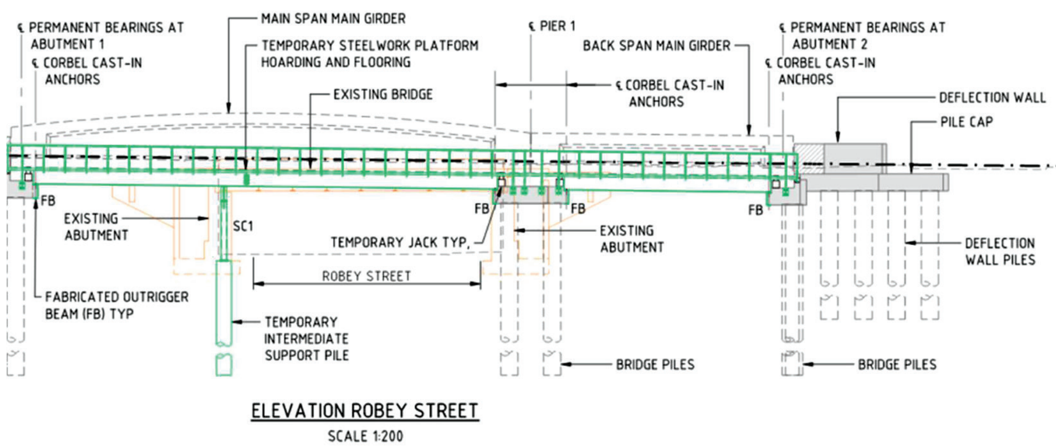

***Figure 9** – Bridge elevation view, showing falsework structure in green.*

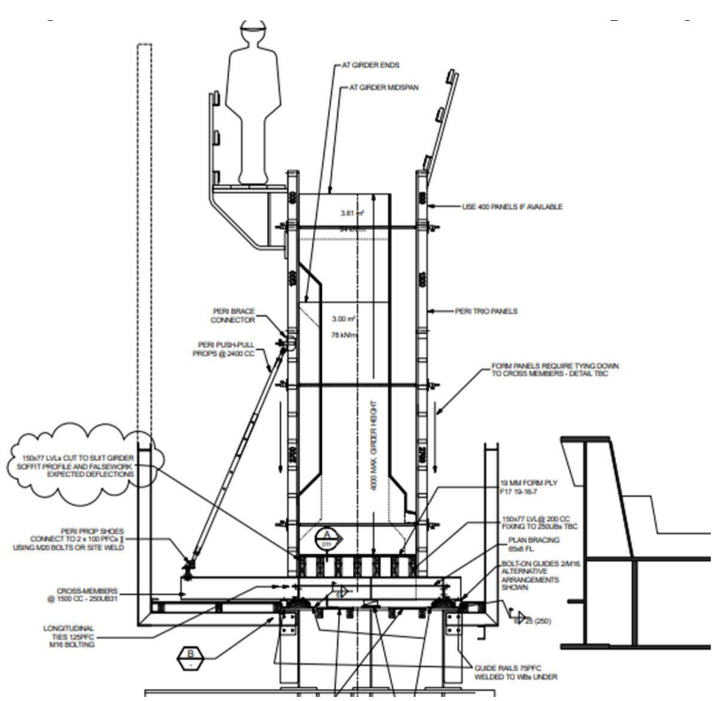

***Figure 10** – Section of main girder formwork on top of falsework, next to the existing bridge.*

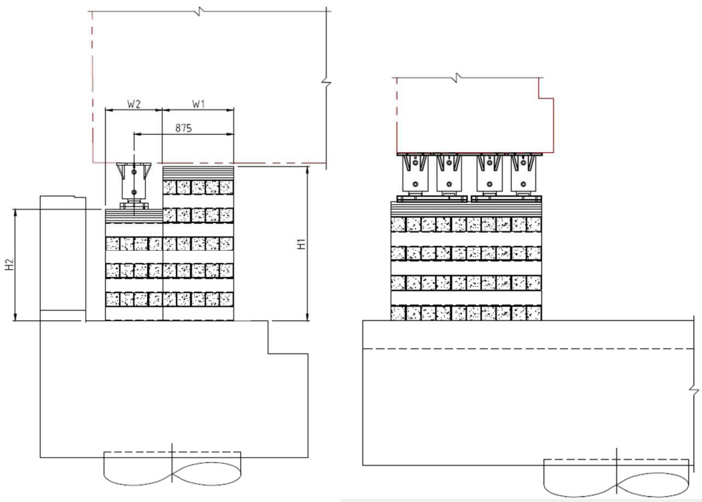

Figure 11 *– Elevation (left) and section (right) of the lowering system between the girder and abutment headstock.*

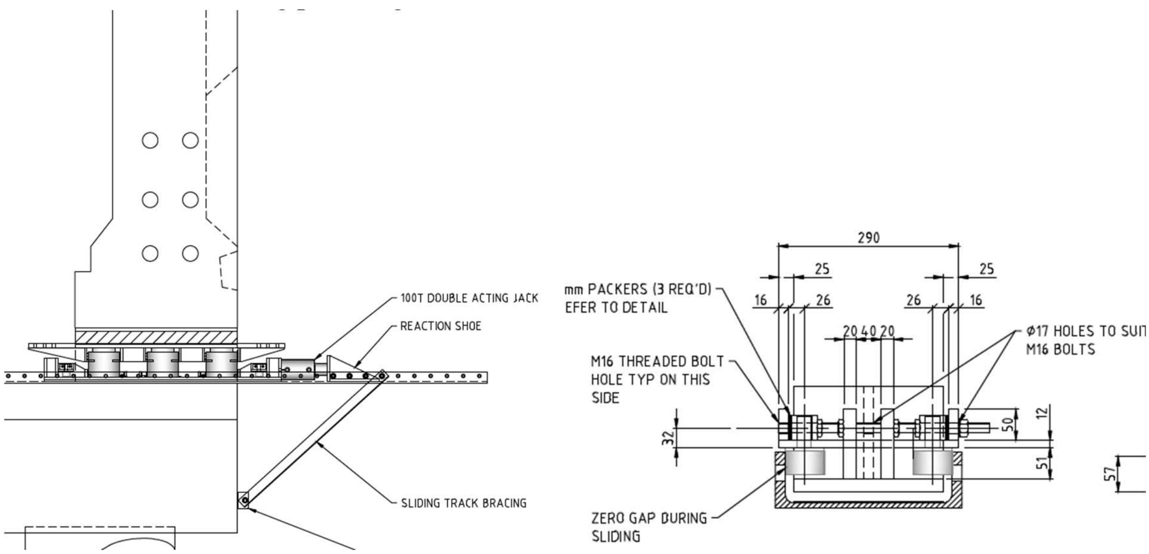

Figure 12 *– Elevation (left) and section (right) of the sliding system.*

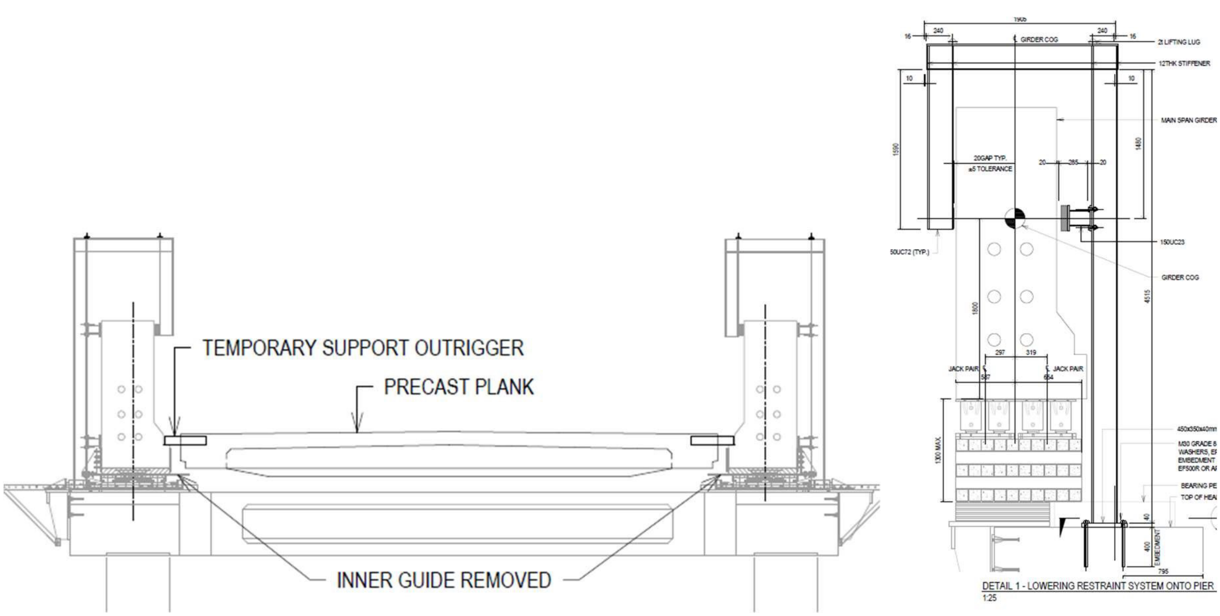

Figure 13 *– Temporary girder restraint column.*

the system also had to resist the overturning force from the plank weight eccentric introduction.

Two steel columns were designed to resist these loads and install around the girders to cover the various heights.

During the 5 days shutdown, the following critical activities were performed:

4 The existing steel bridge had to be removed. The existing bridge was a steel bridge with concrete deck, which weighted 152 tonnes. The works sequence involved jacking the bridge up first to ensure the bearings were not frozen or stick and risk increasing load on the crane. 80 t capacity lifting lugs were then designed and welded to the top of the bridge main girders. A lift study was performed, with spreader beams to equalise the load in the slings.

Figure 14 *– Photo of the girder restraint system on site.*

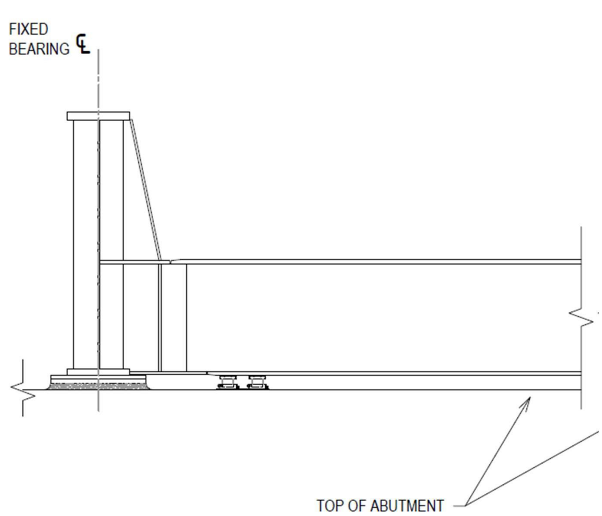

Figure 15 *– Jacking of existing bridge to free the bearings.*

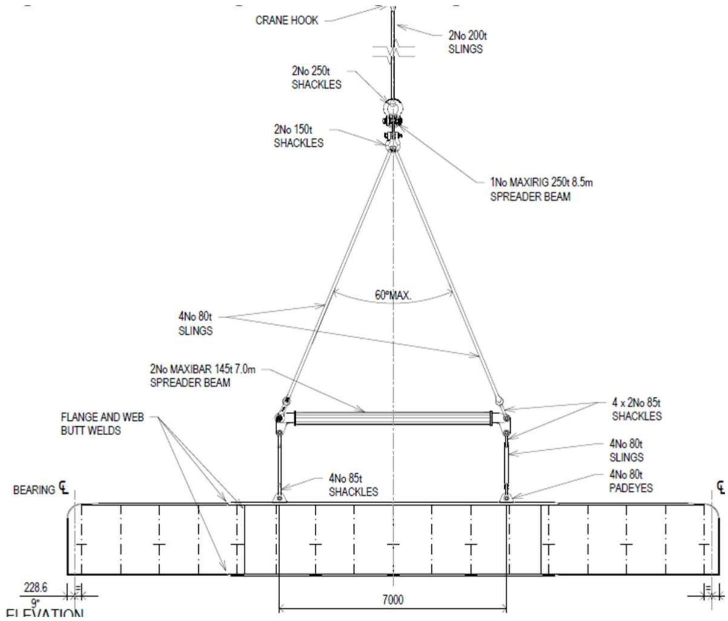

Figure 16 *– Lifting plan of existing bridge.*

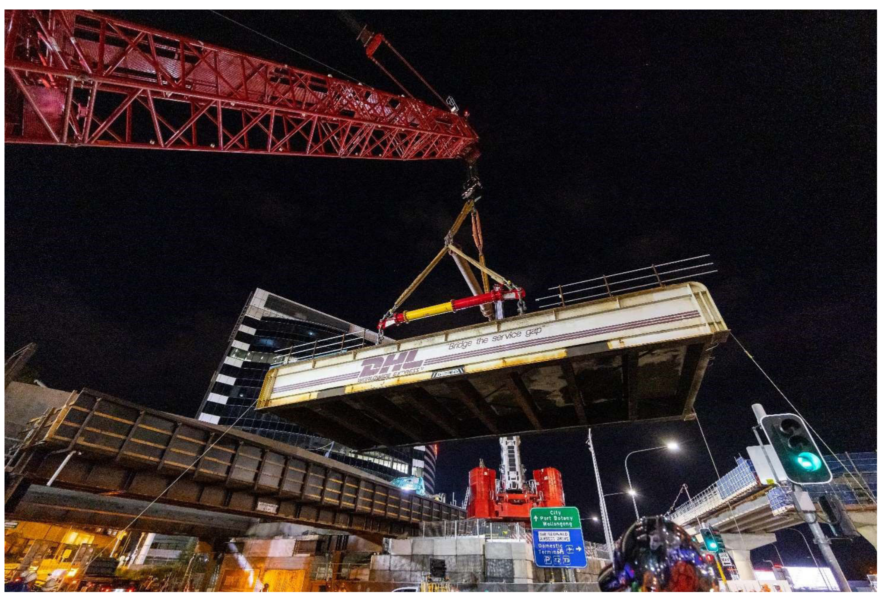

Figure 17 *– Removal of existing steel bridge.*

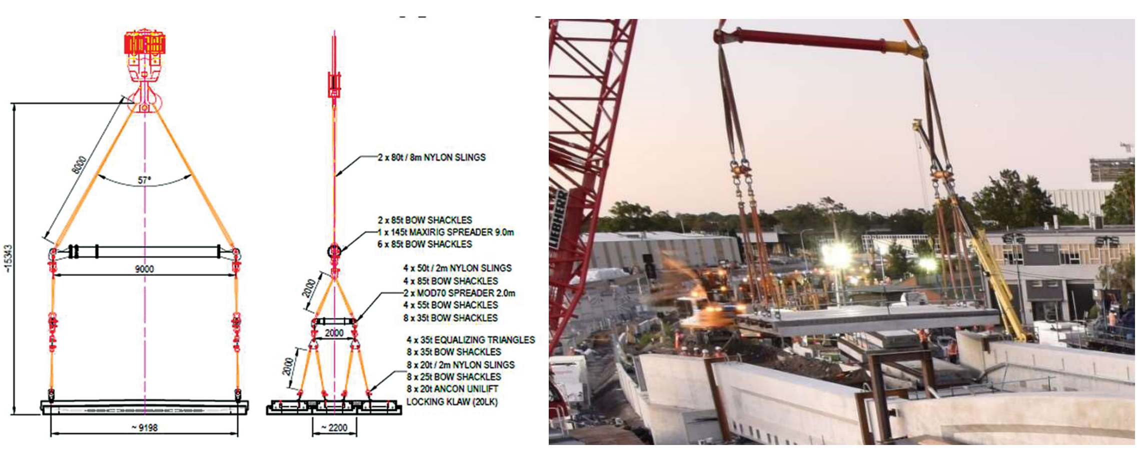

Figure 18 *– Rigging arrangement of 3 plank 90 t lift on the drawings and in photo on site.*

5 Once the existing bridge removed, the abutment and precast headstocks had to be lifted in position and connected with the stiches. Then, the same operation had to be done with the precast planks. There were 24 planks to install, each weighting on average 30t. To speed up the installation, up to 3 planks were designed to be pre-stitched and lifted together. Cast-in foot anchors were used during precasting.

6 Finally, after the planks were stitched to the main girders. Transverse post-tensioning was installed. The structure was completed and rail construction activities such as ballast mat and waterproof membrane could be installed in the remaining 3 days of the shutdown.

Overall, the site activities were highly coordinated in 24-hour shift work, to ensure works progressed as scheduled. The new bridge was reopened to rail traffic exactly 5 days after the traffic had been stopped.

Conclusion

The Botany Rail Duplication project managed to build a new rail bridge, at the same location as an existing bridge, by stopping the rail traffic during only 5 days. This was achieved using extremely careful planning, innovative structural design to maximise the activities which could be done outside the footprint of the existing rail and smart connections between precast and cast in situ elements, unable using UHPFRC, as well as clever temporary works and construction methods to assemble the different elements in the quickest way possible.

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