# IRON COVE BRIDGE DUPLICATION

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**Abstract** The $175 million Inner West Busway project was awarded to the Bridge to Bay Alliance in October 2007 and involved the implementation of a new city bound bus lane on the 3.5 km section of Victoria Road between Gladesville Bridge and the Crescent in Sydney's Inner West. The project was delivered under an alliance model with the scope including environmental and planning approvals and communications in addition to the usual design and construction. The management of the planning approvals in parallel with the design was successfully achieved and saved considerable time for the project. The alliance comprised the client, The Roads and Traffic Authority of NSW, the contractor Baulderstone PL and consultants Hyder and Manidis Roberts. In addition to the challenging road works the centrepiece of the project is a 475.525m long, 16.845m wide bridge over iron cove complimenting the existing steel truss bridge. The new bridge curves gracefully adjacent to the existing bridge and incorporates two vehicle lanes, an a.m. peak dedicated bus lane and a shared cycle/pedestrian path. The bridge design consists of an 8 span, 3.3m deep single cell post tensioned reinforced concrete box girder with a typical span length of 53m to match the spans of the existing bridge. Due to clearance requirements beneath the bridge adjacent to the abutments and the presence of an optic fiber cable pit, a single 18m supertee span connects the abutment with the first span of the box girder at the Rozelle abutment. Similarly, two supertee spans of 25m and 27.5m connect the box girder to the Drummoyne abutment, in order to provide sufficient clearance underneath the soffit. Despite initial concerns about the viability of the method due to site constraints, incremental launching was finally selected as the construction method for the box girder. Although significant additional temporary works were required as part of the ILM scheme due to the site geometry, the ILM solution provided the least impact upon the many stakeholders and was considered to have the least safety and environmental risks compared with other solutions.

The innovations included locating the casting bed in front of the abutment over the top of the first permanent pier, casting the first segment as a short unit at the rear of the casting bed, construction of a substantial temporary pier in front of the casting bed for the jacking equipment and construction of a second temporary pier for load distribution. Baulderstone entered into a sub alliance with specialist contractor Freyssinet Australia for all stressing and launching operations. Construction commenced in July 2009 and the bridge was opened to traffic two months ahead of schedule at the end of January 2011. Defect free handover of all bridge works and roadworks together with submission of all quality documentation and work as executed drawings was achieved two months later at the end of March 2011.

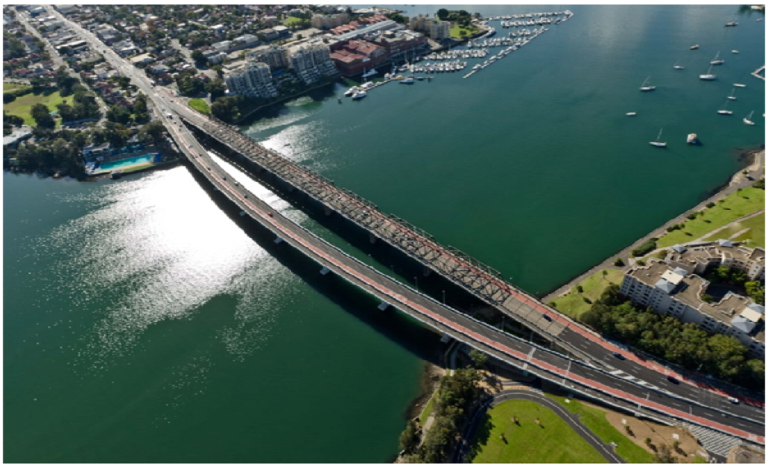

**Fig. 1.** Overall view of the completed Iron Cove Bridge between Rozelle and Drummoyne.

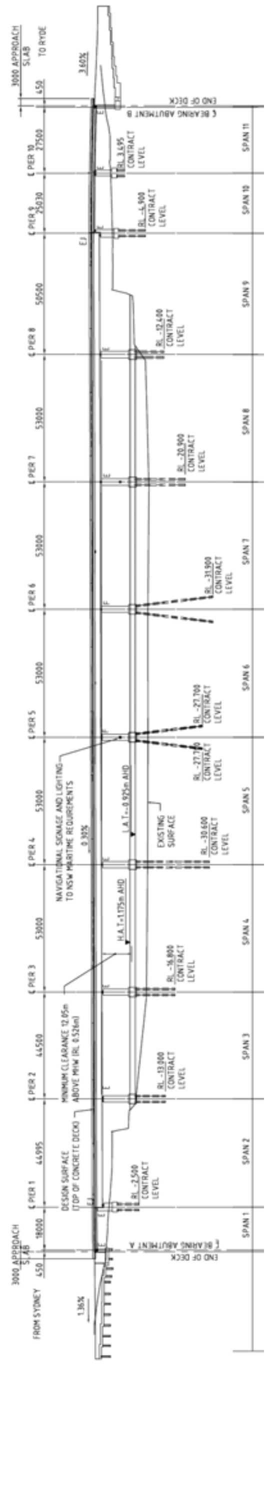

**Fig. 2.** Elevation View

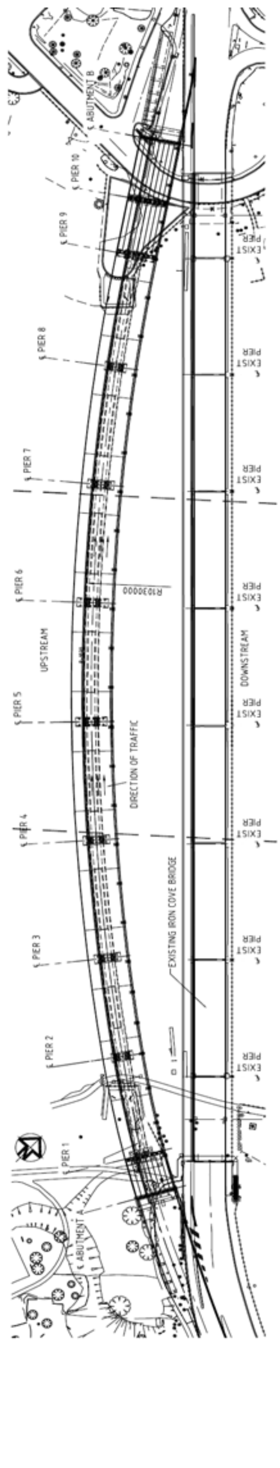

**Fig. 3.** Plan View

## Introduction

This paper outlines the construction of the bridge and focuses on the construction of the superstructure by incremental launching. The decision by the alliance to enter into a sub alliance with a specialist subcontractor for post tensioning and other specialised bridge related tasks during the early stages of the bridge development proved to be valuable in aligning design and construction schemes.

## Substructure

The marine piers are each supported on between 8 and 12 number 750 mm diameter driven tubular steel piles which were socketed 3m into rock. All piles were driven by specialist contractor Waterways Construction using a 16 tonne hydraulic hammer from a purpose built piling rig known as the “Kochi”. The piles were concrete filled for the top 8 m of pile and ranged in length between 17m and 35m. All of the piles were delivered to site pre spliced to eliminate the need for site splicing. This required a careful geotechnical analysis to accurately determine the founding levels.

The pile caps were constructed off site by Waterways as precast tub structures and were transported by barge and erected onto the pile group by the Kochi. The units were sealed, dewatered and then concrete filled following completion of the reinforcing steel installation. This method provided a rapid means of constructing the relatively large pile caps and provided a high quality exposed outer concrete surface. The piers were constructed using conventional formwork using marine based craneage.

## Casting bed arrangement

Lack of space behind the abutments dictated that the casting bed be established in front of the abutment together with a substantial temporary pier to mount the launching equipment. The steel form casting bed was located in front of the Rozelle abutment on top of pier 1 and was designed for construction of a half span length segments of 26.5 m. The form bed was mounted on a steel grillage which was supported on two spline beams during the casting operation. Side guides with 40 tonne capacity rollers were attached to the casting bed and to the upstream and downstream faces of each pier.

The casting bed was serviced by a tower crane located adjacent to the casting bed and a tower mounted concrete placing boom. Due to lack of space the rebar jig had to be located parallel to the bed rather than in the normal location behind the bed. Accordingly all cages had to be lifted from the jig into the mould in 4 to 5 elements using the tower crane thereby placing a heavy demand on hook time.

**Fig. 4.** General view of the inside of the casting bed.

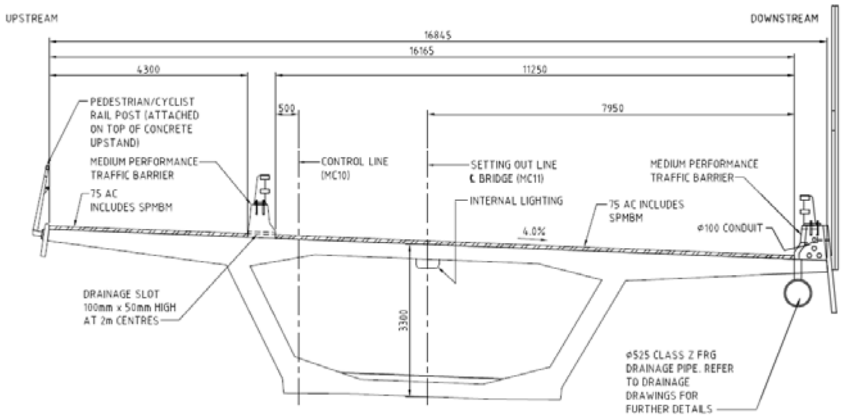


**Fig. 5.** Section of the bridge

## Segment construction

The segment construction operation was undertaken in two stages; base and webs followed by top slab with the diaphragms being cast integrally with the web pours. Typical combined deck and web pour sizes were around 340 m3 for intermediate units and 380 m3 for the diaphragm segments.  To maintain a uniform concrete placement rate over the length of the segment the tower boom pump was supplemented with a mobile boom pump for each pour. A strong focus was placed on form preparation, cleanout and concrete compaction resulting in a high quality densely compacted product without defects.

To guarantee the programme, an evening makeup shift was implemented for the duration of the box girder construction operation. This ensured that the optimum launching cycle was maintained and provided additional crane hook time for installation of the stormwater line and precast concrete parapet units using the tower crane. A rapid learning curve was experienced and typical 7 day casting cycles were achieved together with several 6.5 day cycles. The implementation of the makeup shift provided a significant programme benefit through the extended period of inclement weather throughout the latter part of 2010.

Concrete maturity testing was successfully utilised for verification of early age concrete strength in lieu of test cylinders. This method provided an accurate means of establishing the actual strength of the in situ concrete and was not prone to the strength variations which can occur in early age testing of cylinders resulting from casting, handling and ambient conditions. The early age strength results were used for determination of strength prior to lowering of the form bed and prior to stressing.

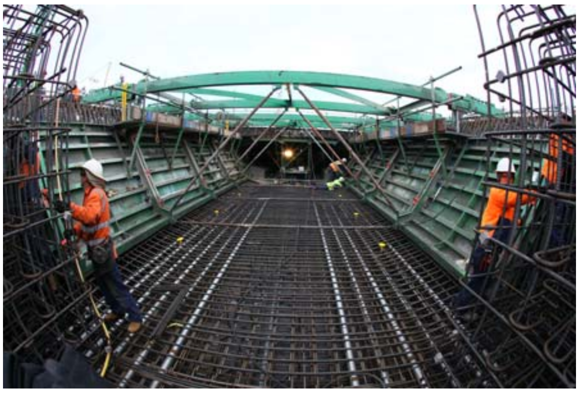

**Fig. 6.** View of the bottom section of segment being installed

## Post tensioning

The post tensioning used on the Iron Cove Bridge serves two purposes:

- ***Launching post tensioning:***

Concentric post tensioning was used in the top and bottom flange of the box girder to carry the temporary loads imparted on the structure during the incremental launching operation. A total of 233T of strands was used for the 16 segments of the bridge.

13 & 19 strands tendons were used for the launchings and were installed in a straight layout into the top and bottom flanges of the box girder. The bottom ducting was prefabricated in the rebar jig together with the reinforcement cage and was subsequently lifted into the casting bed with the cage for the first stage of the construction cycle. The top tendons were installed in situ as part of the second stage pour. 13 strands tendons were installed in the cantilevered deck slabs for the 4 first segments only.

**Fig. 7.** Prefab installation of Bottom ducting

**Fig. 8.** In situ top ducting installation

Typically 12 tendons were installed in each flange (24 tendons per segment) but only 8 of them were stressed before every launching operation. Each tendon extended through 3 segments and as such all tendons were overlapping. In order to avoid the use of couplers and cast in dead end anchors, blisters were constructed inside the box girder in the top and bottom locations enabling conventional anchors to be used. This method made the installation of strands more flexible as the threading did not affect the casting operation. During the typical cycle bottom tendons were threaded after the first pour and top tendons were threaded prior the second pour, allowing a fast stressing operation when concrete transfer strength was reached.

The stressing was carried out using two jacks in parallel on the top and bottom flanges. The tendons were stressed from one end only at the construction joint location. The blisters provided a good alternative for re-stressing should it have been necessary.

**Fig. 9** .Stressing Jack threaded on top tendons

**Fig. 10.** Blisters inside the box girder. Dead end anchors are visible with strands uncut

- ***Continuity post tensioning:***

The continuity tendons were installed in the webs in a draped arrangement and were not required for the construction process. Accordingly the continuity tendons were only stressed upon completion of the launching operation. These 31 strands tendons provided the deck with sufficient capacity to resist the forces applied to the deck when the bridge is opened to traffic.

Typically the 31 strand ducting was prefabricated in the rebar jig together with the web reinforcement of the first stage pour. The threading of strands commenced when the bridge launching operation was close to completion and tendons were subsequently stressed when the bridge reached its final position. The fixed bearings located at pier 5 and 6 had to be relocated into their permanent position prior to commencement of stressing.

The continuity tendons overlapped on 3 spans and were 160m long. Due to their length these tendons were stressed inside the box girder from both ends. Continuity tendons were stressed from the face of internal diaphragm using a purpose built lifting frame designed for the narrow access to anchors in the top corner of the box.

**Fig. 11.** Stressing continuity tendons from Segment 1

**Fig. 12.** Stressing continuity tendons from the diaphragm inside the box girder

## Launch nose

Freyssinet Australia designed, supplied, installed and operated the launch nose. The purpose of the nose is to reduce the high negative bending moments the superstructure is subjected to during the incremental launching operation.

The launch nose was a 75T steel structure composed of two parallel main girders. The overall length was 31m, which is 60% of the typical span, and the height varied from the tip to the connection base. Due to site constraints the nose was split in 3 segments of 8, 12 and 11m allowing the steel structure to be gradually dismantled when it passed over the last launching pier. Space beyond the last pier was restricted as the last approach span was already completed prior the launch completion. The 3 segments were connected by way of bolted splice connections. Structural rigidity was provided by lateral cross braces bolted to each girder.

**Fig. 13.** Launch nose at the last launching pier P9

**Fig. 14.** Launch nose has just been jacked up onto launch pot bearings.

The structure of the launch nose was straight but it was connected to segment 1 with a predetermined angle in order to follow the bridge alignment curvature. The nose was fixed to the bridge superstructure by 50mm diameter stress bars cast-in to the adjoining bridge segment 1.

The structure included two curved steel beams rolled to the radius of the bridge segments. These beams provided a lateral guide for the side guides rollers. The “side guide beams” extended over the full length of the launch nose acting as a continuation of the plane of the bridge segments and maintained the same curvature, alignment, and orientation. This ensured that an accurate alignment of the superstructure was maintained during the launching process.

To overcome deflection of the launched cantilever a steel jacking box was provided at the tip of the launching nose. The hydraulic jacks in the box raised the tip of the nose to the level of the launching bearings as it continued to slide over the bearings.

Due to the limited space available the launch nose was fully assembled adjacent to the casting bed then lifted into the bed. Due to lifting limitations the nose was installed at the rear of the casting bed and then dragged forward into position in order to cast the first segment. After segment 1 was poured the first launch was undertaken using a similar pulling system using stress bars. At this stage the Eberspächer launching jacks were unable to be used for the launching as the weight over the jacks was insufficient to develop the necessary friction.

**Fig. 15.** Launch nose fully assembled and lifted into the casting bed

**Fig. 16.** Launch nose dismantled by section as it passes over Pier 9

## Launching system

The Eberspächer launch system relies upon sufficient friction being developed between the bridge soffit and the lifting ram contact surface for the shifting jacks to overcome the sliding resistance of the bridge. An Eberspächer jack is a combination of two kinds of jacks that allow the lifting and the shifting of the bridge. The units provided for the Iron Cove bridge included:

- • 2x 1100T lifting jacks (2200T total lifting capacity)
- • 6 x 150T shifting jacks (900T total shift capacity)

The two launching jacks were installed on a temporary pier in front of the casting bed. This unusual arrangement was dictated by site area restrictions. The lifting jacks on the Eberspächer system are mounted on a sliding plate, enabling the shifting movement to occur with the jack in the raised position.

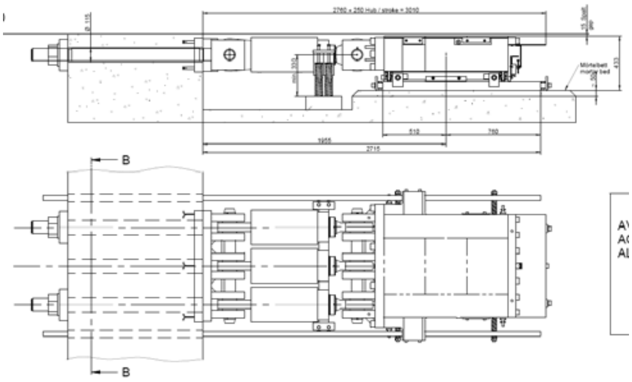

**Fig. 17.** Section & plan view of the Eberspächer jacking system

**Fig. 18.** Eberspächer during installation on TP1

Two Eberspächer launch jacks were used in parallel for the launching process and were synchronized in order to apply uniform forces to the structure. The double acting rams on the shifting jacks had the capacity to move the bridge backwards as well as forward. This provided a recovery mechanism in the event of problems being experienced during launching.

The steps of a typical launching operation are as following:

1. 1. Lift the bridge (brake saddle is cleared)
2. 2. Shift the bridge (forward or backward)
3. 3. Lower the bridge on the brake saddle and retract lifting jacks
4. 4. Retract shifting jacks

Between two lifting operations the bridge remains seated on two brake saddles installed behind the jacks. These saddles consist of steel gripping pads that lock the superstructure due to friction and prevent movement between launching operations.

The sequence was repeated as many times as necessary to launch each bridge segment. The maximum stroke of shifting jacks is 250mm. A typical segment was 26500mm so a launching operation needed 106 launching sequences to achieve the full launch. As a launching cycle was between 2 and 3 minutes long depending on the speed used, the overall launching operation was around 4 hours.

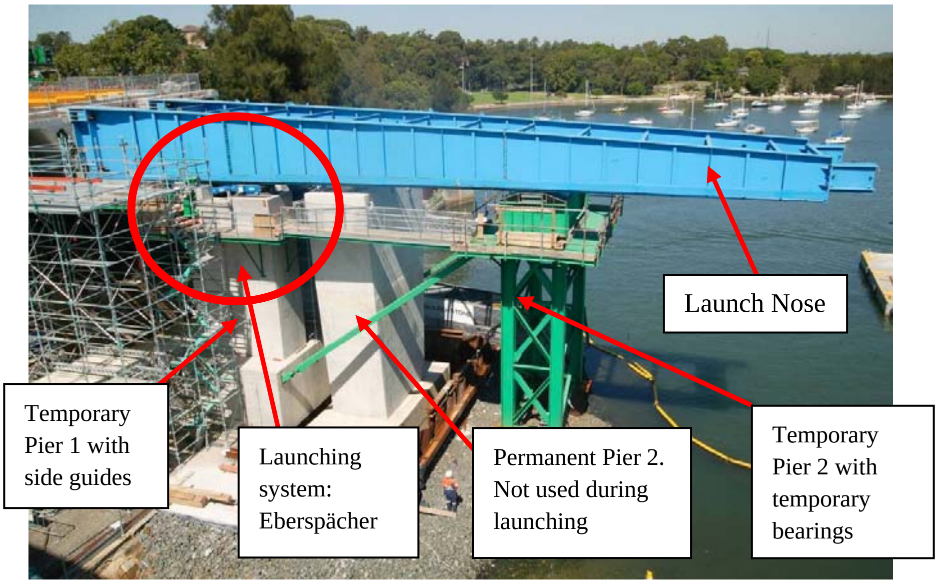


**Fig. 19.** Launching system setup

## Launch over pot bearings

An innovative feature of the project was the successful use of launch over pot bearings. The use of this system simplified the post launch operations and provided significant benefits in program and safety. The successful use of launch over pot bearings in Australia has been uncommon.

Freyssinet Australia designed, supplied, installed and monitored all of the pot bearings.

Of the 10 permanent piers on the project only 7 were used for launching. The only temporary bearings were located on Temporary Pier 2. Two pot bearings were installed on every permanent pier and the bearings on the piers that were involved in the launching were dual-purpose pot bearings.

Dual purpose pot bearings were installed on P3 to P9. They were dual-purpose in a sense that these bearings incorporated a temporary sliding surface on top of the permanent bearing which was removed upon completion of the launch operation.

The launch over bearings also incorporated a fuse system designed to prevent any damage to the pot bearing during launching in the event that a sliding pad was inserted upside down or that the longitudinal force on the bearing exceeded the design force for any reason.

**Fig. 20.** Bearings being lifted on top of pier


**Fig. 21.** Bearings in temporary position. The launch nose slides over it.

Typical sliding pads were inserted between the stainless steel sheet and the soffit. The bottom face of the sliding pad covered with PTFE remains in contact with the stainless steel sheet to provide a low friction sliding plane. Friction is assumed to be between 4% and 6% at start-up and down to 2% while moving

After launching completion the dual-purpose pot bearings were shifted into their permanent position by jacking up the deck beneath the girder web above the pier and relocating the pots to the predetermined permanent location. The gap between the bearings and the deck soffit at around 20mm was then grouted. A force of more than 2000T was required at each pier to lift the deck.

The use of launch over pot bearings provided an important benefit at the end of the project when time was critical and access was limited. The safety benefit of eliminating the requirement to exchange temporary bearings for permanent was considerable.

**Fig. 22.** Jacking of the deck and shifting of pots to their permanent position

**Fig. 23**. Bearings completed: shifted, bolted and grouted on their permanent position.

## Conclusion

The use of the incremental launching method for construction of the Iron Cove bridge duplication resulted in an efficient and high quality structure which was completed on budget and ahead of schedule. The adverse impact on the many stakeholders was minimized by the use of this method and the safety outcome was exemplary. The alliance initiative of entering into a sub alliance with a specialist subcontractor early in the planning stages was reflected in the outstanding result.