INNER WEST BUSWAY
NEW BRIDGE OVER IRON COVE

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ABSTRACT

The $175 million Inner West Busway project was awarded to the Bridge to Bay Alliance, comprising of the client, The Roads and Traffic Authority of NSW, the contractor Baulderstone and consultants Hyder and Manidis Roberts, in October 2007.

The Inner West Busway combines new road infrastructure, including a new 475 m long, 16.8 m wide bridge over the Iron Cove complimenting the existing steel truss bridge, and an intelligent traffic system that set new benchmarks for transport design ingenuity.

The result is a 3.5 km integrated traffic solution which maintained the existing lane capacity for peak direction traffic while providing a new city-bound bus lane in the busy morning peak. In addition to the public transport improvements the project also delivered substantial benefits to the local community; including the highly-regarded 'Constellation Playground' in King George Park, and extensive improvements to local cyclist and pedestrian facilities.

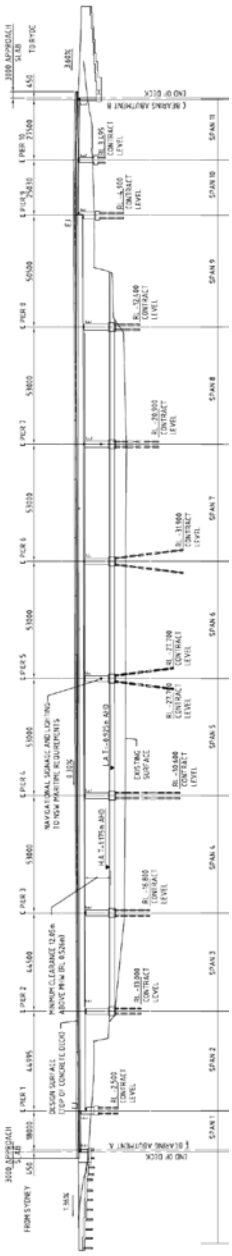
The project leaves a legacy of exceptional solutions and Australian first-time achievements with wider applications for the industry at large, including:

- the first to launch a bridge from in front of the abutment;
- the first large span bridge to launch over permanent bearings in Australia;
- the first in NSW to install corrosion ladders;
- the first to use a Quick-change Moveable Barrier System in Australia and the first in an urban environment;
- the first to replicate line marking with LED in-pavement lighting; and
- the first to combine a pedestrian fence and narrow slip-formed trief kerb.

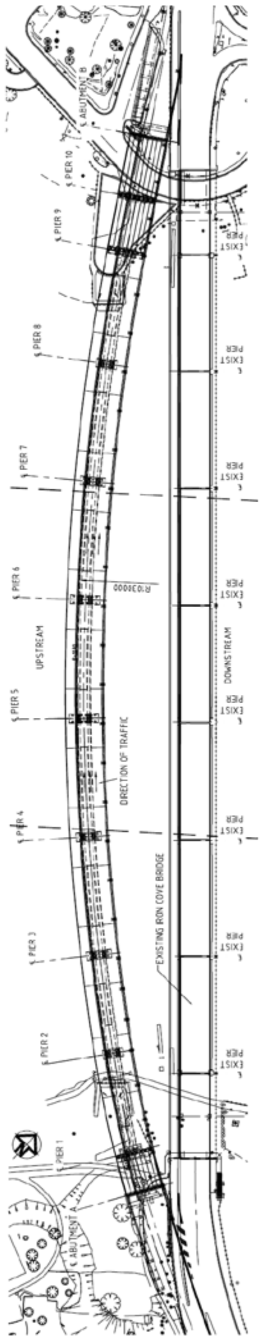
The bridge was opened to traffic two months ahead of schedule in January 2011.

Defect free handover of all bridge works and road works together with submission of all quality documentation and work as executed drawings was achieved in March 2011.

Key Words: Iron Cove Bridge, segmental launch system, launch nose, pot bearings.



Elevation



Plan view

INTRODUCTION

This paper specifically 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 were supported on between ten to twelve 750 mm diameter driven tubular steel piles which were socketed three metre into rock. The two central piers five and six were each supported on twelve raking piles due to the bridge fixity at the mid-span. All other piers are supported on ten vertical piles. 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 with a plug for the top eight to twelve metres of pile and ranged in length between 17 m and 35 m.

All of the piles were delivered to site pre-spliced and driven full length to eliminate the need for site splicing. This required a careful geotechnical analysis to accurately determine the founding levels. Rigorous underwater inspection was also required at each pier location to determine the location of submarine cables as well as to ensure that no debris remained from the original nineteenth century bridge located on much of the alignment. No obstructions were encountered and the piling was completed one month ahead of schedule in December 2010.

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 which had a 200 tonne maximum lift capacity. A robust access platform was erected around the perimeter of the precast unit prior to removal from the casting yard. This provided access throughout the entire construction stage of the substructure and superstructure.

After erection 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 for the box girder were rectangular in plan and measured 6.5 m by 2.5 m at the top of the pier. The piers are a solid section and tapered on a 1:12 slope on the wider rectangular face down to a minimum of around 4.5 m at the base reducing the visual weight of the structure and saving up to 32 m^3 of concrete per pier.

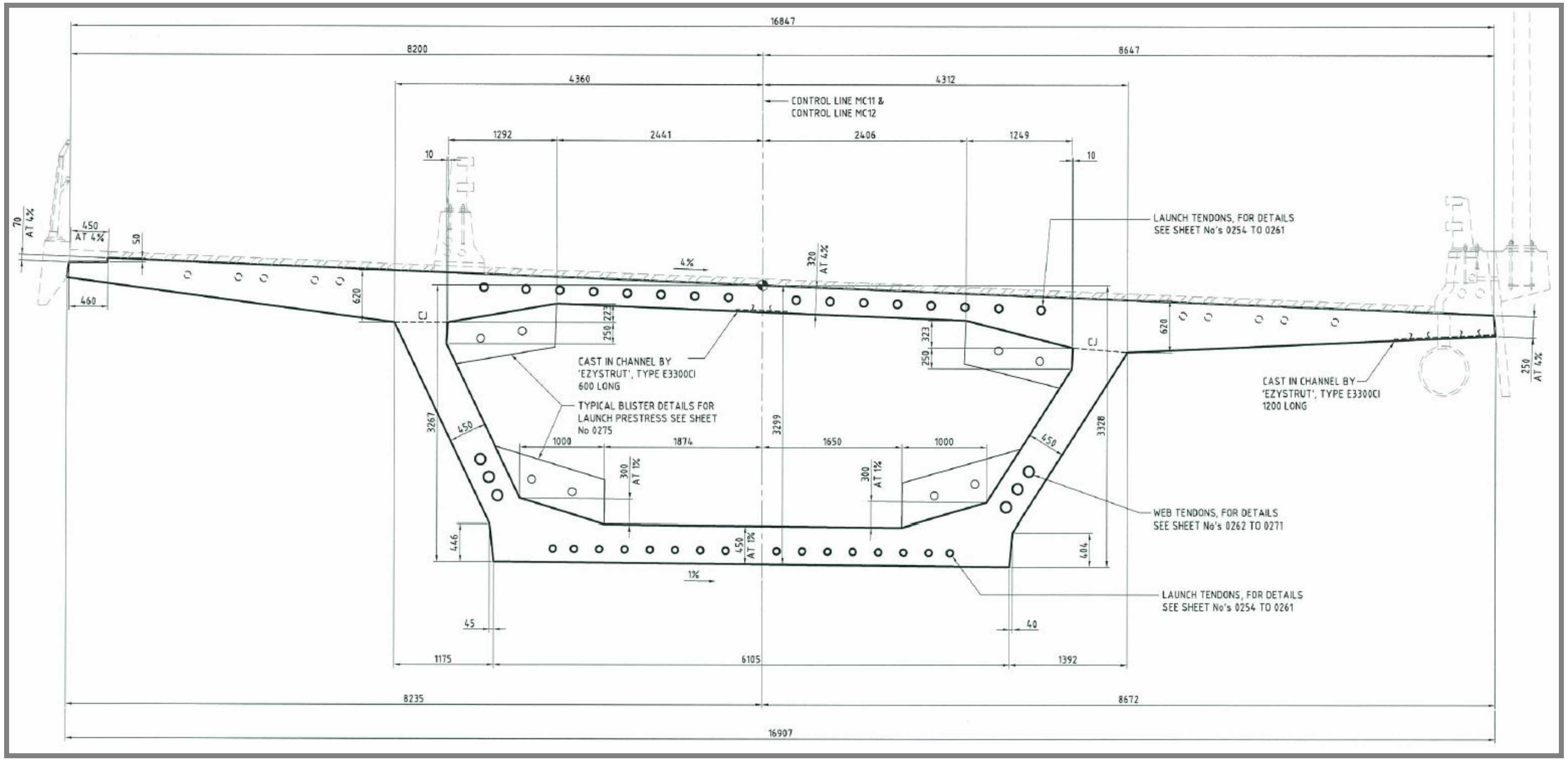
The piers were constructed in lift heights of up to six metres using conventional formwork with marine based craneage and a service barge. The reinforcing cages were prefabricated on the service barge and lifted into position. Concrete was placed by pump using a secondary pump located on a barge adjacent to the pier as a placing boom.

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 one 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 four to five elements using the tower crane thereby placing a heavy demand on hook time.

Casting bed preparation



Typical Cross Section of 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 m^3 for intermediate units and 380 m^3 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 program, 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 seven 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. Test cylinder results after 28 days were utilised for verification of permanent works strength in accordance with code requirements.

POST TENSIONING

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

1) 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 233 tonne of strands were used for the 16 segments of the bridge.

Rebar cage installation

Between 13-19 strands tendons were used to provide launching capacity and were installed in a flat arrangement in the top and bottom flanges of the box girder. The bottom ducts were bunched in plan to clear the opening in the diaphragm. 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. Thirteen strand tendons were installed in the cantilevered deck slabs for the first four segments and 19 strand tendons were utilised for the remainder.

Rebar Jig installation of Bottom ducting

In situ top ducting installation

Typically twelve tendons were installed in each flange (24 tendons per segment) but only eight required stressing prior to each launching operation. Each tendon extended through three segments (approximately 80 m) and as such all tendons overlapped. 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 to 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 although no cases of duct blockage were encountered.

Stressing blisters inside box girder

Launch tendon stressing

2) 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 strand tendons provided the deck with sufficient capacity to resist the live load deflections resulting from 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 five and six had to be relocated into their permanent position prior to commencement of stressing.

The continuity tendons overlapped on three spans and were 160 m 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 and the diaphragm.

Stressing continuity tendons from Segment 1.

Stressing continuity tendons from the diaphragm inside the box girder

LAUNCH NOSE

The purpose of the launch nose was to reduce the high negative bending moments imparted on the superstructure as the deck passed over the last pier during the incremental launching operation. The nose was purpose built for the project and was provided and operated by Freyssinet Australia.

The launch nose was a 75 tonne steel structure consisting of two tapering parallel main girders. The overall length was 31 m, which was 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 eight, twelve and eleven metre allowing the steel structure to be gradually dismantled when it passed over the last launching pier during the final launching operation. Space beyond the last pier was restricted as the last approach span was already completed prior the launch completion. The three segments were connected using bolted splices and structural rigidity was provided by lateral cross bracing bolted to each girder.

Launch nose jacking box on the bearings

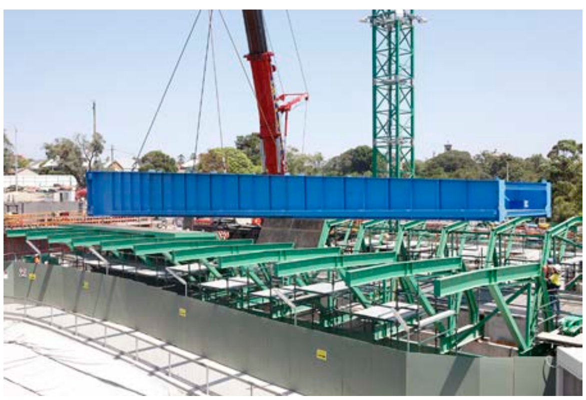
75t launching nose – pier 6

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

The structure included two curved steel beams rolled to the radius of the bridge segments which 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 (typically around 150 mm) 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 one 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.



Launch nose fully assembled and lifted into the casting bed

Launch nose dismantled by section as it passes over Pier 9

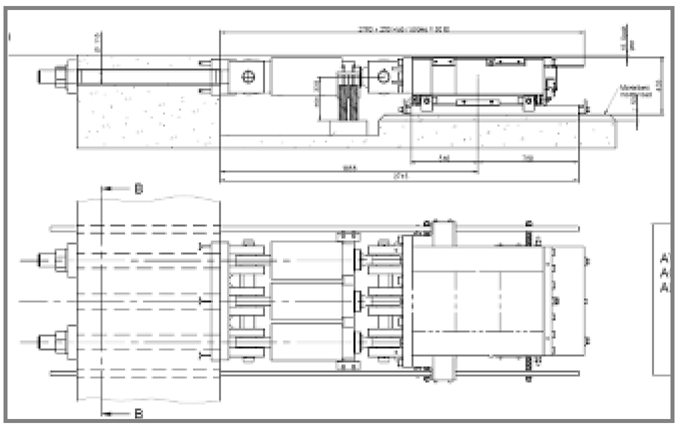
LAUNCHING SYSTEM

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 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.

The units provided for the Iron Cove Bridge included:

- 2x1100 tonne lifting jacks (2200 tonne total lifting capacity)
- 6x150 tonne shifting jacks (900 tonne total shift capacity)

The two launching jacks were installed on a temporary pier (TP1) in front of the casting bed. This unusual arrangement was dictated by site area restrictions which precluded the location of the casting bed behind the abutment.



Section & plan view of the Eberspächer jacking system

Eberspächer Launching Jack

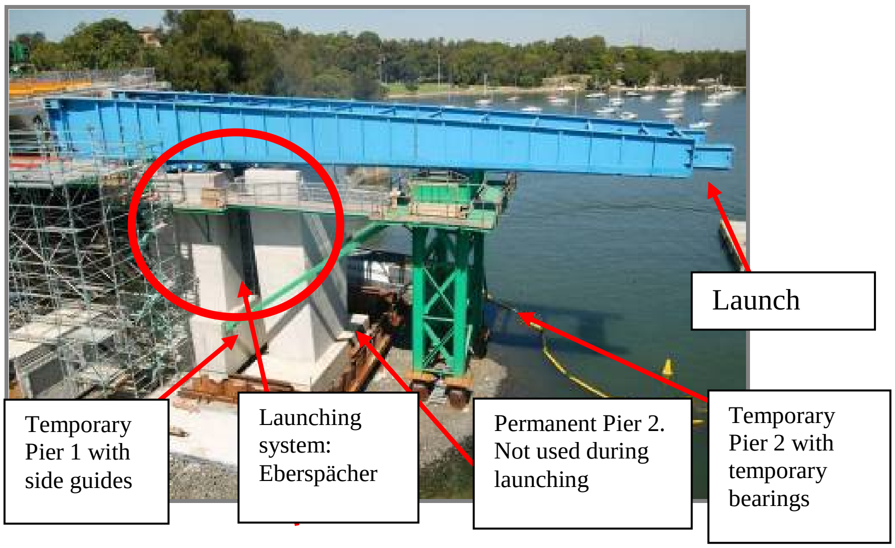
Two Eberspächer launch jacks were used in parallel for the launching process and were synchronized in order to apply uniform forces to the structure. The double acting rams on the shifting jacks had the capacity to move the bridge backwards as well as forward providing a recovery mechanism in the event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

The steps of a typical launching operation are as following:

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

Between two lifting operations the bridge remains seated on two brake saddles installed behind the jacks. These consist of knurled 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 250 mm. A typical segment was 26,500 mm so a launching operation needed 106 launching sequences to achieve the full launch. As a launching cycle was between two and three minutes long depending on the speed used, the overall launching operation was around four hours.



Launching system arrangement

DUAL PURPOSE POT BEARINGS

An innovative feature of the project was the successful use of launch over pot bearings (alternatively known as dual purpose bearings). These bearings incorporated a temporary sliding surface on top of the permanent bearing which was removed upon completion of the launch operation. A conventional launching operation utilised temporary launch bearings, which were replaced with permanent bearings upon completion of launching. This was a complex and time consuming task.

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 and is unknown on a bridge of this size.

The Alliance commissioned Freyssinet Australia to improve the design to reduce the risk of inadvertent damage to the bearing during launching as this had been problematic on previous ILM projects. The modified design incorporated a fuse system which was designed to prevent any damage to the pot bearing in the event that the longitudinal force on the bearing exceeded the design force on the bearing for any reason. This event could typically be caused by a sliding pad being inserted upside down.

All of the pot bearings were supplied, installed and monitored by Freyssinet following agreement on the suitability of the dual purpose bearing incorporating the fuse system. Of the ten permanent piers on the project only seven were used for launching and these were all dual purpose bearings. Two pot bearings were installed on every permanent pier.

Bearings being lifted on top of pier

Bearings in temporary position during launching

Eberspacher sliding pads were inserted between the stainless steel sheet and the soffit during the launching operation. The bottom face of the sliding pad covered with greased PTFE remained 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 diaphragm above the pier and relocating the pots to the predetermined permanent location 380 mm towards the pier centreline. The gap between the bearings and the deck soffit of around 20 mm was then grouted. A force of more than 2000 tonne 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.

Relocation of pot bearings

Bearings in permanent position with keeper plates installed

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.

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- This paper draws upon material previously published in a paper submitted at the 2011 AUSTROADS Bridge conference titled Iron Cove Bridge Duplication by Tim Pittaway, Adrien fortot and Etienne Combescure.