Construction of the Second Gateway Bridge
Brisbane, Australia

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New Gateway Bridge

Synopsis: The Gateway Upgrade Project is a Queensland State Government initiative delivered by Queensland Motorways and the Leighton Abigroup Joint Venture. The project involves the upgrade of 20 kilometres of Brisbane’s Gateway Motorway, with its signature feature comprising duplication of the 1.6km-long Gateway Bridge, with a central main span of 260m.

The approach structures to the main span are constructed using a pre-cast balanced cantilever method, while the main span is built using a cast in-situ balanced cantilever method. When complete, the second Gateway Bridge will join its twin in the top 10 longest of its kind in the world. The second Gateway Bridge includes the addition of a 4.25m wide pedestrian and cycle facility, making it a total 28m wide and requiring a different design and construction method to its existing counterpart.

This paper will discuss detail the methodology and challenges involved in constructing the second Gateway Bridge.

1. Introduction

Established to provide a city bypass and link between two major South-East Queensland highways, the original Gateway Bridge was completed in 1986 after six years under construction. On completion, it was the longest of its kind in the world, with a 260 metre balanced cantilever box girder main span. Its unique shape is a result of stringent air and shipping navigational clearance requirements. These requirements also presented a challenge in construction.
Upon opening, the Gateway Bridge formed a vital river crossing for approximately 17,000 vehicles per day. In 2006, the Gateway Bridge carried approximately 100,000 vehicles each day, with the resulting congestion meaning an increased need for provision of a new river crossing.

In 2005, the Gateway Upgrade Project was announced. The project includes construction of a second Gateway Bridge 50 metres downstream from the existing bridge, as well as 20 kilometres of motorway upgrade, and will be delivered by Queensland Motorways with design, construction and maintenance by the Leighton Abigroup Joint Venture (LAJV). Forming part of the LAJV for the delivery of the Gateway Bridge is VSL Australia, world leaders in the design and construction of balanced cantilever bridges, and instrumental in construction of the original Gateway Bridge.

At 1,627m long, the Gateway Bridge is being constructed using a cast in-situ balanced cantilever method for the 260m long main span, and a segmental balanced cantilever match-cast method for the approach spans. The bridge will stand on 17 piers, with two main span piers located in the Brisbane River. The bridge will have an additional 4.25m-wide shared pedestrian and cycle facility constructed on the eastern side, making it around 5m wider than its counterpart.

The new bridge also breaks new ground quality-wise, with a requirement set by its owner, Queensland Motorways, to construct with a design life of 300 years. This specification makes it one of, if not the longest design life bridge structure in the world.

On completion, the second Gateway Bridge will become a six-lane, dedicated southbound crossing, while the existing bridge will become a dedicated northbound crossing. The introduction of eToll in July 2009 will contribute to a free flowing traffic environment on the bridges and for the Gateway Motorway.

2. Pre-cast Manufacturing Facility

Construction of the bridge approaches has been fast-tracked by use of segmental match-casting, a solution provided by LAJV after award, and previously employed by the two companies in their capacity as joint venture contractors (Abigroup Leighton Joint Venture) for Sydney’s M7 Westlink Project. A reduction of several months in the construction period was offered to and accepted by Queensland Motorways by utilising the match-cast segments produced in LAJV’s Pre-cast Manufacturing Facility. These segments are being used to build the 750m-long northern and 350m-long southern approach spans.
In addition to strong controls in quantity and specifications, the choice to cast segments in an in-house factory environment enabled the durability requirements of the 300 year design life to be delivered.

The existing Gateway Bridge used full width pre-cast segments at around 23m wide each to construct the required six lanes. As the second Gateway Bridge required six lanes, together with the addition of a shared user path, the deck width needed to increased to 28m. Following their experience in building Sydney’s M7 Westlink project, the LAJV built on their technical expertise in casting “small” 12m- to 14m-wide segments. From a risk management perspective, they opted to form the 28m-wide bridge deck width by using a twin spine of smaller, 13m-wide segments joined by a longitudinal stitch to build the northern and southern approach spans.

Figure 2: Approach span cross-section

Figure 3: Segments being match-cast
The twin spine arrangement required a total 730 number of nominally 2.8m long “standard” match-cast segments to be cast, each weighing up to 80 tonnes each. These were manufactured at a rate of around four to five per day from five moulds. At peak production, 25 segments were consistently produced per week.

A further 12 match-cast halving joint segments were cast in a separate manufacturing area. These segments, weighing up to 210 tonnes each, were designed to accommodate the expansion joints for the bridge. Given their weight and complex design requirements, the halving joint segments were cast in two separate, unique moulds.

The Pre-cast Manufacturing Facility was located on an 11 hectare site adjacent to the northern approach span of the second Gateway Bridge. The location was chosen for ease of transport and availability of required space. Along with match-cast segments for the second Gateway Bridge, the facility was set up to cast a variety of other products, including 43,000m of octagonal piles; 850 number 1800mm deep and 150 number 1500mm super tee beams, over 4,000 parapet shells, pre-stressed and non pre-stressed planks and a range of other minor concrete products used across the Project.

The facility produced around 160,000 tonnes of product in total, and was in operation from July 2007 until March 2009.

It is believed that the Gateway Upgrade Project Pre-cast Manufacturing Facility was the largest of its kind to be set up in Australia.
3.0 The construction process
3.1 Main span – substructure

Two of the 17 piers for the second Gateway Bridge, henceforth referred to as piers P6 and P7, are located in the Brisbane River. These twin blade piers, each towering 54m high, are the largest for the bridge and are designed to support the 260m-long main span and 130m-long side spans. Pier P6 on the southern side of the river is located within 12m of the river bank, while pier P7 is located 140m out into the Brisbane River.

Given the critical nature of the foundations to the main span piers, test piles were commissioned as the first works on site, one adjacent to P6 and one adjacent to P7. The test piles, scaled down to 1500mm diameter, were constructed using “Osterberg” cells. They were heavily instrumented and loaded to 3 times ultimate to confirm the geotechnical properties of soil and rock. Test piling commenced in March 2007, around five months after contract award.

To enable ease of access to P6 and P7, both within the Brisbane River, LAJV constructed islands of clean graded rock to allow for a land-based operation. Before works to construct the islands commenced, around 35,000m3 of silt material was dredged from the river bed, and silt curtains placed.

Given P6 was only 12m off the river bank, the team were able to move rock from the river bank to form the island. At P7, 140m out, the team first constructed a rock causeway before forming the island from rock. In all,
around 200,000 tonnes of material was used to form these bases for main pier construction.

Following completion of works to construct the bridge, the rock islands will be pared back to -1.5m below the water’s surface, and extended around the river piers for the existing bridge. They will act as ship arrestor islands to protect the piers in the event of collision from wayward vessels.

The foundation solution for each river pier was 24 number 1800mm piles founded between 50m and 65m in depth, totalling 4,300m3 of concrete for each pier. Bored piling took approximately eight weeks to complete for each pier. Taking into consideration the stringent expectation from client Queensland Motorways regarding durability, strength and quality for the river pier foundations, the team inspected each of the rock sockets with an underwater camera to ensure the base was clean after completion of the air lifting process.

On completion of piling, a 3.2 metre thick pile cap over 19m long and 17m wide was constructed for each pier. Containing around 230 tonnes of reinforcement steel and 1050m3 of concrete, each cap was poured over a 12 hour period. Given the large volume of concrete and thick section the internal concrete temperature during curing needed to be controlled. This was carried out by placing 200mm pipes within the section and forcing air through them. The heat exchange of the pipes and forced air was sufficient to control the temperature of the concrete.

![Figure 6: Pile cap with stainless steel reinforcing 'cover' visible](image)

With the pile caps located in the ‘splash zone’ of the Brisbane River, therefore being in the most aggressive environment of the entire structure, a 150mm thick stainless steel reinforced cover was formed around the structural steel
prior to casting of concrete. Construction of this cover plays a key role in reaching the 300 year design life specification, and the main span pile caps were the only area requiring use of stainless reinforcement steel.

The twin-blade pier columns were constructed parallel to one another using a climbing formwork system. Internal forms were crane-lifted into place, while external forms were attached to the climbing frame. The self-lifting system used a hydraulic “screw” jacks to lift after the completion of each concrete pour. Columns were built over 20 lifts using around 300 tonnes of reinforcement steel and 1700m$^3$ of concrete.

A 75m high free standing tower crane services each of the main span piers, with a capacity of 24 tonnes at minimum radii.

### 3.2 Main span - superstructure

Pier head construction is the starting point for balanced cantilever construction of the main spans. Each pier head took around 5 months to build with a self-lifting platform and concrete pumped from ground level. The pier head structures are 15m high and contain around 1,920m$^3$ of concrete, 260 tonnes of reinforcement steel and 40 tonnes of stressing bar in each. The concrete was poured in 6 lifts, with the largest comprising 455m$^3$ of concrete. The pier heads to the main span have been and are the most complex elements within the second Gateway Bridge.

On completion of the pier heads, construction of the 260m-long main span and 130m-long side spans commenced, with the first cast in-situ segment poured in March 2009. Two pairs of form travellers, weighing 250 tonnes each, were set up on rails on the pier heads to support formwork for the span segments. The heaviest 28m-wide segment weighs up to 350 tonnes. The design of the traveller was constrained by a height limit of 19m above the deck for aircraft clearance and 3m below the soffit of the bridge for ship clearance.

Each segment comprises of twin cells and a varying depth from 15m at the pier head to 5m at the centre of the river span, with a uniform width of 28m. There are 30 segments on each side of the piers. Up to 150m$^3$ of concrete is contained in each segment. Each segment is stressed with 3 number 6-19 strand tendons, totalling around 2,500 tonnes of steel in the entire span, before the traveller advances on rail beams using hydraulic rams in preparation for the construction of the next segment to set the formwork for the adjoining segment.

This is the first time an overhead form traveller has installed prefabricated web reinforcement cages. This has been achieved by skewing the A frames so that they do not obstruct the segment webs. By prefabricating the web cages, the in-situ work has been minimised and cycle time optimised.
4.0 The construction process
4.1 North and south approach spans substructure

The 750 metre-long northern approach requires 10 piers, while the 350m-long southern approach requires 5 piers.

4.2 Piles and Sub-structure

Nine of the ten piers on the northern banks are founded on approximately 45 number 550mm octagonal piles, with the tenth (Pier 8, closest to the river) founded on 8 number 1500mm diameter bored piles to increase its load-bearing and stiffness capacity.

Due to the presence of high quality rock on the southern bank of the river, no driven piles were required. Instead, spread footings were cast directly onto exposed rock, with piers then constructed above, while bored piles were required for Pier 5, again the closest pier to the river.

Upon completion of piling, pile caps 2m thick were cast below ground level and then back-filled. Pier columns ranging in height from 15m to 47m were then constructed using climbing formwork. Following this, pier heads were constructed to act as the starting point for balanced cantilever approach span construction.

4.3 Super-structure (match cast segmental)

Developed in the 1960s by French engineer Jean Muller, match-cast segmental construction works through the principle that ideal matching can be obtained by casting successive segments in a bridge deck against one another in a production line. Geometric layouts which are curved and complex can be obtained in this way.
The 750m-long northern and 350m-long southern approach spans are being constructed using match-cast segmental installation. Together, the approaches total 15 spans, each at 71m long. As the pier heads were cast in-situ, a concrete stitch was required between the pier head and the first segment on each side. The first segments were supported on hanger beams during this process.

Each cantilever is comprises 48 segments, each of which weigh between 70 and 100 tonnes. The first five spans were constructed using segments lifted into place by a 600 tonne crawler crane. Due to a loss of efficiency in continuing to use a crawler crane for the taller piers closer to the river caused by ground conditions and height issues, the remaining approach span segments have been lifted into place by an 800 tonne, 165m-long overhead launching gantry, which worked on the 5.3% deck gradient.

The gantry was assembled at ground level on the northern bank of the Brisbane River before being raised into position at Piers 14 and 15 by the 600 tonne crawler crane. It was commissioned over a number of weeks and then launched to rest on Piers 11 and 12 to commence lifting segments for the remaining spans.

Two heavy duty mobile winches, each rated at 105 tonnes, were mounted on the launching gantry on either side of the piers and were used to lift the segments from the ground, up to 50m below, with two side-by-side segments combining to form the full deck width.

As each segment is fitted with its partner, its face is coated with an epoxy which acts as a lubricant during installation and a water-proofing agent. The segments are then post-tensioned together. High-tensile steel tendons are inserted and threaded through purpose-built openings in the segment, before being attached to the preceding segment. The tendons are jacked and over 240 tonnes of force applied, pulling the tendons tight and effectively tying the segments permanently together. This ensures strength and durability for the structure. The process is repeated as each segment is installed.

At three points along the 1.6km-long structure, movement joints were constructed at ¾ point of the span. A highly complex operation, the construction and handling of joints were a challenge. The joints were installed to the cantilever using either the launching gantry or the 600 tonne crawler crane. Once installed, the segments were held together with 3 number 400 tonne support jacks, grout pads and 11 number 75mm stress bars running longitudinally. Once the cantilevers were completed and stitched, and the continuity post-tensioning was stressed, the sliding bearings were grouted in place and the joint released. The temporary devices were then removed.
6. Conclusions

The design and construction of the second Gateway Bridge is a collaboration between Queensland Motorways and the Leighton Abigroup Joint Venture, which, amongst others, comprises VSL Australia, Cardno, Maunsell and SMEC.

Forming a significant and iconic landmark for Brisbane and South East Queensland, the largest bridge and road infrastructure project in Queensland’s history will be over 4.5 years in construction. With a significant challenges requiring innovative solutions, the second Gateway Bridge will be an achievement in design, construction and delivery.

7. Acknowledgements

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