## Gateway Upgrade Project, Brisbane



# 2012 Australian Construction Achievement Award TECHNICAL PAPER



"Together with our client Queensland Motorways we have created a new landmark for Brisbane and undoubtedly, an engineering masterpiece which is a testament to the expertise and passion of each and every person involved in its design and construction. Our vision and innovation has made the iconic Gateway Upgrade Project a reality...and a success," Hugh Boyd, Project Director, Leighton Abigroup Joint Venture.

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## Gateway Upgrade Project, Brisbane





Gateway Upgrade Project Corridor

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### Abstract

# 'One Road, One Team' ... safely delivering to Queensland the infrastructure project of the decade.

The multi-billion dollar Gateway Upgrade Project (GUP) was a critical component of the Queensland Government's transport infrastructure strategy to ease Brisbane's traffic congestion and improve road safety; provide much-needed infrastructure for the future growth of Queensland; and provide better connectivity to Australia Trade Coast precinct including industrial areas in Eagle Farm, Pinkenba, Murarrie, Brisbane Airport and Port of Brisbane.

The project was delivered under the management of Queensland Motorways Limited through a fixed price design and construct contract (D&C) with principle contractor, the Leighton Abigroup Joint Venture (LAJV).

Totalling 24km and delivered during a construction boom, this technically complex project is the largest bridge and road project in Queensland's history. Often referred to as 'three projects in one', the sheer scale of the project presented a massive safety challenge with a workforce of some 1800 at peak and almost 10,500,000 man-hours worked. Add to this the impact of construction on more than 100,000 motorway users per day and many thousand more residents and businesses and the enormity of the task becomes even more evident.

Despite the complexity and a range of other challenges associated with working at height and alongside 'live' traffic; significant structures work; operation of a large precast yard; and significant soft soil and ground improvement issues, LAJV succeeded in delivering the project ahead of time and achieving exemplary performances in safety, community relations, quality and environmental management.

The enormity of the task is best illustrated through the diverse scope of works and the corresponding challenges LAJV faced. These included:

- Construction of a second and five metre wider Gateway Bridge (renamed Sir Leo Hielscher Bridge –South) to meet a client specified 300-year design life. The new bridge included a shared pedestrian/cycle path.
- Refurbishment of the original Gateway Bridge (renamed Sir Leo Hielscher Bridge – North) working under 'live' traffic conditions, within a restricted footprint with extreme access limitations and with complex tie-in works.
- Construction of a new 7 km six-lane Motorway north of the Bridges including the construction of 17 elevated structures and bridges along a corridor that required significant ground improvement treatments due to extensive soft soil issues as well as working within a busy industrial and transport precinct.
- Upgrading 16 km of Gateway Motorway south of the Bridges involving multiple interchanges; widening existing or new construction of some 15 elevated structures; and working under 'live' traffic conditions day and night with over 100,000 plus vehicles per day. Added to this were client specified requirements to maintain traffic flows and provide safe passage for motorists, while also minimising the impacts on thousands of neighbouring residents, businesses and sensitive flora and fauna environments.

Early delivery of the original scope, seven months ahead of schedule, was achieved through contractor initiated value for money solutions and innovation in design and construction to improve motorway functionality, deliver cost and program savings during construction and maintain the highest standards of safety for all internal and external stakeholders. These solutions included:

- New Bridge approach structures constructed using match casting, a first for Queensland. This initiative saved three months on program.
- An onsite precast factory to produce most of the Project's 10,000 plus concrete components, saved three months on program and guaranteed supply and quality of precast products.
- Six lanes instead of four lanes over Kedron Brook improved the new Motorway's functionality and utilised cost savings from the above solutions and a re-scope of the works in the north.
- Additional on and off-ramps to Kingsford Smith Drive, Eagle Farm improved motorway functionality and provided localised road network benefits.
- Upgrading a section of the Gateway Motorway to eight lanes instead of six improved the functionality with longer term client cost savings.
- Gateway Upgrade Southern Extension was a significant contract variation that increased motorway functionality with the addition of a 4.3 km of motorway upgrade.

Delivered progressively (six separable portions) to expedite benefits to motorists – a key client deliverable, GUP has greatly enhanced the functionality and performance of this critical national and state transport network link while also providing the client with cost savings in respect of whole of life costs.

The successful delivery of this mega project required a whole of team approach in which collaboration and proactive relationships across all project partners were paramount. Our vision - *One road, one team ... safely delivering to Queensland the infrastructure project of the decade* - encapsulated the strength of the relationships particularly with our client, Queensland Motorways – a relationship that went far beyond the terms of the hard dollar D&C contract, and which drove best for project outcomes across design and construction while also underpinning the team's ability to satisfy or exceed all project objectives and deliver exemplary performances in safety, quality, community relations and environment.

It was the realisation of this vision that drove the outstanding achievements on GUP.

### **Key Words**

Queensland Government, Queensland Motorways, Brisbane, Gateway Bridge, Sir Leo Hielscher Bridge, Gateway Motorway, Leighton Contractors, Abigroup, AECOM, SMEC, Coffey Geotechnics, VSL Australia, alliance, balanced cantilever, match casting, concrete, soft soils, ground improvement treatments, traffic, stakeholder, community relations, environment, piling, precast, innovation, design and construction.

### 1. The Project Team and Scope of Works

#### 1.1 The Team

LAJV's project management team was developed in response to the scale, complexity and scope of the project works, utilising resources and world class expertise from:

- LAJV's partners Leighton Contractors and Abigroup (close to 400 strong management team)
- VSL Australia, as part of the Gateway Bridge Alliance, an alliance between LAJV and VSL Australia, which was established to manage the construction of the new Gateway Bridge and refurbishment of the existing Gateway Bridge
- Frankipile Australia, Vibropile and Keller Australia as part of the Gateway Piling Alliance; and
- Specialist designers (peaking at approximately 150) and subcontractors, brought into the delivery team as subconsultants or alliance partners, including:
  - AECOM and SMEC Design Joint Venture, as Principal Designers (for the full project works)
  - Specialist Designers including:
    - Cardno and AAS-Jakobsen (specialist bridge designers)
    - Coffey Geotechnics (geotechnical and pavement designers)
    - Heggies Australia (acoustic consultants).
- SKM, the Independent Verifier and Proof Engineers Benaim and Golders

LAJV's management team structure was based on the delivery of three sub-projects (North, Gateway Bridges, and South).

#### 1.2 Scope of Works

The scope of works included the duplication of Brisbane's landmark Gateway Bridge and construction of a new and upgrading of the existing and heavily trafficked Gateway Motorway between the Pacific Motorway (in the south) and Nudgee Road (in the north). Specifically the project included:

- A new 7 kilometre six-lane motorway on the northern side of the Brisbane River including a much needed second access to the Brisbane Airport, the construction of 17 elevated structures and bridges along a corridor of predominately soft soils that required significant ground improvement treatments.
- The upgrading of the existing Gateway Motorway south of the Brisbane River with multiple interchanges and construction over major arterial roads and the widening of existing overbridges all undertaken under 'live' traffic conditions. A multimillion dollar contract extension for a further 4.3 km motorway upgrade (to the south) was agreed in April 2010.
- Construction of a new 1.63 km Gateway (renamed Sir Leo Hielscher) Bridge South with six-lanes, a shared pedestrian cycle path and extensive urban design and feature lighting. The client specified 300-year design life for the bridge added another significant level of technical requirements and construction complexity.

 Refurbishment of the existing Gateway (renamed Sir Leo Hielscher) Bridge – North, under 'live' traffic conditions, with complex construction staging and tiein works and a requirement to maintain traffic flows and tolling revenues.

The scope and complexity of the project (represented by over 7,000 IFC drawings) is best illustrated by the following:

- 34 elevated structures (total deck area of 133,500 m<sup>2</sup>) requiring different design considerations and construction methods
- Construction of the duplicate Gateway Bridge using balanced cantilever matchcasting method for the approach spans – a first in the State; and cast in-situ segments for the main span (44,000 m<sup>2</sup> of deck area). The original bridge took over five years to construct while the new bridge was constructed in just over three years
- Operation of a large on-site pre-cast factory for 18 months with a 250 strong workforce and producing over 10,000 concrete components including super tee girders; noise wall panels; octagonal piles, and parapets
- Working beside 16 km of 'live' motorway traffic (100,000+ per day) and close to residential areas, businesses, sensitive waterways and bushland
- New construction or upgrading of eight major interchanges
- Construction of elevated road structures over a floodplain requiring significant ground improvements (using varied methods) across multiple areas (over 16,000 piles)
- Extensive earthworks (with 2,650,000 m<sup>3</sup> of fill) for embankment works and ground improvement treatments
- Refurbishment of the existing Gateway Bridge under 'live' traffic conditions, multifaceted construction staging, complex tie-in works and a tight timeframe.

NEW GATEWAY BRIDGE (NGB)			
Length	1,630m		
Width	26.92m for six traffic lanes plus a shared pedestrian /cycle path		
Height	59.2m - river level to centre of main span (underside)		
	64.5m at its highest point (approx. height of a 20 storey building)		
Main Span	260m balanced cantilever (cast in situ)		
Main Side Spans	162m (x 2) balanced cantilever		
Approach Spans	71m (x 13) & 60m (x 2) at abutments, match-cast		
Main Piers	54m in height Founded on 24 bored piles extending to a depth of 50 m below the river Twin blade pier columns contain 1,700m <sup>3</sup> of concrete and 300 tonnes of steel reinforcement		

#### Table 1 - Key project facts and figures

NEW GATEWAY BRIDGE (NGB)					
Main Pier heads (2)	<ul> <li>15m in height</li> <li>2.5 m thick, 1,920m<sup>3</sup> or 4608 tonnes of concrete and 300 tonnes of steel for reinforcement and tensioning</li> <li>35 workers and 5 months to construct.</li> </ul>				
Construction Methodology	Main Span and Main Side Span – cast in-situ balanced cantilever Approaches – pre-cast segmental balanced cantilever using match cast segments				
Main Span and Side Spans – cast in-situ using form travellers	700+ tonnes of balanced cantilever traveller steelwork were installed atop of the main pier heads (6 & 7) and worked simultaneously to construct the 260 m main span and the two 162 m main side spans				
Approach Spans – no. match-cast segments	742 segments comprising 730 standard and 12 halving joint segments				
Approach Spans – weight of match-cast segments	60 - 80 tonnes 12 specialised segments that house expansion joints 210 tonnes each				
Approach Spans – use of main gantry erection truss	<ul> <li>Weight - 800 tonnes</li> <li>Made up of two 165 m long, 6 m deep trusses, joined together at</li> <li>6.4 m centres by two link trusses</li> <li>Two 28 m-wide transverse support beams allow the gantry to</li> <li>translate from left to right on high capacity bearings</li> <li>Length of the gantry allows it to self-launch by spanning two 71 m</li> <li>spans at one time and 'leap frogging' the transverse support beams</li> <li>to the next pier</li> <li>When erecting segments the gantry cantilevers 47 m from the pier,</li> <li>allowing it to lift the segments from 50 m below on the ground at a</li> <li>35m cantilever</li> </ul>				



New Gateway Bridge – 260 m Main span under construction (May 2009)

#### Table 1 - Key project facts and figures (continued)

GATEWAY UPGRADE PROJECT – FULL PROJECT SCOPE						
Metric / Work Element	South	Gateway Bridge	North	Southern Extension	Project Total / Comments	
Length	12km	1.63km /	7 km /	4.3km	24.3km	
Length Soft Soils	1 km	N/A	5 km	N/A	6km (approx. 25% of project had soft soil issues)	
Bridges	13 (new/widening of existing bridges)	1	17	3	34 (some bridges are counted as two)	
Bridge decking	17,000m <sup>2</sup>	44,000m <sup>2</sup>	65,000m <sup>2</sup>	7,500m <sup>2</sup>	133,500m <sup>2</sup>	
Bridge Super-tee Girders	167	N/A	850		1,000 produced in pre-cast yard - 39.9m span (one of longest in Australia) – six lane Kingsford Smith Drive overbridge	
Concrete	54,900m <sup>3</sup>	65,000m <sup>3</sup>	50,000m <sup>3</sup> (in situ)	4,700 m <sup>3</sup>	Approx. 174,600m <sup>3</sup> ; large pours included: NGB Pier 6 and Pier 7 pile caps – 1,200m <sup>3</sup> each incorporating an air-cooling pipe system to reduce the heat of hydration during the pour North - southern bifurcation voided (post- tensioned) slab pour of 2,300m <sup>3</sup>	
Reinforcement	2,698 tonnes	11,600 tonnes	8,000 tonnes	902 tonnes	23,200 tonnes	

GATEWAY UPGRADE PROJECT – FULL PROJECT SCOPE						
Metric / Work Element	South	Gateway Bridge	North	Southern Extension	Project Total / Comments	
Piling	<ul> <li>16,065 piles and columns across the whole project; incorporating both structural piles and columns, and those used for ground treatment in soft soil areas; largest piling operation ever to be undertaken in Australia (at the time of construction) Peak number of piling rigs: 21</li> <li>NGB foundations:         <ul> <li>Main Piers = 48 bored piles (structural)</li> <li>Approach Piers = 290 driven piles (structural) + 30 bored piles (structural)</li> </ul> </li> </ul>					
Octagonal Piles (driven structural piles)	N/A	10,000 m	33,600 m	N/A	43,600m (2,000 piles manufactured in pre-cast yard; 15,000m <sup>3</sup> of concrete; 2,300 tonnes of reinforcement)	
Wick Drains	89 km	N/A	1,200 km	N/A	1,289 km (treatment of soft soils and piling operation)	
Fill Material	300,000m <sup>3</sup>	150,000m <sup>3</sup>	2,200,000m <sup>3</sup>	100,000m <sup>3</sup>	2,750,000m <sup>3</sup>	
Geotextile Fabric	40,200m <sup>2</sup>		80,000m <sup>2</sup>	16,000m <sup>2</sup>	136,200m <sup>2</sup>	
Road Base Material	250,000 tonnes	N/A	200,000 tonnes	200,000 tonnes	450,000 tonnes	
Asphalt	359,000 tonnes	24,000 tonnes – NGB & EGB	200,000 tonnes	130,000 tonnes	713,000 tonnes Two mobile asphalt plants were established, production as follows: South - 800 tonnes per night at peak North – 2,000 tonnes per night at peak	

GATEWAY UPGRADE PROJECT – FULL PROJECT SCOPE						
Metric / Work Element	South	Gateway Bridge	North	Southern Extension	Project Total / Comments	
Landscaping (plants)	624,402	29,220 plus one hectare of native grass seeding	Sep B 652,853	105,634	1,405,634 (mix of feature trees, shrubs plus areas with seeding of trees, shrubs and native grasses). The landscaping program is one of the largest landscaping requirements for a Queensland road infrastructure project to date.	
Noise Barriers (new/existing)	5 km	N/A	N/A	3.05 km	5,193 concrete panels; 20 concrete noise barriers; 5 timber noise barriers; and 3 steel noise barriers	
Fauna Fencing/ Underpasses	18 km 4 underpasses	N/A	N/A	8 km	26 km of fauna fencing; 4 fauna underpasses	
Precast Manufacturing Facility	<ul> <li>Key construction planning initiative generating cost, time and other benefits</li> <li>Instrument in realising three months time saving, in addition to providing means to guarantee both quality and supply in a stretched construction resource market)</li> <li>Total concrete - 150,000 tonnes or 60,000m<sup>3</sup> (largest operation of its kind in Australia at the time); 18 months of production and over 10,000 items cast. Included production of precast box segments for NGB approaches; prestressed piles and super-tee girders for other bridges; precast panels for noise barriers; and parapets and walls as well as prestressed and post-tensioned deck units.</li> <li>Reinforcement: Total of 11,000 tonnes</li> <li>250 workers (25 engineers and foremen)</li> </ul>					

### 2. Project Key Performance Areas and Outcomes

LAJV's performance on GUP, which represents an outstanding construction achievement, can be measured against its project vision and seven Key Result Areas (KRAs) - safety, quality, stakeholder satisfaction, environment, sustainability, cost and time - which were intrinsically linked to the client deliverables and project objectives.

#### 2.1 Safety KRA – 'One Life, One Message, Work Safe'

GUP engaged 13,612 people with almost 10,500,000 man-hours worked. An improved safety culture and behavioural changes were achieved through the introduction of workforce engagement initiatives and comprehensive training programs, which focused on critical risks. The outstanding outcomes from this approach to safety included:

- Reduced positive drug/alcohol testing ratios from 1:10 to 1:100 thanks to a "Fitness for Work" program and extensive awareness campaign
- Substantially decreased Workcover claims from 128 in 2008/2009 to 36 claims in 2010
- No fatalities, three periods of 1,000,000+ man-hours LTI free and continuous improvement in safety performance with 12-month rolling LTIFR improved from 4.15 in January 2009 to 0.83 at project completion
- Approximately 1,700,000 man-hours LTI free in full year 2010 a fantastic achievement recognising that this was the year of peak construction, peak interfaces and multiple Separable Portion completions
- Eliminated injuries caused by manual handling tasks attributed to series of innovations developed by work crews and inspired by Manual Handling Training Program
- Implementation of new procedures to review Safety in Design in line with new Queensland legislation.

The project was awarded the prestigious Federal Safety Commissioner's Award for Occupational Health and Safety Excellence (2009).

#### 2.2 Quality KRA

The quality requirements of the project related to delivery of all aspects of the works as defined in the Project Specifications and Technical Requirements (PSTR). As in all projects the quality requirements must be satisfied or exceeded to achieve successful delivery.

LAJV drew from its proven quality systems to implement quality management processes that enabled full compliance with the requirements of the PSTR, through design development and construction of the works.

Collaboration between LAJV and Queensland Motorways, its designers, SKM – the Independent Verifier (IV), and Queensland Department of Transport and Main Roads (DTMR) enabled all parties to gain an aligned understanding of project requirements and expectations (a number of which were subject to change) with a 'best for project' approach to assessing design, construction methodologies, and cost and time saving options.

Project audit schedules were established early and complemented design and construction programs ensuring key construction activities were identified. Key performance indicators were established and regular assessment undertaken (including rework costs, process efficiency, product conformance and completion of separable portions).

LAJV's specialist quality team worked with the IV and Queensland Motorways to ensure ongoing review, auditing and adherence to the technical specifications and requirements was achieved and any quality issues were identified and addressed in a timely manner.

Three areas of quality are worthy of mention – the need to increase the durability of the New Gateway Bridge compared to normal bridges, this was defined by a client specified enhanced 300-year design life for the New Gateway Bridge (a first for Australia); the requirement to reduce long term settlements in the motorway defined stringent settlement criteria in complex soft soil areas along the road alignment and related bridges; and the design and review process.

#### CASE STUDY 1 – New Gateway Bridge Durability – 300-year design life

This was achieved primarily through the development and implementation of the 3C's (Cover, Compaction, Curing) solution by an integrated design, construction and verification team.

Once the concrete design parameters and specifications were developed for the new bridge, it was up to construction team, working in collaboration with SKM (the IV for the project) and Queensland Motorways to deliver this quality requirement. To this end, significant effort was placed by LAJV on:

- Educating the construction team on the critical importance of the 3C's in delivering a 300-year design life for the bridge
- Implementing comprehensive method statements, ITPs and checklists to control inspection and testing of all of the bridge concrete works
- Maintaining the IV's involvement in the concrete design for the bridge and the development of controls for delivering such through construction.



# **CASE STUDY 2** - **Process for achieving expected settlement outcomes in complex soft soil areas**

A major long term residual risk for Queensland Motorways was excessive settlement of pavements built on new embankments over soft soil foundations particularly in the Kedron Brook floodplain (e.g. large long term settlements like on the old Gateway Motorway)/ To reduce this risk, proof engineering of soft ground design by the IV and embankment settlements not exceeding 200mm (with probability of exceeding of less than 1%) were specified.

At bridge approaches this criteria was tightened to 50 mm settlement and differential settlement of less than 5%, i.e. 2.5 mm over 5 m. This theoretical criterion sets very high levels of certainty compared to traditional geotechnical engineering and it is consequently difficult to demonstrate that these requirements will be achieved.

LAJV demonstrated that the best way of achieving greater certainty in the geotechnical settlement predications and reduce the chance of excessive long term settlements was to follow an extensive testing and monitoring regime and construct embankments accordingly. This included:

- designing the embankments and embankment supports to smooth out deflections, i.e. reduce instantaneous bumps using a rock mattress structure and to build embankments support structures (i.e. embankment piles)
- monitoring actual settlements in detail and back calculating predicted settlements – in some case this lead to additional embankment structures (piles) or extended embankment consolidation periods
- Coffey as an integral member of LAJV's design team used its resources worldwide to deliver the soft soil design once the issues relating to reliability became apparent. At its peak, about 50 geotechnical design staff were mobilised to the project to deliver the designs to the required approaches, all when design resources within the industry were very limited due to the activity in the sector
- LAJV also sought to use design capability within other sections of the design team to provide alternative designs for some transition zones. The designs were also based on the observational approach and were aimed at reducing the costs associated with the soft soil ground treatments. The construction phase of the work required a close working relationship between the designers and the construction team. Predictions about timing for ground treatments were fed back to the construction team to allow program review and construction planning. Ground treatments were identified for over 100 areas. These were reviewed and discussed formally on a weekly basis, and informally more frequently. Where construction could not accommodate the timing of ground treatment completion, or where the soft soil conditions were not in line with the design assumptions, changes to the design were implemented.

#### **CASE STUDY 3 - Design and Review Process**

The D&C contract essentially required design in accordance with the PSTR, and then construction in accordance with the design and the PSTR. To this end the D&C Deed specified three stages of design review and approval, namely:

- Stage 1 concept design
- Stage 2 detailed design including designer certificates of compliance
- Stage 3 issued for construction design with designer and IV certificates

At end of this process Queensland Motorways retained for 10 days the right to reject a design. A KRA was set that there should be no such rejections. This objective was fully achieved in a timely manner by the rigorous application of processes by LAJV, the designers, the IV and QML. Some of the key processes applied were:

- the designers and IV's extensive review and quality procedures
- the "circle of trust" a process that facilitated the open discussion of issues, compliance and change without the encumbrance of having to first finalise documentation
- compressive change management with the designer, QML and IV
- strict document control and numbering procedures, and
- a method for identifying, reviewing, and certifying partially completed designs for use in early construction works.

#### 2.3 Stakeholder Satisfaction

#### 2.3.1 Client / Project Owner

A Key Performance Indicator (KPI) was established under LAJV's Stakeholder KRA to measure the strength of the relationship that was established between LAJV and Queensland Motorways to drive 'best for project' outcomes. To this end relationship management groups were established across all levels of management as follows:

- Senior Management Relationship Group led by LAJV's Project Director
- North Project Relationship Group
- South Project Relationship Group
- Bridge Alliance Project Relationship Group
- Project Support Relationship Group representing Safety, Quality, Environment, Design and Stakeholders and Community, across the whole project.

This initiative was a genuine commitment by all parties to drive better value outcomes through collaboration, and went beyond the pure 'master/servant' of the D&C Contract between the parties.

Each group monitored its performance against relationship and values objectives. This process enabled each group to address issues and behaviours that impacted on the strength of the relationship and consequently the ability to deliver best for project outcomes. Addressing issues and behaviours, and finding a means of resolving these, contributed to strong and productive relationships at all project levels, and alignment on 'best for project' outcomes.

#### 2.3.2 Stakeholders and Community

A 'no surprises' approach was taken with a comprehensive engagement and communication program focused on provision of timely information, relationship building, and open and honest communication. Independent annual stakeholder surveys

indicated high acceptance and satisfaction with the project and the manner in which the community was kept informed.

In addition to delivering a technically complex project, LAJV was tasked with creating a well informed and engaged community through genuine relationships that would endure beyond project completion.

The sheer scale of the 24 km project, with multiple work fronts, the engagement of over 13,600 workers, 100,000+ motorists, and over 150,000 other stakeholders, required a thorough understanding of stakeholder needs, expectations and construction impacts, programs and priorities.

LAJV reviewed client research, commissioned independent surveys and conducted comprehensive stakeholder mapping to identify issues and opportunities. The community team was integrated with construction teams ensuring construction information was shared and community concerns considered in a timely manner.

Despite the challenges the communication program was an overwhelming success and every opportunity to inform and engage was utilised. The program delivered effective issues management; high community awareness; proactive project champions; a complaints rate well under target; a well informed community; and project reputations were enhanced.

Ongoing monitoring and evaluation ensured the program remained relevant and effective. Client priorities and stringent technical requirements included:

- Progressive delivery of the works deliver benefits to motorists sooner
- Minimise impacts on surrounding communities
- Minimise impacts on motorists no lane closures during peak periods
- Effective community engagement and regular communication
- Provide opportunities to promote project benefits and milestones
- Deliver community benefit.

If these priorities were not effectively addressed through the community relations and communication program the risks of project delays and negative reputational impacts were clearly apparent. Conversely, if the program was managed well, the project would be delivered on time and the reputations of project partners strengthened.

Key achievements of GUP's communication and engagement program include:

- Consistently maintained complaints rate of less than 4 complaints per month
- Delivered 245 project presentations to 10,245 attendees (business, community and education groups)
- Distributed 2,013,313 items of communication via letterbox drops and email
- Distributed 18,430 Project information packs
- Responded to 4,427 emails and 4,780 telephone calls from the community
- Hosted 250+ site tours for 3,000+ local, interstate and international visitors
- Website Averaged 5,000+ visitors monthly
- Welcomed 12,522 visitors to the community information Centre.

Clear evidence of the success of the above communication and engagement program includes:

- The fact that no time was lost as a result of stakeholder and community issues
- An exceptionally low complaints rate; and
- Surveyed evidence of six stakeholder and reference groups, which met 93 times, showing:
  - o 93% satisfaction with their level of involvement; and
  - o 86% of who felt their input was valued.

#### 2.4 Environment (and Cultural Heritage) KRA

LAJV initiated early engagement and collaboration with authorities and local environmental interest groups. Through this process productive relationships were formed, and were further strengthened by the relationship LAJV had with the project owner, Queensland Motorways.

This approach to environmental management resulted in a number of key achievements, including:

- Timely environmental approvals to meet construction program
- Full compliance with all environmental management requirements, including those related to works through sensitive watercourse areas and in the Brisbane River, koala and other fauna and flora habitats – including program to protect an endangered flora (Zieria Furfuracea subsp. Gymnocarpa)
- Discovery and preservation of several cultural heritage items, including a ship cargo stencil and old abattoir bottles
- Establishment, during drought conditions, of a desalination plant, and a program of water collection, waste reduction and recycling initiatives, thereby reducing the reliance on potable water; and
- The proactive and timely clean-up of a fuel spill on the existing Gateway Motorway (outside of GUP project corridor and unrelated to GUP works), utilising project environmental management processes for chemical or fuel spills, which was highly praised by the Queensland Environmental Protection Agency.

#### 2.5 Sustainability KRA

This KRA was not used however LAJV's performance against this KRA can be retrospectively assessed, as follows:

- Achievement of a 300-year design life for the NGB, a structure with a value in excess of \$300 million (from a sustainability perspective, this is a fantastic outcome)
- Refined process for achieving greater certainty in the geotechnical settlement predications in soft soils resulted in cost-effective design solutions over six kilometres of the project.
- In line with environmental management requirements of the PSTR, LAJV was instrumental in implementing sustainable water saving initiatives referred to above
- Introduction of additional south heading ramps at Kingsford Smith Drive (KSD) which eliminated the need for an additional lane on the old Gateway Motorway

north of the Brisbane River (i.e. reduced construction scope by better utilising existing infrastructure)

- LAJV implemented to the maximum extent possible materials reuse strategies including:
  - o widening of existing bridges
  - use of deep strength (asphalt over cement stabilised base) as opposed to full depth asphalt pavements in the south (enabled reuse of existing motorway pavement materials)
  - re-use of the M7 equipment in NGB construction (including precast segment moulds)
  - on completion, significant cost recovery from sale of project's construction assets (offices, sheds, plant, equipment and vehicles)
- LAJV successfully worked with the client to provide additional lanes to increase traffic flow on motorway:
  - o eight (instead of six) lanes south of Old Cleveland Road; and
  - six (instead of four) lanes along the motorway north of the Gateway Bridges
- Environmental Management Plans incorporated strategies to reduce emissions, pollution and waste through design, construction and operational phases.
- Evidence of the social benefits of the project, and community acceptance of the upgraded motorway was demonstrated with over 150,000 people came to the opening.

#### 2.6 Cost KRA

From the outset of the project, LAJV was committed to recognising and proposing value for money outcomes to the client to improve the expected levels of service for the completed project.

During the six month tender period, LAJV identified a number of opportunities to enhance the original project scope, improve Motorway functionality and provide additional benefits to motorway users and the community. This involved rigorous investigation and assessments, traffic modelling, the engagement of specialist consultants, extensive program analysis and detailed consideration of construction methods. While a conforming tender was submitted a number of 'value adds' were included for client consideration.

On award of contract and with input from Queensland Motorways, further investigations were undertaken and cost and program benefits were realised.

The key contractor initiated 'value for money' solutions offered and delivered included:

- Construction of the duplicate Gateway Bridge approach structures using segmental match-casting and balanced cantilever methodology – saved three months on program
- Establishment of an on-site precast factory to produce most of the Project's concrete components – saved three months and guaranteed supply and quality

- Six lanes instead of four lanes over Kedron Brook and new Gateway Motorway improved the new Motorway's functionality and utilised cost savings from above solutions
- Upgrading a key three kilometre motorway section (Wynnum Road to Old Cleveland Road) to eight lanes instead of six – improved motorway functionality with longer term client cost savings.
- Additional on and off-ramps to Kingsford Smith Drive, Eagle Farm improved motorway functionality and network connectivity
- The use of deep strength pavements (asphalt over cement stabilised base), as opposed to full depth asphalt pavements in the south, enabled cost-effective reuse of existing pavement materials from the old motorway.
- An additional 4.3 km extension at the southern end of the project a significant contract extension to the original scope of works that was negotiated in the spirit of improving the overall capacity and operability of the Gateway Motorway.

The ability to deliver enhanced value on this project was attributed to the open and collaborative relationship between LAJV and Queensland Motorways which enabled scope alignment on a 'best for project' basis, and lowest possible cost outcomes. Many of these value-add options, as demonstrated by the following traffic modelling case study, contributed to a superior end product and were delivered within the client's overall project budget.

#### **CASE STUDY 4 - Traffic Modelling**

*Issue:* Throughout development of the project starting with the tender phase it was apparent that there were opportunities to improve the design and add value to the project. Indeed QML in its request for proposals invited the tenders to submit alternatives. The issue was how to demonstrate that alternatives truly added value.

**Outcome:** Although not required under the PSTR LAJV, during the Tender Phase, invested in a Micro-simulation traffic model (Paramics) as a tool to help support the "Value Bid" non-conforming submission. A number of proposed improvements were workshopped between LAJV and the designers to maximise the benefits and presented to the client. Some of these, at tender were:

- South facing on/off ramps to Kingsford Smith Drive (KSD)
- Six lanes improvement from four lanes to the north of Gateway Bridge
- Revised interchange at Southern Bifurcation
- Revised off ramp configuration to Lytton Road southbound and Port of Brisbane Motorway.

As part of this submission a brief review and report was done on the improvements to patronage across the Gateway Bridge and therefore potential toll revenue increases. It was visibly evident that congestion was less and this would give rise to increased revenue to QML by approx \$25M over 20 years. It was also demonstrated that the overall trip travel time through the project was reduced by up to 13 minutes.

The traffic modelling also demonstrated that it was more cost effective to provide the KSD ramps then upgrade the existing Southern Cross Way alignment. LAJV proposal was

to leave the existing ramps as is, but construct extra ramps to service the heavy truck traffic from the south (major movement) into the Australia Trade Coast Area.

Post award the traffic model also assisted in highlighting the congestion "Hot spots" and eliminating them through the re-configuration of lanes and was also used for the review of major temporary traffic management schemes.

Through the life of the design and construction phase the traffic model was used to support ongoing improvements to the project. They include:

- Extending the eight lanes up to Old Cleveland Road as opposed to the specified six lanes.
- Gateway Southern Extension (4.3 km) from four lanes to six lanes to the Pacific Motorway.
- Upgrade of Mt Gravatt Capalaba Road Interchange.

#### 2.7 Time KRA

#### 2.7.1 Original Contract Scope minus Southern Extension

The contract for this original scope of works was completed on 29 November 2010, seven months ahead of the contract completion date of 30 June 2011.

This achievement was attributed to the high performance of the project team and a three month gain resulting from Queensland Motorways' acceptance of LAJV's alternative offer to:

- To construct the duplicate Gateway Bridge approach structures using segmental match-casting methodology; and
- To establish and utilise an on-site precast factory to produce most of the project's concrete components including match-cast segments.

Four of the five delivery milestones for Separable Portions A-E were met or bettered, fully satisfying Queensland Motorways' requirements for progressive handover and providing early benefits to motorway users.

Major construction works (beyond early and establishment works) commenced on 9 March 2007, resulting in a major construction works phase of approximately 45 months.

Construction of the New Gateway Bridge (NGB) was completed in just over three years, compared to five and a half years for the original Gateway Bridge, completed 25 years earlier.

#### 2.7.2 Original Contract Scope plus Southern Extension

The award of the Gateway Southern Extension, in April 2010 did not extend the contract completion date of 30 June 2011. This extension to the contract was completed on 31 July 2011.

This short delay did not attract liquidated damages – the collaborative relationship between Queensland Motorways and LAJV was very strong, and the delay was clearly attributed to exceptionally inclement weather in Queensland during 2010/2011.

# 3. Construction - complexity, difficulty and optimisation of the construction task

GUP can be described as a 'mega project' – a project that has significant size, high dollar value and a long construction duration; is comprised of a number of complex and technically challenging elements; requires detailed logistically planning, particularly in the context of significant construction constraints; and a project that requires innovative design and construction methodologies to deliver the desired product.

The complexity and difficulty of the construction task is attributed to the scale of the project and key design and construction issues with:

- Soft ground conditions along 25% of the road corridor
- Building a 1.63 km long bridge structure with 260 m centre span peaking at 64 m above the Brisbane River
- Refurbishing the existing Gateway Bridge under 'live' traffic conditions, within a constrained work space, and under a lane closure restriction limited to a maximum three of the six lanes at any one time; and
- Most importantly, fulfilling the need to upgrade an existing and heavily congested motorway, with traffic flows up to 100,000+ vehicles per day over 16 km of the project, with significant community and stakeholder interfaces.

Optimisation of the construction task was attributed to first-class design and construction planning. Elements of the design and adopted construction methodologies were innovative for road and bridge construction in Queensland, and underpinned LAJV's ability to successfully deliver the project. Failure to deliver innovation in design and construction would have resulted in an inferior end project, high cost to the client and prolonged construction duration.

#### Case Studies – North, Bridge and South projects

Case studies are presented in each area, North, Gateway Bridge and South, to illustrate LAJV's approach to optimisation of the design and construction task, and the management of key community and stakeholder interfaces.

#### 3.1 North Project

This sub-project comprised a new six-lane 7 km motorway with 17 bridge structures and a major interchange connecting to Brisbane Airport. Key issues in construction of the area north of the Brisbane River were;

- The interface with Brisbane Airport Corporation (BAC) and maintaining uninterrupted services and access to the Airport 24 hours per day
- Floodplain management around the Trade Coast area and the Airport
- The development of a new six lane motorway and multiple interchanges over the existing roads and infrastructure e.g. Airtrain, Airport Drive, Kingsford-Smith Drive, old Gateway Motorway, new land developments and Kedron Brook.
- The construction of 17 bridges (65,000m<sup>2</sup> of deck) some with large skews and extra long spans

 The extent, scale and complexity of the soft soil treatments required through this area to achieve tight performance criteria which put immense pressure on the program and tight resources.

The following case study is presented to illustrate LAJV's approach to optimisation of the construction task, as it related to these issues and construction of works in soft soil areas.

#### **CASE STUDY 5 - Close coordination with Brisbane Airport Corporation**

*Issue:* Construction of a significant section of the new motorway through the busy Brisbane Airport Precinct required close coordination with Brisbane Airport Corporation across all design and construction disciplines. Construction included: a new carriageway over a floodplain, under the Airport Airtrain elevated structure and over Airport Drive – the airport's primary access road. In addition, construction of a new interchange (Airport interchange) to provide a vital link to a new airport access road being constructed by Brisbane Airport Corporation (Northern Airport Access Road – Moreton Drive).

**Outcome:** The Gateway Upgrade Project provided the critical link for Brisbane Airport Corporation's delivery of a new second access to Brisbane airport, known as the Northern Access Road Project (NARP). The communication coordination between the two projects was crucial, because of concurrent construction timing and potential impacts on mutually shared stakeholders.

With this in mind, the Gateway Upgrade Team, including project management and communication officers, developed a program of regular meetings with BAC's NARP team over a two year period to ensure potential construction overlaps that could directly affect stakeholders were avoided or mitigated through timely distribution of relevant information.

#### **CASE STUDY 6 - Flood Modelling and Drainage**

*Issue:* Within the 24 km Gateway Upgrade Project site there are two large waterways (excluding the Brisbane River) that required detailed flood assessment and analysis. These are:

- Kedron Brook, northern end
- Bulimba Creek, south of Gateway Bridge.

**Outcome:** For both of these catchments the LAJV consortium built 3D hydrologic models to assist in clear and open discussion and gaining approvals from Brisbane City Council (BCC), Brisbane Airport Corporation (BAC) and the Independent Verifier (SKM). The models were used to demonstrate that there was 'no-worsening' or additional afflux (increase in flood height) due to the works proposed for the upgrade.

Using these MIKE21, 3D simulation models, LAJV were able to reduce the overall span (opening length) of the Kedron Brook and Bulimba Creek crossings. This resulted in the reduction of overall costs without increasing flood height at the adjacent properties. These models were also used to minimise and confirm fill embankment height through the floodplain.

The flood modelling contributed and assisted LAJV in the validation and costing of alternative proposals. The model was used to fine-tune the design to ascertain the optimal level of the formation and span of the bridges and to maximise the benefits to the community and the Airport. This in turn assured BAC optimal immunity to a major flood (up to ARI 100 years) and accommodated any future development in ever growing Australia Trade Coast Area.

As part of the process there were a number of lesson learnt through dealing with the carious authorities. They are:

- Always agree the design parameters and constraints early with each authority
- Bring the authorities along with you on the "Journey" so there are no secrets and no hidden agendas.

#### CASE STUDY 7- Motorway Alignment and Use of Extended Design Domain (EDD)

*Issue:* As a requirement of the tender submission, a conforming bid submission was mandatory. This meant that the design had to conform with all the standards and codes of the day as specified in the Deed and Project Scope and Technical Requirements (PSTR). It was obvious to the LAJV Consortium that this would not give the client, the community and the road users maximum 'Value for Money', safety and maximise benefits.

**Outcome:** At this early stage the consortium decided, in consultation with the client, that a 'Value Bid' be submitted employing Extended Design Domain (EDD as defined by Queensland's DTMR manuals) to some of the motorway alignment to allow maximum benefit with minimum cost and inconvenience. Some of the areas where EDD was applied were:

- Mt Petrie Cutting negated rock cut/blasting
- Minimised property resumption
- Minimised inconvenience to adjacent property owners
- Minimised inconvenience to road users
- Allowed the Project to be built within the restricted corridor boundaries
- Minimised structure bridge length e.g. over Airtrain.

On award of the project to LAJV the "Value Bid" was accepted and the use of EDD was applied, after detailed discussion with DTMR, QML, the IV, the contractor and the designers, to numerous locations throughout the 24 km length of the Gateway Project. A few examples include:

- Vertical curve reduced design speed to negate the excavation of rock in the crest curve, this eliminating any need of blasting adjacent to a heavily urbanised area
- Reduced radii at the northern end of the project to keep the alignment within the existing corridor to add more lanes but not affect the adjacent Nudgee Golf Course (in short-term)
- Greatly reduced length of Airport Drive Viaduct Bridge by application of reduced vertical curve radii and length. EDD was used to change the original design which had a long high viaduct over the existing Airtrain viaduct and Airport Drive to short viaduct over Airport Drive only and an at grade motorway under Airtrain's existing viaduct.

In the project there were up to 30 areas where EDD was applied to increase benefit and reduce costs with no reduction in safety for the Project. The application of EDD is safe as it requires the use of manoeuvring sight distance and wide shoulders to compensate for the revised standard. The use of EDD has not been used as the desirable standard but as an exception not a rule. The design has not used EDD applications adjacent to each other, thus avoiding in a compound effect. It has been used in isolation within the normal standard.

This alignment was extensively workshopped with major input from DTMR, Queensland Motorways, the IV, designers and the contractors so that each application of EDD was properly and extensively reviewed for viability and cost effectiveness. These issues were then put into a Multi Criteria Analysis process to determine the most beneficial outcome to the Project and client.

The achievements from the application of EDD to the project resulted in a cost effective solutions thus allowing LAJV to offer more usable infrastructure to QML. Some examples being:

- Less temporary traffic management movement changes due to less major cuts in rock etc.
- Additional lanes in the north i.e. from four to six lanes
- Extended eight lanes up to Old Cleveland Road.

#### CASE STUDY 8 – Design and construction solutions in soft soils areas

*Issues:* The extent, scale and complexity of the soft soil treatments required through these areas to achieve tight performance criteria put immense pressure on the program and tight resources.

The PSTR also specified both the design process and the performance requirements. This meant that if LAJV followed the design process, and if it did not perform, there was a question as to who carried the responsibility. The outcome of this would have been ground treatments for settlement that were significantly greater than would have 'typically' been selected (e.g. higher preloads, more extensive rigid inclusions supporting embankments etc). For stability, this would have meant larger berms, flatter slopes, etc.

**Outcome:** Through a process of discussion with Queensland Motorways, an alternative approach based on the Observational Method was adopted. This method allowed the selection of design parameters using a more 'typical' approach, then building the resulting design and monitoring the outcomes.

Ground improvement techniques were selected by an integrated design and construction team, to ensure a safe working environment, minimum disruptions to the community and traffic and no adverse effects on the construction program. In particular, appropriate ground improvement methods were selected at the interface of the existing embankment on the northern (Gateway Bridge) abutment area using advance numerical analysis followed by appropriate instrumentation and monitoring during construction to ensure any effects on the existing pavement would be minimal and not affecting the safety of traffic. Improvement techniques, incorporating the use of wick drains, included:

- Removal/replacement of material
- Various pile/stone column techniques
- Preloading and surcharging; and
- Dynamic compaction.

The complexity of the ground treatments to address the soft soil issues and the task of achieving continuity along the sections of embankments is most evident at the interchange areas of the motorway. Rapidly varying embankment heights and changing ground conditions over short distances combined with differing settlement criteria necessitated different ground treatments over what were often small areas of the site. From a design perspective, the merging of the ground treatments to provide a smooth and even pavement surface required careful consideration and analysis to prove that the desired outcomes could be achieved.

Continuous back-analysis of the actual parameters and prediction of the post construction settlements allowed for problem areas to be identified early, and adjustments to the design to be made.

In most cases, construction sequencing was critical to the outcome, and this was achieved by the construction team who developed work methods and schedules to accommodate the required sequencing.

Only where parameters outside the selected range were apparent, was an increase in the requirements for ground treatments adopted. The outcome was a reduction in the costs of ground treatments compared with that which would have been apparent with reliability. It also meant that by using the actual back-analysed parameters to predict the post construction settlement (PCS), the confidence in the long term performance is actually better than that would have been achieved using the reliability method.

It is worthy of note that Queensland's DTMR adopted this approach in calling tenders for the Port of Brisbane Motorway Upgrade, based on the learnings from GUP. The soft ground engineering was a major legacy of GUP project.

#### **CASE STUDY 9 - Ground Treatments for Soft Soils**

#### a) Geological Setting

The Gateway Upgrade Project traverses about 7km of riverine floodplain to the north of the Brisbane River and about 1km in the south within the vicinity of Bulimba Creek. These floodplain soils were deposited over the last 10,000 years (Holocene aged) as sea levels rose to their current level. Prior to the sea level rise, the ground surface was variable resulting from changes in the location of river and its tributaries, as they carved their way through the underlying Pleistocene aged sedimentary soil deposits. At this time, locally at a waterway, the shape of the banks is also variable with steeper banks towards the faster flowing outer bends and flatter banks along the inner slower flowing sections. Figure 1 is a block diagram [Reference 1] showing the elements of a meandering river system that would have been evident at this time.



Figure 1 - Block Diagram of a Meandering River System

With sea level rise, the process of sedimentation over this landscape has therefore resulted in an overlying soil deposit of variable and often rapidly changing thickness over very short distances. The young age of this soil deposit and the fact that it has not been overlain by any subsequent deposits means that it is near normally consolidated, and hence soft in nature. The result is a variable thickness deposit that is difficult to predict in terms of the strength and compressibility.

#### b) Prescription of Reliability Based Engineering Design

Embankment levels within the soft soil areas were typically defined by flood levels, and as a result most were in excess of 3m above existing ground level. In most areas, the placement of such embankments resulted in applied stresses to the soft soils being in excess of the pre-consolidation pressure. This results in primary consolidation occurring under the embankment loads, and/or creep settlements being evident in the longer term.

The PSTR provided the design framework for the project, including, where necessary, the process of design of the soft soil ground treatments. It specified the use of Terzaghi's one dimensional consolidation theory for the calculation of the anticipated settlements, and identified reliability limits to be calculated in accordance with Duncan and Wright [References 2 and 3] for the adopted soft soil treatments. Specifically, the PSTR identified that the calculated reliability of settlements at bridge and structure approach embankments must be 99% and for other areas it must be 95%. A similar reliability level was specified for the stability of embankments. This required a significant volume of data on soil properties for the relevant soil units, which could then be analysed statistically to enable parameters to be selected that would provide the necessary levels of reliability. Essentially, the intent of the requirement was to increase the level of confidence that the design outcome would function as intended during construction and over its design life.

Some of the difficulties in the method specified in the PSTR became evident during the design process, including:

- The method provides a mathematical calculation of probability that the future performance of the embankment in terms of stability and settlement will be within the designated performance criteria. To provide the required confidence, the design must consider the variability in parameters to cater for all ranges of potential outcomes within the desired degree of probability. The outcomes of such a calculation can only depend on the accuracy of the inputs, including the scatter of the data. Where an unexpected situation occurred (e.g. infilled palaeo-channels) the model could not provide the necessary level of confidence.
- The methodology relied largely on laboratory parameters for time based settlement parameters. It is often the case that the field performance differs from the laboratory performance for some compressibility parameters (e.g. horizontal coefficient of consolidation) and therefore the accuracy of the calculations may be questionable.
- The accuracy of predictions of key parameters such as over-consolidation ratio, and the potential for variability over short distances due to unknown historical loading conditions and the like.
- The need to meet reliability criteria such as that specified requires that parameters towards the upper end of the possible spectrum are selected, when in fact those conditions may only occur at a few locations with depth and along the project. This will generally result in an over-prescription of the ground treatments with associated cost and time consequences.

The prescription of the reliability based method also had potential contractual difficulties in that the design and construction would be the result of the PSTR prescriptive approach combined with PSTR performance based specification and therefore the settlement criteria would not necessarily be achieved.

#### c) Adopted Method of Design and Construction of Soft Soil Ground Treatments

Through a value engineering process an alternative approach was recommended by the project team that involved the use of the Observational Method [Reference 4] but applied with more rigor and additional monitoring to reduce the chance of excessive settlements or instability. The approach involved developing a rigorous design based on the available information on the geological model and material characteristics, and then during construction, the implementation of an intense program of monitoring.

The design required the development of a geological model to develop an understanding of the behaviour of the soils. Model development included data from:

- Existing geotechnical and geological investigations;
- Review of morphology, aerial photographs and other published information; and,
- Extensive additional geotechnical investigations and laboratory testing results.

This information was used to develop a design using the principles and methodologies specified in the PSTR.

#### d) Comparison of Reliability and Observational Methods for Settlement

To provide a subjective representation of the comparison of confidence levels of the two approaches, each has been considered in terms of the knowledge on which predictions about the post-construction settlement are based. These are shown as Figures 2 and 3 below.



Figure 2 - Reliability Based Approach



Figure 3 - Observational Method Approach

The figures provide an illustration of the differences in the magnitude of ranges of scatter of the predicted post construction settlements that the designer has to deal with when designing based on a reliability based approach compared with an Observational Method based approach.

Using the reliability approach, the designer must make his predictions on postconstruction settlement at Position 1, (i.e. at the pre-construction stage). The designer has to deal with six major parameters and three minor parameters in the calculations. Each parameter is a statistical variable with its own mean and standard deviation. To design ground treatments and predict the post construction settlement performance with so many variables from Position 1 and achieving a high confidence level (e.g. 99% reliability) is difficult to achieve because of the uncertainties that are evident in the input information. Essentially, the design must accommodate all settlement outcomes within the range of possibilities for the given reliability requirement.

Under an Observational Method based approach, the process of monitoring and backanalysing the parameters as construction proceeds allows the inherent variability in the parameters to be significantly reduced. Depending on the outcomes of the backanalyses and the parameters obtained, adjustments to the design can be made during construction such that the forecast future performance is in line with the designated criteria. On Figure 3, the point at which back-analyses are carried out and adjustments (if necessary) to the design are made is represented by Point 2. Note that, in fact, Point 2 is not a single point but represents a range of times where analyses are carried out and decisions made in relation to required design adjustments. The process is such that by the time the ground treatments are at Point 3, any design adjustments have been made, and by virtue of achieving 90% primary consolidation, the parameter variables have been reduced to one (the rate of creep,  $c_{ae}$ ). By virtue of considering relationships such as those presented by Mesri [Reference 5], the potential variability of the  $c_{ae}$  parameter has also been reduced based on its relationship to the compression ratio (CR), and hence the confidence in the future performance is increased significantly.

It should be noted that use of the enhanced observation method on such a large scale helped reduce otherwise excessive ground treatment works but also required the constructor to reprogram material handling, bridge construction sequences and to be able to change the program and construction sequence if the geotechnical results in a particular location where not as anticipated.

#### e) Application of the Observational Method for Soft Soils on the Gateway Upgrade Project

Both the design and construction phases required careful consideration about the key issues of stability and settlement. From a construction perspective, the monitoring requirements were focussed on stability during construction, which is the critical scenario and settlement during construction to predict times for completion of ground treatments and long term settlements. The various monitoring instruments adopted for the project are summarised in the table below.

Table 2: Summary	y of M	onitoring	Instruments
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Instrument	Purpose
Settlement Plates	Primary measure for monitoring of settlement and for back-analysis of parameters
Surface Settlement Point	Identification of settlement related anomalies between SP's and analysis of change-in-grade.
Extensometers	Monitoring of settlement within various units of the soil profile
Hydrostatic Profile Gauges	Monitoring of settlement across the width of the embankment
Piezometers	Monitoring of pore pressures within the soft soil units for assessing stability and settlement
Inclinometers & survey points located at the toe of the embankment	Monitoring for signs of instability.

The monitoring data was fed into a purpose built database system, equipped with a 'trigger' function that allowed easy identification of areas where monitoring results were outside expectations.

Consideration of stability was made using combinations of the settlement plate and inclinometer data, and the piezometer data. Graphs of the readings were developed and interrogated daily to identify if problem areas existed. The use of the inclinometer and settlement point data is demonstrated in Figures 4 and 5 below.



Figure 4 - Example of Stability Monitoring Arrangement



Figure 5 - ymax vs Smax Plot Relating to Stability

While the measured movement profile itself from the inclinometer will provide an understanding of the subsoil behaviour it is usually found that the ratio  $y_{max}/S_{max}$  (Figure 5) provides a better tool for the plastic behaviour of the soils below the embankment. When  $dy_{max}/dS_{max}$  (say M<sub>a</sub>) approaches unity it basically implies that the soil is undergoing undrained deformation and plastic flow is occurring and therefore imminent failure may result (Figure 5). When this occurs, rate of construction can be slowed, completely stopped, or in rare instances, embankment fill can be removed to prevent likely major instability issues. To provide a margin of safety, an appropriate value of M<sub>a</sub> below one should be adopted.

From a settlement perspective once sufficient embankment was constructed and once sufficient information becomes available to establish trends in the time vs settlement behaviour, comparison of the actual data against the predicted outcomes can provide strong indications of the performance of the ground treatments. For GUP, a process of curve fitting against the actual data was adopted. Key parameters were adjusted to provide a good fit to the time vs. settlement curve, and that information was used to project the time for completion of the ground treatments. This provided a tool to inform the construction team about issues that might affect program, and enabled variations to the ground treatment to be adopted where issues were evident.

Site specific data and established relationships between the primary consolidation parameters and the creep parameters [Reference 5] were used to enable forward post-constructions settlement predictions to be developed. Again, these predictions were used to inform the design and construction process as to where changes to the ground treatments where required. Figure 6 presents an example of actual settlement data from the project, with the curved matched line from the back-analysis.





#### f) Implementation of the Alternative Approach

Demonstrating that this approach would deliver the same if not better levels of confidence in the performance of the project to that prescribed under the PSTR was paramount to the ultimate success of the project. The process of demonstration relied on the key relationships between QML and its advisors and the project team. Through a series of workshops and technical papers, the validity of the method, and its value to the project to alleviate any potential contractual and project confidence level related issues was demonstrated, which allowed the approach to be implemented.

The implementation of the approach relied on a strong link between the design and construction teams. Regular interactions between the design and construction teams allowed the results and options to be discussed and the best approaches for the project to be implemented.

#### 3.2 Gateway Bridge Project

This sub-project included construction of the new Gateway Bridge and the refurbishment of the existing bridge. From the outset it was recognised that early opening of the duplicate bridge and the refurbishment of the existing bridge would provide the maximum benefit in terms of improved level of service to the travelling public.

The alliance formed with VSL Australia enabled speedy mobilisation of technical and construction staff with appropriate major bridge experience and expertise.

The adoption of match-cast precast segmental and balanced cantilever methodology for the approach spans together with the dedicated precast facility adjacent to the bridge significantly reduced the risk of delays. This approach was innovative for bridge construction in Queensland, however a proven methodology for both VSL and LAJV, who successfully used this approach for a significant length of bridge and interchange structures on the M7 Project in Sydney.

Carrying out pile load tests on test piles on land with Osterberg Cell testing long before construction commenced to confirm pile parameters and provide confidence to the client and its advisors ensured smooth progress of pile construction without delays to the construction program. This was the first time this form of testing had been used in Australia.

Close coordination with the Harbour Master ensured unimpeded passage of vessels, including cruise ships, along the Brisbane River during the bridge construction.

The detailed planning and design of the complex temporary works systems enabled good construction progress. The original bridge took five years to construct, whereas the duplicate (wider) bridge took three years.

The following case study is presented to illustrate LAJV's approach to optimisation of the construction task, as it related to the New Gateway Bridge (NGB) and Existing Gateway Bridge (EGB)

# CASE STUDY 10 – Optimal Design and Construction Solutions for New Gateway Bridge (NGB)

*Issue:* To find design and construction solutions for the NGB which satisfied the requirements of the PSTR and provided for lowest cost, fastest construction of this critical element of the overall project works.

**Outcome:** LAJV through its alliance with VSL, and world class bridge designers, in AECOM and SMEC, AAS Jakobsen, and Cardno, brought unparalleled experience and expertise to the task of optimising the design and construction of the NGB.

Constructed on 17 piers, the duplicate Gateway Bridge was built using 65,461m<sup>3</sup> of concrete and 11,600 tonnes of reinforcing steel. Aside from the typical engineering challenges, the 300-year design life is not covered by any international bridge design code. It is a world first.

LAJV addressed this challenge using an integrated design and construction approach delivering best practice outcomes including:

- Adoption of balanced cantilever method of construction for main, main side and all approach spans
- Amended approach spans length (71 m) provided for a 162 m main side span thereby providing the optimal juxtaposition of main side span and approachspan cantilevers
- Use of oblique overhead form travellers (main span) to install prefabricated web reinforcement cages, which were key to optimising the in-situ segment cycle time
- Use of prefabricated web reinforcement cages:
  - prefabrication of reinforcement cages is not unusual, but this process was taken to new levels of scale and complexity to produce parallel work fronts and reduce construction times

- reinforcement for typical 6 m high lifts of the approach piers (9.8 m x 2.3 m with two internal voids in plan) was assembled in a single cage, requiring simultaneously lapping during placement with several hundred starter bars
- vertical reinforcement for approach span segments was fabricated in planar jigs with out-of-tolerance bars rejected
- the vertical "slices" were assembled with horizontal reinforcement in a 3D jig, and then lifted as a single cage into the casting mould
- successful utilising of this initiative on such a scale were achieved by thorough planning, use of fully detailed shop drawings, and adherence to tight supply and fabrication tolerances with the aid of jigs, and special lifting beams for craneage
- o cycle time of four days for in-situ segments was achieved.
- Use of match-cast segmental construction for approach spans a first for Queensland (presented as LAJV alternative and accepted by Queensland Motorways):
  - Queensland Motorways' concerns about durability at the joints in the completed match-cast approach spans were overcome by designing for a minimum compression of 1 MPa at all joints and additional layers of protection by means of an epoxy-filled groove at the top of the joint and an extra layer of waterproof membrane.
  - movement joints were introduced at the contra-flexure point within three approach spans and at the abutments, making the whole bridge a series of multi-span portal frame structures
  - the redundancy that makes the structure robust also presented the challenge of structural halving joints at the movement joints, which had to be temporarily fixed during balanced cantilevering
  - the complexity of staged articulation changes and on-going restrained shrinkage and creep was addressed in the design of movement joints and adopted construction methodology
- Main span pier foundations fewer and larger river pier piles than those used on the EGB allowed for more efficient construction (24 piles of 1.8 m diameter with typical depths exceeding 50 m, compared to 48 piles of 1.5 m diameter).
- The river pier pile caps measure 19.5 m x 17.6 m x 3.2 m thick and therefore required special attention to control early thermal strains and peak temperatures from generated heat of hydration. A detailed description of the approach taken is given in Reference 4. A special concrete mix with extra fly ash and blast furnace slag was developed to reduce heat of hydration. Cooling ducts were also introduced to moderate both peak and differential temperatures. An outer layer of stainless steel reinforcement was used to achieve the design life in the aggressive tidal zone
- Main span pier protection against ship impact this was achieved by means of submerged rock-fill islands which is an effective and durable method and a first for a major bridge in Australia. Rock-fill islands used for river pier protection were connected to shore and raised above water level during construction thereby enabling land-based construction of the piers – pile caps were designed above water to facilitate this method for constructing the piers, and the extra

height of rock-fill used for construction was re-used as rock-fill protection for the adjacent piers on the EGB

- In accord with LAJV's commitment to safe construction, the original specification for personnel to inspect pile sockets and bases was replaced by other methods (to ensure quality: test and production piles using the Osterberg test method (first time in Australia), was used)
- Satisfying the requirements of a 300-year design life for the NGB was achieved through both design and stringent construction controls:
  - design and construction effort was focussed on achieving stringent specifications for concrete particularly in the areas of cover, compaction and curing
  - a workforce awareness campaign under the banner of "Cover, Compaction and Curing (3C's = 300 years)" was used to drive exacting standards for concrete works.



New Gateway Bridge - Northern approach construction with match cast segments

# CASE STUDY 11 – Comparison Existing Gateway Bridge (EGB) with New Gateway Bridge (NGB)

*Issue:* QML envisaged that the twin bridges EGB and NGB only 50 metres apart would be of the same form and appearance. However, while the NGB has six traffic lanes like the EGB, it also had to carry a 4.5m wide shared pedestrian/cycle path, traffic loads had increased and design standards had changed since EGB was designed in the early 1980s, plus there was the requirement for an exceptional 300-year design life for NGB. Construction materials, methods and plant had also progressed.

**Outcome:** There were a number of significant differences from EGB, as summarized in Table 1. However, after the EGB was refurbished the 2 bridges sitting side by side look twins. More detailed descriptions of the design are given in References 1 and 2.

Design or Construction Aspect	EGB	NGB
Main spans lengths	145 m, 260 m, 145 m	162 m, 260 m, 162 m
Main spans cross section	Single cell box with 12m wide bottom flange	Two cell box with 15m wide bottom flange
Bridge Width	23 m	28 m
Main spans construction method	Cast-in-place balanced cantilever	Cast-in-place balanced cantilever
Approach spans lengths	60 m (abutment end) 71 m (typical internal) 88 m (adjacent to main spans, requiring temporary pier)	60 m (abutment end) 71 m (remainder)
Approach spans cross sections	Twin-cell precast box with wide, reinforced cast-in-place joints.	Two single cell match-cast precast boxes with epoxy joints and a longitudinal stitch pour.
Approach spans construction method	Span-by-span construction	Balanced cantilever
Longitudinal fixity	Abutments and river piers	All piers
Movement joints	2 No. (in main side spans) with load transfer by steel needle beams)	5 No (at abutments and in 3 No, approach spans) with load transfer through halving joints.
Bearings	Abutments, top and base of all approach piers, needle beams	Abutments, halving joints

#### Table 3 - Selected Comparison of EGB and NGB

Following the completion of NGB (southbound traffic) six months early, EGB was refurbished to convert it to a one-directional bridge (northbound traffic) with new expansion joints and ITS, lighting, screens, and drainage to update it to the standard of NGB and delivered ahead of program.

#### **CASE STUDY 12 – Balanced Cantilever Construction**

The construction team favoured the balanced cantilever method for the construction of the approach spans. Moreover, match casting of segments was preferred to accentuate the speed and economy of this construction method. Match casting was not permitted for a conforming tender, and an alternative design was produced and accepted by QML after durability concerns were addressed by designing for minimum compression at the joints of 1 MPa, detailing to ensure no voids in the epoxy at deck level, and providing an extra layer of deck waterproofing. Furthermore the span lengths were changed by shortening the 88 m intermediate spans used in EGB to the typical 71 m and thus avoiding the need for temporary piers. The articulation was changed to greatly reduce

the number of bearings and to minimise the scale of and difficulty of future bearing replacements, particularly given the extended design life.

The main span superstructure was constructed as cast-in-place balanced cantilevers with depths of 15.6 m at the piers, and 5.2 m at mid span of the main 260 m span. Segment lengths are 3, 4 and 5 metres, as segment depths progressively decreased. On this critical path, progress was accelerated by design for new-to-old prestressing and design of the travellers with oblique arms to enable placement of prefabricated web reinforcement cages. Cycle times were progressively improved to four days, representing world best performance.

Movement joints are at the abutments and at halving joints at the contra-flexure points of three approach spans. The halving joints were complicated by the need to temporarily fix them to enable balanced cantilevering before subsequently releasing them.

The result then is a bridge which consists of four multi-span continuous frames separated by movement joints. It follows that shrinkage, creep, and thermal strains will induce stresses in the indeterminate structure, as well as govern the range of movement at the joints.

A shrinkage and creep testing program was commenced early in the detailed design phase and continued for more than six months. With respect to thermal movements, the opportunity was taken to install instrumentation in EGB to log joint movements and internal air temperature every 30 minutes. After more than one year the results were compared with data from the nearby Brisbane Airport weather station and with the provisions of AS 5100.2. This investigation is reported in more detail in Reference 3, where it was concluded that bridge movements were related to the preceding eight hour moving average air temperature and that AS 5100 is conservative in the prediction of average bridge temperature ranges for large bridges such as the EGB and NGB.

#### CASE STUDY 13 – Precast Yard

*Issue:* The timely manufacture of thousands of good quality pre-cast concrete elements, piles, super T, match cast segments and noise wall panels needed for the project.

**Outcome:** A state-of-the-art casting yard was established on site to produce precast box girder segments and prestressed octagonal piles for the NGB approach spans, tee-roff beams, deck units, barrier shells, architectural panels, etc. Box girder moulds were recycled from a previous project. Over 10,000 precast items were produced in 18 months. The casting yard was critical to the project achieving overall construction program.



Precast Manufacturing Facility (2008)

# CASE STUDY 14 - Pedestrian, Cycle and Accessibility Special Interest Group (PCA SIG)

Issue: Need to satisfy PCA SIG needs and requirements.

**Outcome:** Amendments were made to the design of the pedestrian and cycle path on the new Gateway (Sir Leo Hielscher) Bridge. The challenge was striking a balance between compliance with Australian road and disability legislation and cyclist and pedestrian safety and comfort. To facilitate a compromise in the most co-operative fashion, the CR team brought together relevant group members, the Project team and DTMR in a separate forum. As a result, variable-grade landings were included on the pedestrian side of the path only, keeping a constant grade on the cyclist side.

#### 3.3 South Project

Widening 16 km of the Gateway Motorway under 'live' traffic (up to 100,000+ vehicles daily), with no impact on peak period traffic flows; multiple interchanges; 16 elevated structures; construction over arterial roads; a rail line and a sensitive waterway (Bulimba Creek); and working beside neighbouring residents and sensitive environments made this one the most challenging section of the project.

Complex construction staging involving hundreds of major traffic 'switches', and thousands of minor 'switches', highlighted the necessity for effective traffic management, while the widening of the carriageway over key arterial roads highlighted four priorities – safety, programming, community and construction methods. Much of this work was undertaken at night to minimise the impact on motorists – the success of this strategy was attributed to excellence in construction planning, construction staging, and particularly traffic management.

An open, honest and responsive approach to community relations was implemented, including six Stakeholder Reference Groups, a project website, distribution of over 2,000,000 communication items, a site based Community information Centre, targeted strategies including night works noise reduction plan, and a 24/7 hotline number. This

commitment to best practice resulted in no community issue threatening project delivery.

LAJV also committed significant dollars to resourcing necessary traffic management and traffic control on the project. Tight delivery timeframes and scope change in early 2009 to widen a key section of the Motorway already well advanced in construction resulted in design changes; the need for extended periods of 24-hour shifts six days per week and the minimisation of additional impacts on the community and environment.

To the South of Bulimba Creek deep soft soils occur and ground treatments were carefully selected to minimise effects on the existing motorway as safety was the primary objective.

The following case studies are presented to illustrate LAJV's approach to optimisation of the construction task, as it related to construction of bridge widening and pavements in the south with complex traffic staging.

#### CASE STUDY 15 – Existing Bridge Widening

*Issue:* Constructing widening or lengthening of 13 existing bridges (17,000m<sup>2</sup> of deck) carrying upwards of 100,000 vehicles a day without closing existing lanes or constructing detours.

**Outcome:** The bridge widening and/or in-fill decks between bridges were achieved by using night works with partial lane closures, diverting heavy vehicles at night and carefully control concrete mix design and reinforcement detailing. Lytton Road Bridge was extended under traffic by adding an extra span to the existing bridge using top-down construction in stages as night works and strengthening the bridge foundations.

#### **CASE STUDY 16 – Pavement rehabilitation strategy**

*Issue:* The PSTR encouraged sustainable construction methodologies.

**Outcome:** In its efforts to deliver sustainable construction methodologies, LAJV identified a rehabilitation strategy for pavements. This entailed leaving the existing CTB in place as a working platform for the new pavement thereby achieving an economic and sustainable outcome.

This rehabilitation strategy was supplemented through the recovery of cut material which could be suitably worked through a pugmill and re-used to form part of the new pavement working platform. This was a key sustainability outcome.

#### CASE STUDY 17 – Pavement construction around live traffic

*Issue:* Extensive pavement works forming part of the motorway upgrade had to be executed around live traffic peaking at 100,000+ vehicles per day.

**Outcome:** Pavement construction over the full width of the upgraded motorway carriageway required detailed planning, staging of works, and a significant number of traffic switches. Each carriageway was required to have the same pavement across the full width of the carriageway, but differing pavement sub-grade conditions due to numerous stages of previous construction (existing motorway) resulted in challenges for the construction team. Furthermore, carrying out early pavement sub-grade

investigations was not possible under live traffic conditions, so issues typically only presented themselves during the investigations carried out immediately prior to construction or during construction. Collaboration between LAJV's construction and design teams and Queensland Motorways, coupled with a logical staging of the works and planned traffic switches, resulted in high quality pavements fully meeting the requirements of the PSTR to be completed ahead of schedule.

#### CASE STUDY 18 - Approach to Pavement Design, Construction and Verification

*Issue:* The approaches to the design and construction of pavements between the northern and southern sections of the project were significantly different. Apart from the more obvious pavement arrangements that involved Full Depth Asphalt in the north and a Deep Strength Asphalt pavement in the south, the approach to design documentation was necessarily very different because the southern construction involved complex traffic staging and existing bridge widening. Therefore sub-grade and pavement testing could only be carried out once a section of motorway was closed to traffic.

The northern section of the project was constructed largely over a greenfield site, where all embankments were new and the materials within those embankment could be chosen to suit the designated pavement design. In the south however, the construction predominantly involved widening of the existing motorway embankments, which necessitated an understanding of the nature and characteristics of the existing embankment materials.

**Outcome:** Traffic on the Gateway Motorway was in excess of 100,000 vehicles per day and this traffic had to be accommodated during construction. Therefore the prospect of carrying out extensive geotechnical investigations to establish existing pavement sub-grade conditions before the design stage was impractical over the full length of the motorway upgrade. Not having the necessary design data therefore necessitated a novel approach to the design and approval of pavements within the southern section.

The approach proposed by the project team comprised:

- 1. The development of a series of design pavements that would cater for the range of sub-grade conditions that are expected to be encountered based on the limited amount of testing carried out for tender. These designs were developed in accordance with the requirements of the PSTR, with preliminary pavement layouts provided on construction drawings.
- 2. The verification of those designs in terms of the compliance to the designated design methods was carried out by the Independent Verifier.
- 3. As temporary traffic management measures were progressively implemented that took traffic off sections of the existing motorway, access became available to carry out the necessary geotechnical investigations. To meet construction timetables, a rapid turnaround for the pavement sub-grade information was required and was achieved with the design and construction teams working together to review data at a preliminary stage, then verify the sub-grade once testing results were available. The process of road section closure to sub-grade verification typically took about two weeks.

4. The results of these investigations were used to review the nominated pavement layout, with the final approved pavement and any subgrade treatment requirements captured in the project quality control system through hold points. This provided the Independent Verifier the opportunity to review and approve the nominated pavement types before their implementation, thus 'closing the circle' on the approval process.

The issue of construction drawings with only preliminary pavement layouts was a significant issue that was overcome by the trust that was developed throughout the project, and the systems implemented to provide the approving parties the prior opportunity to verify the design. The actual process adopted is a variation on the Observational Method, similar to that adopted for the soft soil ground treatments.

Throughout construction, additional pavement types were developed to better accommodate the existing ground conditions. These additional pavement types were approved through the design process and implemented through the project quality control system.

Wherever possible in the south, existing bound pavement base and sub-base materials were re-used. Whilst the differences in vertical alignment limited the areas of pavement rehabilitation, existing bound materials were milled and re-processed for use as working platform for the new pavement. Similarly, wherever lightly bound materials were utilised for temporary pavements, these materials were removed and processed for use as working platforms. Both approaches provided significant benefits, including reducing the importation of materials and creating a more sustainable project.

Ultimately, the approach was very successful, with no significant issues evident during the construction works.

### 4. Leadership and management of project delivery

The Gateway Upgrade Project (GUP) was a project that benefited from strong leadership within a project management team with the experience and competencies to deliver the full scope of the project works.

LAJV's management team structure was based on the delivery of three sub-projects (North, Gateway Bridge, and South).

LAJV was committed from the tender phase of the project to deliver a project that fully satisfied or exceeded all project objectives. To this end, LAJV adopted a 'one road, one team' approach.

This approach extended also to the establishment of strong collaborative relationships with its client, Queensland Motorways, and the project's Independent Verifier - the purpose of these relationships was to foster an environment where alignment on project vision and project scope, and a focus on 'best for project' outcomes. Despite the onerous hard dollar D&C contract the collaborative relationship was maintained throughout the duration of the project and provided many benefits.

#### 4.1 Integrated Design and Construction Functions

The management structure described above and the project management system developed and implemented by LAJV provided the necessary resources, accountabilities, and processes to plan and control both design and construction of the project works.

Due to the nature of the works, it was imperative to have fully integrated design and construction processes. This integration was facilitated through the collaborative efforts of both the design team and construction teams, led respectively by the Design Director and Construction Director.

The Design Team included the full engagement of designers working out of a single project office.

The Construction Team included engagement of two key alliances:

- The Gateway Bridge Alliance, which brought the experience and expertise of VSL Australia into the construction team
- The Gateway Piling Alliance, which brought the specialist expertise and resources of Frankipile Australia, Vibropile and Keller Australia into the construction team.

Fundamentally, construction planning of the works, preferred methodologies and constructability inputs drove design. The Design Plan for the project recognised and provided for the input of the construction teams. Similarly design and design expertise in critical areas such as geotechnical, balanced-cantilever bridge design, and concrete durability strongly influenced how the construction works had to be executed.

The ability to enrol members of the construction teams in the design of the works, and similarly, maintaining a design team presence in the project offices of the construction teams, was critical to optimising design and construction outcomes. To this end the Construction Plan recognised the role of the design team through the construction phase of the project.

#### 4.2 Contribution in the Design Processes

Under a D&C Contract, LAJV was accountable for delivery of both the design and construction of the Gateway Upgrade Project. As outlined above, the full project works, i.e. design and construction of the project, were delivered by a unified team.

Design was an integrated effort of both LAJV's design and construction teams. Importantly design was developed and assessed on a multi-criteria assessment (MCA) basis, which not only considered cost and time, but also other criteria including safety, quality, environment, stakeholder and community, and traffic management. The focus of this design approach, particularly with LAJV's commitment to fully engage Queensland Motorways in the process, was the achievement of 'best for project' outcomes.

The design office was established on site, connected to LAJV's main project office. This enabled the construction and design teams to work collaboratively to deliver design. It also facilitated collaboration in the areas of risk assessment, safety in design, value engineering, whole of life optimisation and material selection.

#### 4.3 Innovations Generating a Legacy for the Construction Industry

This is best evidenced in the design and construction of the duplicate Gateway Bridge to a 300-year design life. Key considerations in the use of concrete materials led to best practice outcomes from durability and performance perspectives. A 3C's (Cover, Compaction, Curing) workforce awareness campaign was carried out to ensure the required outcome was achieved.

Other innovation to allow the 300-year design life to be provided are evident at the northern abutment of the New Gateway Bridge, where a free standing reinforced soil abutment was constructed on a piled raft over up to a 25 m deep soft soil deposit. The removal of the 'hard' link between the bridge and abutment resolved the issue of the abutment potentially affecting the 300-year design life of the bridge structure itself.

LAJV negotiated and adopted an alternative methodology to assess the bridge foundations which allowed Queensland Motorways and LAJV to avoid in-situ inspections of rock sockets some 50 m below the riverbed in piles of 1.8 m diameter. During construction, a remote camera sent down in an open ended diving bell was used to confirm the materials and condition of the base prior to pouring of the piles.

Other key innovations involving the bridge piles were the use of Osterberg load cells (hydraulic jacking cells) in two test piles on land in the design stage long before construction commenced and in two prototype piles (one in each main span pier support). This was an Australian first. Osterberg cells are placed into the pile itself, and effectively 'jack apart' the lower section and the upper section. This allows assessment of design parameters and proving of load capacities of the piles for the design verification, without the need to carry out difficult and time consuming above ground load tests. The cells in the production piles were later grouted to re-join the pile as one complete piece, allowing these tested piles to form one of the actual piles supporting the bridge.

The construction of rock fill causeways were an innovative solution adopted for the new Gateway Bridge construction, to convert the marine based activities, (e.g. construction of pier foundations and arrestor islands in the Brisbane River), to land-based activities. This was done by the clever use of causeway embankments and temporary raisings of the underwater arrestor islands for ship protection as temporary construction platforms. This approach reduced construction risk significantly in addition to accelerating construction, saving cost and improving quality. The construction of these rock fill embankments involved innovatively using controlled mud-waving of the soft soils to achieve an adequate foundation. The design for ship impact is not usually so severe in Australian conditions, but the need to do so was converted into a cost saving to the project by partially constructing the arrestor islands as a first task and using them as a construction platform to build the massive main span piers.

Other bridge construction innovations generating legacies for the construction industry include:

- Inclusion of safe access and work space into the concept design for all jump and travelling forms
- Use of segmental technology in Queensland for bridge construction

- Decision for Gateway Bridge construction to maximise rebar prefabrication from safety and efficiency point of view
- Skewed frames on the form traveller to allow rebar prefabrication
- Use of a temporary horizontal prop during launching of the erection gantry to provide access to the forward pier.

Outside of the bridge, LAJV's approach to designing and executing soft ground treatments using an alternative approach based on the Observational Method (refer above) has resulted in a legacy to road and bridge construction industry in Australia. The legacy is in the form of a cost-effective design and construction solution for soft soil treatment.

#### 4.4 Use and Development of New Technologies

LAJV made a large commitment to research and development particularly in respect of a large number of soft soil foundation treatments, the development of innovative methodologies for construction of the new Gateway Bridge, and research into the achievement of a 300-year life for the duplicated Gateway Bridge structure. The cost benefits of this research and development were realised in the delivery of the project.

Soft soils solutions for foundation of road construction and bridge abutments and piers will form the basis of the design of similar works on future Queensland projects, and throughout Australia.

Advances in bridge design and construction methodologies, including in the area of match-cast segmental construction; in-situ casting of main span segments, pier foundations and river pier protection, bridge articulation and jointing; concrete durability; right down to use of 'state of the art' LED lights (in lieu of fluorescent feature lighting) will be capitalised upon by Leighton Contractors, Abigroup and VSL on future bridge projects.

Furthermore, the sustainability benefits of the 300-year life solution will be enjoyed by the bridge owner over a design life three times longer than that traditionally specified for bridge structures in Australia.

### 5. Conclusion

# 'One Road, One Team' safely delivering to Queensland the infrastructure project of the decade.

The successful completion of the Gateway Upgrade Project by the Leighton Abigroup Joint Venture is a testament to the expertise, commitment and passion of the joint venture and its project partners including the client, Queensland Motorways.

Delivered progressively to expedite benefits to motorists – a key client deliverable, GUP has greatly enhanced the functionality and performance of this critical national and state transport infrastructure asset while also providing the client with cost savings in respect of whole of life costs.

Despite the scale and complexity of this mega project contractor initiated value for money solutions were considered within a whole of team approach in which

collaboration and proactive relationships across all project partners were paramount. Our vision - One road, one team ... safely delivering to Queensland the infrastructure project of the decade - encapsulated the strength of the relationships, which went beyond the terms of the hard dollar D&C contract, helping to drove best for project outcomes; innovative design; and efficiencies in construction methodologies while also underpinning the team's ability to satisfy or exceed all project objectives including exemplary performances in safety, quality, community and environment.

The success of this approach is exemplified by the number of time and cost saving initiatives that were implemented to improve motorway functionally and performance, including the negotiated award of a significant contract extension for an additional 4.3 kilometre upgrade of the motorway south to the Pacific Motorway in April 2010.

"LAJV consistently provided value for money solutions and innovation in design and construction of the Project. A key deliverable of the Project that LAJV fulfilled was to progressively deliver completed sections of the Project to provide benefits to motorists sooner." **David Wright**, **General Manager, Gateway Upgrade Project, Queensland Motorways** 

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