Abstract
The 2.7km, 78 span Ted Smout Memorial Bridge duplicates the existing Houghton Highway across Bramble Bay from Brighton to Redcliffe Peninsula in Brisbane. This is the first time that the knowledge gained from Hurricane Katrina in 2005 has been incorporated into a bridge design in Australia, which resulted in an increased elevation of approximately 3.8m. The Ted Smout Memorial Bridge is designed to withstand a 1-in-2000 year storm event.

Each span consists of eight Super T girders with an approximate length and weight of 35.2m and 82t each. Each pier has two 1500mm diameter cast in situ piles with a load capacity in excess of 1400t each. The bridge incorporates three southbound traffic lanes and a combined cycle/pedestrian lane. An adjoining fishing platform has been constructed adjacent to the Pine River channel on the eastern side of the bridge.

Introduction
The Houghton Highway resides within the Metropolitan Region of the Department of Transport and Main Roads and is part of a state-controlled road network which forms the key transport link across Bramble Bay from Brighton to Redcliffe Peninsula. On 20 April 2005, the Premier of Queensland, the Minister for Transport and Main Roads and the Member for Redcliffe jointly announced the duplication of the Houghton Highway between the Deagon Deviation at Brighton and Elizabeth Avenue at Redcliffe. The duplicate bridge has been named the Ted Smout Memorial Bridge in honour of Queensland’s last World War I veteran.

During the planning and design stages of the Houghton Highway Duplication Project, it was identified that the Houghton Highway shared a number of similarities with bridges that were destroyed in southern states of USA as a direct result of Hurricane Katrina in 2005 (3). The Ted Smout Memorial Bridge will be the first time this knowledge is incorporated into a design in Australia and resulted in an increased elevation of approximately 3.8m. As such, the Ted Smout Memorial Bridge is designed to withstand a 1-in-2000 year storm event and have a minimum design life of 100 years in accordance with the Australian Standard AS5100 Bridge Design.

Once the new Ted Smout Memorial Bridge is operational, the Houghton Highway will be surfaced with an asphalt running surface with epoxy nosing expansion joints.

1 Queensland’s last World War I veteran, Edward ‘Ted’ Smout OAM, was born on January 1898 and joined the Royal Australian Army in 1915 when he was seventeen. Mr Smout passed away on 22 June 2004 aged 106 years.
Contract
The detailed bridge design was undertaken by consulting engineers Kellogg Brown & Root. The bridge was constructed using a Road Construction Contract (RCC) and the contract was awarded based on a two stage tender process. Stage 1 included a review of all proponents and shortlisting based on non-price criteria only. In Stage 2, the two shortlisted proponents were invited to supply a price only and the ensuing tender was selected on the lowest price. The contract for the $258.4M (GST inclusive) Ted Smout Memorial Bridge was awarded on 14 December 2007 to the Hull Albem Joint Venture. The joint venture was formed between JF Hull Holdings and Albem Operations Pty Ltd. The project is due for completion in mid 2011. The land reclamation, bridge approaches and associated road works are being constructed via subcontract with Bilby Holdings Pty Ltd.

General description
The existing Houghton Highway will carry northbound traffic while the Ted Smout Memorial Bridge will carry southbound traffic. The Ted Smout Memorial Bridge has 78 spans at 35.2m per span with a total bridge deck length of 2746m. Each span consists of eight Super T girders approximate length and weight of 35.2m and 82t each. Each pier has two 1500mm diameter cast in situ piles with a load capacity in excess of 1400t each. During construction of the original Houghton Highway project in 1979, Decker Park adjacent to the southern end was used extensively as a site of casting yard. For the Ted Smout Memorial Bridge, a smaller area of Decker Park has been utilised and was used primarily for the site office and for temporary storage of materials. The girders and kerbs are manufactured off-site by two suppliers — Con Tec and Enco. The girders are delivered to site approximately twice per week between 2am and 5.30am. They remain on the transport vehicles and are off loaded directly onto the bridge without double handling. Concrete is manufactured off site by Hanson Australia Pty Ltd and is supplied from two separate manufacturing facilities.

A section through deck is shown in Figure 1. The bridge will have one T2 transit lane, two normal traffic lanes and a combined cycle/pedestrian lane (1). The deck wearing surface of the traffic lanes will be asphalt while the cycle/pedestrian lane is concrete. Lighting services are carried in the concrete parapets with communication and electrical cabling carried in the cycle/pedestrian lane.

Due to the marine environment, exposed metal components are manufactured from either stainless steel or aluminium alloy.

Bridge foundations and substructure
The alignment of the Ted Smout Memorial Bridge was initially planned between Houghton Highway and the Hornibrook Highway. A geotechnical survey was performed on this alignment. However, there were concerns about the safety of the structures; if a crane was to accidently fall across the Houghton Highway and secondly, but to a lesser degree, were the implications of a Katrina-like event lifting decks from the Houghton Highway and depositing them against Ted Smout Memorial Bridge. To eliminate these risks, the bridge alignment was shifted to approximately 35m east of the Houghton Highway. Geotechnical data was then obtained for the new alignment. Hence there is a high degree of confidence with the geotechnical data as there is now three data sets: the original 1979 Houghton Highway, the initial western alignment and now the final eastern alignment.

The existing Houghton Highway foundations were comprised of five pre-stressed octagonal piles. Because of their length, these piles were driven in two sections. The bottom section of the pile was initially driven to a few metres off water line. Precast holes in the bottom section mated with stainless steel dowels in the top pile section. The two pile sections were joined with epoxy resin and the extended pile driven to the required depth.
The Ted Smout Memorial Bridge is supported on two cast in situ piles sunk approximately 36m at the deepest point below seabed level (Figure 2). A pile is first constructed by driving an open 1500mm diameter liner. A thick walled beveled cutting edge is welded to the toe of the liner. The liner is driven to founding depth with an IHC S-280 hydraulic hammer. The hammer output can be adjusted up to a maximum output of 280kNm per blow. The pile toe embedment is approximately 300mm to 400mm into the weathered sandstone founding layer.

Figure 2. Pile founding depth

After the pile is driven, excess liner is cut to the required level above water level. The amount of liner wastage is reduced as the accurate geotechnical data allows for accurate prediction of founding levels. The pile is excavated to approximately 10m below seabed level using a crane and clam shell bucket. As there was a possibility that the excavated material contained acid-sulphate soil and hence posed a project risk, all excavated materials were safely dumped off-site. With the majority of piles, the excavation was dry. However, on those piles where the pile toe had not formed a watertight seal, a concrete plug approx 2m long was used to seal the pile.

Prefabricated steel formwork allows the accurate transition from the 1.5m liner diameter to the finished pier size of 1.2m (Figure 3). The difference in heights of the two transition pieces is due to the 3% deck cross fall.

Figure 3. Pile transition formwork

Next the steel reinforcing cage is installed and the pier cast. The concrete is a flyash/concrete/super plastisers mix design to MRS11.70 specifications.

These piles differ from most cast in situ piles in that the load transfer mechanism from the concrete pier to the foundations is not through end-bearing of the concrete pier. Instead the load is transferred from the concrete piers to the steel liner via internal circumferential rings (Figure 4). The steel liner in turn transfers the load through skin friction in combination with the liner cutting edge bearing on the founding material. Corrosion of the unprotected structural section of the liner is deemed not to occur as this area is in the anaerobic zone. The area above the anaerobic zone will corrode with time.

Figure 4. Shear rings welded inside pile
The steel formwork transition pieces used to cast the piers were kept in position to provide support for a lower work platform and the headstock falsework support beams (Figure 5). The headstock steel reinforcing cage is prefabricated on land and lifted into position. Additional formwork and blockouts are installed to provide bearing pads recesses and transverse shear blocks. The finished headstock is shown in Figure 6.

**Figure 5. Falsework supported on transition formwork**

**Figure 6. Finished headstock**

**Bridge superstructure**

The girder bearings are conventional multi-plate neoprene. The eight Super T girders are installed with horizontal bearing pads. As standard design girders are installed with the top flange parallel with the base, a step is formed with adjoining girders due to the 3% crossfall. The gap between girders is sealed with bitumen impregnated fabric strip prior to casting the deck (Figure 7). A cross girder, approximately half the girder height, is installed at both ends of the deck, however no other cross girders are installed. The cross girders are cast monolithically with the deck.

**Figure 7. End cross girder reinforcement and bitumen impregnated strip between girders**
As mentioned earlier, the Ted Smout Memorial Bridge is designed to withstand a 1-in-2000 year storm event. A storm surge can damage a bridge structure in a number of ways — displace a bridge deck sideways off its bearings, lift the deck up over shear blocks or in cases of very high surges, create sufficiently large uplift forces which cause stress reversal in the bridge decks. To counter potential tidal surges, the bridge is built above the tidal surge zone and the decks are anchored to the headstocks (Figure 9).

Side forces on the structure are resisted by the Super T beams bearing against the shear blocks. At the contact point, the shear blocks are faced with stainless steel plates which have a square strip welded around the circumference on three faces which creates a pocket when combined with the flat web of the abutting girder. Figure 10 shows this stainless steel plate prior to fixing. Once the Super T beams are installed, a rubber block with one bonded PTFE face in inserted into the recess.
Every five consecutive spans are joined together at deck level to reduce the number of expansion joints. The connection between the spans is essentially an extension of the deck. The super T beams are not joined to form a structurally continuous beam. The joints between these continuous spans may be considered as a flexible hinge, which allows the spans a limited amount of rotation in the vertical plane. The yellow arrow in Figure 11 indicates the width of de-bonded area beneath the connecting slab.

**Figure 11. Yellow arrow shows the limit of the de-bonded area**

At the expansion joints, the neoprene bearings are greater in height than the standard bearings to cater for the increased horizontal movement. The expansion joints are finger type joints manufactured from aluminum alloy (Figure 12).

**Figure 12. Aluminum alloy finger expansion joints**

**Fishing Platform**

The Ted Smout Memorial Bridge includes a purpose built fishing platform located on the eastern side of the bridge. The platform is approximately 50 metres long by 10 metres wide and is located adjacent to the Pine River channel. The fishing platform is accessible via a ramp from the shared pedestrian/cycle path and is designed for wheelchair access.

**Figure 13. Part of the fishing platform**

**Erection methodology**

Work platform — Because Bramble Bay is very shallow and a large part of the alignment is accessible by foot at low tide, the use of barges for construction would make the timing of works dependent on the tides.

The erection methodology adopted was to erect a temporary work platform on the eastern side of the bridge. This platform is used to support one side of the overhead gantry cranes, material transfer, equipment storage and a work platform for the track cranes.

The platform is erected by initially driving hollow steel liners which have a reinforced concrete pile toe (Figure 14). The liners are driven using a BSP CG180 hydraulic hammer. The liners are cut to length and a prefabricated cap inserted into the liner. A steel headstock, diagonal bracing and girders are installed next.
Each span of the work platform is a quarter of the bridge span or approximately 8.8m. Reinforced concrete deck slabs are bolted into place followed by fitting a single rail line to support one leg of the gantry cranes and rail lines for a motorised rail carriage used for material transfer. Because these components are used many times over to span the 2.7km bay, the complete system is designed to be reusable with the exception of some liner repairs.

Drive eastern liner — A large tubular piling frame is next bolted to the underside of the platform girders. A vertical pile frame is bolted to the end of this frame as a ‘leader’ for the pile driving operation. The eastern 1500mm diameter liner is then driven and trimmed to length. During piling operation, all weight of the piling frame and hammer are cantilevered off the work platform (Figure 15).

Drive western liner — An extension support frame is inserted between the pile frame and the previous section. Most of the weight of the cantilevered frame is now supported by the eastern pile. The western pile is driven and trimmed to finished length.

Casting piles — After the piling frame is removed, the eastern pile is trimmed to final length. The material inside the liners is excavated using a track crane and a clamshell bucket. The excavated material is loaded into a skip, transferred by rail wagon to the end of the work platform and eventually transferred by truck for disposal. The transition formwork is then fitted to the liners (Figures 3,17), followed by installation of the reinforcing cages. Concrete is pumped from the end of the work platform and tremied into the liners.
Headstock construction — Once the columns are poured, the transition pieces support transverse beams which in turn support the headstock formwork. The preassembled headstock reinforcement, shear block and bearing block-outs are installed and the headstock is cast.

Deck construction — The girders are supplied directly from the casting yards and the vehicle is driven across the bridge to the new construction area. Operating in tandem, the two gantry cranes lift a Super T beam from the transport vehicle, traverse over previously constructed bridge decks and lower the beam into position.

Gantry crane — To support the gantry rail on the western side, a triangular shaped truss is clamped below the headstock. A separate triangular erection truss which is approximately 140m long is supported by four headstocks. As work progresses the erection truss is launched forward sliding on the headstock supports. The gantry wheels run along a rail on top of the launching truss and along the work platform.

Work cycle — The work cycle for construction of a bridge span is four to five days. As the work platform advances, the daily cycle is to disassemble the last bay of the work platform and transfer the deck slabs and beams to the front of the platform on the rail wagon. As one bay is removed from the end of the platform, one bay is constructed at the front of the platform. As the length of four bays of the work platform are equivalent to a span length of the bridge, on average every four days one span of the bridge is constructed.
Pile driving frames are attached to two large beams which are launched/cantilevered from the front of the work platform. Figure 21 shows a work platform pile that has been driven to depth, trimmed to length and the pile cap inserted.

The work platform piles are extracted with a hydraulic vibratory extraction device which has jaws that grip the top of the pile wall. A crawler crane maintains a constant upward force during the extraction process. Once the piles are extracted they are sent ashore to be repaired and extended. A small number of liners could not be extracted as skin friction was too high resulting in the extractor tearing away the steel wall. These ‘difficult’ liners will be cut off at least 1m below sea bed level.

Summary
Initially the construction was slow, however as work practices were refined the construction and systems developed, the final rate and quality of construction was high. The construction of the Ted Smout Memorial Bridge is on schedule and is due to be completed by mid 2010. The total project including demolition of the old Hornibrook Highway and refurbishment of the Houghton Highway is due for completion in mid 2011.

The relationships between all contract parties were very good. The Hull Albem Joint Venture team must be given credit for creating a good working environment.

References

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