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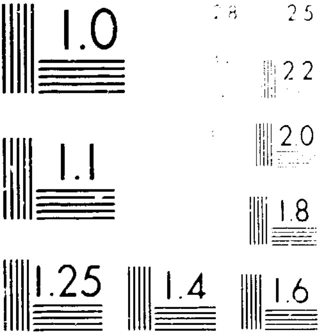
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POST TENSION SEGMENTAL BRIDGES: THE HOUGHTON HIGHWAY VIADUCT ACROSS BRAMBLE BAY *

by

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1. INTRODUCTION

The need to provide increased traffic capacity on the "Hornibrook Highway" linking the cities of Redcliffe and Brisbane has been evident for some years. The existing timber and concrete bridge, being 6.8 m wide between kerbs, has no provision for passing a disabled vehicle when there is heavy two way traffic. Because of the length of the bridge, approximately 2.7 km, the time necessary to obtain assistance and remove such a vehicle is considerable and long delays are unavoidable. Even though an emergency telephone system has been installed, increasing delays have caused the Department to take action to provide additional traffic capacity.

2. PRELIMINARY INVESTIGATIONS

Preliminary investigations with a view to constructing either a bridge, causeway or combination thereof were commenced by the Department in 1973. A foundation report completed late in that year indicated good foundations adjacent to each bank but poor foundations of compressible mud and sandy materials between the shipping channels of Pine River and Hay's Inlet. Accordingly, it was considered that the alternatives condensed into either bridging the whole length or using causeway at each end and bridging the central section (approximately 1.2 km long)

If a causeway of any extent was to be constructed, then a detailed Environmental Impact study had to be commenced, particularly as the site is adjacent to a marine habitat reserve. In addition, any restriction on the width of the available waterways was likely to affect flood levels in the Pine River. Both of these effects were likely to be controversial, expensive to investigate and take a considerable time to resolve.

As so much of the length had to be bridged in any case, the potential saving of the causeway/bridge alternative over a full bridge was only $357,000 in a total estimated cost of $6 million. This was not considered sufficient to outweigh the difficulties involved.

3. DECISION FOR BRIDGE

In mid 1974, a decision was made to bridge the whole length and designs were prepared for a crossing located 60 m downstream from the existing bridge. The position of the new structure is such that, should the need arise to provide a third bridge at the end of the useful life of the existing one, it can be located between the new and the old bridges.

4. DESIGN CONSIDERATIONS

4.1 Clearances

Upon application to the Marine Board, shipping clearances of 7.4 m at Pine River and 5.3 m at Hay's Inlet were determined for prescribed shipping channels. The Pine River channel is angled to the bridge and the maximum clearance points in both new and old bridges do not line up. In order to define the channel, day and night navigation marks are provided on the new structure.

The height of the remainder of the bridge away from the channel crossings was determined by a policy of keeping the girders above maximum water level. This level was fixed from information obtained from the Harbours and Marine Department and the Bureau of Meteorology in respect of tide levels, storm surge and wave heights for both maximum expected and observed values. Typical values used were:-

Mean High Water Spring Tide	..	..	2.12 m
Highest Spring Tide	..	..	2.32 m
Storm Surge (1:100)	..	..	0.91 m
Storm Surge (max.)	..	..	1.22 m
½ Wave Ht. (max.)	..	..	1.22 m

A final deck level of RL6 was determined. This is 1.61 m higher than the existing bridge over which waves have broken in the past.

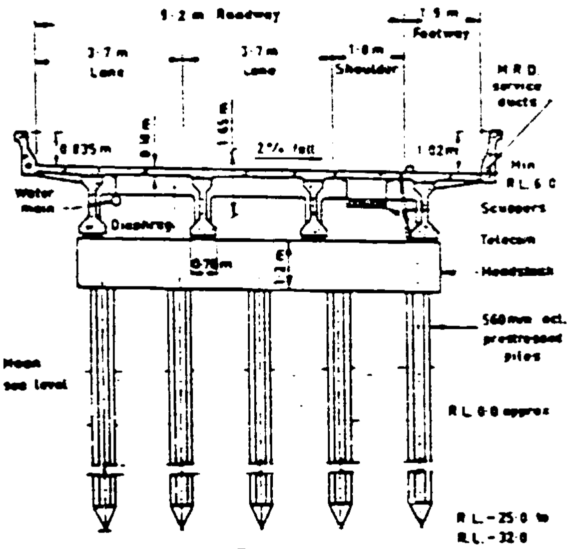

FIG. 1

4.2 Deck Cross Section

The new viaduct provides for two 3.7 m wide traffic lanes, a 1.8 m breakdown lane and a 1.8 m footway. (See section shown in Fig. 1.) This arrangement provides the greatest flexibility in the use of the deck width by allowing:-

(a) Two 3.7 m lanes plus breakdown lane plus footway; or

(b) Three 3 m lanes plus footway (for short term tidal flow arrangements); or

(c) Three 3.7 m lanes (by removing the kerb and using the full width for one way traffic or for long term two way tidal flow).

The bridge is fitted with concrete parapets to provide greater safety for vehicles on impact and also to reduce the effect on vehicles of wind and spray. This does not incur any cost penalty to the bridge because an alternative steel barrier, designed to the new NAASRA loadings would, in both initial cost and maintenance, be more expensive.

Barrier height was chosen at 0.83 m on the upstream side so that no additional steel rail was necessary. On the downstream side, the barrier height will be 1.02 m which is sufficient for pedestrian safety. The absence of steel rails will greatly improve lateral visibility for car occupants which is a considerable advantage for a bridge in such a picturesque location.

No bituminous wearing surface has been provided although the section is designed to accommodate it if required at a later date. To control skidding and aquaplaning, the concrete wearing surface has a broomed finish to produce an average texture depth of not less than 0.75 mm as determined by the "Sand Patch Test".

Another feature of the cross section is the shallow depth of the diaphragms which are only one third of the depth of the girder. Apart from minimizing cost, this has allowed formwork for the deck to be lowered onto carriages supported off the bottom flange of the beams and moved to the next location. Similar carriages may be used for the installation and maintenance of services which are suspended between the girders from the underside of the deck.

4.3 Design Loads

The design was based on a live load of three MS18 trucks in accordance with the 1970 NAASRA loadings. In addition, the bridge has been designed to carry an abnormal load of 196 tonnes travelling down the centre line of the structure.

Longitudinal braking forces were determined as either 5 per cent of the MS18 lane load applied along the bridge or equal to the weight of an MS18 truck applied as a point load (320 kN). This latter requirement was a considerable increase over the existing NAASRA loads and was used because a major determinant in the design of this type of bridge with its buffer pads distributing longitudinal forces, is the braking load. Research work undertaken in the United Kingdom has indicated that this increased load is possible and should be considered.

Design wind velocity derived from cyclonic conditions was calculated at 60 m/s. The resultant wind force can be accommodated without causing permanent damage to the bridge while higher forces could be taken with some temporary cracking occurring in the piles.

4.4 Durability

The whole of this structure is in the salt spray zone and hence corrosion resistance and durability are prime considerations. To satisfy these requirements the following policy was adopted:-

(a) Prestressed concrete to be used where possible to reduce cracking, e.g. beams and piles;

(b) Use of dense high strength concretes throughout, e.g. 30 MPa in decks and headstocks, 45 MPa in beams and piles;

(c) Increase in concrete covers, e.g. 75 mm on piles, headstocks and abutments, and 40 mm on beams and decks;

(d) Control of concrete cracking at serviceability loads (0.1 mm maximum);

(e) No exposed structural steelwork, railings, etc.;

(f) All metal couplings for future attachments, e.g. lamp-standards and services are stainless steel treated with an anti-corrosive compound and capped.

4.5 Economy

Any bridge which has 2 700 m of exactly the same type of structure must be designed so that the concrete section is as efficient as possible. This was achieved by minimizing the areas of concrete that are not significant load carrying members. The deck cross section was designed for the minimum number of supporting beams and each beam was designed to obtain the minimum cross section. This optimisation process was not constrained by the need of the beam to conform to any standard profile as the length of the structure was more than adequate to "write off" the cost of special formwork.

Bridge spans of 18.3 m, 27.4 m and 36.6 m (in multiples of the 9.2 m spans of the existing bridge were investigated and the 27.4 m size was selected as being the most economic in total cost.

Precast prestressed piles were chosen as the most economic form of substructure and every effort was made to keep the number of piles to a minimum (since their lengths exceeded 35 m in places) and to keep them vertical if possible to speed conrtruction. This latter objective was met in all areas except for the higher sections of the bridge over the river channels where the outer piles in each group were raked to increase the resistance to lateral forces. 560 mm octagonal piles were selected because of their increased bending capacity.

Consideration was given to making the structure continuous under live load. This proposal was not adopted because of:-

(a) Increased cost in the substructure to provide additional capacity to resist longitudinal loads;

(b) Increased cost of providing prestressed continuity between spans outweighed any saving in beam requirements. Continuity obtained using reinforcing steel was not acceptable because the resultant deck cracking could not be protected without a bituminous wearing surface;

(c) Reduced flexibility and ease of construction;

(d) The need to provide higher movement capacity bearings and expansion joints which would be difficult to keep free of corrosion.

Therefore it was decided to use four pretensioned simply supported beams for each 27.4 m span supporting a reinforced concrete cast-in-place deck. Expansion joints at each headstock consist of an open 12 mm gap which from previous experience, should prove relatively noiseless and smooth riding.

To keep the number of piles to a minimum, a system was devised whereby longitudinal forces (braking loads) were distributed between several piers instead of each pier taking the full force applied to its supported span. This was achieved by inserting between the ends of the beams at each headstock, a rubber buffer which could transmit longitudinal forces from one span to the next but still accommodate the change in length of each span due to temperature, shrinkage and creep of the concrete. (See Fig. 2) To allow for these changes in length, the pads are precompressed 20 mm with a screw mechanism during installation.

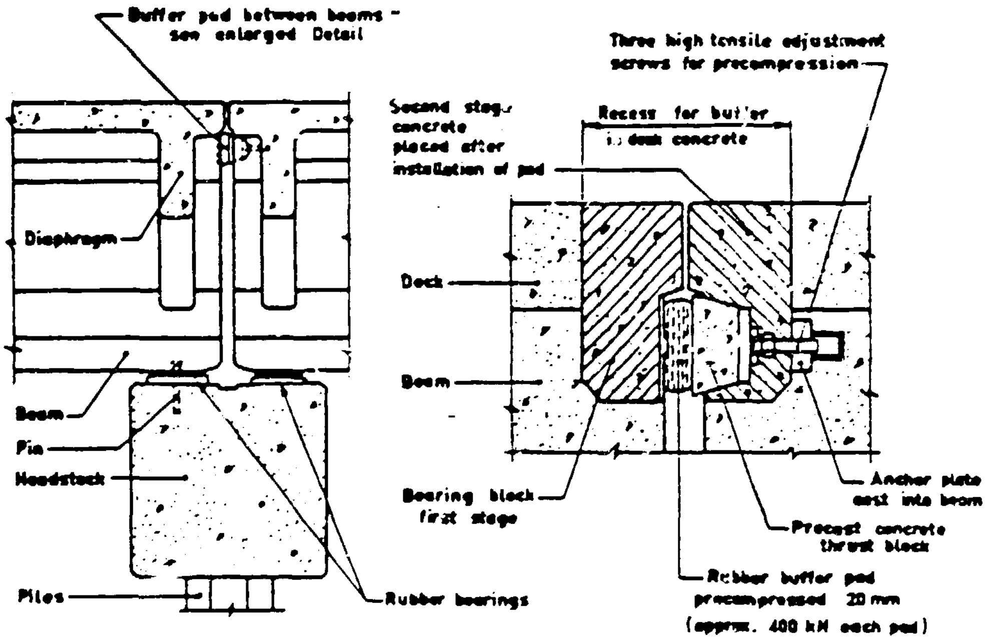

FIG. 2

4.6 Aesthetics

Within the limitations of obtaining maximum economy, aesthetics were considered in ensuring continuity of line of all exposed faces of the structure such as the parapets, deck cantilevers and beams. Improvement could have been obtained by setting the piles further in from the face of the headstock, by using fewer piles, or by concealing the headstock within the depth of the girder. However, the resultant increase in cost was prohibitive on this length of bridge.

Attention was given to drainage to prevent staining of girders and headstocks. Lack of these provisions often scars the most attractive bridge.

4.7 Services

Cast-in sockets are provided on the underside of the deck for support of a 300 mm diameter water main and six 100 mm diameter Telecom ducts.

Short lengths of ducting for each of these services are provided at each abutment to carry them to the edge of the formation.

Ducting is provided within the parapets for future roadway illumination and for lighting of navigation markers.

5. CONSTRUCTION

5.1 The Precasting Yard

A precasting yard with batching plant, mixer, steam generator, two 20 tonne gantry cranes and other services was set up on site. The contractor obtained a steel-truss beam casting bed previously used on Section D of the Riverside Expressway to cast the 396 pretensioned beams. A 40 m long steel pile bed was fabricated to cast 15 000 m of 560 mm octagonal piles. On average, 170 m of pile and five 36 tonne beams were produced per week.

5.2 Pile Driving

A specialist subcontractor fabricated a piling rig and drove the 518 prestressed piles. The rig consisted of three moving platforms supported on a temporary steel pile and rail system as shown in Figure 3. The 15 ton air hammer was driven by two large compressors and operated by a remote-controlled valve mechanism. Piles were transported along the finished bridge, loaded onto pontoons by the gantry cranes, and floated out to the pile rig at high tide.

Piles over 20 m long were formed in two parts and joined by a heat-cured epoxy splice. The splicing operation took less than two hours. Because of the variable level of the sandstone founding layer, additional drilling was required during the contract. A small floating drilling platform with hydraulically operated legs was fabricated for this task by MRD.

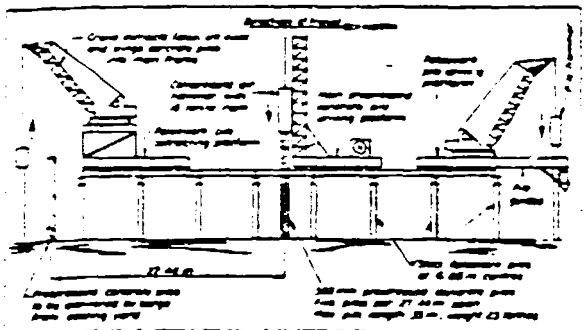

FIG.3 [illegible]

5.3 Temporary Falsework for Deck Construction

The Contractor proposed a falsework system supported by the permanent structure. This arrangement was checked by MRD and after minor modifications was approved. Steel friction-grip collars support twin steel beams, and these support the concrete headstock formwork and the Acrow Panelbridge. The Panelbridge (a modified Bailey bridge) extends over 5 spans of the bridge and carries two diesel-electric 20 tonne gantry cranes.

This arrangement allows work to proceed as illustrated in Figure 4. completing a 27.4 m span in five working days.

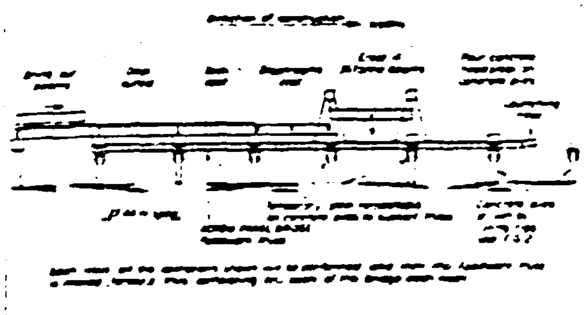

FIG.4 [illegible]

5.4 Deck Formwork

Two sets of deck forms were used. A special bracket fastened with one HT bolt was designed to clamp around the lower flange of the prestressed concrete girders. This bracket supported the deck and diaphragm formwork props, and held rails for five small hydraulically operated trolleys. These trolleys enabled stripping of the formwork, movement forward beneath the next formed deck and erection of the formwork on the leading span. The forms were steel framed and ply faced. However, after about 20 deck pours, the forms were faced with 3 mm steel sheet which lasted the remainder of the job. The deck concrete was delivered premixed, placed by the gantry cranes, and levelled by a full width vibrating screed. The height of the screed could be adjusted hydraulically and driven from a central control panel in either direction.

5.5 Development and Testing

Because of the large number of repetitive operations, it was economical to design special equipment for this project. During the early stages, an extensive testing programme was conducted on both construction materials and temporary falseworks. Relaxation and tensile tests were conducted on the prestressing strand. Creep and shrinkage tests are continuing on the concrete. The friction collars were designed and tested to 180 tonnes, twice their working load. The formwork support brackets on the beams, and the holding-down devices for the deflected prestressing strand were tested to destruction.

A concrete testing laboratory was installed on site. Tests were conducted at 18 hours, 3, 7, 14 and 28 days, or whenever loading was to be applied to concrete members. In general, concrete in decks and headstocks was heavily loaded by concrete trucks and gantry cranes at between 4 and 10 days. Precast piles were subjected to hard driving at 48 hours when a pile length had to be changed in an emergency. The precast concrete was steamed overnight and the temperature in the long line beds was controlled by a 12 channel thermocouple recorder. Mean 28 day strength was 53-56 MPa, characteristic strength (28 day) 47-49 MPa and 12 month average strengths 60-70 MPa.

A special test rig was made up by MRD for use on the pile rig. Every epoxy splice was tested before driving. Average strength was 100-110 MPa in compression

6. CONCLUSION

The original tendered price in December 1976 was \$6.4 million. With some extras and rise and fall payments, the total contract price will rise to about \$7.5 million.

The current (October 1979) cost of this structure is \$250 per square metre, about 60% of the current price for similar, but shorter bridges, reflecting the economy of scale such a project offers the Contractor. The bridge will be completed by the end of this year, several months ahead of schedule.

7. ACKNOWLEDGEMENTS

The bridge was designed and supervised by the Main Roads Department, and constructed by Barclay Bros. Pty. Ltd. The pile driving was carried out by Vibropile (Vic.) Pty. Ltd.

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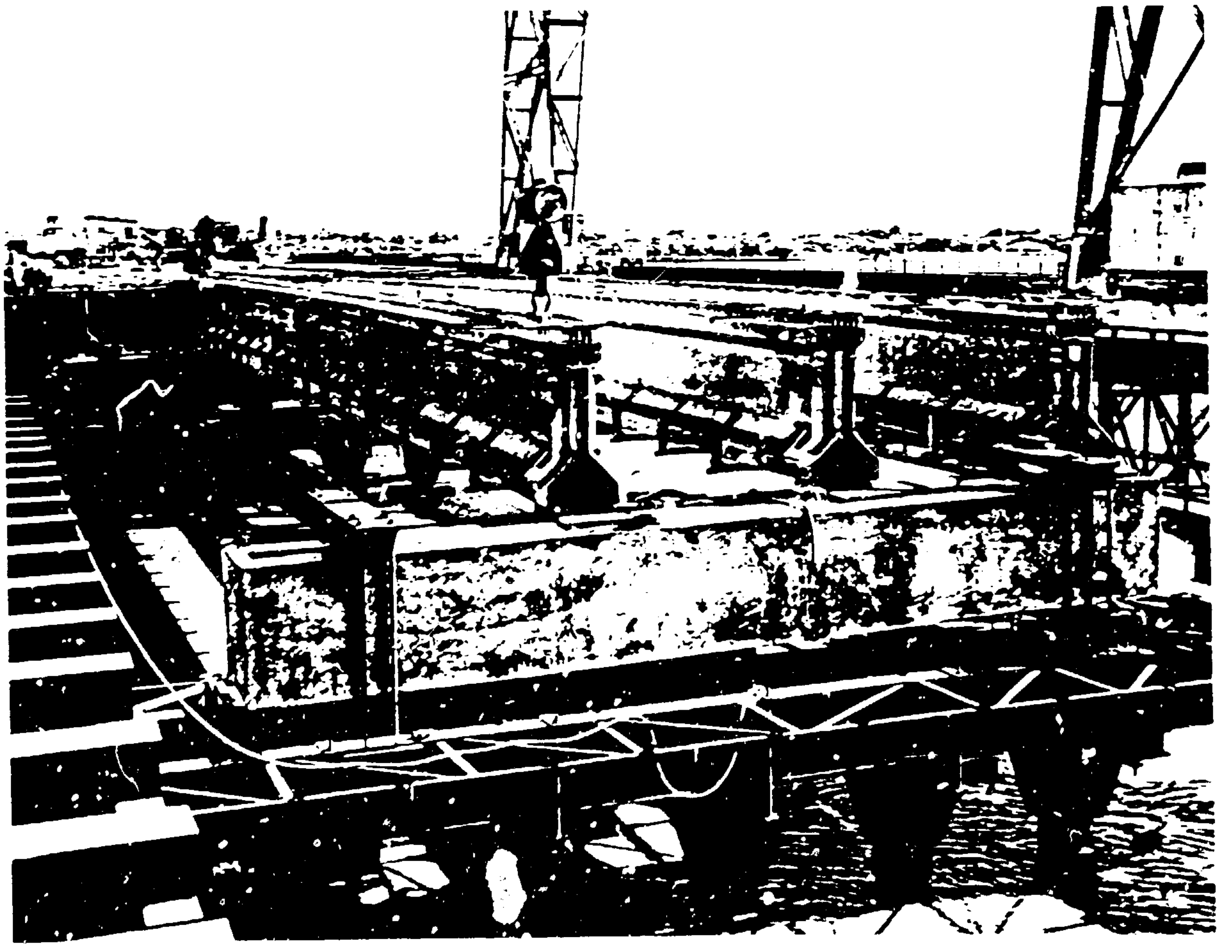

THE HOUGHTON HIGHWAY ACROSS BRAMBLE BAY