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10. Fahaheel Expressway (Kuwait)

Owner: Government of Kuwait, Ministry of Public Works

Consulting Engineer and Designer: W.S. Atkins Overseas Limited

Beam Manufacturer: Real Estate Construction & Fabrication Company

Works Duration: 27 months.

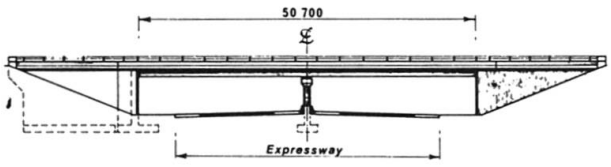
In mid-1978 the Kuwait Government Ministry of Public Works appointed W.S. Atkins Overseas Limited to design and supervise major improvements to the existing 39 km long Fahaheel Expressway which leads southwards out of Kuwait city towards the Saudi Arabian border. The improvements involve the provision of 16 grade separated interchanges, footbridges, numerous culverts, together with a number of other junction and road improvements.

Bridges

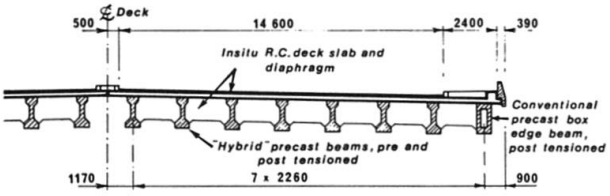
The various improvements required the construction of 17 bridges of various skews.

With little geometry variation except for skew, which in itself only varied from 0°-25°, the bridges presented an ideal case for standardisation.

The typical form of standard bridge deck chosen consisted of two simply supported spans constructed of AASHTO-PCI Type 4 precast concrete I beams, 1,350 mm deep, spaced at 2,260 mm or 1,980 mm centres, with exterior precast concrete box beams of the same depth. The beams supported and acted compositely with a 200 mm minimum thickness in situ reinforced concrete deck poured on steel or grp permanent formwork panels. Column piers, abutments and return wing walls are of conventional in situ reinforced concrete, founded on spread footings.

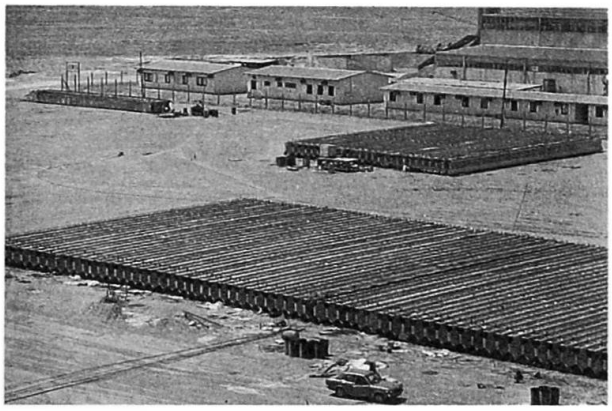


Elevation of typical overbridge



Half cross section through deck

The success of the standardisation is indicated by the fact that all but one of the bridges were catered for by only two beam lengths, 25.8 m and 28.45 m. These lengths were also applicable to the special exterior box beams and the tee beams used for the footbridges. A further element of standardisation was introduced by reducing the spacing of the longer beams to 1,980 mm, such that the same cross section and the same amount of prestressing could be used for both beams. This meant that beams of different lengths could be cast and pretensioned on the same line.



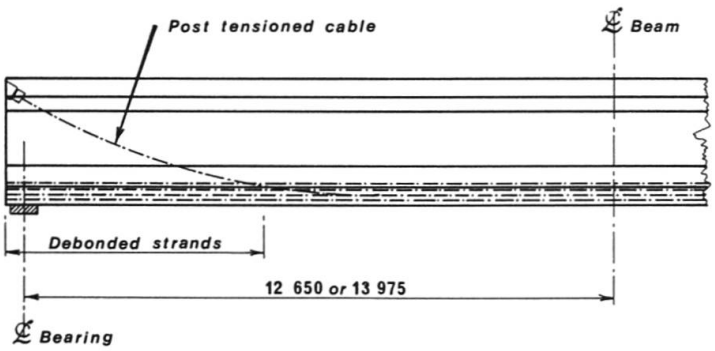
General view of beam storage area

Bridge beams

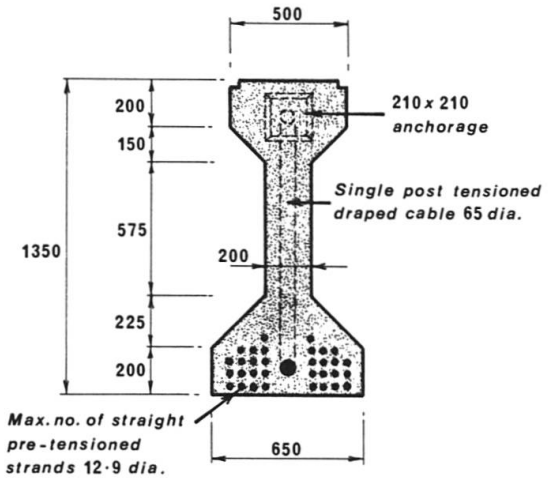
A total of 592 number bridge beams were required for the project.

At the commencement of the project a survey was undertaken to ensure that existing precast concrete manufacturers in Kuwait possessed the capability to cast and stress the beams. It was established that these yards had previously produced somewhat smaller prestressed concrete elements, though the available casting beds could accommodate beams up to 30 m long with appropriate cranage, which covered the maximum beam sizes proposed. However, there were several problems relevant to any prestressing proposal, particularly pretensioning:

1. Stressing bed capacities were limited to about 400 tonnes.
2. There were no facilities for tendon deflection, which is usually required for large pretensioned beams.
3. High concrete strengths were difficult to attain because local sound aggregate is not readily available.



Half elevation of beam



Cross section

"Hybrid" beam

"Hybrid" beams

The project was dominated by the near 500 AASHTO-PCI type 4 I beams required for the road bridges. Initial design indicated a pretensioned beam with a maximum pretension force of some 560 tonnes, well in excess of the available pretension bulkhead capacity.

Also, with this force a large number of tendons would require uneconomical debonding or deflection to minimize tensile stresses at the ends of the beams and to limit the transfer strength to the already high value of 45N/mm². As the available local concretes were stretched to gain this value for 28 day strengths, it was implied that there could be a disruptive one month wait before tendon release, leading to uneconomic beam production.

It was the limitation of the pretension bulkhead capacity which lead to the adoption of an unusual "Hybrid" prestressed beam. The term "Hybrid" is used because the prestressing consisted of a beneficial combination of pre- and post-tensioning. Pretension strand was used together with a single draped post-tensioned cable with the anchors accommodated in the end faces within the top flanges.

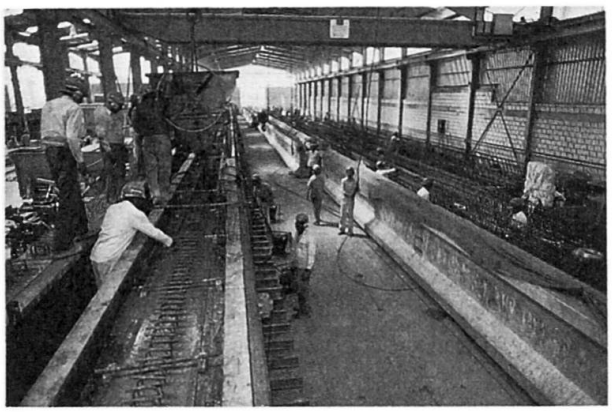
Beam manufacture

The production of the "Hybrid" beams proved relatively straightforward although there were initial problems with concrete:

a) It proved difficult to find a suitably graded sand as local materials tend either to contain excessive fines or be single-sized.

b) The presence of the post-tensioning duct within the comparatively narrow web plus the congestion of reinforcement within the top flange anchorage zone meant that a high workability mix was required. A super-plasticiser was used successfully, although experience of rapid loss of workability caused early problems.

The accompanying photographs give some impression of the very modern and well equipped precasting yard and pretensioning beds, together with various stages in producing the "Hybrid" beams.



Beam concreting

Conclusion

The "Hybrid" beam was developed in 1978 because of the then limited facilities for precast concrete bridge beam manufacture in Kuwait. Experience has shown that the "Hybrid" concept of pretensioning followed by topping-up post-tensioning offers considerable advantages, especially when end thickening is not required to cater for the post-tension anchorages. Not least among these advantages are:

a) the beneficial substitution of a simple draped post-tensioned cable for the more complex deflected pretensioned cable;

b) the ability to lift the beams off the pre-tensioning beds at an early stage and at lower concrete transfer strengths.

(B. P. Pritchard)