Pamban Bridge : aspects of project management-II

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The first part of the paper, published in the November 1988 issue of the Journal, dealt with some of the important construction features of the bridge. The second part of the paper, published here, highlights special provisions made to ensure the,durability of the bridge in hostile environments.

Special provisions for durability

The bridge is exposed to one of the most hostile environmental conditions. The foundations are constructed over the sea bed. The substructure is in the splash zone. The enormous waves induce spraying of salt-laden water to a considerable height above high-tide level on to the surface of the piers. The temperature reaches to about 35°C during summer. The humidity levels are very high, in the range of 70 to 80 percent most of the time. The steel reinforcement is prone to higher levels of corrosion at high temperatures coupled with high humidity. Figue 24 shows new scaffolding pipes and clamps, totally corroded over a period of two years of exposure to the sea at Pamban Bridge site.

Corrosion of steel in concrete is an electrochemical process involving reaction between steel and the environment. Corrosion cannot be totally prevented. However, it is possible to control the rate of corrosion in such a manner as to ensure the intended life of the bridge without the adverse effects of corrosion. Considering the very aggressive nature of the environment at the Pamban Bridge site, it became necessary to effect suitable corrosion-control measures to ensure serviceability during the design life of the bridge.

Factors to be considered in this context include:

1. Selection of suitable construction materials.
2. Control of the environment.

Both the factors have been taken into account while planning the construction of the bridge. However, the implementation of the various corrosion-control measures have had a chequered career because of the history of construction of the bridge.

The job specifications were drawn up in the early seventies. The work was started in 1974 but suspended in 1978 due to contractual and administrative problems, after only a part of

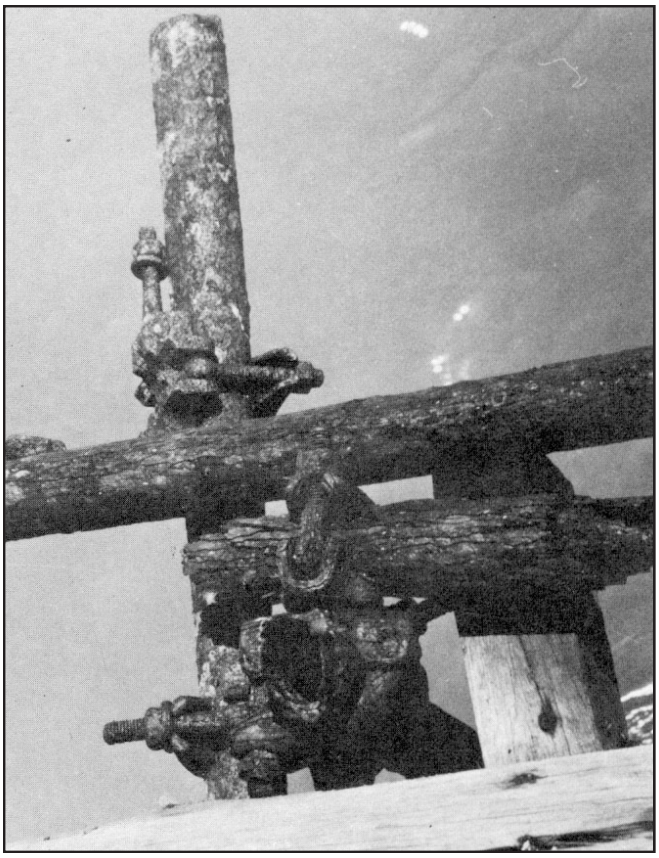

Figure 24. Corrosion of steel scaffolding pipes

the work was done. The work was resumed in 1984 by a new construction agency who were required to utilise the foundations and piers already completed for a number of spans. As such, the geometry of the superstructure was also frozen based on earlier designs.

Based on the state-of-the-art knowledge while resuming the work in 1984, additional durability measures were incorporated. Thus, various durability measures were incorporated in instalments at different periods spread over ten years. The designing and detailing of the various components also involved inputs from the owners as well as two different construction agencies. These factors naturally introduced limitations regarding the measures finally adopted. Some of the specific measures adopted are detailed here.

Concrete quality

1. Use of higher grades of concrete, M35 for substructure and M45 for the superstructure.
2. The water-cement ratio for all grades of concrete is limited to 0.36 to 0.45.

Materials

1. Use of special cement, sulphate-resisting cement for foundations and part of the substructure in the splash zone, and high-strength ordinary Portland cement for the remaining parts of the structure.
2. Superplasticisers have been extensively used to ensure better workability of concrete.
3. Use of mild steel bars (as against high-yield deformed bars) for foundations, substructure and as untensioned reinforcement for the prestressed concrete members. The low carbon content of the mild steel bars is considered a plus point as a corrosion-protection measure.

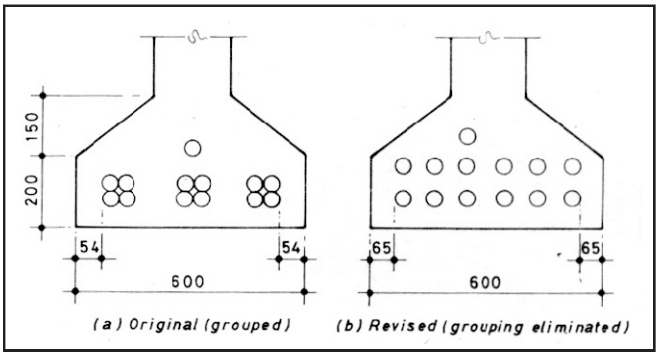

Figure 25. Arrangement of cables for 27-m span

4. The steel storage yard was located at Ramnad, about 40km away, in order to minimise exposure to salt spray. Small batches were drawn, as and when required, for immediate use after bending and anti-corrosive treatment.
5. Galvanised-steel binding wire was used for fixing reinforcement.
6. High-capacity cables consisting of 12 Nos. 12.7-mm diameter strands were used for prestressing the box girders in navigable and anchor spans.
7. Galvanised-metal sheathing ducts of increased wall thickness (0.3mm) have been adopted. These ducts were manufactured at site, using specialised equipment. Such on-site manufacture facilitated the use of long lengths of ducts, minimising the number of joints. Fresh pipes straight from the machine were put to use, eliminating the possibility of corrosion during storage.

Material tests

1. Tests on materials of concrete were regularly carried out at the site laboratory before collection. This included regular tests on the quality of water, including chloride content. Any aggregates subject to prolonged storage at

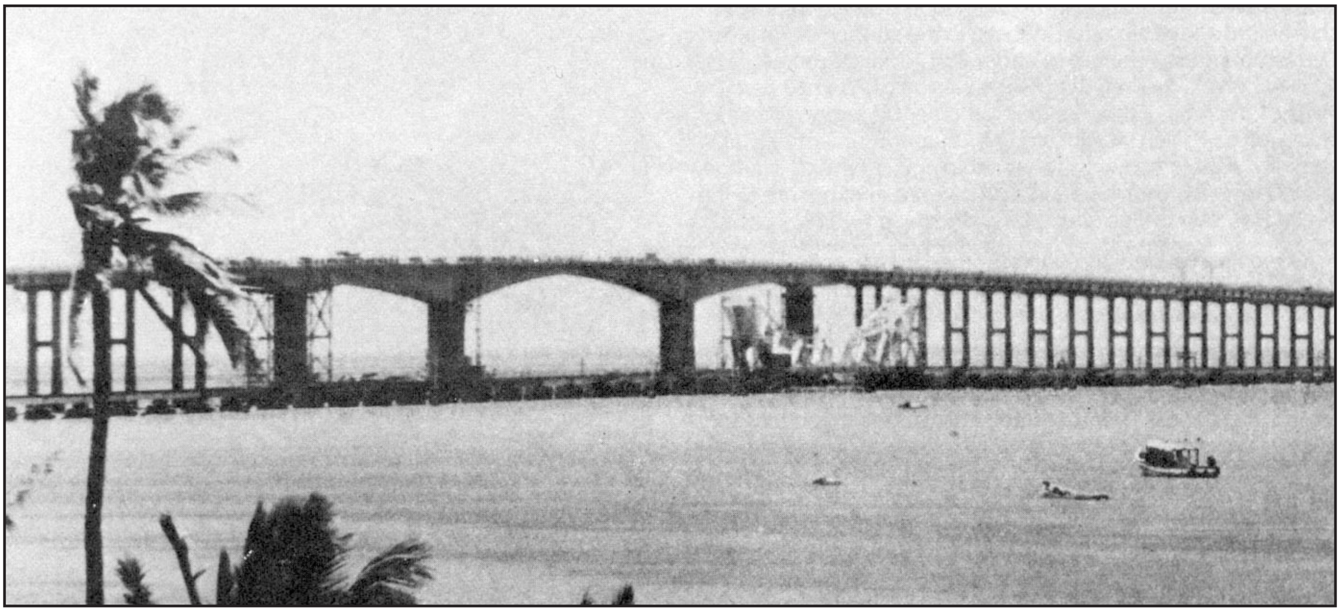

Figure 26. A panoramic part-view of the completed Pamban Bridge

site were retested for chloride contamination before use.

2. For high tensile steel, 1,000-hour relaxation tests have been insisted upon, to be carried out by the manufacturers periodically. Normally, this is not done as a routine test.

Design, detailing

1. Provision of massive foundations.

2. Increased cover to reinforcement; the additional cover varies from 25mm for the deck to 50mm in the tidal and splash zones.

3. Grouping of prestressing cable ducts eliminated, Figure 25.

4. The box girders are designed to account for effects of the thermal gradient of 10°C in the deck, in terms of BS:5400, Section 2.

5. Footpaths are not cantilevered out of the ends of deck slab, but are detailed to rest on the deck slab.

6. Shear reinforcement for the box girders has been provided as per BS:5400.

Prefabrication

1. Use of precasting to ensure better quality assurance. All non-navigable span beams, footpath slabs and railing components were precast and erected.

2. The end blocks for the non-navigable span beams were precast separately in a horizontal position. This enabled effective placement of concrete without voids. The precasting of the end blocks also enabled prestressing to be taken up in time as the precast end blocks would have attained the necessary strength by the time the end block is integrated into the beam.

3. The non-tensioned reinforcement for the precast I-beams was prefabricated as a parallel activity and the cage pushed into the shuttering, prior to concreting.

4. The prefabrication coupled with the steam curing enabled precasting of the beams with a minimum number of moulds. Only two sets of soffits and 1 ½ sets of side shutters were provided in the precasting yard. A maximum of 12 beams per month were precast to match with the programme of launching three spans a month.

Prestressing, grouting

1. The design of I-beams for non-navigable spans constituting 86 percent of the total length was specially tuned to facilitate effective grouting, with a minimum time interval between casting the beams and grouting.

2. Only two stages of prestressing were envisaged for I-beams. With steam curing of the precast beams, it was possible to prestress the first-stage cables within 24 hours of casting and the second stage within a week. Grouting of all cables was carried out after second-stage stressing, generally within eight days of casting.

3. As prestressing of all the cables and grouting activities are completed in the precasting yard prior to launching of the beams, better quality control of prestressing and grouting operations is ensured.

4. Special specifications were evolved to facilitate effective grouting, using low water-cement ratio of 0.40. The grout temperature was maintained at about 25°C by using chilled water for the mix. Electrically-operated, reciprocating positive-displacement type grout pumps were used for grouting. Preparation of the grout was realised using either high-speed mixing units or colcrete mixers to obtain a colloidal mix.

5. One-end stressing was adopted for the non-navigable span beams on Pamban side, which were precast on the staging and side shifted. This facilitated troublefree, fast-stressing operations.

Construction joints

1. Construction joints were reduced to a minimum. By and large, the box girders for the navigable span were concreted without leaving any cold joints. For a few segments adjoining piers, the predetermined locations for the construction joints dictated the pours.

2. The interface joints between 'the precast and in-situ portion of the deck slab were treated with epoxy in order to make the joints watertight.

3. Apart from the cross-prestressing cables, no non-tensioned reinforcement was projecting out of the precast portion.

Provision against stressing losses

1. Dummy cables were provided for in the design to be activated for making good any shortfall in extensions during prestressing of regular cables. However, there was no occasion or need for activating dummy cables in the case of non-navigable spans. As such, the cables were withdrawn and the duct was grouted. In the case of navigable spans also, there were no shortfalls in the extension during actual prestressing. However, the dummy cables were also prestressed in the last stages of construction, in order to provide additional levels of stressing as a safety against possible excessive losses of prestress over a period of time.

2. Additional structural reinforcement was provided in the deck to compensate for possible additional loss of prestress of the order of 15 percent. This is in addition to the prestressing loss already provided for in terms of the IRC code requirement.

Bearings

1. Special spherical bearings imported from FREYSSINET, Paris, were used for the navigable spans in conjunction with PTFE bearings. The choice of materials for these bearings was dictated by considerations of durability and protection against corrosion.

2. Special platforms have been provided near the top of the piers of the navigable and anchor spans to facilitate maintenance and inspection of the bearings.

3. The design also provides for the contingency of easy replacement of bearings, at a later date, as and when the need arises.

Curing

1. Potable water, transported from a considerable distance, was used for curing. The concrete wearing coat was cured for a minimum of four weeks in order to provide a durable surface. A rich concrete of M35 grade was adopted for the wearing coat.

Anti-corrosive protection monitoring

1. Provision of anti-corrosive treatment for the mild steel bars after bending, but before fixing, as per specifications evolved by Central Electrochemical Research Institute (CECRI), Karaikudi.

2. Protective coatings for concrete surfaces, as per specifications of CECRI, Karaikudi.

3. Suitable instrumentation is being provided by Central Electrochemical Research Institute for monitoring the corrosion behaviour during the service life of the structure. Probes have been embedded in the structure at various locations for the purpose,along with necessary electronic transducers. In addition, transducers are provided for measurement of strains and temperatures. It is for the first time in India that such a detailed system of observation of the behaviour of the structure has been envisaged.

Well foundation

1. The navigable spans were supported on four concrete wells which were partly constructed by the previous agency, before 1978. In order to provide improved durability for the foundations, taking into account the inordinate time-gap between commencement of the wells by the previous agency and completion, it was decided to fill the wells with lean concrete for the full height instead of filling with sand.

2. All underwater concreting work for plugging of the wells was carried out, using the tremie method.

Logistic problems

Apart from the hostile environment, the transportation of construction materials and machines across the open sea to the various locations posed the biggest challenge. Because of the shallow water for most of the length coupled with the rocky bed, it was not possible to use conventional barges or pontoons. Special barges were designed and fabricated with a view to having a very small draft. Due to rough sea conditions movement of barges was difficult or uncertain on many occasions, thus dislocating construction activities.

Strong winds exceeding 50km per hour speed were not uncommon at the site. On several occasions it was physically impossible for people to even stand on the deck, leave alone carrying out construction activities. The work had to be suspended on such occasions. Even the trains do not run on the adjoining railway bridge at high wind velocities.

In order to minimise the exposure to hazardous weather, an attempt was made to transport the aggregates at least for the navigable span substructure through the railway bridge and unload the aggregates near the navigable spans on specially-erected platforms. This involved the stopping of the train, with wagons containing the aggregates, and unloading in the middle of the railway bridge. Though an unusual proposal, the railway authorities readily responded to such a request, considering the importance of the bridge. Substantial quantities of aggregates were thus moved to locations during difficult weather conditions.

Construction time

Tender documents stipulated the contract period of three years for the balance works (started in 1984). However, even during the pre-award negotiations, the contractors had submitted that in view of the hostile environment and difficult working conditions, a contract period of four years would be more appropriate. In addition, quite a few changes in specifications were effected during the operation of the contract with a view[1] to improve the durability of the bridge. These changes resulted in additional work involving additional construction time. Considering these factors, the actual construction period of about 4 ½ years appears to be in tune with the expectations at the time of the award of the contract for the balance works.

A view of the major portion of the completed bridge is shown in Figure 26. The bridge was completed in all respects in September '88 and has been formally opened to traffic on October 2, '88 by the Honourable Prime Minister of India.

Credits

Owners	:	Ministry of Surface Transport, Government of India.
Represented by	:	Highways Department, Government of Tamil Nadu.
Designed by	:	Highways Department, Government of Tamil Nadu and Gammon India Limited, Bombay.
Contractors	:	Neelakantan Brothers, Madras (initial stages) and Gammon India Limited, Bombay (major balance works).

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