
Salient design features of the second Thane Creek bridge

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The paper highlights the salient design features of the second Thane Creek bridge. The concept of quality assurance has been incorporated in the design of the bridge. It is for the first time in the history of design work carried out by PWD, Maharashtra that the assistance of a reputed proof consultant has been sought in the design of a bridge.

The process of finalising the design parameters of the bridge was initiated right from the project preparation stage. The Public Works Department (PWD) was fully aware of the problems in respect of the first Thane Creek bridge, constructed in the early seventies. The recommendations of the Technical Committee, appointed for the first bridge, were therefore made applicable for the second bridge. This was done prior to the publication of Indian Roads Congress (IRC) guidelines on supplemental measures for design, detailing and durability of important bridge structures¹. During the prebid conference after floating of the tender, views of various intending firms were taken into consideration. Accordingly, the design criteria was further modified giving common sets of deviations.

The work was awarded to Uttar Pradesh State Bridge Corporation Ltd. (UPSBC). Considering the magnitude and complexity of the work, STUP Consultants Ltd., who were consultants to the contractor, in turn appointed Messers PX Consultants, a leading French consultancy firm, as their advisors. In the meanwhile the process of appointing a proof consultant of international standing was initiated by the IPWD. Rendel Palmer and Tritton (RPT) of U.K. were appointed as proof consultants from the Government side, to assist the department and its designs organisation. Thereafter the process of approval to the design of components was taken up, one by one. The approvals to design were given by the Designs Circle with concurrence obtained from the Chief Engineer (Special Projects), duly considering the views of

designers, their advisors and proof consultants.

Under the guidance of RPT, aspects of quality assurance in design have also been made applicable for this bridge. In the history of bridge design work carried out by PWD, Maharashtra, it is probably for the first time that the assistance of a reputed proof consultant has been sought in the design of a bridge.

Span arrangement

With a view to minimise the cost of approaches on both sides, it was decided to locate the new bridge as close as possible to the old bridge.

In view of the close proximity of the two alignments, it was decided that piers and abutments of the new bridge should be in alignment with the piers and abutments of the old bridge. This type of arrangement was confirmed by model studies carried out by the Central Water and Power Research Station (CWPRS), Pune. The linear waterway of the new bridge was kept the same (1,837.09 m) as in the old one.

Considering the durability problems encountered with the first Thane Creek bridge, the Technical Committee set-up by the Government of Maharashtra, recommended that the soffit level of the superstructure at abutment locations be kept at R.L. +6.5 m, sufficiently above the top of splash zone. A vertical navigational clearance of 9.14m was prescribed between pier No. 12 to 14.

Salient details

Salient details of the bridge are given below.

1. Length : 1,837.09 m
2. Width of bridge : 25.68 m (2 carriageways 11 m

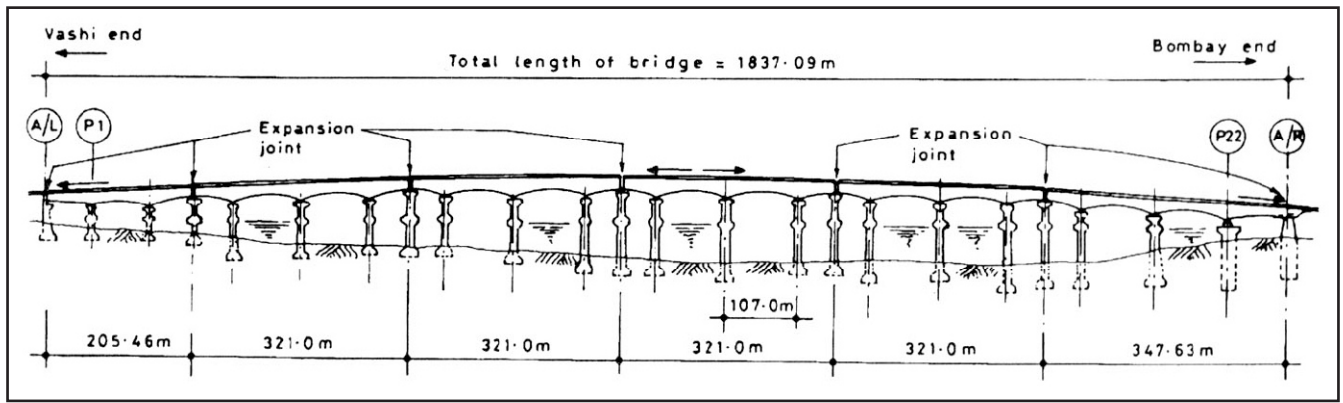


Figure 1. Longitudinal section of the second Thane Creek bridge

	each + central median verge 1.2 m + 2 walkways 0.60 m each)	on all piers - Pins for providing longitudinal restraint on "Rocker piers"
3. No. of spans	: 23	
4. Details of span		10. Live load : 3 lanes of IRC Class A or one lane of IRC Class 70R for each carriageway
- Units from Vashi end:		
1 unit of 3 spans (61.95 + 80.935 + 62.575)	: 205.46 m	
- 4 intermediate units of 4 spans (53.5 + 107 + 107 + 53.5) = 321 m	: 1284.00 m	
- 1 unit of 4 spans at Bombay end - (55.43 + 103.30 + 107.10 + 81.8) = 347.63 m	: 347.63 m	
Total length of 23 spans	: 1837.09 m	
5. Navigational spans	: 2 (each of 107 m on centres)	
No. of spans		
Navigational clearance (Vertical)	: 9.14 m (above M.H.W.S.R.L. of +3.19m)	
6. Superstructure	: Prestressed concrete single cell box girder of varying depth; one box for each of the 2 carriageways	
7. Substructure	: RC solid piers 1 independent pier below each carriageway (22 piers and 2 abutments)	
8. Foundation	: Double "D" well at Bombay end abutment - RC open foundations at Vashi-end abutment and all piers excepting P22.	
9. Bearings	: PTFE - stainless steel sliding bearings on pot bearings - Side restraints with PTFE - stainless steel sliding arrangement for taking lateral forces	
		1. structures, which require material for which foreign exchange will have to arranged by the PWD
		2. abutments resting on approach embankments
		3. superstructure other than reinforced concrete or prestressed concrete box type girders
		4. for conventional type of bridges, main girders of structural steel superstructure other than open web trusses
		5. superstructure with articulated supports or joints and hinges including pendulum type bearings
		6. superstructure with expansion joints at spacing less than 145 m or more than 400 m
		7. pile foundations
		8. superstructure of simply supported box with continuity only in the deck slab
		9. precast segmental construction; the segmental construction being defined as a method of construction in which primary load supporting members are composed of individual units called segments joined and post-tensioned together.

Restrictions on types of structures

Taking into consideration the experience gained by the PWD, Maharashtra, over the years and also considering the durability aspects, the following types of structural arrangements were not permitted:

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3. superstructure other than reinforced concrete or prestressed concrete box type girders
4. for conventional type of bridges, main girders of structural steel superstructure other than open web trusses
5. superstructure with articulated supports or joints and hinges including pendulum type bearings
6. superstructure with expansion joints at spacing less than 145 m or more than 400 m
7. pile foundations
8. superstructure of simply supported box with continuity only in the deck slab
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Specifications for design Loads

The design was done as per IRC codes with standard IRC loadings. The barge impact force considered in the navigational spans was 500 tonnes acting at any angle, varying from 0 to 45°. For all other spans, a barge impact force of 300 tonnes was considered. Fifty percent of design live loads were considered with barge impact.

Temperature gradient

A temperature gradient across the depth of deck was considered varying from 24°C at top, reducing to 6°C at a depth of 300 mm, and further reducing to 0°C at the centre of the remaining depth.

Wave pressure

Wave pressure was not considered in the design.

The design criteria also provided for inspection accesses, lighting and instrumentation for monitoring the performance of the bridge. It also included the arrangements for fixing the removable type of coffer-dams to facilitate inspection, main-tenance and repairs of piers in dry condition.

Permissible stresses and factors of safety

Over and above the normal factor of safety and permissible stresses as per IRC standards, for both seismic as well as barge impact conditions, the following factors were considered:

Factor of safety against overturning	:	1.50
Factor of safety against sliding	:	1.25
Maximum loss of contact at foundation	:	33 percent
Maximum increase in base pressure after redistribution	:	50 percent
Permissible increase in stresses in steel	:	50 percent but limited to 90 percent of yield stress
Permissible tensile stress in concrete	:	10 kg/cm ²
Permissible excess in compressive stresses in concrete	:	upto 50 percent
Buoyancy		
For rock stratum	:	50 percent
Other than rock stratum	:	100 percent

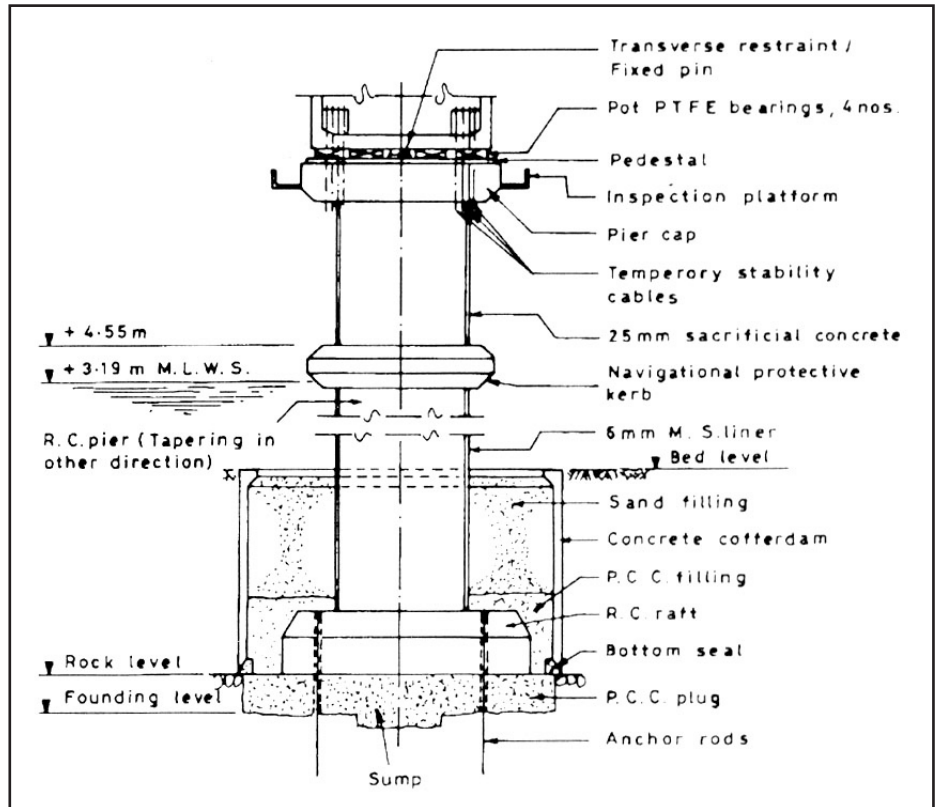


Figure 2. A typical cross-section of the bridge

Foundations

The adoption of pile foundations was ruled out in view of the uncertainties associated with them, particularly in view of the possibility of heavy barge impact and large depth of foundations. Damage to even one pile could substantially endanger a foundation. Therefore, only open type and well type foundations were considered. These options were given to the contractor and out of the 24 foundations, the contractor could carry out open type foundation work for 22 foundations and well foundations for the remaining two, that is, for P22 and right side abutment.

The open foundation system adopted for this bridge required coffer-dams for construction of the piers, which were constructed under dry conditions. The coffer-dams were also used for carrying out the rock excavation under dry conditions after dewatering and this was advantageous, in that the founding strata could be inspected under dry conditions. With such inspection one can be absolutely certain about the type of foundation strata met with and there are no uncertainties regarding foundation conditions generally associated with other types of foundations.

Substructure Piers

For substructure, solid type of piers with a minimum wall thickness of 2 m were specified. The piers were proposed to be provided with 6-mm thick epoxy-painted mild steel liner. Pier surfaces above high water level were provided with 25-mm

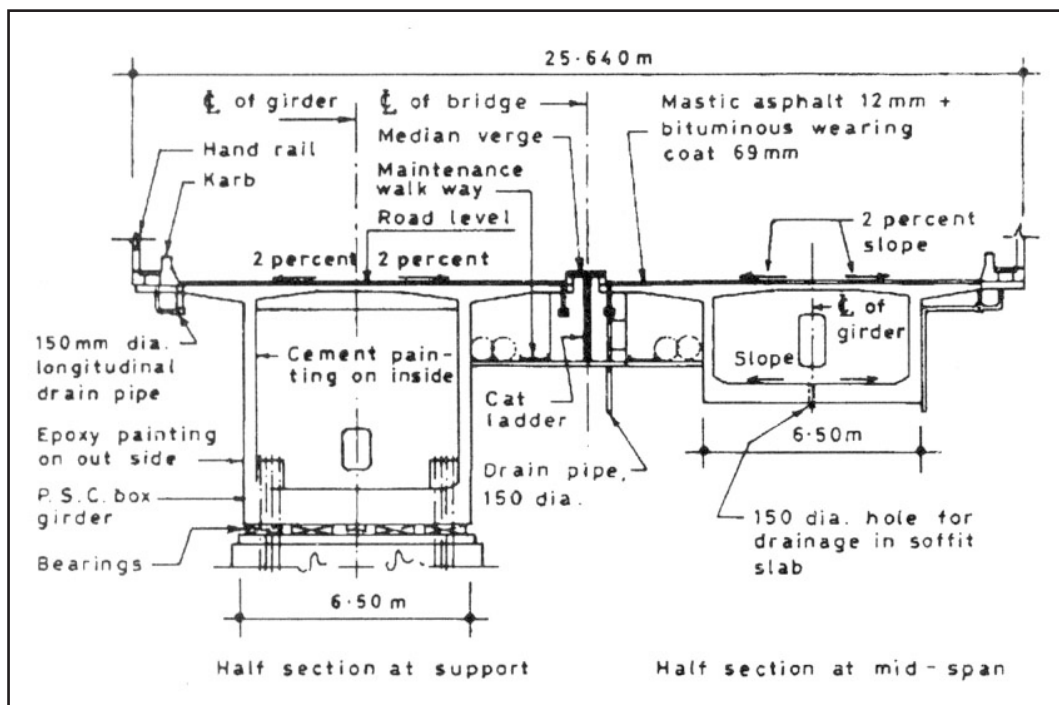


Figure 3. A cross section of the superstructure

thick sacrificial concrete. A reinforced concrete navigational protective kerb at high water level to protect the structure from the impact of floating vessels was proposed. Permanent fendering system was also proposed for navigational span piers. Construction joints located in splash zone were cast in dry condition within a cofferdam and were given proper treatment to ensure durability.

Considering the construction tolerances and the possibility that one arm of the cantilever could have higher dead loads and also considering the fact that the closure of units may not be possible before monsoons and also considering the vertical components of wind on the curved soffit, higher unbalance forces were considered in the design of pier during construction stage.

The IRC codes do not specify very clearly, how the apportioning of horizontal forces should be done over bearings under continuous spans. As per recommendations of the RPT, it was considered that there is a possibility of piers moving out of phase under seismic forces. To guard against this, a pier in each continuous unit was designed to cater to the entire seismic force attracted by that unit.

Abutments

Abutments resting on approach embankment were not permitted. Therefore, spill-through type abutments have been adopted. For the cantilever returns, reinforced concrete tie beams have been provided, tying them back with the dirt walls to prevent opening out of the corners between dirt wall and returns and cracking at these locations. At these corners, vertical column-type thickenings have also been added for strength and stiffness to suit the design assumptions. The thickness of rectangular reinforced concrete columns provided

in the abutments, is kept 1m (minimum). Adequate provisions have also been made for protecting the abutments from scour by rubble pitching, etc.

Superstructure

Only box type superstructure was accepted taking into consideration the durability aspects. For the superstructure, continuous box decks with box girders or structural steel trusses were specified with expansion joint spacing to lie between 145 m and 400 m and the final design stipulated a typical spacing of 321 m. Only seven

expansion joints were proposed in a total length of 1.83 km. Provision of minimum number of these joints is expected to minimise maintenance problems and improve riding quality.

During the specification stage it was thought fit to avoid any trouble-prone structural systems which may have a bad effect on the serviceability. Accordingly for the continuous deck, hinge-type joints or articulations were ruled out in view of their known tendency to create problems during service. For the second Thane Creek bridge, a finger-type joint was provided with an additional pier below the expansion joint, though such piers result in non-uniform span arrangement. With the adoption of cantilever construction, the reaction at such joints from the superstructure would be negligible and to avoid 'knocking' of bearings under live loads a counterweight has been provided inside the box.

Provision was made for additional prestressing upto 20 percent at a future date. For designing of box girder, guidelines given in publication by Prof. Schlaich were followed in addition to the provisions in the codes. There was no restriction on the number of cells in the box girder. However, as per recommendations of RPT, a single cell box was finally approved from durability consideration.

Design aspects

The design is generally done by serviceability stage method and checked for ultimate stage wherever necessary, as for instance for prestressed concrete box and for design of piers during construction stage. For all the reinforced concrete elements a maximum crack width of 0.1 mm under permanent loads was considered. For the box girder apart from the usual loads a temperature gradient along the depth of 24°C at top fibre reducing in two stages to zero near about mid-depth is

considered along with 50 percent design live load. Partial prestressing has been avoided though this is ideal for taking care of temperature stresses.

Prestressing

It has been recognised that prestressing is the main strength for the deck and accordingly a number of precautions were taken from the design stage itself. Cables with anchorages on the top surface of the deck or anchorages with divided trumpets were ruled out. Grouping of cables was altogether avoided to minimise congestion due to too many tendons. Above all, tendons were located wholly within the top slab or soffit slab, avoiding their location in the tall thin webs where they can pose problems for concreting. Mild steel sheathings with 0.5 mm wall thickness were proposed as it was felt that the usual 0.3 mm thickness would be inadequate from durability consideration. Galvanised sheathings were not used for fear of galvanic corrosion between dissimilar metals.

It was specified that proper care should be taken to store high tensile steel in carefully controlled environment where the temperature and humidity are regulated. It was also suggested that H.T.S. be generally used within two months of supply and cable fabrication be done carefully to avoid contamination with harmful salts. A number of precautions were also suggested for the grouting of prestressing tendons. The anchorages were proposed to be sealed with 15mm thick epoxy mortar and epoxy paint after stressing and grouting.

As a further precaution, provision of 4 percent reserve cables to take care of any cable failures during construction and a provision for application of 20 percent of initial prestressing force in future to take care of any loss in prestress due to unforeseen circumstances were prescribed. Provisions for anchoring and for deviating these future cables to get a trapezoidal profile were made in transverse diaphragms over piers and in transverse top and bottom beams at quarter-span points.

Miscellaneous provisions

Drainage

The deck has a good crossfall of 2 percent towards either side to ensure quick drainage. A 12-mm thick mastic asphalt waterproofing layer is proposed directly over the deck slab concrete to minimise water seepage inside structural concrete.

The run-off water would be collected through a number of downtakes to longitudinal runners (on either side) which drain the collected water through down spouts at locations away from piers. Catch drains were also provided at abutment locations to prevent run-off water from going over the abutment elements. Drip moulds were provided on the soffit of the cantilevering overhangs of the deck slab near the tip.

Inspection

The internal depth of the box is sufficient to facilitate free inspection. A maintenance walkway was proposed to be

provided for each deck in the gap between the two decks to facilitate inspection of the bridge. The pier caps were provided with inspection platforms all around to facilitate inspection of bearings comfortably. Provisions were also made for suspending a temporary coffer-dam below high water level for inspection of pier surface during service.

Expansion joints

Expansion joints have been specified to be either of epoxy-coated mild steel finger-type joints or preformed elastomeric type joints, with final choice favouring the former. The expansion joints are of replaceable type and provision is made to collect the water draining through the open joint to conduct it away from the bearings and pier cap.

Bearings

The specifications avoided the use of neoprene bearings as well as the cut or segmental roller bearings for spans over 40 m. It has been ensured that bearings can be replaced in future if required.

At each pier, four sliding type of bearings of PTFE-stainless steel sliding surface over a pot base (to facilitate two-directional movement as well as multi-directional rotation) were proposed with a transverse steel restraint provided at the centre to resist lateral loads. On one pier of each continuous unit, a pin restraint is provided instead of the transverse restraint to resist transverse loads and all longitudinal loads of the entire continuous unit. Cast steel is used for the steel portions for better corrosion resistance.

Protective coatings

The external surfaces of the box girder are proposed to be painted with three coats each of 80-micron dry film thickness, of a paint consisting of a two-pack air-drying polyamide cured pure epoxy component or high-build epoxy component with micaceous iron oxide pigment of approved percentage. The internal surfaces are to be painted with three coats of a waterproof cement-based paint.

The deck top surface is sealed with a mastic asphalt layer. All structural steel used in the work is galvanised. Mild steel liner (with three coats of anticorrosive epoxy tar coating with total dry film thickness of 210 micron) and sacrificial concrete are provided around the foundations and substructure below and above high water levels, respectively.

References

1. _____ Guidelines on Supplemental Measures for Detailing and Durability of Important Bridge Structures, IRC-SP-33, Indian Roads Congress, New Delhi.

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