Railway bridge across the Thane Creek

The construction of a 1.87-km long railway bridge across the Thane Creek was the most difficult task of the Mankhurd-Belapur railway project. The bridge has 35 spans of 53.5m each. Constructing the foundations of the bridge was a formidable task, for which floating caisson method was used. The method involved the use of submersible barges for casting and launching of partially precast cassions which were sunk using the compressed air technique. The box-type superstructure of the bridge weighing 800t was precast and prestressed in the casting yard and then launched in position during high tide with the help of a specially-fabricated equipment. To ensure the long-term durability of the bridge, stringent quality assurance programme was implemented. The paper highlights the broad construction features of the bridge, which was completed in a record time.

The railway bridge across the Thane Creek forms a vital link in the rapid transit system linking the metropolis of Bombay with its satellite, the New Bombay, which is developing at a fast rate, thanks to the efforts of the City and Industrial Development Corporation (CIDCO). The completion of this bridge is expected to give a new impetus to the all-round growth of New Bombay region and the new Jawaharlal Nehru Port at Nhava Sheva. The commuters residing in New Bombay will greatly benefit with the opening of this bridge to rail traffic.

This prestigious project, entrusted to the Metropolitan Transport Projects (Railways) under the Ministry of Railways, was awarded to the Asia Foundations and Constructions Ltd

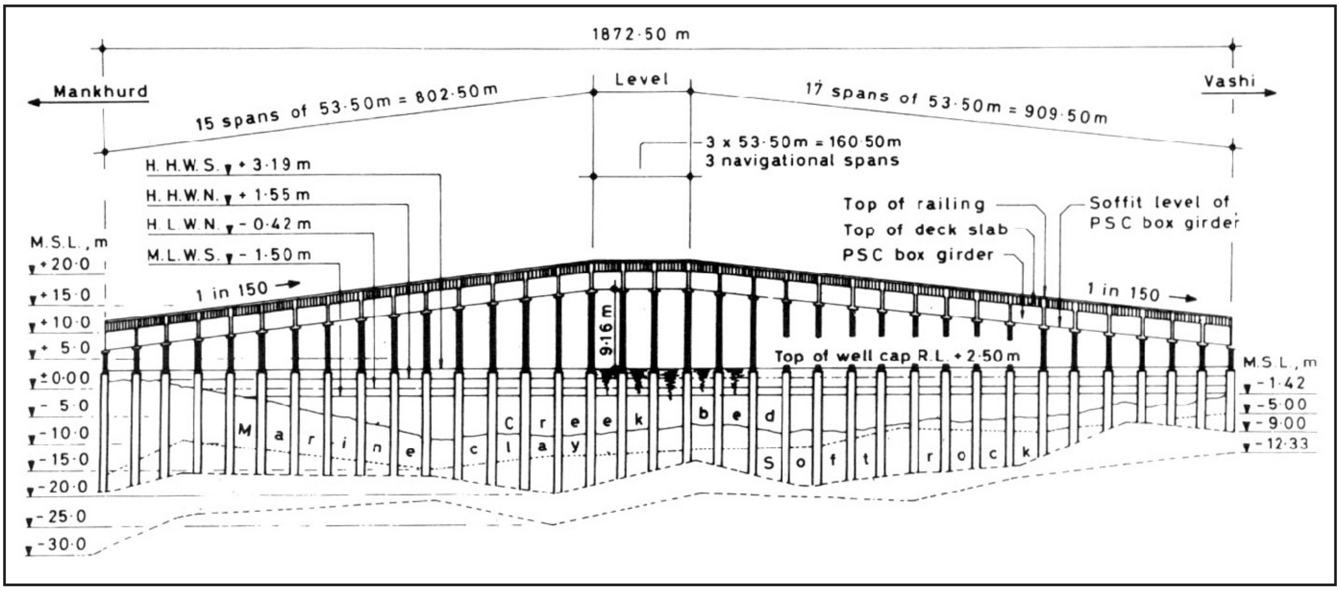


Figure 1. Elevational layout of the Thane Creek Bridge

The structure is illustrated, among others, on pages 256 to 260.

(AFCONS) in September 1986. The contract covered thedesign and construction of the entire bridge. Messrs Tebabau GmbH of West Germany were consultant to AFCONS for project planning and construction aspects.

Salient features

The general elevation of the bridge is shown in Figure 1. The salient features of the bridge are as follows:

Total length of the bridge	:	1.8725 km
No. of spans	:	35
Length of a span	:	53.5m
Types of foundation	:	Abutment No. 1 - well foundation constructed by diaphragm wall method Pier No. 1 and 2 - on pile foundation Pier No. 3 to 34 and abutment No. 2 - well foundation constructed by floating caisson method
Diameter of the well	:	9.50m (outer)
Pedestal	:	8.3m x 3.3m x 2.5m thick reinforced concrete pedestals provided to protect the piers from accidental collision by barges
Type of substructure	:	Two hollow cylindrical piers, with 3.0m outside and 1.80m inside diameters
Pier cap	:	3m x 3.95m x 1.5m deep pier cap provided under each girder
Inspection platform	:	800mm wide platform provided all-round pier cap to permit inspection of bearings
Type of superstructure	:	Two precast prestressed concrete box girders
Size of each box girder	:	53.4-m length; 5.7-m width at top and 2.8 m at bottom; 3.70m (average) depth
Weight of each girder	:	800t
Method of launching the girder	:	The precast girders are launched during high tide with the help of a specially-fabricated equipment, Catamaron
Bearings	:	Neoprene bearings with steel pin on either end
Hydraulic data	:	H.T.L = MSL + 3.19m L.T.L = MSL -1.5m Average water depth from MSL = 6m Average depth of clay = 7m
Concrete grade	:	M-45 for superstructure M-30 for substructure
Concrete cover	:	75 mm for substructure 75 mm for sheathing 50 mm or superstructure.

Caisson foundation

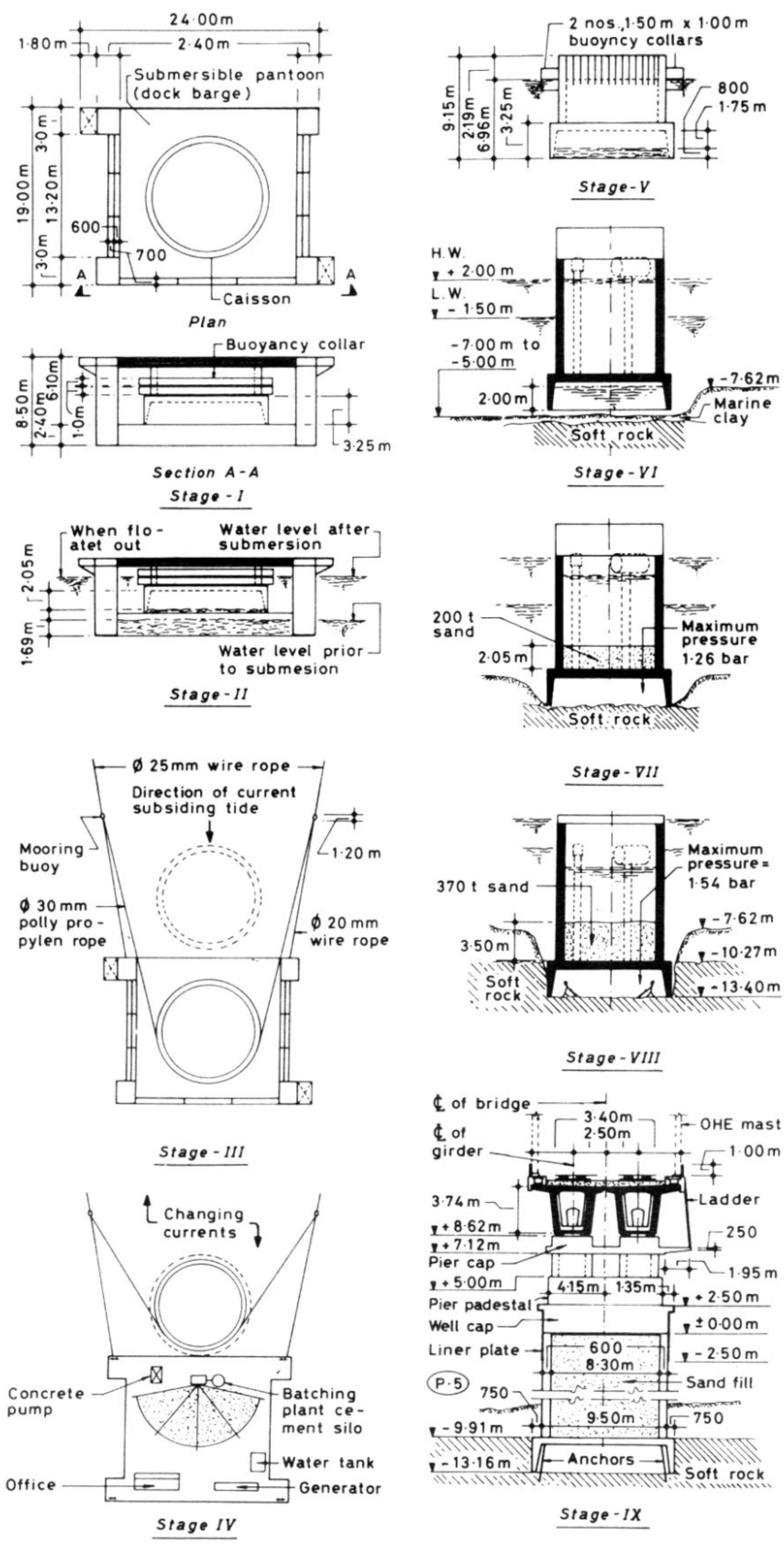
An innovative type of caisson launching scheme was adopted for the construction of wells from P3 to P34 and for A2. For the first time in India, caissons are sunk using compressed air technique from the start to end. Two submersible barges of 19.2 m x 24 m x 2.4 m size were fabricated at site. A reinforced concrete pressure chamber of 11-m diameter and 3.55-m height, and a circular well steining of 9.5-m diameter, 0.6-m wall thickness and 3.6-m height are cast on the submersible barge near the jetty with the help of a batching plant and a concrete pump. The concrete is transported by a 100-mm diameter pipe line. The main advantage of pumpingbeing that the well unit is cast under controlled conditions. Two sets of buoyancy collars of 1.5 m x 1.0 m cross section are fitted with the well steining to provide additional buoyancy and stability to the well in the floating condition. Figure 2 shows various construction stages of the caisson.

The submersible barge with the caisson of 7.15-m height is towed during high tide to a location where approximately 10-m depth of water is available. With the helpof valves, water is admitted in a set sequence into the 14 tanks of the submersible barge to gradually sink it. As the barge sinks the caisson floats in the water. The caisson, with the help of tugs is pulled out of the barge and is towed to its final location. During this operation, air pressure of 0.24 bar is maintained in the pressure chamber. The barge is refloated by pumping compressed air in the tanks. The air ejects water and the barge slowly comes up and is ready for casting of the next caisson. Figure 3 shows the pneumatic sinking arrangement.

Further raising of the steining is done in the floating condition. Ballasting is done i nside the well and the well is grounded after the necessary survey. Then the human and material locks are attached. The workers enter the pressure chamber and remove the clay by water jetting. After increasing the air-pressure, the clay is expelled out from the underside of the shoe of the pressure chamber. By this method, 400 to 500 m^3 of clay is excavated in a period of three to four days.

After the clay excavation, rock excavation is done by employing jack hammers. Blasting of rock is not permitted because of the distressed condition of the existing road bridge which is just 170m away from this railway bridge site.

The sinking effort is achieved by reducing the pressure inside the chamber. In case the tilt or shift is excessive, the well can be refloated by removing ballast which was filled in before grounding and then increasing the air pressure in the pressure chamber.



Stage I

Prefabricating lower part of the caisson on submersible pantoon up to a height of 6.10m with the help of land borne equipment. Two sets of buoyancy collars of 1.5 m x 1.0m are attached.

Stage II

Floating of caisson is achieved by submersing the pantoon, approximately 5.5-m deep from deck level, and providing compressed air in the working chamber to keep 2.05-m deep portion dry.

Stage-III

Caisson in the floating position and is being towed.

Stage IV

Raising of caisson 7-m per lift, keeping in mind that fresh concrete should not get in touch with the sea water within a period of 72 hours after concreting. Formwork is erected by floating crane. Concreting is done by pumping from floating batching plant.

Stage V

After pouring first lift, the caisson will have a freeboard of 2.19m.

Stage VI

– Bed level at final location is lowered by dredging to – 9.00m.

– Caisson roughly located in final position.

– Air locks for personnel and for removal of excavated rock are installed.

– Caisson held in approximate position by four anchors, two for rising water and 2 for subsiding water. Anchor capacity = 20t (each).

Stage VII

– Caisson positioned accurately.

– Ballast of 200t provided (sand gravel quarry run).

– Marine clay formed into slurry by high pressure water jets and pumped out with 'Toyo' pump DB 50 B. This operation is performed by personnel working in the chamber under a maximum pressure of 1.26 bar.

– Caisson gradually lowered on to the murrum/weathered rock formation.

– Level of the caisson and its position is checked, and if required adjusted.

Stage VIII

– Commencing excavation in murrum/weathered rock by mannually operated pneumatic tools.

– Excavated material filled into a special bucket which is hoisted through the material shaft and lock.

– Suitable material is used to supplement the ballast fill.

– At any time ballast provides a minimum downward load of 70t in excess of the uplift force.

– When reaching the predetermined foundation level of – 13.40 m the ballast shall not be less than 370t.

– To facilitate handling of the caisson and the sinking operation ballast may be increased 10 percent at any intermediate stage.

Stage IX

– When final foundation level is reached, checking plumb level and position of caisson and if required, adjusting the same.

– Drill and grout rock anchors.

– Filling working chamber with plain concrete of grade M25 by means of a pump under pressure to make sure that the chamber is filled to its ceiling.

– Removing the material/personnel from shaft and locks.

– Supplement internal fill with sand-gravel or quarry-run up to a height of 0.15 m under the well cap.

– Concreting well cap and constructing the pier.

Figure 2. Construction stages of caisson foundation

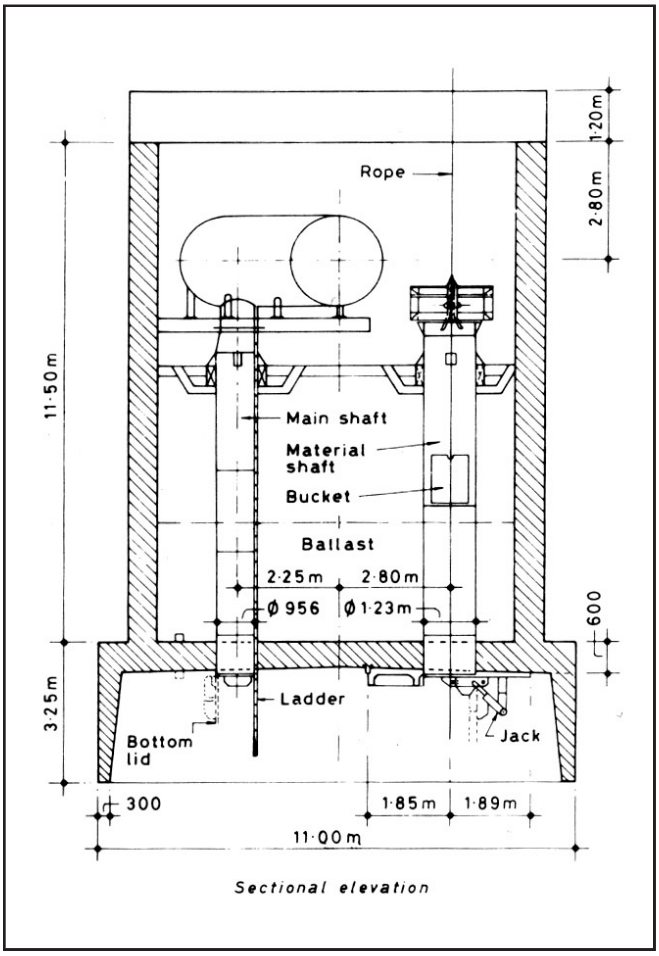


Figure 3. A typical pneumatic sinking arrangement

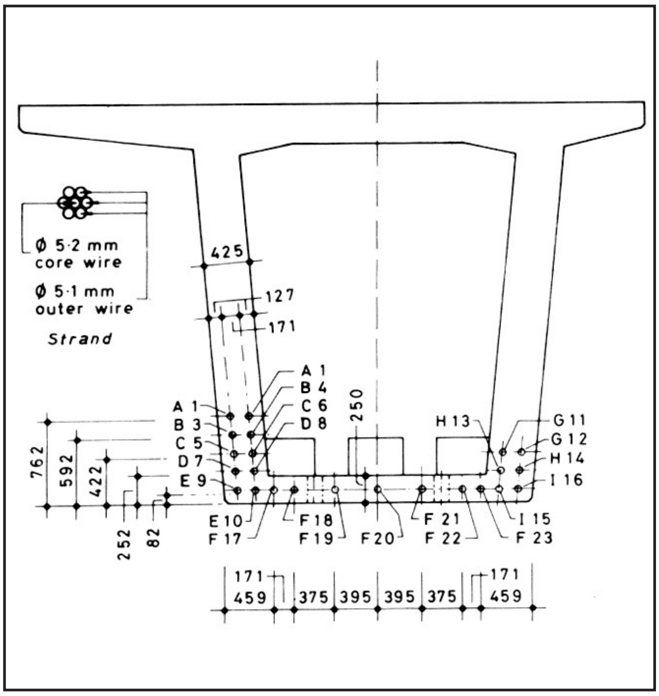


Figure 4. Cross section of the box girder showing cable location at the centre of the span

The well is taken to the rock which is excavated by pavement breakers and the excavated material is taken out from material lock. The founding strata is inspected by MTP(R) representative. In addition, unconfined crushing strength of rock is determined. Sixteen anchor rods of 32mm diameter and length of 2m are provided. The rock bed is cleaned and bottom plug concreting is done with M-20 mix. The air pressure is maintained for 24 hours after concreting, and again cement grout is pumped to fill the gap between the concrete and the bulkhead. This gap is created due to shrinkage and bleeding of concrete.

Over the well, a solid concrete pedestal is provided to protect the two cylindrical piers against the impact of a ship or a country craft.

The interesting and noteworthy features of the floating caisson method are :

1. the caisson concreting is done on-shore under controlled conditions and the sea water does not come in contact with the green concrete
2. it is possible to refloat the well at any stage, if it tilts or shifts excessively during the sinking operation
3. excavation is carried out in dry condition and the rock strata is inspected visually before deciding the founding level
4. the bottom plugging is done in dry condition.

The total time required between launching of a caisson to the installation of bearing pads is about 90 days.

Superstructure

The bridge has two precast prestressed concrete box girders in each span, one for the down track and the other for the up track. The entire concreting of the girders is done in one single operation without any construction joint.

Casting facilities

The following facilities were created/brought at site for the casting and launching of girders:

1. sheath making machine
2. fully-covered cable threading yard
3. covered reinforcement tying platforms, 2 Nos.
4. two casting beds (laid over lined piles going upto rock) with a movable shed
5. two sliding beds
6. girder launching jetty
7. floating crane with two towers called 'Catamaron'.

Casting

Initially, the reinforcement of both the webs and bottom slab is tied on the reinforcement-tying platform. The sheaths are manufactured at site and the cables are threaded in a fully enclosed area to protect them against water vapours and gas fumes. The cables are introduced in the reinforcement cage which is then moved with the help of rollers to the casting bed. The track over which the inside shuttering moves is assembled and the shuttering moves from the adjoining casting bed. Cable profiling is done for the two webs and the anchor zone reinforcement is assembled. Both the exterior shutterings are then moved in position. The work of tying of top slab reinforcement and fixing of end anchorages is carried out simultaneously.

The girder is concreted in a single operation. Two batching plants (one is a stand-by) and two concrete pumps are used. The temperature of concrete is kept below 30-C by precooling theaggregate. The details of the concrete mix M-45 are as given below:

water/cement ratio	=	0.39
aggregate-cement ratio	=	3.60
cement content	=	480 kg/ m^3
slump	=	120 mm to 150 mm
stiffening time	=	5 to 6 hours
superplasticizer	=	1.2 percent

The concrete sequence has been so designed that even if one batch and one pump fails, there shall be no cold joint in the concrete.

The first stage of prestressing which constitutes 30 percent of final prestressing force is done after 3 days when the concrete attains a strength of 20 N/mm^2 to cater for tensile stresses due to shrinkage and temperature. The inside shuttering is then moved to the second casting bed where the next girder cage is ready to receive it. The diaphragm walls are cast after the interior shuttering moves ahead.

The outer shuttering is also moved after 7 days of concreting. The curing of the girder is done from the very first day to keep the shuttering plates cool. Curing is done fora minimum of 14 days.

The second stage of prestressing is carried out when the concrete achieves a strength 32 N/mm^2. The prestressing force is 70 percent of the final prestressing force. The upward net vertical deflection is 13.386 mm. The girder is moved from the casting bed to the sliding bed, where third stage prestressing and grouting is done when the concrete attains a strength of 40N/mm^2. The maximum force in a tendon is 1.988N. The tendon elongation is about 270mm. The upward net deflection is 35.5mm.

Grouting of cable ducts

The extra length of strands, leaving 20 mm projection beyond the wedge, is cut by an electric cutter. The cable ends are sealed by 1:3 cement:sand mortar. The ducts are washed fully and then grouted by fresh ordinary Portland cement grout. The composition of the grout is:

strength	:	17N/mm^2
water-cement ratio	:	0.45
cement	:	ordinary Portland cement
admixture	:	superplasticizer at 227 gms per bag of cement
pressure of grouting	:	5 bars.

After the grouting of cables, the anchor plates, wedges etc. are cleaned by sand blasting. Two coats, of solvent-free coal tar epoxy are applied on two successive days. On the third day, the strand ends, bushes and wedges are covered by an epoxy putty. A third coat of coal-tar epoxy is applied over the putty and quartz sand mix No. 10 is sprinkled with hand over the painted area to make it rough so that concreting done over the anchor heads shall develop a good bond with the strands and anchor plates. The anchor plates are covered by concrete, so as to give strand ends a cover of 75mm. The concrete area covering strands is also painted with 2 coats of tar epoxy.

External prestressing (temporary)

The distance between the bearings is 50.7 m and the girder is lifted at two points, 40-m apart. To counteract the hogging moment and to prevent cracks in the deck slab, external prestressing with the help of 72 strands is done 2 days prior to the date of lifting the girder. The total prestressing force = 980t.

Launching

The launching of the girder from the jetty on to the pier top is the most interesting operation of this project. The lifting device consists of two barges of size 14 m x 40 m, connected by lattice girders making the latticed barge of size 39.50 m x 40.0m. It has two towers, 17.75 m high. There are two cantilevers of 9.20 m x 2.0 m connected with these towers. On the top of each tower 4 hydraulic jacks of 125-t capacity each are installed. These jacks can lift or lower the girder at a rate of 300 mm /minute. This device is locally called 'Catamaron'. It is brought during high tide in the jetty area. In the next tide the girder is lifted and the Catamaran is towed to the span and is aligned with the help of four winches. The girder is lifted above bearing level and the Catamaran is taken in the span. After aligning the girder, it is lowered on to the bearings.

The temporary stressing system is removed. On the deck, waterproofing layer, and over it, a 75-mm thick concrete wearing coat is laid. The track is laid over it after providing 300-mm thick, 40mm size ballast.

Specifications

The bridge is located in an aggressive marine environment and so a Total Quality Programme (TQP) from the conceptual to completion stage was implemented to ensure the strength and durability of the bridge. Specifications for the bridge were drawn keeping this factor in mind. The important items included in the specification are given below.

1. Anti-corrosive treatment is provided to all the MS/HYSD bars as per a method patented by Central Electrochemical

Research Institute, Karaikudi

2. High tensile steel wires are coated with water soluble oil
3. No green concrete is permitted to come in contact with sea water for the first 72 hours
4. Steel liner plate is provided from low tide level to high tide level
5. In the splash zone, that is, from RL + 2.5 m to RL +5.0 m, the concrete is painted by solvent-free coal tar epoxy paint scheme
6. The prestressed concrete box girder is precast without any construction joint
7. The web thickness is purposely kept high. Whereas it could have been designed with 300 mm thickness, or even less, the actual thickness provided is 425 mm
8. No cables are taken into the deck slab
9. Grouting of cables is done within a month of the final stage prestressing
10. The concrete cover is 75mm for substructure and cables, and 50mm for superstructure
11. High tensile steel strands are manufactured 1 month prior to their use
12. Water-cement ratio = 0.45 (maximum) Cement content = 400 kg/ m^3 (minimum), 540 kg/ m^3 (maximum)
    Permeability = 25mm (maximum).

The reinforced concrete sections used are thick, giving enough space for putting 60-mm vibrator and sharp corners have been avoided. The reinforced, cable support chair, and the window locations are predetermined and shown on the drawings. The design is such that placement of concrete is easy.

Quality control

Cement:

Special grade cement is only used on this bridge. The results are consistent and the quality is good. The cement manufacturers have been awarded a running contract for the full project period and they agreed to supply every month cement, which is not more than 3-week old. The C_3A content is between 4 percent to 8 percent.

Sand:

Whereas the sand from Kalyan is too coarse, that from Mumbra is too fine and contains clay lumps and has very high chloride and silt contents. The Mumbra sand was therefore washed by filtered water and then blended with Kalyan sand. The three important factors, namely, silt content, salt content and fineness modulus are monitored regularly and continuously.

Coarse aggregate:

The aggregate is manufactured at the site itself to get the proper grading. The flakiness index is controlled upto 15 percent. Aggregate with higher flakiness is not permitted, since flaky particles align themselves in planes and thus affect durability.

Water :

Filtered water is used for sand washing, concreting and curing. Water samples are tested once a week at site and once a month in an engineering college laboratory.

Permeability:

The permeability is the most important aspect which controls durability of concrete. On this particular project, the permeability of the concrete, as measured as per DIN-1045, is restricted to 25 mm.

Quality assurance

The concreting is done under controlled conditions with strict supervision. The control mix design is done in the site laboratory. All railway engineers, inspectors and concrete supervisors were trained thoroughly in the following disciplines :

1. concrete mix design
2. how to inspect sand, aggregate, cement and other materials
3. how to make the formwork leakproof
4. designing concreting sequence and method of providing construction joint
5. grouting of cables and manufacturing of sound, impermeable cover blocks.

The construction of the bridge was carried out with the help of 30 concrete supervisors, 16 inspectors (Junior Engineers) and 6 engineers.

Special features

It was possible to construct this bridge at a remarkably high speed because of the following features, some of which are described earlier.

Movable sheds for girder concreting

AFCONS fabricated and erected a movable shed, 55-m long x 10-m wide x 8.50-m high to cover the casting bed of the girder. This shed is moved by winches from one bed to the other in the longitudinal direction in about two hours.

Mobile platform for assembling reinforcement for PSC girder

This platform on the west side of the casting bed is made of timber planks supported on steel frames which have been provided with rollers. The entire platform along with reinforcement cage and prestressing steel is moved in about three hours.

Mobile shutters

Both inner and outer shutters were mounted on rollers which helped in achieving a cycle time of 10 days for every prestressed concrete girder.

Permeability test on concrete

For this test, carried out to DIN Standards, the contractors have imported a testing machine from Germany. Under DIN Standards, permissible penetration of moisture is 25mm. The tests carried out by the contractors have revealed that the values are of the order of 10mm to 15mm.

Single pour of 280 m^3

The entire girder is concreted in a single pour of 280 m^3 in 16 hours without formation of cold joints. This is considered as an achievement.

Handling of PSC girder of 800t

It is probably for the first time in India that precast girder of 800t is handled, raised and placed in position by hydraulic power or otherwise.

Submarine barge for precasting the caisson and launching

The contractors specially fabricated two submersible barges of 600t capacity for launching the partially precast caisson every 20 days.

Compressed air for caisson sinking

This is probably the first time in India that caissons are sunk by using compressed air technique from start to end. This system has a number of advantages as described earlier.

Sheathing

The machine imported by the contractors conform to the latest technology in Europe, so as to manufacture double groove sheathing which is strong and yet flexible.

New system of bearing

The use of high tensile steel pin bearings as per German Railway Practice is the first example in the Indian Railways.

Quantities

Major quantities of construction material involved in the work are:

cement	=	27,000.00t
reinforcement steel	=	5,200.00t
structural steel	=	2,000.00t
H.T. steel	=	1,800.00t

Credits

The above feature is based on an article "Construction of a railway bridge across Thane creek", by S.C. Gupta in this Journal (November 1989 issue) and also on other information collected from different reliable sources connected with the construction of the bridge.

(Source: ICJ May 1992, Vol. 66, No. 5, pp. 241-247)

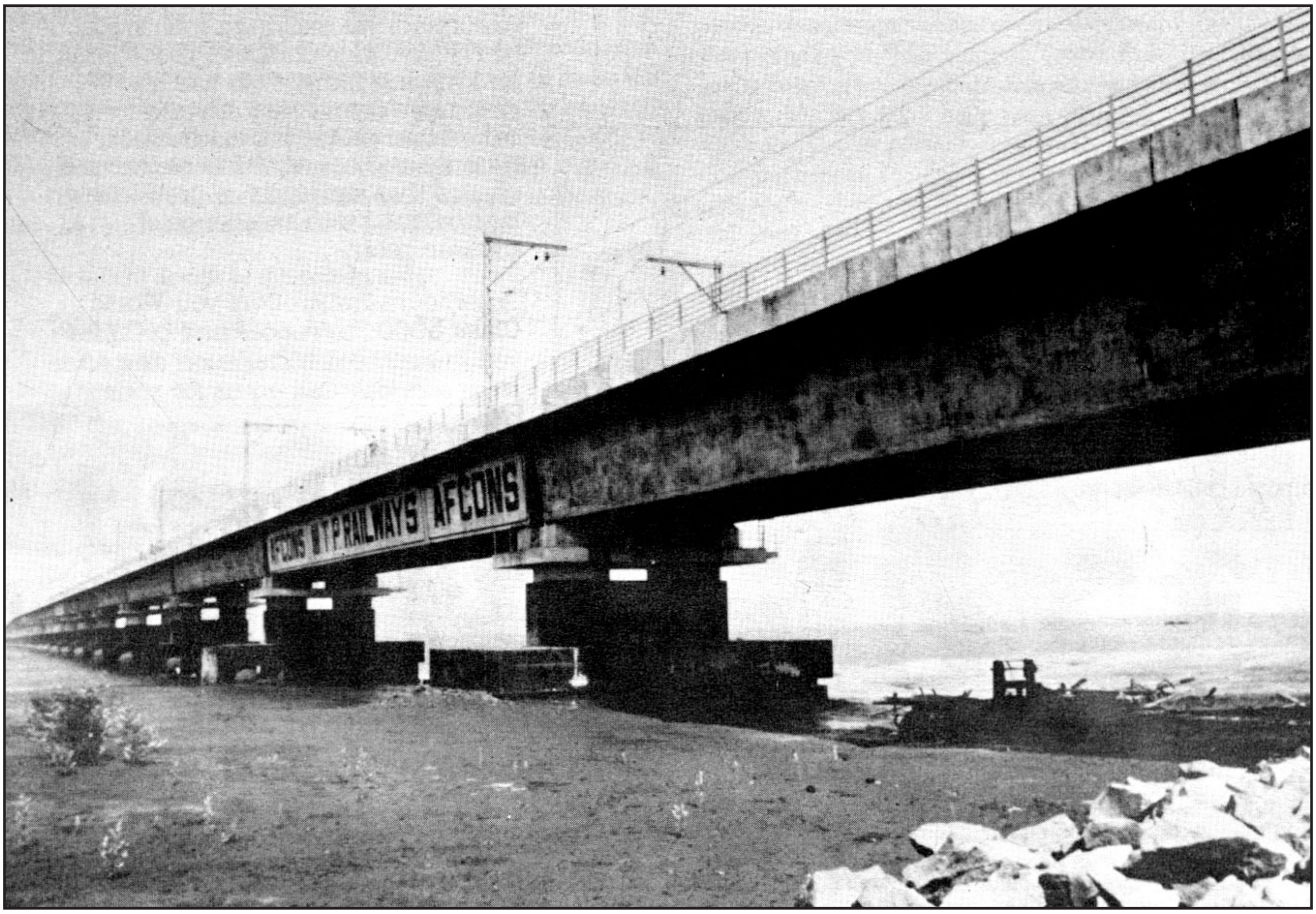


Figure 5. A panoramic view of the completed Thane Creek railway bridge