Construction of a railway bridge across the Thane Creek

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The construction of a new railway bridge across the Thane Creek, which is in full swing at present, is expected to be completed by March 1991. This 1.8725 km long bridge will provide a reliable and speedy railway link to the New Bombay city which is developing at a fast pace. The bridge has 35 spans, each 53.5m in length. Constructing the foundation of the bridge was a formidable task, for which floating caisson method was used. The box-type superstructure of the bridge weighing 800t was precast in the casting yard and then launched in position during high tide with the help of specially fabricated equipment. As the bridge is located in an aggressive marine environment, special precautions are taken to ensure its long-term durability. The paper highlights the broad construction features of the bridge.

The rail transport needs of the metropolis of Bombay are being met today by five railway corridors - two on the Western Railway and three on the Central Railway. The two corridors on the Western Railway extend from Churchgate to Borivli. Out of the three corridors on Central railway, two corridors are between Bombay V.T. and Kalyan which further extends to Kasara in the north-east and Karjat in the south-east separately. The third corridor is between Bombay V.T. and Mankhurd/Bandra, which runs parallel to the harbour from Masjid Rd. to Vadala Rd. and then bifurcates in two sections at Raoli Junction, one section going to Mankhurd and other to Bandra, Figure 1.

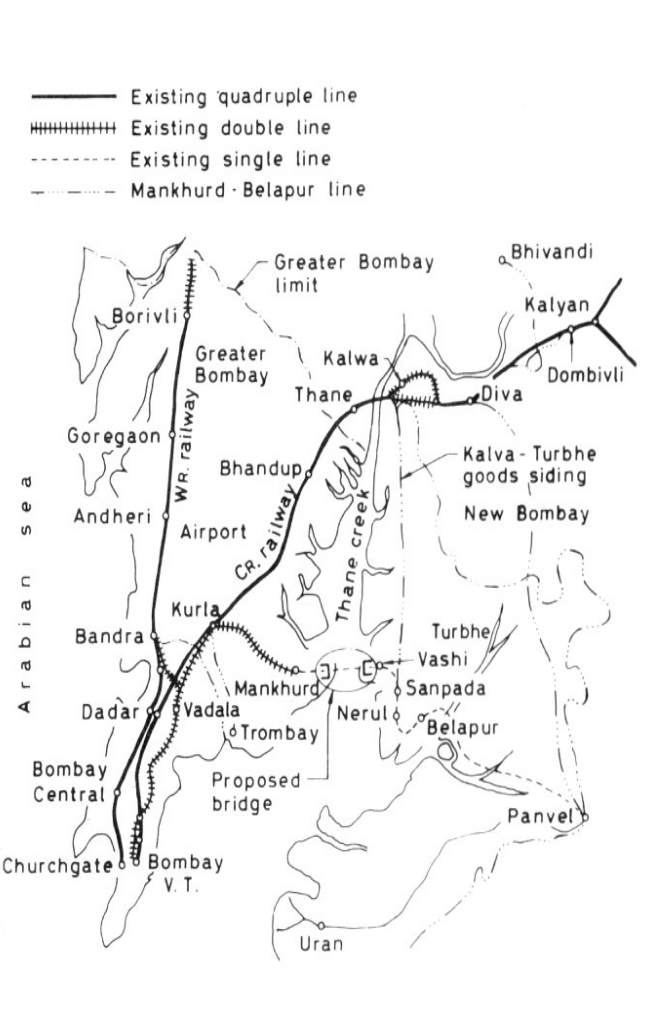


Figure 1. Index map showing the location of the railway bridge across the Thane Creek

New Bombay city is under development by the City and Industrial Development Corporation (CIDCO) under the Maharashtra Government. It will have a population of 30 lakhs and will provide all modern facilities consisting of central business district, industrial area, residential complexes and integrated transport and commercial services. To provide a reliable and noise-free transport system to the new city, the project of the extension of railway line from Mankhurd to

Belapur was sanctioned at a cost of Rs. 130 crores. Whilst the Government of Maharashtra is sharing 2/3 cost, the Ministry of Railways is sharing 1/3 the cost of the project. The railway line from Mankhurd to Belapur is 17.96-km long and includes a 1.87-km long bridge across the Thane Creek. The construction of Thane Creek Bridge is the most difficult and critical activity of the project. The estimated cost of the bridge is Rs. 24 crores. The bridge work commenced in January 1987 and is expected to be completed by March 1991. Figure 1 shows the location of the bridge.

Salient features

The general elevation of the bridge is shown in Figure 2. The salient features of the bridge a re as follows:

1. Total length of the bridge : 1.8725 km
2. No. of spans : 35
3. Length of a span : 53.5m
4. Type of substructure : 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
5. Diameter of the wells : 9.50m (outer)
6. Type of superstructure : Precast prestressed concrete box girders
7. Size of each box girder : 53.4-m length; 5.7-m width at top and 2.8 m at bottom; 3.65-m depth
8. Weight of each girder : 800t
9. Method of launching the girder : The precast girders are launched during high tide with the help of specially-fabricated catamaron
10. Bearings : Neoprene bearings with steel pin on either end
11. 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
12. Concrete grade : M-45 for superstructure M-30 for substructure
13. Concrete cover : 75 mm for substructure 75 mm for sheathing 50 mm for superstructure

Foundation and substructure

A new type of caisson launching scheme is being adopted for the construction of wells from P3 to P34 and for A2. 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 3.55m 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

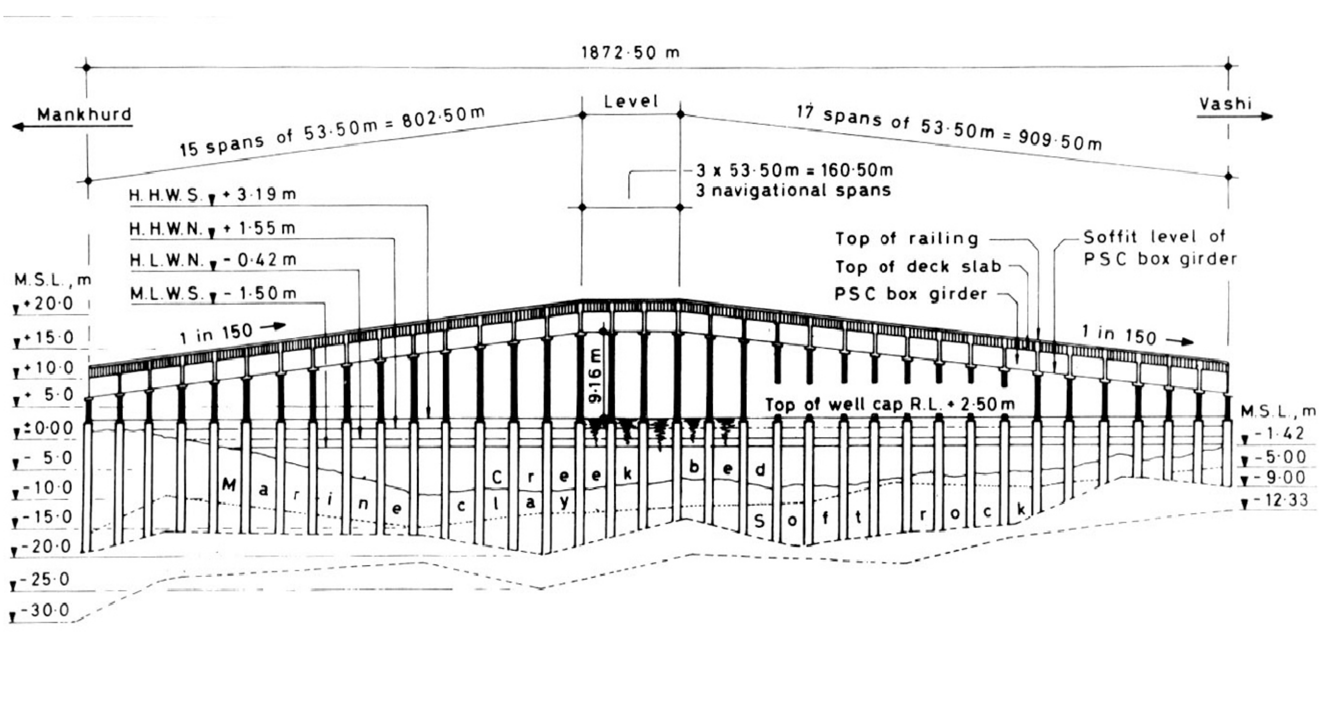
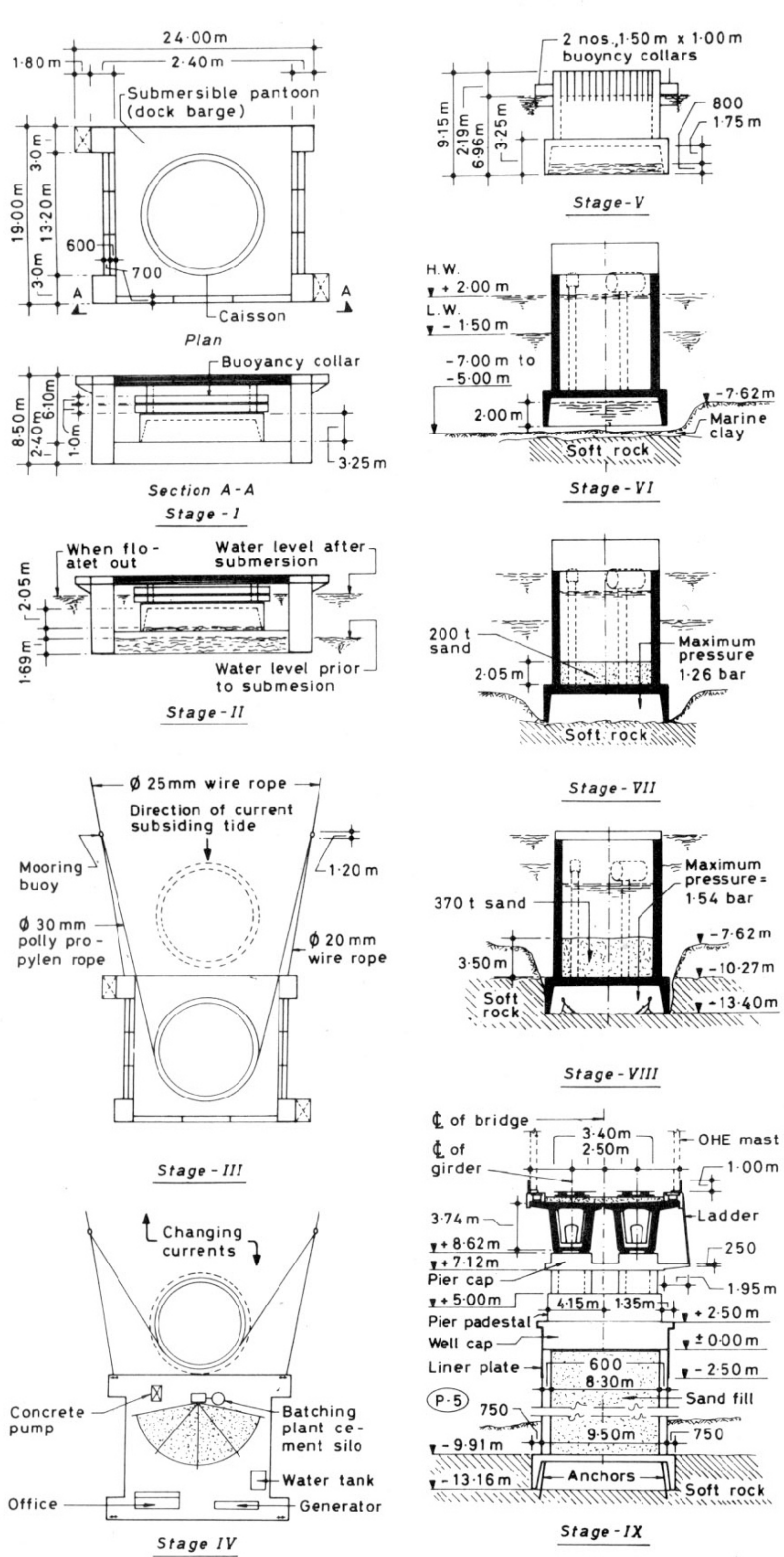


Figure 2. Elevational layout of the bridge



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 3. Construction stages of caisson foundation

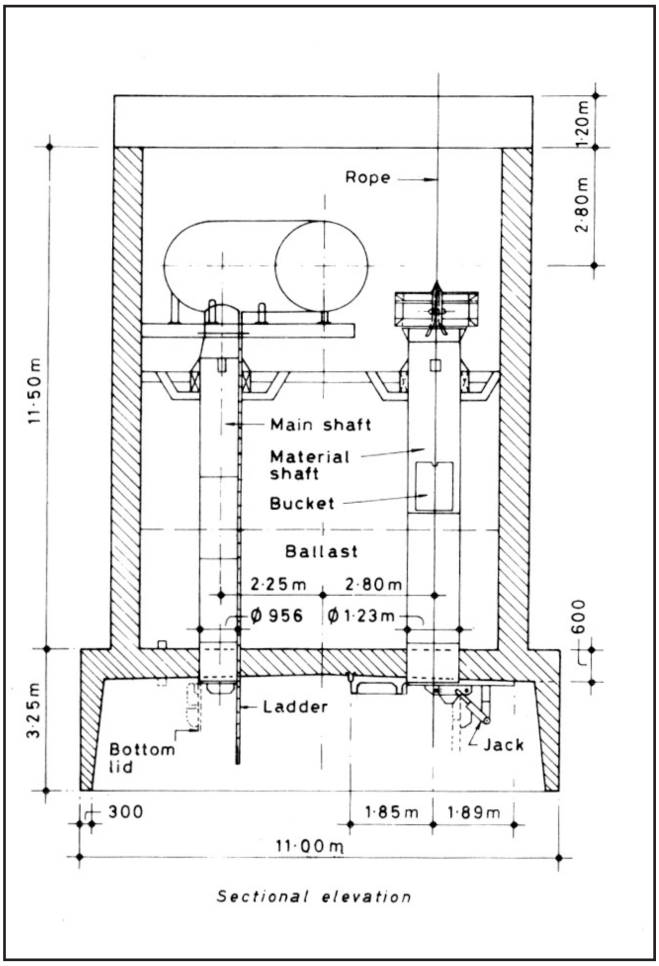


Figure 4. A typical pneumatic sinking arrangement

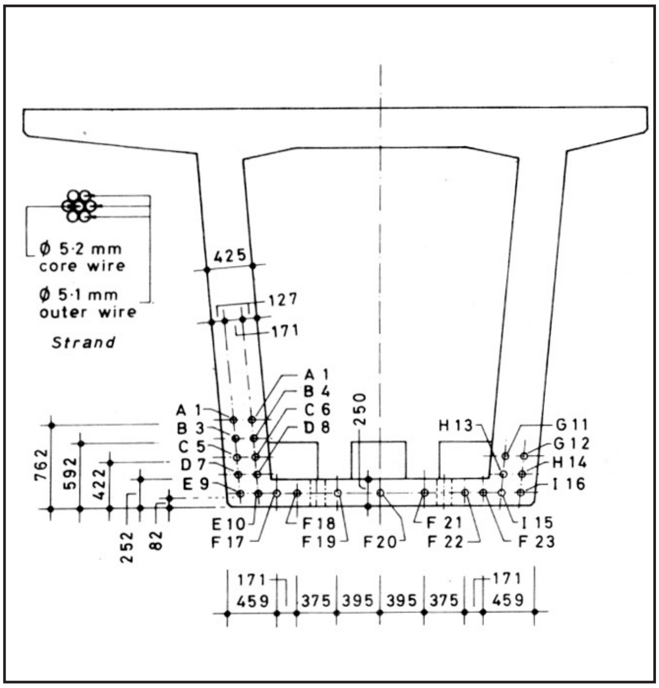


Figure 5. Cross section of the box girder showing cable location at the centre of the span

batching plant and a concrete pump. The concrete is transported by a 100-mm diameter pipe line. The main advantage of pumping being that the well unit is cast under controlled conditions. Two sets of buoyancy collars of 1.5 m x 1.0m cross section are fitted with the well steining to provide additional buoyancy and stability to the well in the floating condition. Figure 3 shows various construction stages of the caisson.

The submersible barge with the caisson of 7.15m height is towed during high tide to a location where approximately 10-m depth of water is available. With the help of valves, water in a set sequence is admitted into the 14 tanks of the submersible barge to gradually sink it. As the barge sinks by 8.1m, the caisson floats in the water. The caisson, with the help of tugs is pulled out of 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 4 shows the pneumatic sinking arrangement.

Further raising of the steining is done in the floating condition. Ballasting is done inside 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 loosening it with 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.

The well is taken to the rock which has a safe bearing capacity of 200 t/m^2 with a factor of safety of six. 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 has been 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 for the foundations 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. the 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 the dry condition.

Superstructure

The bridge has two precast prestressed 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. The salient features of each girder are as below.

1.	Length of girder	:	53.40 m
2.	Girder width at top	:	5.70 m
3.	Girder width at bottom	:	2.80 m
4.	Depth of girder	:	3.65 m
5.	Volume of concrete	:	300 m^3
6.	Weight of girder	:	800 t
7.	Reinforcement (Torsteel)	:	42 t
8.	Prestressing strands	:	16 t
9.	No. of tendons	:	23 Nos. having 12 strands of nominal diameter 15.24mm each, with 7 wires of 5.0mm diameter (min)
10.	Total prestressing force	:	44.815 kN (4,570t)
11.	Prestressing system	:	Tensacciai (Italian)
12.	Cement type	:	Special grade cement-IRS T-40
13.	Quantity of cement	:	150 t
14.	Time taken for concreting	:	18 to 20 hours.

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 hatching plants (one is a stand-by) and two concrete pumps are used. The temperature of concrete is kept below 30°C by precooling the aggregate. The details of the concrete mix M-45 are as given below:

W/C ratio	=	0.39
NC ratio	=	3.60
Cement content	=	480 kg/m^3
Slump	=	120 mm to 150 mm
Setting time	=	5 to 6 hours
Superplasticizer	=	1.2 percent

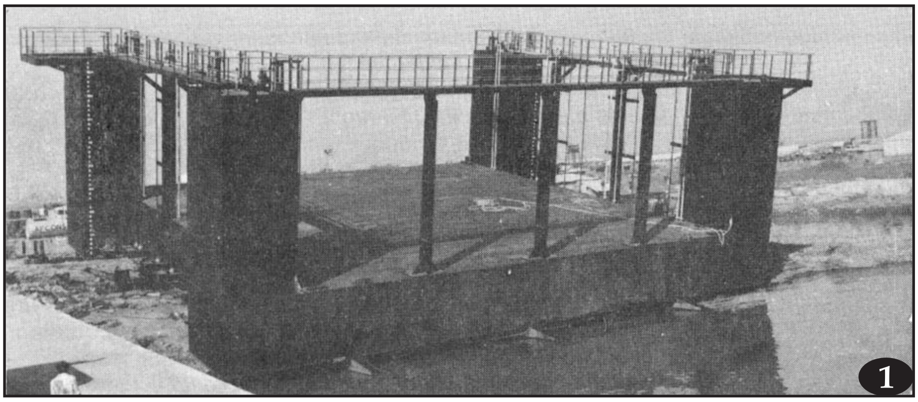
The concrete sequence has been so designed that even if one batch and one pump fails, there shall be no cold joint in the concrete. The cold joint in a concrete structure in aggressive marine environment is not desirable as it may lead to corrosion of reinforcement, since the chlorides, sulphates and acids find their way through this weak zone in concrete.

The first stage of prestressing which constitutes 30 percent of final stage 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 for a 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 40 N/mm^2. The maximum force in a tendon is 1,988N. The tendon elongation is about 270mm. The upward net deflection is 35.5mm.

Photo Feature



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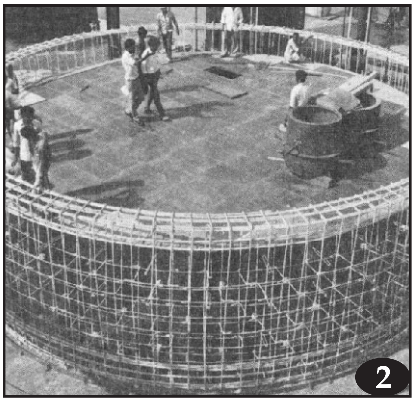

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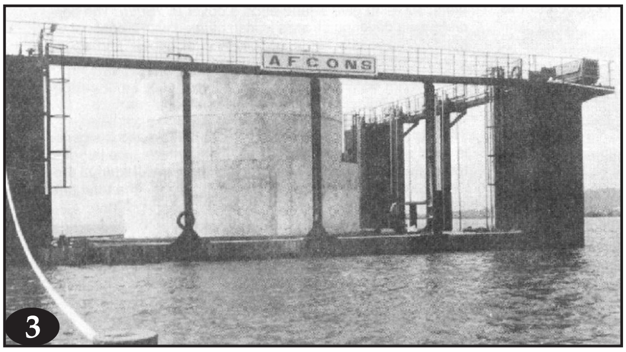

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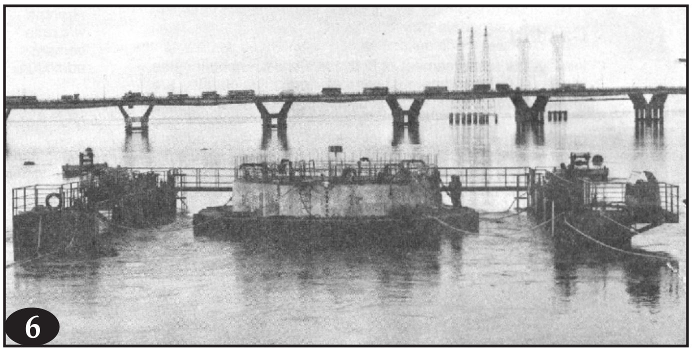

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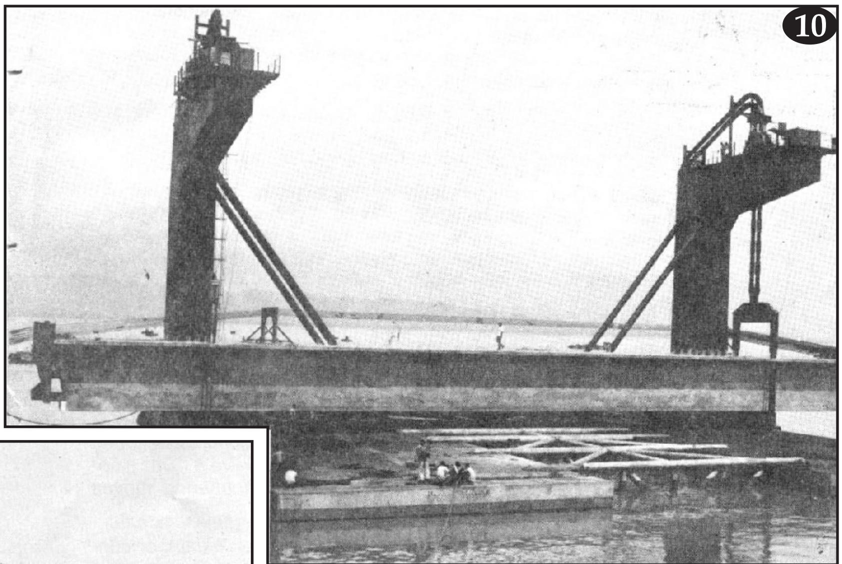

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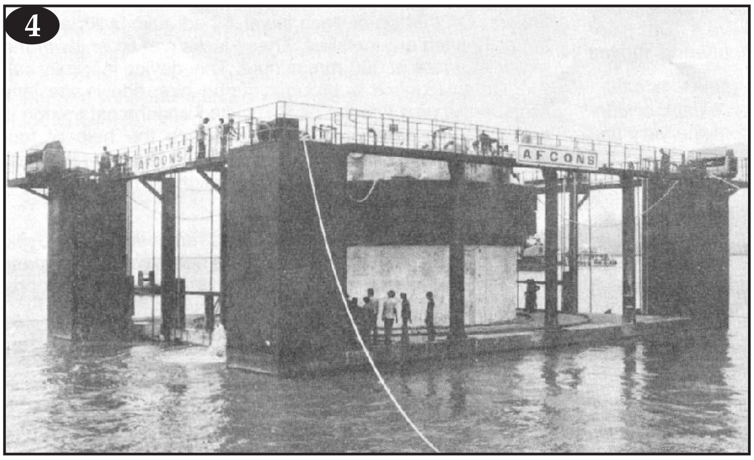

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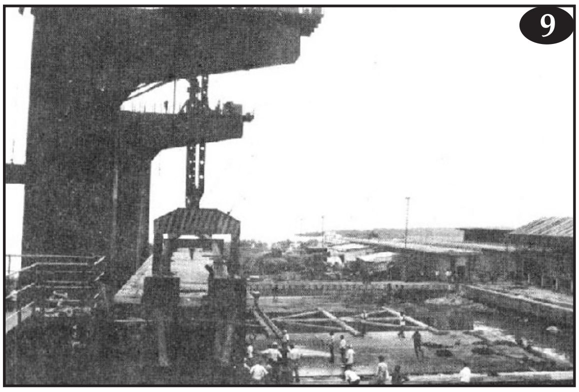

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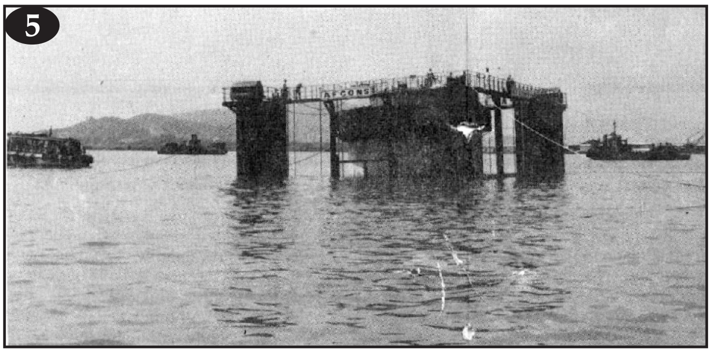
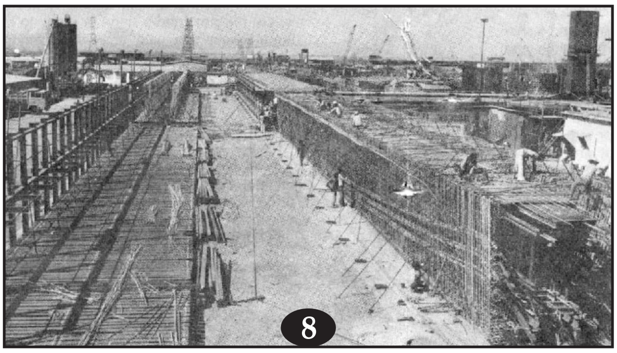
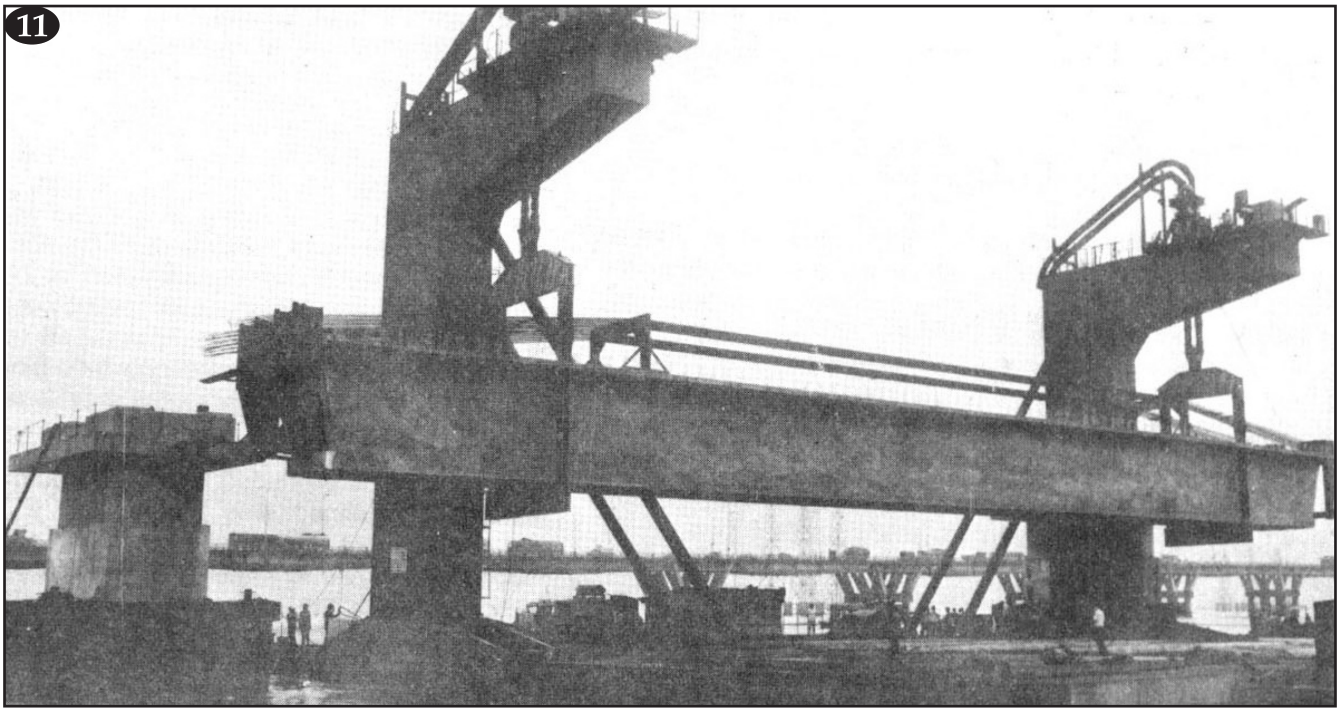
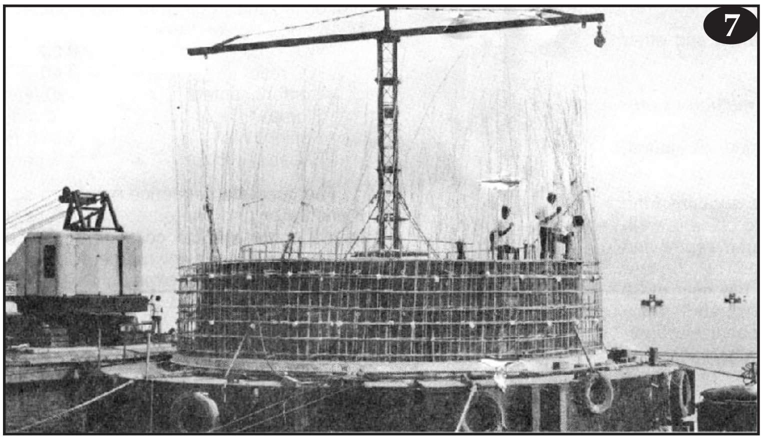






Construction Highlights



1. Submersible barge being launched in the sea after fabrication
2. Pressure chamber inner shuttering and treated reinforcement in position over the deck of submersible barge
3. Pressure chamber and two lifts of caisson steining cast over submersible barge
4. Two buoyancy tanks fixed around the caisson steining
5. Submersible barge being sunk in water
6. Caisson in the floating stage. The old bridge is seen in the background
7. Raising of steining being carried out in the floating stage
8. Prestressed concrete box girder reinforcement cage and inner shutter in position. Casting beds, reinforcement tying beds and concreted girder are also seen in the photograph
9. Girder being lifted from the launching jetty
10. The girder is lifted by a floating crane from the jetty
11. Floating crane being moved between the piers for positioning of the girder

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. OPC used is not older than four weeks. The composition of the grout is:

strength	:	17 N/mm^2
w/c ratio	:	0.45
cement	:	ordinary Portland Cement
admixture	:	Conbex 100 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 (Araldite GY 225-100 parts, hardner XY 45-100 parts by weight) are applied on two successive day. On the third day, the strand ends, bushes and wedges are covered by an epoxy putty (Araldite GY 255, hardner XY-45 and silica flour in the ratio of 100:100:200 respctively).

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 to be 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. These two items i.e. grouting of cables and epoxy painting of anchor ends, will ensure that no corrosion takes place in the strands.

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. The total prestressing force = 980t.

Launching

The launching of the girder from the jetty on to the pier top is the most interesting operation in 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 hadraulic 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 catamaron is towed to the span and is aligned with the help of four winches. The girder is lifted above bearing level and the catamaron 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, water proofing layer, and over it, a 75-mm thick concrete wearing coat is laid. The track shall be laid over it after providing 300mm thick, 40mm size ballast.

Total quality programme

The bridge is located in an aggressive marine environment and so a Total Quality Programme (TQP) from the conceptual to completion stage is being implemented to ensure the strength and durability of the bridge. When a structure fails, the blame is put on either poor quality of material or the poor workmanship. The effect of aggressive environment sorrounding the structure is normally underestimated. The fact remains that irrespective of high quality of construction, a structure can still deteriorate. The main factors causing concern are: the chemical corrosion of concrete, the elctrochemical corrosion of steel and stress corrosion of prestressing steel. These factors are responsible for the premature failure life of structures.

Specification

Specifications for the Thane Creek Bridge have been drawn keeping the above factors 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 Central Electrochemical Research Institute, Karaikudi's method
2. High tensile steel wires are coated with watersoluble oil
3. No green concrete is permitted to come in contact with sea water for the first 72 hours
4. Steel filler plate is provided from low tide level to high tide level
5. In the splash zone, i.e. 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 more. 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 its use
12. The strands were tested for fatigue in the Federal Republic of Germany (there being no facility in the country)
13. W/C ratio = 0.45 (maximum)
    Cement content = 400kg/m^3 (minimum), 540 kg/m^3

(maximum)
Permeability = 25mm (maximum).

The reinforced concrete se:lions used are thick, giving enough space for putting 60-mm vibrator and sharp corners have been avoided. The reinforcement, 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 manufacturer 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 weeks old. The C_3A content is between 4 percent to 8 percent. The use of cement from one source is very important; otherwise fresh trials for the mix design are required to be done again.

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 is washed by the filtered water and then blended with Kalyan sand. The three important factors i.e. 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 is tested once a week at site and once a month in an engineering collge 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 the 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.

No new officer or inspector is permitted to supervise the work unless he is trained for the job. The site office is well-equipped with a library, training-room, computer-centre and general facilities like rest-rooms, kitchen, etc. The construction of the bridge is being carried out with the help of 30 concrete supervisors, 16 inspectors (Junior Engineers) and 6 engineers. The minimum qualification for the concrete supervisors is HSC with a working knowledge of mathematics and science. These supervisors are trained thoroughly only in one or two aspects of concreting which they have mastered. Their work has been found to be most praise-worthy.

Process Control

The concrete is produced by two batching plants and transported by pipelines. It is compacted by using needle and shutter vibrators at pre-determined locations, so as to avoid honeycombing, cold joints and segregation. The deck-slab concrete needs tamping when it starts setting to reduce the shrinkage cracks. The curing is done by filtered water. 6-mm thick sponge at the joints of shuttering plates or with the concrete are used to prevent the loss of grout and thereby honeycombing.

The concrete cover blocks are scientifically manufactured, cured for 28 days and if the cube strength is more than the concrete strength of the main member, then only the blocks are used. The construction joints are prepared with proper hacking, water jetting and cleaning, to ensure that all laitance from the top surface has been removed fully including that from the corners and around the reinforcement bars. The G.I. binding wires are bent towards the centre of the section so that they do not reduce the clear cover.

A detailed computerised record of the technical data is being maintained for future guidance.

The 'Total Quality Programme' being implemented with the help of sincere, trained and hard-working supervisors, inspectors and engineers is bound to ensure the durability of this important structure which, in fact, will be the lifeline of New Bombay.

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(Source: ICJ November 1989, Vol. 63, No. 11, pp. 533-540)