Salient construction aspects of the second Thane Creek bridge

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The article describes the salient features of construction of the 1.837-km long second Thane Creek bridge. An innovative type of open foundations have been adopted for this bridge. Such a type of foundation enabled construction of footings and piers under dry condition when the depth of standing water is as high as 10m. The continuous type of prestressed concrete box-type superstructure is constructed by balanced cantilever method. All these are briefly enumerated in the article.

The second Thane Creek bridge, which is running east-west, consists of two carriageways, each carrying 3 lanes. In fact, each carriageway is an independent bridge, but for the common precast slabs on the central verge. The bridge is 1837.09-m long between abutment centres and consists of 6 continuous units. The central units, each of 321 m in length, have continuous span arrangement involving span lengths of 53.5 in + 107 m + 107 m + 53.5 m. Vashi end unit, 205.46 m in length, comprises of three spans of 61.95 m + 80.935 m + 62.575 m, whereas Bombay end unit is 347.63-m long and has four spans of 55.43 m + 103.30 m + 107.10 m + 81.80 m.

Foundations

Investigation

Trial bore hole data at the bridge site revealed that the rock level is dipping towards Bombay side, and that the depth of over burden of "soft to dense marine clay" increases towards Bombay end and varies from about 2 m to 15 m.

The rock below is classified as amygdaloidal basalt, which is weathered in the upper portion. To ensure a proper seating for foundations in good rock, about 5 to 6-m deep excavation is involved.

The minimum depth of standing water in the creek is of the order of 10 to 12 m. The creek is affected by tidal variation and its maximum extent at the bridge site is about 5 m.

Choice of foundation

Notice inviting tender for the construction of the bridge did not permit pile foundations. The bidders were given the option of either open foundation or well foundation. The contractor finally opted for open foundations, except for Bombay-end abutment. The method of open foundation adopted by the contractor envisaged the use of cofferdams. It is probably for the first time in India that open foundations are being adopted for a location where the depth of standing water is as high as 10 to 12m.

On Bombay side, an earthen approach road was constructed in the shallow bed of the creek upto pier P22 and thereafter about 50-m long jetty was constructed between piers P22 and P21. Even after this, adequate draught is not available during low tide between the jetty and P20 for the pantoons, which are required to carry materials, such as aggregate, washed sand, cement, reinforcement, fresh water, etc. from the Bombay side bank. It therefore became obligatory to transport the material from the jetty, only during the high tide period of about an hour when the current is practically stable. However, movement of pantoons, carrying batching plant, concrete pumps, cranes, etc. is not affected by the tidal variation between piers P4 and P20.

General scheme

The general scheme of constructing foundations consists of sinking cofferdams of required diameter and height upto the hard strata. Once the hard strata is reached, the cofferdam is dewatered and further excavation in hard strata is done under dry conditions. Such a method also enabled the construction of footings and piers under dry conditions.

The foundation work is carried out in two different ways.

Foundation construction with cofferdam

In the first method, Fig 1, a reinforced concrete cofferdam of

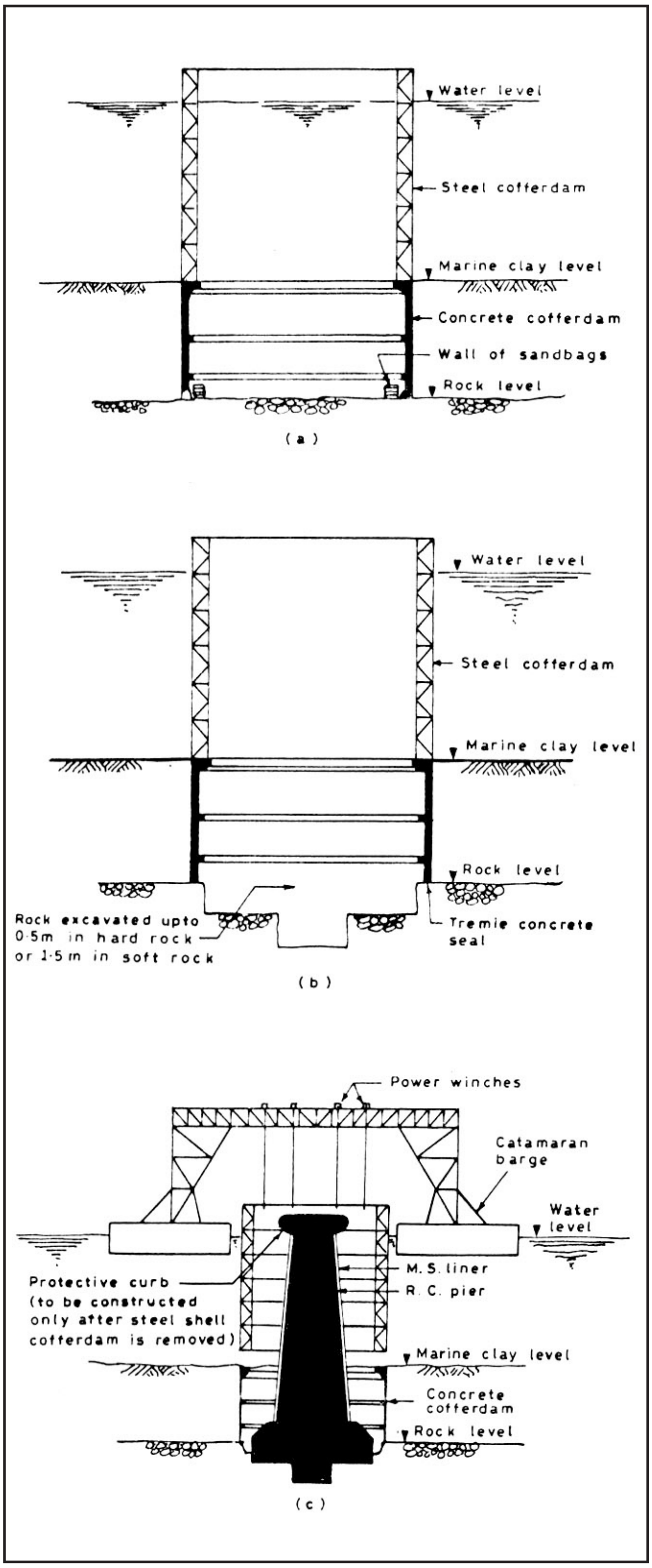

Figure 1. Open foundation construction Vith a cofferdam, (a) concrete-cum-steel shell cofferdam sunk upto rock level, (b) excavation in rock completed inside the cofferdam under dry condition, (c) construction of footing and pier completed under dry condition inside the cofferdam. Steel shell cofferdam is removed by a floating gantry after construction

required height and diameter, generally 4 to 5 m in height and 11 to 13 m in diameter (depending upon the location of foundation), is cast on a pantoon. It is brought to the pier location by towing and then connected to the floating gantry, already anchored at the required location, Figure 2. The cofferdam is lifted up, off the pantoon by the gantry and the pantoon is withdrawn. Steel shell cofferdam ring, about 1.2 m in height, is added over the top of concrete cofferdam each time and is lowered down. The process goes on till this composite cofferdam reaches close to the ground level.

During the lowering operation, care is taken to ensure that the steel shell portion is kept well above the high tide level. The cofferdam is further lowered and allowed to rest on the bed at the time of high tide when current forces are minimum. The location is checked, and if found correct, the annular space between the steel shell is filled up with water and the cofferdam sinks through the overburden. At times, airlift pump is also used to pump out the slush. This helps the sinking process.The floating gantry is then withdrawn.

Further sinking is done by grabbing and chiselling with the help of floating cranes. This is continued till hard strata is reached, Figure 1(a). Divers are also sent in, as and when found necessary. The cofferdam is then dewatered. A concrete ring is cast, at the cutting edge level to seal the joint between the cutting edge and the hard strata below. Further excavation in dry condition is carried out, inside this ring, Figure 1(b). The excavation is done by grabbing and by pneumatic breakers. Blasting of any kind is not permitted in view of the proximity of the first bridge. Then the plain concrete plug, reinforced concrete footing and the pier stem are cast in dry condition. The steel shells are required to be removed before the construction of navigational protective kerb, the bottom of which is located at H.T.L.

Foundation construction with interlocked sheet piles

In an alternative method, Figure 3, interlocked steel sheet piles are driven to form a circular enclosure at pier locations near the shore where the depth of standing water is less. This enclosure is filled with stone dust or sand to form an island. Reinforced concrete cofferdam is cast over this island and is sunk like any other conventional well, till it reaches the hard strata, Figure 4. Further excavation and construction of foundations and piers arc done as described in the earlier method.

Superstructure

Each carriageway consists of a single-cell box girder, the depth of which varies parabolically from 7 in (above pier location) to 3.5 m (at mid span). The superstructure is constructed by balanced cantilever method. Cast-in-place segments are added on either side above the pier with the help of cantilever construction equipment. Finally, a key segment is cast to establish continuity of the unit.

Pier segment and vertical stability cables

"Pier segment" or "pier table" which is 5-m long and which serves as a starting base for the cantilever construction, is cast

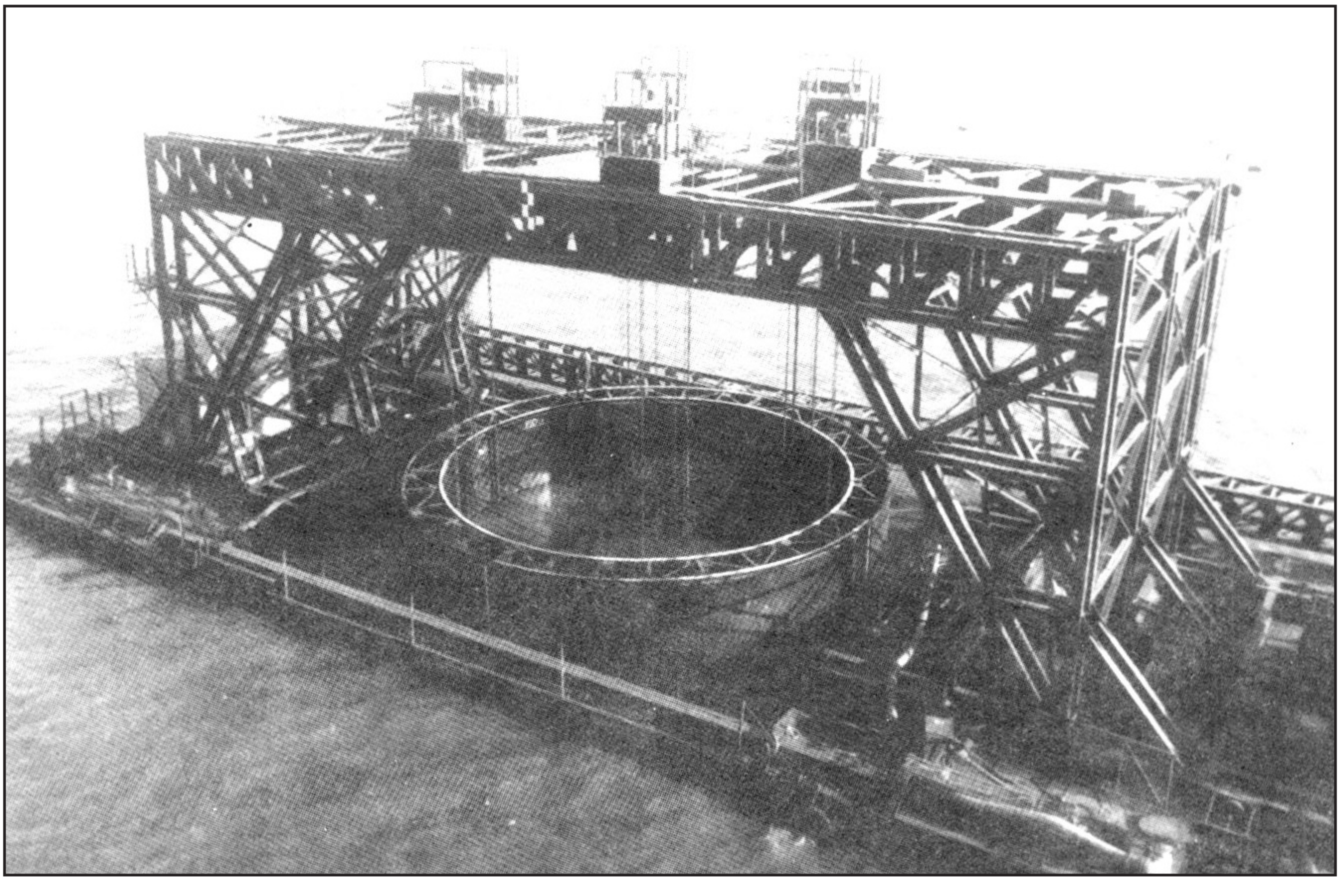

Figure 2. Steel shell cofferdam being loaded with the help of a floating gantry

over the pier cap along with bearings in position on the pedestals and the steel packings. Alternatively, it is cast over well-confined reinforced concrete blocks, placed on the pier cap symmetrically on either side and at the same level as that of the bearings. Twenty such packings are required over a typical main pier. Each packing is provided with one hole for the stability cable.

Four reinforced concrete pedestals, two on either side of the central diaphragm located at the corners inside the box girder, and one each at the junction of central diaphragm, web and the soffit slab, with vertical holes for stability cables, are cast monolithically with the pier segment.

The superstructure is tied to the substructure by 10 vertical cables on either side of the diaphragm in two groups, each of 5 cables, through reinforced concrete pedestals, steel packings and pier cap. This is done to counteract the effect of differential unbalanced moment caused during construction. Cantilever construction equipment is then erected over the pier segment and the segment of specified length is cast on either side. It is ensured that at any moment, not more than one segment will have unbalanced effect. After casting all the segments, 16 numbers on either side in case of a typical span, the key segment is cast and continuity in the span is established.

Transferring the load to bearing

The steel packings, earlier placed under the pier segment symmetrically around the bearings, are required to be removed to transfer the load of the superstructure to permanent bearings. Vertical stability cables are first destressed.

Eight numbers of special low-height hydraulic jacks (200-mm in height with lifting range of 50 mm), each of 500-t capacity, are introduced between the soffit of the box girder, and the pier cap, symmetrically around the bearings. The girder is then jacked up by about 10 to 15 mm and steel packings are removed. The jacks are then released slowly and steadily. In a continuous unit, the farthest pier from the fixed pier is tackled first. Third stage stressing is then started as per the prescribed sequence.

Stressing of cables

Multi-strand system of stressing is adopted. Each cable consists of 12 numbers of 12.7-mm diameter (7 ply-uncoated stress relieved) strands of class II high-tensile steel. The cables are threaded just before stressing. Middle-grip stressing jacks of C.C.L (U.K) M-3000 type or Usha Ismail M-1800 jacks are used for stressing simultaneously from both ends. The sequence of stressing is described below.

First stage cables :

These are the construction-stage cables which are located in and come out of the face of the deck slab and are required to be stressed, generally four in number, after casting each segment.

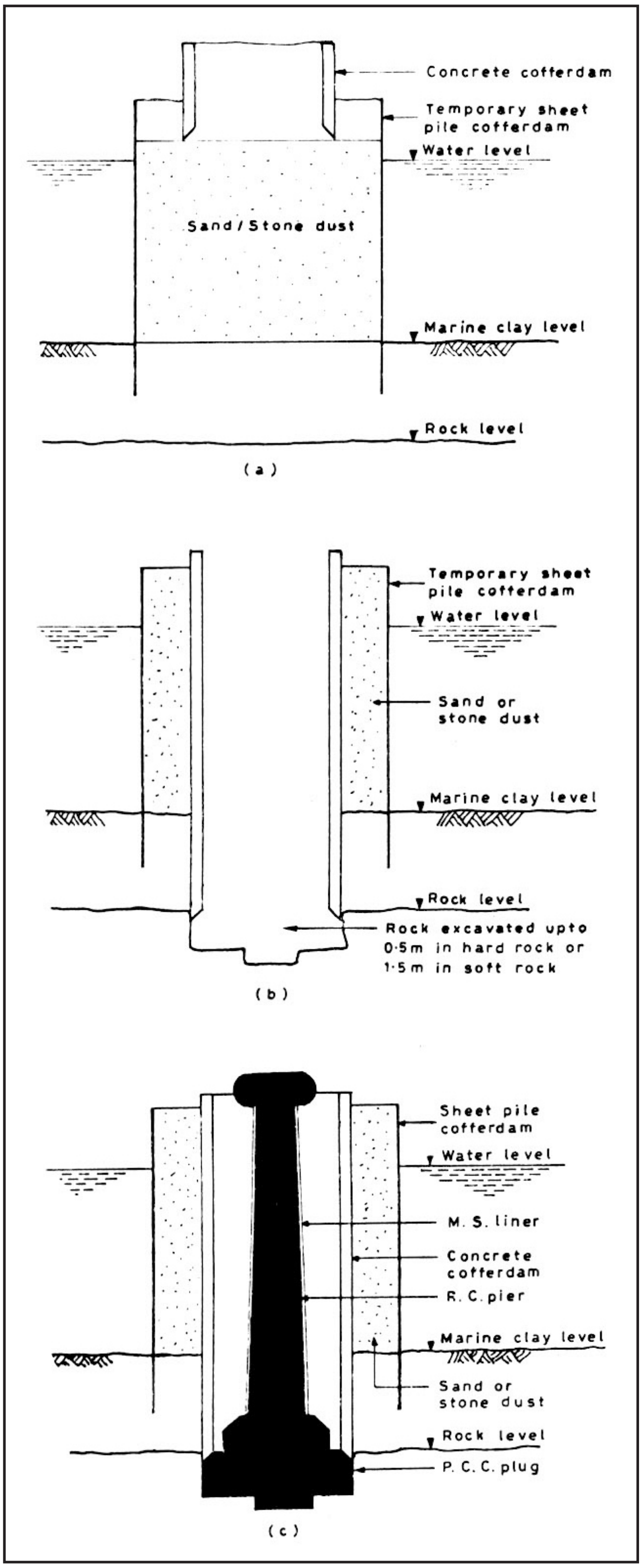

Figure 3. Open foundation construction with interlocked steel sheet piles : (a) concrete cofferdam being cast on sand island constructed with sheet piles, (b) excavation in hard rock completed inside the sheet pile cofferdam, (c) footing and pier are constructed inside the sheet pile cofferdam under dry condition

Table 1 : Details of design concrete mixes

Grade of concrete	Wic ratio	A/c ratio	Cement content, kglin3	Plasticiser, percent by wt. of cement	Slump, mm	Mix proportion C:S:AI:A2
M25	0.43	4.40	425	0.30	90-100	1:1.5:1.23:1.67
M30	0.42	3.89	465	0.30	90-100	1:1.32:1.01:1.56
M40	0.37	3.45	511	0.40	90-100	1:1.1:0.97:1.38

**C: cement, S : fine aggregate, AI : coarse aggregate (10 mm), A_2 : coarse aggregate (20 mm)*

Second stage cables :

The second stage cables are stressed after casting the key segment, when the continuity of a typical unit is to be established.

Third stage cables : These are the main continuity cables which are stressed in a specified sequence. Approximately, one-third cables are located in the top deck slab and are anchored inside the box girder in blisters located at the junction of vertical web and the deck slab. The remaining two-third cables are in the bottom soffit slab and are anchored similarly.

Sheathing

For sheathing, 75-mm diameter ducts prepared from 0.5-mm thick bright metal are used. Sheathing ducts of required length --- slightly more than the segment length --- are placed in position during the placing and binding of reinforcement. P.V.C. pipes are inserted in the sheathing duct before concreting. During concreting, P.V.C. pipes are moved to-and-fro. Such movement not only helps in maintaining the shape of the sheathing but also prevents blockage of sheathing due to leakage of cement slurry, if any. No specific problem was experienced while threading the cable, which was mostly done manually.

Concreting

Concrete of grades M-40, M-30 and M-25 have been used for prestressed concrete, reinforced concrete and plain concrete works, respectively. All the materials such as aggregates, cement, fresh water and the required machinery are placed on pantoons and brought to a place where concreting is to be done. "Elba" ba telling plant (semi-automatic) with an output capacity of about 35 trt3 per hour is used. Mostly, pumped concrete is used and 80 to 90-mm slump is found adequate. Super-plasticiser is also used to achieve the required workability. The water-cement ratio was generally not more than 0.38 for M-40 mix used for prestressed concrete work and 0.42 for M-30 used for reinforced concrete work. The details of the design concrete mix are as given in Table 1.

Profile monitoring for cantilever construction

The most critical practical problem of cast-in-place segmental construction is deflection control. A very accurate deflection monitoring is needed to achieve the desired final geometry at the time of casting the key segment and to avoid a vertical mis-match at the junction of the two cantilever arms.

The design provided the theoretical levels required after

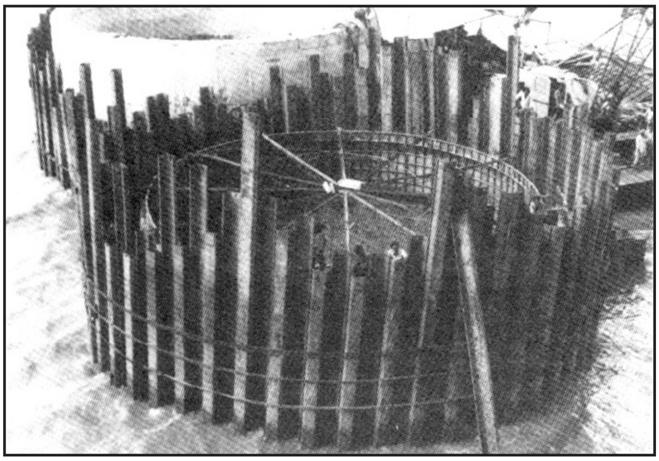

Figure 4. Reinforced concrete steining being constructed inside the sheet pile enclosure filled with sand

stressing all the segments cast, as well as the levels required for shuttering before and after concreting.

During the erection of shuttering for a segment, the level of the crown at the tip of the segment is maintained as per given levels. The levels are again taken after placing the concrete and stressing the required number of cables of a segment at this point and all such points of previous segments. The record of all these levels is maintained in the form of a "tree chart" for all the piers. One such tree chart for pier P17 (N) is shown in Figure 5.

The levels 'D' achieved after stressing, are found to be well in agreement with levels "A" in the tree chart, Figure 5.

If any mismatch at the tip in vertical profile is noticed after casting all the segments (16 nos. for a typical span) of the

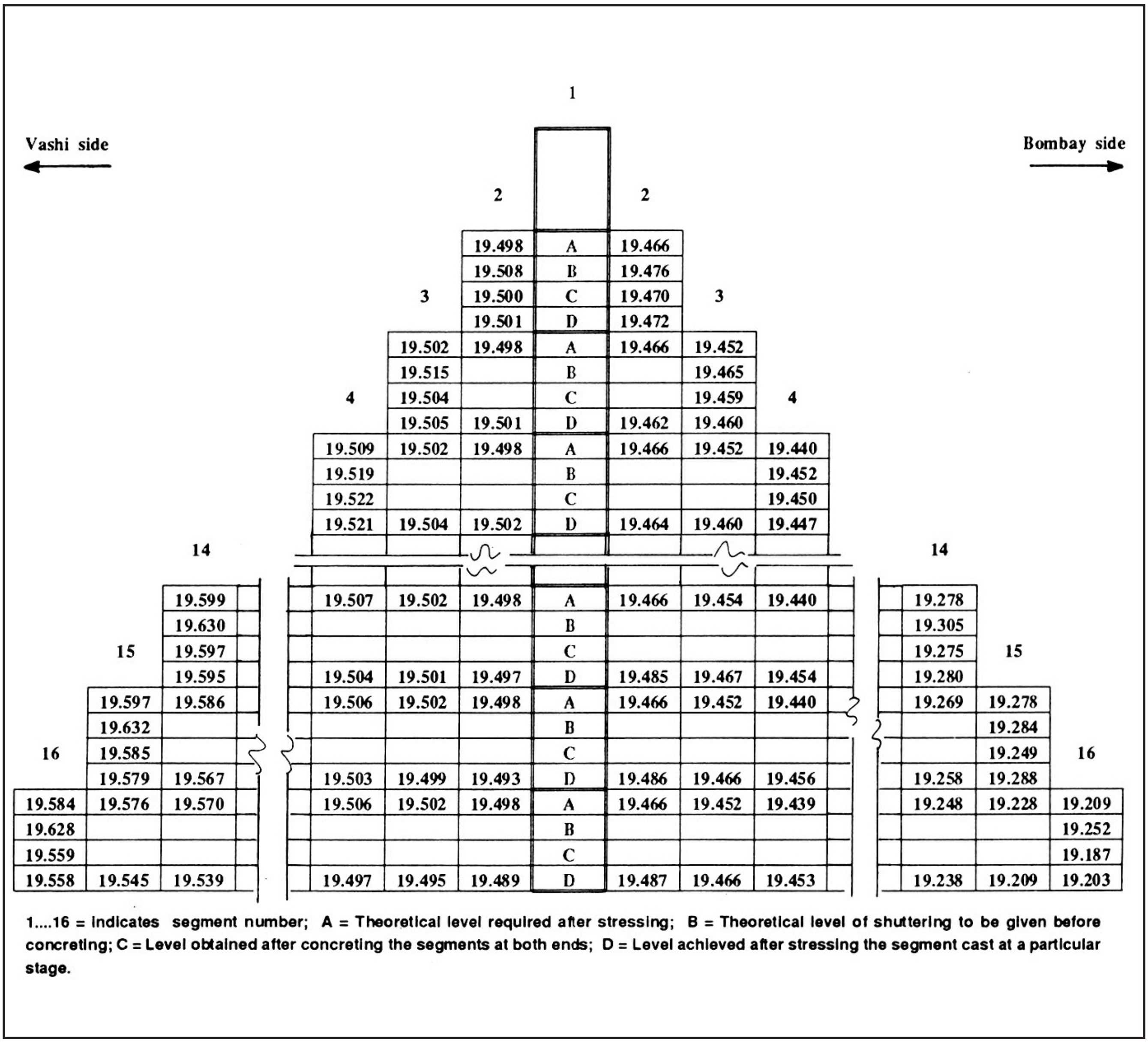

Figure 5. A "tree chart" indicating the record of different levels maintained for pier P17 (N)

adjacent cantilever arms in a span, the same can be rectified by shifting the concrete counter-weight blocks suitably.

Expansion joints

Replaceable mild steel finger-type expansion joints are being adopted for the north carriageway. These arc fixed in location by high tensile bolts. A profile cutting machine for cutting the fingers out of the un-laminated plates of required thickness is set up in the workshop at the site of work.

However for south carriageway, a better type of expansion joint is being envisaged.

Present status

The emphasis in construction has been to complete the north carriageway first and open it to traffic. The construction of both substructure and superstructure for this carriageway is almost completed. The work of constructing crash barriers and railings is presently in full swing and two out of three lanes in this carriageway are to be opened to traffic shortly. This would indeed give considerable relief to the Bombay-bound traffic crossing the Thane Creek. The third lane on the north carriageway is proposed to be used for construction activities for south carriageway, which is scheduled to be completed within the next two years.

A number of durability measures have been adopted for this bridge by incorporating appropriate specifications in the design criteria, for the materials to be used and for workmanship. However, they are not touched here as they have been dealt with in detail elsewhere.

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