Construction of Airoli bridge across the Thane creek

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With rapid infrastructural developments taking place in Navi Mumbai, its connection with Mumbai has been made easy with the construction of Airoli bridge which will come as a relief to hundreds of commuters. The paper discusses some of the salient aspects involved in the construction of the bridge.

The development of Navi Mumbai has reached such a stage that more number of road and rail connections between Mumbai and Navi Mumbai are necessary. Presently there are two road links connecting Mumbai and Navi Mumbai on the mainland, one at the northern end through Thane city and another at 15 km downstream at Vashi in Navi Mumbai. Traffic studies carried out by the City and Industrial Development Corporation of Maharashtra Ltd, (CIDCO) established the necessity of constructing at least one more road link across the Thane creek to serve the needs of present and future traffic. Thus a decision was taken to have a sixlane road bridge at Airoli, connecting Thane-Belapur road in Navi Mumbai to the Eastern Express highway in Mumbai at the junction of the latter with Goregaon-Mulund Link road at Mulund.

Traffic projection and studies

Zoning

For the purpose of estimation of travel demand on the proposed bridge over Thane creek at Airoli, the planning parameters and travel data given by Central Road Research Institute, (CRRI) New Delhi in the study "Planning of road system for Mumbai metropolitan region" were used. CRRI has considered 107 zones in the entire Mumbai metropolitan region, however, for this analysis, 21 zones were considered by regrouping 107 zones of CRRI. While regrouping, care was taken to keep more number of zones in north side and less in south side as the proposed bridge is expected to be used more by suburban traffic. Similarly, trips for 107 zones were regrouped to get trips for 21 zones and used for assignment purpose.

Road network

For preparing the road network plan, all the major roads of greater Mumbai, national highway, state highway and major district roads in Mumbai metropolitan region were considered. A new link connecting Thane-Belapur road and eastern express highway at junction of Mulund road were added, being the proposed link via Airoli between greater Mumbai. Link distance and nodes were coded to work out the shortest path tree for assignment purpose with the help of computer analysis. Figure 1 shows the index map with location of bridges.

Analysis, results and benefit

Having trip matrix for 21 zones and shortest path tree, trip loading was carried out on shortest path tree without capacity restraint.

The result from the above analysis indicates that, 3,137 taxis, 14,833 goods vehicle, 13,301 cars, 6,732 buses and 3,500 two wheelers amounting to 84,639 PCUs (per day two way flows) will be using the proposed Airoli bridge in the year 2001. The traffic. load using the above bridge in 1994 worked out to 69,861 PCUs.

It is found that on an average, the above bridge will reduce the trip distance by 3.6 km for the vehicles using this bridge. The total distance saved for various modes of vehicles in 1994 and 2001 is given in Table 1. Maharashtra State Road Development Corporation Ltd, (MSRDC) has been entrusted with the project of improving transportation of Mumbai and has been authorised to collect toll at every entry point to Mumbai. Hence a decision was taken to hand over the Aimli bridge to MSRDC as part of an integrated transportation system at Mumbai and to collect toll to recover the cost of the project. After transfer of assets and liabilities to MSRDC, CIDCO completed the balance project work on behalf of MSRDC.

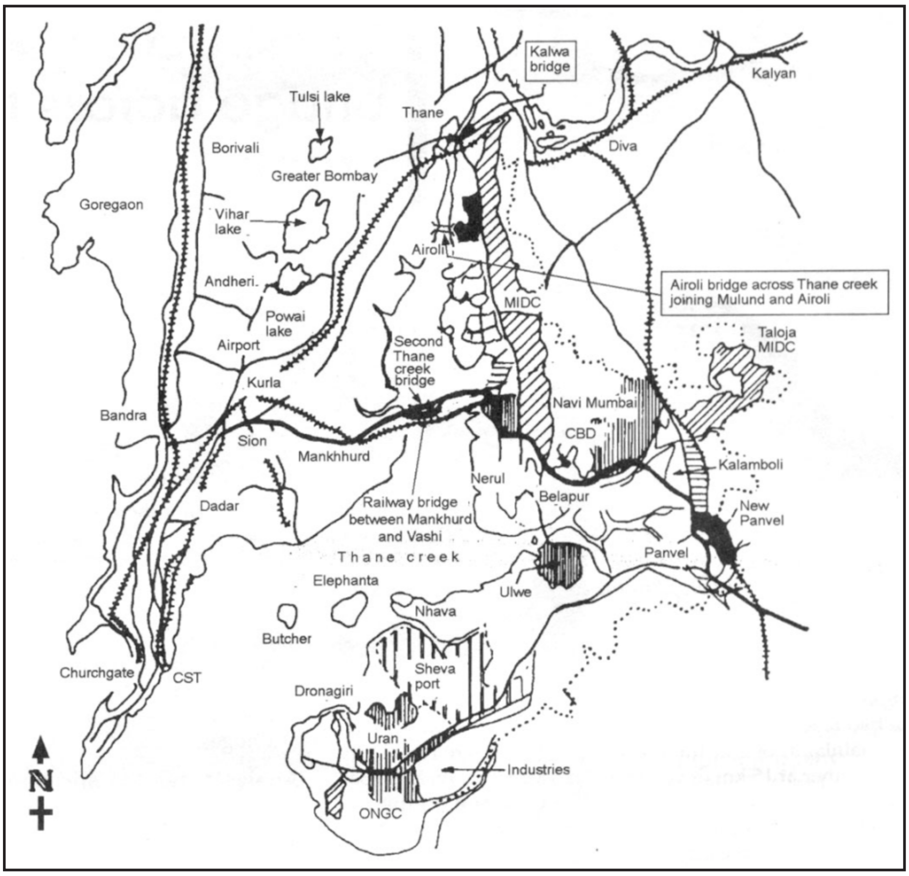

Figure 1. Map showing locations of bridges across the Thane creek

Salient features of Airoli bridge

Airoli bridge is 1030-m long, having two carriageways of three lanes in each direction, that is, total six lanes. There are 19 spans of 50 m on centres of piers and two spans of 40 m at either end, Figure 2. Open foundations resting on weathered rock having safe bearing capacity (SBC) of 70 t/m^2 have been adopted. Piers are reinforced concrete (RC) hollow circular shafts, while abutments are solid and non-spill through type. The superstructure consists of prestressed concrete box girders, simply supported on piers, Figure 3. The salient features are given in detail in Annexure 1.

Sub-soil profile

At the Thane creek, a layer of soft marine clay is encountered at bed level. This is followed by layers of stiff to very stiff marine clay, completely weathered/ decomposed rock in the form of hard clay. Underneath these clay layers, highly weathered basaltic rock has been encountered at depth varying between 6.6 m to 11.6 m. Moderately weathered rock has been observed, at a depth of 7.6 m to 14 m. Detailed subsoil investigation h indicated that slightly weathered to fresh basalt is available at a depth of 16 to 21 m. Hence, unlike the railway and road bridges across Thane creek where caissons have been found on sound, fresh rock with a SBC of 200 t/m^2, it was decided to provide deep open foundations resting on weathered rock with a SBC of 70 t / m^2 and with a minimum 1.5 m embedment in weathered rock.

Construction of foundations

Construction of open foundations has been carried out by preparing cofferdam at each pier location. The three types of cofferdams have been adopted for foundation construction:

1. ordinary cofferdams
2. sheet pile cofferdams
3. sacrificial concrete wells.

Ordinary cofferdams

Due to the availability of founding strata at a relatively shallow depth of 4 m to 5.5 m in case of piers P20 and P19 at the Airoli end and 5 to 6 m in case of piers P2 and P1 at the Mulund end, Figure 2, ordinary cofferdams with the help of sandbag protection, stable slopes and berms were adopted at these four pier locations. The excavated pits were around 9 to 10 m in diameter at the the bottom.

Due to the presence of 3 to 4 m thick soft marine clay at the surface, slope failure was experienced at the Mulund end during construction of pier P2. Construction of cofferdams for Pl, P2 took almost one and half months each.

Sheet pile cofferdams

Starting from the Airoli end, a temporary bridge had been constructed in pile foundations to provide access to each pier location. A sheet pile cofferdam was constructed at each pier location by driving 80 numbers of 12-m long, imported, Larsen-23 sheet pile section. Sheet piles were driven using upto 10 t PTC vibrofonceur upto refusal. Refusal was obtained in weathered rock, by driving these sheet piles with a penetration of 0.3 to 0.5 m. The construction of sheet pile cofferdam required around 8-10 days for each cofferdam. After completing the cofferdam, excavation was started inside the cofferdam.

Table 1 : Total daily vehicle km saved

Mode	1990 vehicle, km	2001 vehicle, km
Taxi	9,846	11,815
Car	36,694	47,633
Truck	41,579	49,895
Bus	23,073	27,687
Scooter/Rickshaw	10,980	13,182

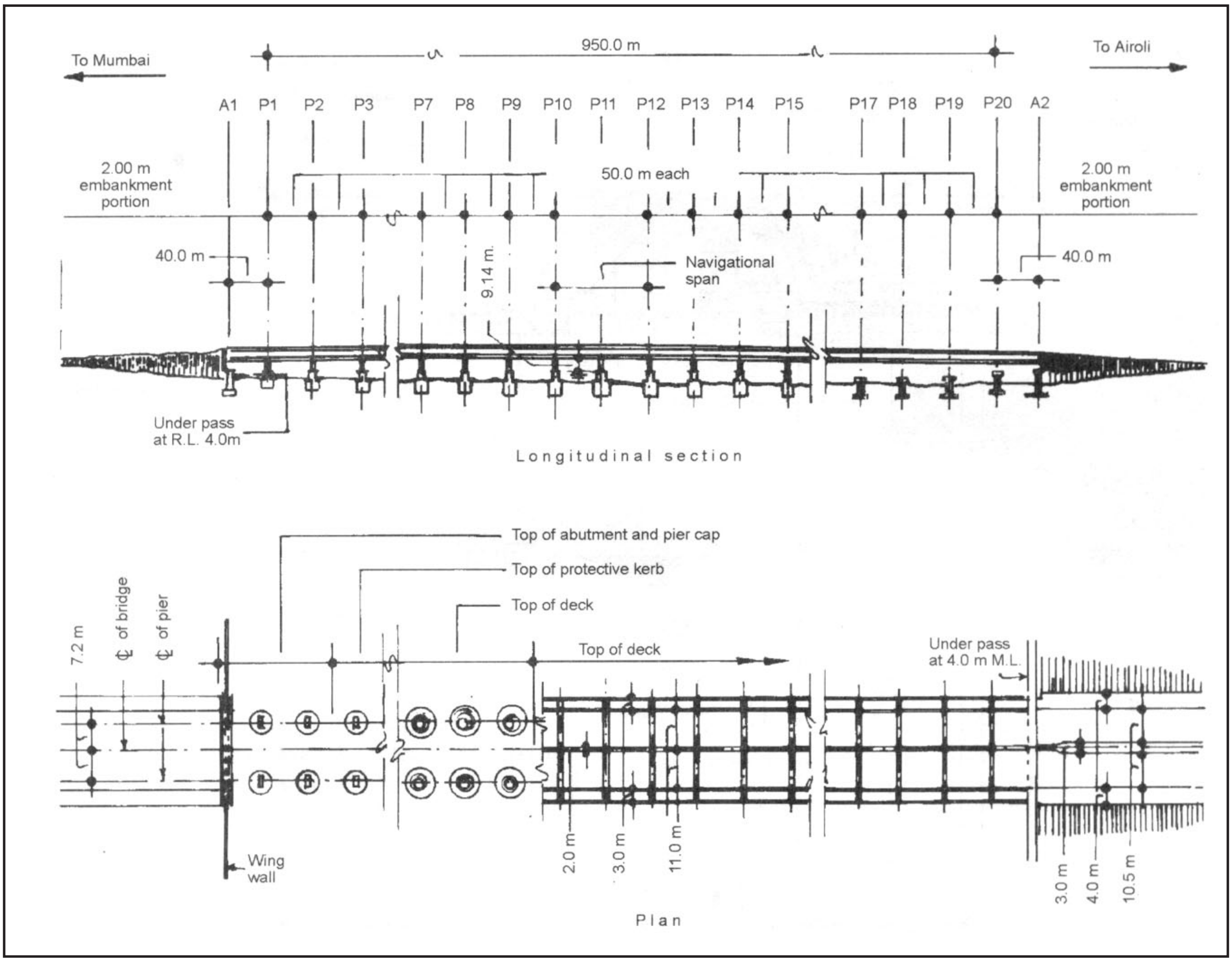

Figure 2. Longitudinal section and plan of the Airoli bridge

As excavation progressed, wailing beams were fixed at two or three locations inside the cofferdam. After reaching the expected founding strata, the foundation was examined and approved for concreting operations. By November 1996, 18 cofferdams were constructed at locations P17 to P9. Excessive water seepage beneath the base of sheetpiles, was observed at P14 (S) on account of failure of weathered rock in the toe region of sheet piles. In this cofferdam, a 6-mm thick, 9.4-m diameter and 3.6-m high mild steel (MS) liner, provided with wailing beams at 0.6-m interval in height, was lowered. After resting on the base of the excavation, the space between ledge and liner was concreted. Once the concrete was set, further excavation upto founding level was carried out below the concrete ring. After reaching the founding depth, the strata was inspected and concrete poured for foundation. Similarly, at location P11 (N and S) due to less overburden on account of deep bed levels resulting in less embedment of sheet piles, instability was noticed resulting in excessive seepage of water from beneath the base of sheetpiles. It was first attempted to drive an additional row of sheetpiles outside for part of the arc and carry out concreting between two rows of sheet piles. However, seepage was not controlled and hence underwater grabbing was done along the periphery of internal sheetpiles. Sacrificial MS liner was kept in position for entire inner area and the space between inner sheetpiles and liner was concreted underwater using tremie method. Thus a concrete beam was created. This measure was successful and P11 (N) could thus be dewatered and excavation up to -7.5 m was completed.

Sacrificial concrete cofferdams

In view of difficulties experienced in construction of ordinary cofferdams on the Mulund side, it was decided to use sacrificial concrete cofferdams (or wells) from P3 to P8.

A RC well with 0.3 m steining thickness, provided with steel cutting edge at bottom, was fabricated at the pier location. After sinking this well by 1.5 m to 2.0 m in the ground, excavation inside the well was commenced. As the excavation progressed, the height of steining was increased in successive lifts of 0.3 m. Finally, the cutting edge rested on weathered rock surface. Such cofferdams were constructed at pier locations P3 to P8. This approach eliminated construction of temporary bridge and sheet pile cofferdams at these locations on the Mulund side.

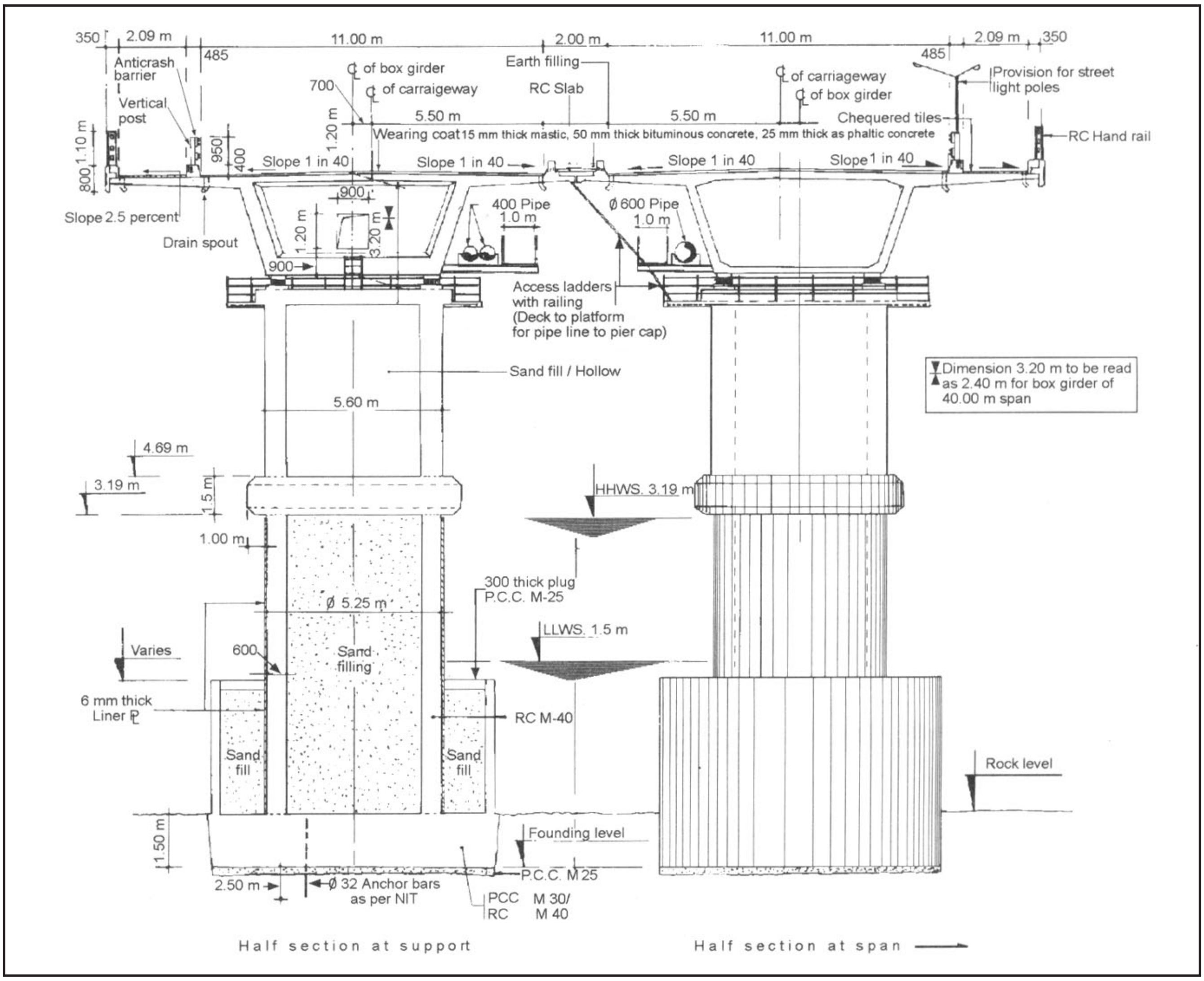

Figure 3. Typical cross sections of the bridge

Anchoring foundations

Rock surface at founding level was thoroughly cleaned with the help of air/water jets before laying a course of plain concrete of grade M30. Anti-corrosive treatment developed by Central Electrochemical Research Institute was given to the reinforcement bars used in the foundation. Concrete mix of grade M40 is adopted for the foundations. 24 nos. of 32-mm diameter high yield strength deformed bars (HYSD) of 5-m length have been provided in each of the foundations as anchor bars. These have been installed by carrying out drilling, insertion of bars and subsequent cement grouting around MS bars.

Construction of superstructure

Precast box girders

The superstructure consists of precast, prestressed concrete box girders of 50 m length and 15 m top width. The girders were cast in casting yard on RC bed supported on RC piles. There were two casting beds for a total of 38 precast box girders. The girders were single cell type and entire section, that is, bottom slab, webs and top slab, needing 450 m^3 of concrete, was cast in a single operation. The total time required was about 18-20 hours. Two batching plants were pressed into service for the supply of concrete. To avoid formation of cold joints, a retarding type superplasticizer was used which delayed the setting time of concrete by five hours. For all the box girders, both precast as well as cast in-situ, 19 T 13 prestressing anchorage system was used in order to provide greater force per cable, resulting in reduction in number of cables. Thus more concreting space was available. Threading of precasting cables was done 24 hours before prestressing of respective cables. During concreting, heavy duty PVC pipes were inserted in the cable duct and pipes were continuously moved to maintain ducts in position. End blocks were also precast.

On the third day, outer formwork for the web was loosened and one cable in each web was prestressed to counteract tensile stress in concrete due to shrinkage and temperature. The inside formwork was loosened and collapsed on the fifth day. Separate beds parallel to the concrete bed had been made for the erection of reinforcement cage and profiling of cables was done simultaneously to be in readiness to move the same at the time of shifting of precast PSC girder from the bed.

After the fourteenth day or on attaining strength of 35 N/ mm^2, whichever was later, second stage prestressing was carried out and the girder was ready to move out of the bed. Two jetties have been constructed perpendicular to concrete bed for casting girders in such a way that at the end of jetty, draft was available to bring barges below box girders during high tides. These jetties have been founded on pile foundations and are heavily reinforced to take the load of box girders. Each jetty has a capacity of six box girders.

Figure 4. Grider being lifted up by hydraulic jacks and towed to bridge location

Transportation and launching of precast girders

After second stage of prestressing and grouting of cables, girders were ready for side shifting. The two ends of the girders were then lifted out above 130 mm for inserting side shoes which were provided with Neoprene pads. After inserting sliding shoes, proper movement of the girder was accomplished by pushing with four 100-t hydraulic jacks and it was brought on jetty and depending upon the availability of space on jetty, girder was shifted to the farthest end and kept along with sliding shoes. End diaphragm were cast and then third stage and final prestressing was done after 45 days of girder casting on the jetty itself. After completion of grouting of cables, girder was ready for lifting and taking to required pier position. At the time of shifting of girder, reinforcement cage was tied with the girder and as girder moved towards jetty, the reinforcement cage also moved from fabrication bed and brought out to concreting bed. Thereafter, outer shuttering from the other bed was moved and brought to concreting bed from where girder had moved out. Vertical posts were erected between two girder beds and by putting temporary rails, inside shuttering in one piece was moved from one bed to the other bed. The shed to cover casting of the girder was also movable type and moved from one bed to other bed where girder concrete was taken up.

The crane barge was then positioned below the girder at suitable high tide and allowed to ground at low tide. At the next high tide, girder was lifted up and load was taken on barge and it was towed to between piers. Then the girder was fully lifted by the hydraulic jacks and barge was manoeuvred into exact position, Figure 4. The two ends of the girders were constantly monitored so that, at bearings the girder was correctly positioned. Thereafter the girder was slowly lowered on the PT/ PTFE bearings. Barge was then withdrawn for anchorage and grouting of anchor bolts of POT/PTFE bearing was carried. Other items like fixing of expansion joints, railing, etc. was carried out at a later stage in due course.

Cast in-situ box girders

End spans of 40 m were constructed by conventional cast in-situ construction. However, bottom slab and webs were cast in one pour and subsequently, top slab was cast, ensuring only one construction joint at junction of top slab and webs.

Figure 5. A view of the bridge nearing completion

Special durability measures

The following measures were taken to ensure long-term durability of the bridge.

1. Anticorrosive treatment to reinforcement bars by CECRI method.

2. 6-mm mild steel liner plates fixed to the foundation and substructure upto the highest high tide level, that is, +3.19 RL.

3. The liner plates were painted with tar epoxy paint.

4. The sand used for concreting was washed with potable water so as to remove all silt and salts therein.

5. PSC box girders were painted externally with epoxy paint, internally with cement paint.

6. Water permeability tests were carried out as per DIN-1048 Part-1 clause 4.7 for all M40 grade concrete.

7. Minimum grade of concrete used was M40 with minimum cement content of 400 kg / m^3 and maximum water-cement ratio 0.40.

Project management

Leading newspapers carried advertisements inviting applications from reputed firms having considerable experience in construction of major bridges. The project management consultant (PMC) was selected based on the consultation of a high level committee comprising of a chief engineer from PWD.

In case of Airoli bridge, PMC was assigned the responsibility for quality assurance, measurements, day-today supervision and checking of designs and drawings, under overall control of chief transportation of communication planner, assisted by superintending engineer. Thus PMC was augmenting the staff of CIDCO's bridge section and performing role of engineer's representative. Apart from CT and CP as (ACEIRP) overall incharge, superintending engineer (SE), was inspecting officer and principal coordinator as well as design approving engineer. A team of executive engineer, assistant executive engineer and one assistant engineer were deputed for co-ordination between CIDCO-PMC and contractor and other outside agencies.

PMC had separate teams as given below.

1. Design checking team headed by principal consultant and other senior and junior engineers to carry out checking of designs and drawings and after due corrections make recommendations to SE(B&ROB) for approval of designs and drawings.

2. Execution team was headed by chief consultant (contract) of PMC. At site PMC had deputed his principal consultant as project manager, who was a qualified civil engineer, having 30 years of experience in various capacities. He was assisted by two deputy project managers, quality control (QC) engineer, quality surveyor, senior and junior engineers and supervisors.

Instrumentation for research studies

The bridge elements were extensively instrumented for monitoring the behaviour of the bridge. The work of instrumentation has been taken up as collaborative project with Structural Engineering Research Centre (SERC), Gaziabad and the corrosion monitoring is being done by Central Electrochemical Research Institute (CECRI). The salient features of the instrumentation scheme are given below.

1. Instrumentation for measurement of deflection, strain, temperature gradient of one of the box girders of the central span of one carriageway on extensive scale by fixing vibrating wire strain gauges, mechanical strain gauges, temperature sensors, bench mark plates, etc.

2. Limited instrumentation for measurement of alternative span of two carriageway, that is, 18 nos of box girders in all by fixing limited number of vibrating wire strain gauges.

3. Instrumentation of one abutment for the measurement of lateral earth pressure by fixing vibrating wire pressure cells.

4. Instrumentation for the measurement of vertical settlement of one of the piers by fixing bench mark plates and monitoring by precision level instrument.

5. Instrumentation for corrosion monitoring by CECRI of two box girders by fixing corrosion monitoring probes.

Acknowledgment

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Credits

Contractor	:	AFCONS Infrastructure Ltd., Mumbai.
Design consultants to contractor	:	Consulting Engineering Services Pvt. Ltd., New Delhi.
Project management and proof consultant	:	STUP Consultants Ltd., Vashi.
Value of work order	:	Rs 73.90 crores.
Concept and execution	:	CIDCO
Owner	:	MSRDC

Annexure I Salient features of Airoli bridge

Road bridge across Thane creek at Airoli with 200 m approach road on each side.

Length of the bridge	:	1030 m.

Design loading	:	Three lanes of class 'A' or 70 R whichever produces maximum stress.
Limiting safe bearing capacity of founding strata	:	70 t/ m^2.
Clear linear waterways	:	850 m

General Arrangements

1. 19 spans of 50 m on centres of pier.
2. Two end spans of 40 m between the centre of pier to face of dirt wall of abutment, with vertical clearance of 5.5 m for the proposed under pass.
3. Two navigational spans with vertical clearance of 9.14 m above MHWS (+3.19m).
4. Total deck width : 30 m
5. Carriage way : 2 nos of 11 m each for three lanes in either direction.
6. Central verge : 2 m.
7. Clear footpaths : 2.225 m clear width in either direction.
8. Kerbs for railing, anticrashbarrier and facia, etc : 1.55 m

Foundation

1. **Foundations :** RC raft foundations, open excavation using sheet pile/ RC well type coffer dam. Grade of concrete M40.
2. **Piers :** A row of hollow circular 600 mm thick RC piers with sand fill inside. Grade of concrete M40.
3. **Abutments :** Nonspill through type RC abutments with minimum thickness of 1.0 m. Grade of concrete M40.

Substructure

1. **Protective kerb :** 1.5 m thick concrete kerb provided over circular pier. Grade of concrete M40.
2. **Rectangular hollow pier :** A hollow rectangular pier 600 mm thick wall, sand fill inside. Grade of concrete M40.
3. **Pier cap :** Rectangular pier cap with walkway platform over rectangular pier. Grade of concrete M40.

Superstructure

Single cell simply supported prestressed (post tensioned) box girders. Grade of concrete M40 for girders and M45 for end block.

Dimension	Nos
50 m x 14.8 m x 3.2 m	38 Nos precast.
40 m x 14.83 in x 2.4 m	4 Nos cast in-situ.
Presiressing system	19 K 13
Total jacking force	200 t

The 50 m precast box girders were concreted in the yard along the creek to be lifted and placed over the piers with the help of barge. Each box girders weighs about 1,050 MT

Material	Quantity, tonnes
Cement	18,500
MS liner	433
Reinforcing steel	4,000
H.T. Strands	600
MS liner	440
Structural steel	305

Quantities of major items

Sr.No.	Structure	MS Liner t	Concrete m^3	Reinforc-ement steel t	HT Starand t
	Foundations				
1.	Raft	-	4050	345	-
2.	Circular pier	308	4030	230	-
3.	Abutment	125	1700	170	-
	Substructure				
1.	Prot. kerb	-	2266	141	-
2.	Rect. pier	-	1767	107	-
3.	Pier cap	-	510	50	-
	Superstructure				
1.	50 m box girder	-	15730	2670	550
2.	40 m box girder	-	1215	210	45
	Other Miscellaneous items				
	Hand rail, kerb, facia, etc.	-	732	77	-
	Total	**433**	**32,000**	**4,000**	**595**

Other features

1. **Bearings :** POT / PTFE bearings -168 nos.
2. **Expansion joints :** Elastomeric expansion joints - 1200 running metre
3. Street lighting and provision of base plate for electrical poles and 100 mm diameter PVC duct in footpath. Fixtures for beacon lights to be provided for navigational spans.
4. **Wearing Coat :** Asphalted wearing coat.
5. **Provision of service pipes :** To carry service pipelines of one 600 mm diameter and two 400 mm diameter pipes and provision of maintenance walkway platform on both sides. Total quantity of galvanized structural steel is 305 t.
6. **Anticrash barrier:** The metallic cold rolled section anticrash barriers with deflector beams were proposed on either side of bridge portion - 2060 running metre.
7. Protective coatings and epoxy paintings were proposed for bridge elements.

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