Substructure for third Godavari Bridge : Construction highlights

B. Deva Singh

The foundation for the third Godavari Bridge consists of 29 double 'D' shaped wells of size 16m x 8m. The wells were sunk to an average depth of about 19m. Caisson foundation was adopted for pier no. 2, where the depth of standing water was about 16m even during the summer. The piers and abutments were constructed in mass concrete. The article highlights the salient construction features of the substructure.

The third Godavari Bridge, which is located at 54m on the up-stream side of the first bridge, has 28 spans of 97.552m (total length = 2, 726.96m). The salient hydraulic and other data of the bridge are as follows :

1.	Maximum design discharge	:	1.21,000 m^3/s in 1986
2.	Design HFL	:	+20.345 m
3.	Low water level	:	+13.640 m
4.	Maximum design scour level	:	(+) 5.5 m
5.	Rail level	:	+26.820 m
6.	Total length of the bridge	:	2726.956 m
7.	Span arrangements	:	28 spans of 97.552 m (on centres)
8.	Foundations	:	29 wells of 16.00 x 8.00 m double "D" shape wells of 2.25 m steining thickness with 2.00 m central steining thickness.
9.	Piers and abutments	:	Mass concrete with temperature reinforcement.

The foundation for the bridge consists of 29 wells of size 16.00 x 8.00 m in double 'D' shape, Figure 1. The wells have been taken to a maximum depth of (-)19.86 m in Kovvur channel and (-) 19.29 m in Rajahmundry channel of the river. The substructure has been designed to Railway's standard revised broad gauge loading of 1975.

There is a barrage on the river at Dowlaiswaram, just about 5km on the down-stream side of the proposed bridge. Flow of the river is regulated and the low water level is generally expected at (+) 13.64 m.

Well sinking operations

Different types of artificial islands were formed to facilitate placement of cutting edges and concreting of the curb for the foundations and also for the substructure work. They were :

1. artificial sand islands, where the water depth was upto 5.00 m
2. sand-bar-cum-islands, where the depth ranged between 5.00 to 10.00 m
3. caisson method where the depth of water exceeded 10.00 m (for P-2).

Sand bar-cum-islands were formed for wells where the depth of water was between 5.00 m to 10.00 m. The wells on central island and on bank were on the dry beds, where the well curbs have been cast directly on the ground.

Formation of artificial sand islands

Artificial sand islands were formed by dumping sand at the proposed pier locations, where the cutting edge and curb concreting was done. Sand was brought to the well location site by means of country boats and it was also pumped to the location by deploying dredgers, which were of 25 m^3 per hour capacity. The size of the sand island was bigger than that required for the cutting edge. The extra space is utilised for keeping the plant and machinery which are required for well sinking.

Two rows of sand-filled gunny bags were dumped all around the periphery of the sand island with bamboo matting. Casuarina ballies of 125 mm diameter and 5 m height were driven at 600 mm intervals with a maximum depth of 2.00 m in the river bed and with a balance height of 3.0 m above bed level. The entire outside ring of casuarina ballies are tied with four wire ropes of 16mm diameter.

Sand-bar-cum-islands

The sand-bar-cum-island is formed in order to reduce the depth of water to 5.00 m for making further artificial island. Thereafter, the procedure for the formation of artificial island is followed. The sand bar is made with 3-m berm all around the artificial island. Two rows of casuarina ballies were driven from the rocker ballies provided at regular intervals.

Fabrication of cutting edges

Cutting edges were fabricated on the river bank with mild steel to the specification of IS:226 by welding. The cutting edges are of two types. They are :

1. cutting edge for ordinary type of well sinking

2. cutting edge for pneumatic well sinking.

In the case of cutting edges meant for pneumatic well-sinking, an extra plate is added on the inside portion of the curb known as 'skin plate'. This plate extends to the full height of the curb. The idea of providing the skin plate is that the concrete surface of the well should not get damaged due to mild blasting which is required to break the rocky strata coming underneath the cutting edge to facilitate the well sinking operation.

The approximate weight of the ordinary cutting edge is 17.068 tonnes and the cutting edge for pneumatic wells is 18.05 tonnes.

The cutting edges were fabricated in 7 pieces at river bank and were transported to the site on pantoons. The pieces were assembled in the shape of double "D" by welding the pieces together with splice plate at the points and keeping them in position of the alignment. The central line has been fixed with the help of a theodolite.

Placement of the cutting edge

Before keeping the cutting edge in its final position, wooden blocks were kept at regular intervals underneath the cutting

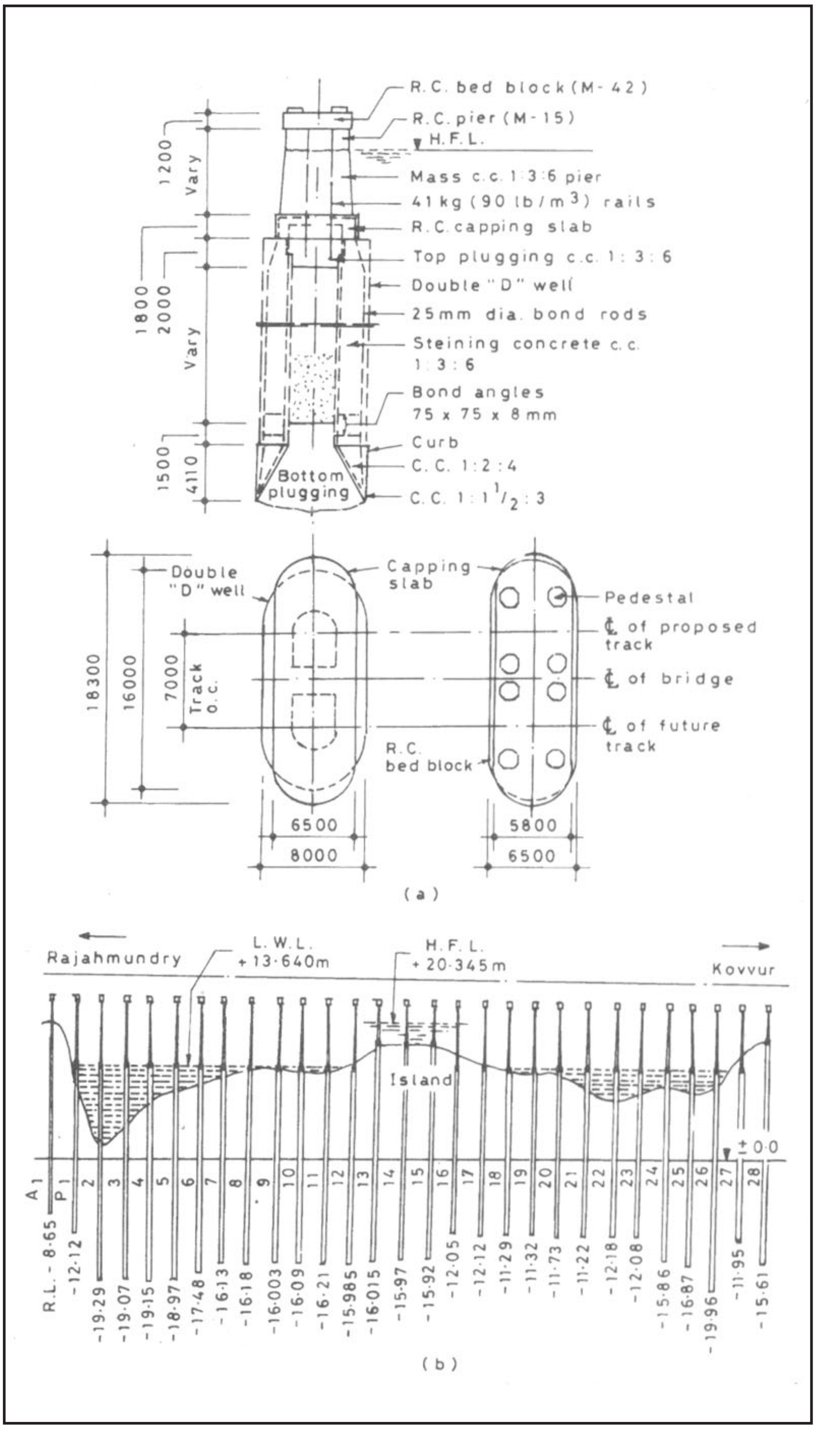

Figure 1. (a) A typical cross section of the pier showing well foundation and plan of pier cap (b) A longitudinal section showing foundation level for piers and abutments

edge and in between the wooden blocks, sand-filled gunny bags were kept. The idea of keeping the wooden blocks and the sand-filled gunny bags is to maintain a level base below the cutting edge and to correct the levels as and when required before and after assembling the full cutting edge in its true position. All the wooden blocks are serially numbered and they need to be removed before grounding of the curb. Any wooden block left over may cause tilt or shift of the well during grounding operations.

Casting of well curb

The reinforcement is fixed in position for the curb portion and the inside conical shutters are fixed and the curb concreting is done by pouring the concrete with the help of buckets attached to the crane. Concrete was poured uniformly all around the periphery of the curb to avoid tilt and shift during the process of curb concreting.

Mix proportion

Thickness of the curb is 2.30 m in the periphery and that of diaphragm wall is 2.00 m. First 1-m depth of curb concreting is done with M-20 grade and the balance 3.11-m height is of M-15 grade.

Concreting of curb is done continuously without any break. Total quantity of concrete involved in each curb is 203.52 m^3. and the weight of the 4.11-m deep curb is 530 tonnes.

Grounding of well curb

For grounding of the curb, workmen were sent into the dredge holes to remove the wooden blocks from both the dredge holes simultaneously and then the well curb was ground in the correct position. Tilt and shift, if any, can be rectified by scooping the earth wherever required during grounding of well curb.

Steining concreting

Thickness of the steining is 2.25 m and the thickness of the diaphragm is 2.00 m. Concrete used for steining is of M-10 grade. Reinforcement with bond rods, both in the inner and outer periphery along with the bond angles, are shown in Figure 1.

Steel shutters have been used both for steining as well as curb concreting with a view to maintain true shape of the wells. Suitable inner star bracing and bracing between the inner and outer walls have been provided. Shuttering for each stage has been fixed with a minimum overlapping length of 150 mm with the previously completed stage of steining and the fixing of the shuttering has been checked with a straight edge. Shuttering for the well steining has been carefully fixed to avoid crooked well and to get a true shape on completing the concreting.

Four gauges in the metric units were paint marked on the faces of the well steining out of which two on the face along the alignment and the other two on the circular portion of the wells on the central line of the well perpendicular to the alignment. These gauges indicated the height of the well completed at any given time. All these gauges started from the cutting edge.

Extension of bond rods for well steining including the well curb has been done by using bottle nuts made of mild steel. These nuts have 25 mm inner diameter and 45 mm to 50 mm outer diameter and a length of 150 mm.

The steining concreting has been carried out with the help of buckets connected to the cranes. About 1.8 m height of steining is concreted in each lift.

Sinking of well

Sinking of the wells was mostly carried out by means of grabbing earth with the grabs of 0.50 m^3 capacity attached to the cranes which are either stationary, mobile on track or mounted on the floating barges of 40 tonnes capacity.

The hard strata was made loose by dropping heavy weight chisels of 8.5 tonnes capacity fixed to the cranes and then the soil was grabbed to sink the well further.

Wells planned for pneumatic sinking where soft sand stone strata was expected at deeper levels were sunk by dewatering process and succeeded in sinking all these wells. One or two number of 25 to 40 HP submersible pumps were installed in each dredge hole depending upon the situation, for dewatering the wells and to sink them further. Dewatering was continued to keep the wells in dry condition and in such situation, workmen were sent inside the dredge holes for excavation of the soil inside the dredge holes. By adopting this method, pneumatic sinking was avoided.

The sinking of well no. 1 was difficult, in that the cutting edge partly rested on a slope of soft sand stone strata on Rajahmundry side and on the artificially made sand island on Kovvur side and also on the up and down stream sides, with a difference of about 2 m in the bed level in a width of about 8 metres, that is, equal to the width of the well across the waterway. If proper care was not taken, there was every possibility for this well to tilt and shift. Sinking of the well no.1 was tried with divers to take the cutting edge on a level ground. Helmet divers were sent inside the well to work on Rajahmundry side periphery of the wells and to cut the sand stone strata with the help of pneumatic drills inside the water. In this process, the well was taken to the level base for its further sinking.

Caisson for pier no. 2

Bed level at the location of pier no. 2 is (-) 1.58 m and the depth of water is about 16.00 m even during summer. Formation of sand-bar-cum-island is restricted only where the depth of water is not exceeding 10.00 m and also due to the inflow of the ground water in the river. Further, the water flow has certain velocity at this location and hence the well could not be sunk by sand-bar-cum island method.

For the caisson, the portion covering the curb and some length of the steining of the well both inside and outside is made up of mild steel plates, suitably strengthened by mild steel angles as stiffeners all along inside and further strutted to keep the shape and distance between the outer and inner layers correctly.

The curb of the caisson was fabricated on the bank of the river on Rajahmundry side as a single unit, using about 70 tonnes steel and the same was pulled into the river from the bank to water edge through a sloping path way, made with wooden sleepers and rails fixed over the slope. Then it was slowly made to slid over the rails and tagged into the river by using 2 motor launches of 35 HP capacity each, with the curb of the caisson being controlled by means of four winches from the bank side, rear of the caisson to avoid slippage or tilting during the process of sliding over the rails into the river.

In this process, the caisson was taken into the river and the curb portion was kept in floating condition. Curb of the caisson along with the sinking set was taken to pier no. 2 location with the help of two motor launches, each of 35 HP capacity and anchored by means of wire ropes of 25 mm diameter to the precast concrete blocks each weighing about 8.00 tonnes, kept in the river about 100 m away from the caisson location on the up-stream side. On the down-stream side, sinking set was tied by means of 25 mm wire rope around pier no. 4.

Each stake made into 7 pieces with height ranging from 1.1 m to 1.2 m were made on the bank on Rajahmundry side and taken to pier no. 2 location and added to the caisson curb. In all 9 stakes were added by welding, and caisson was made to its full height of 17.725m. Finally when the caisson touched the bed level, about 4.175m height of caisson was available above water level.

While adding stakes to the caisson, concreting in the curb portion was done with M-10 grade of concrete and the whole assembly was sunk in the water to the predetermined depth, leaving sufficient height above water level. This process of adding stakes was continued till the caisson touched the river bed. Since caisson is made with heavy structural steel, no bond rods were used upto 1.2 m from the top of the caisson.

M.S. bond rods of 25 mm were used from 1.2 m depth from the top portion of the caisson for the grip criteria. Normal concreting was done for the balance portion of the well.

Grounding of the caisson

Temporary live load was kept on the made-up platform on the top of caisson to ground the same. Alignment points were given with the help of two T-2 theodolites at the time of grounding, out of which one was fixed in the alignment of the new bridge and the other was fixed on pier no. 4 of the first railway bridge opposite to P-2 location of the 3rd bridge. Triangular points were given from P-3, P-5 of the first bridge to check any triangular error for grounding the caisson.

The caisson was grounded with due care and the balance concreting was continued after ensuring that the caisson pierced into the bed to a depth of 0.5 m. Then the live load was removed. The sinking set holding the caisson was removed at this stage. Further concreting and sinking was carried out as per the normal procedure.

Bottom plugging

The wells were taken to the predetermined level and the regular soundings were taken in both the dredge holes of the wells for creating a positive sump having diameter of about lm. Mild charging of the well was done by geletine, keeping about one metre above the cutting edge RL in the water in both the dredges holes after obtaining the positive sump with a view to release any locked up frictional resistance on the outer periphery of the well.

Concreting of bottom plug with M-10 grade with 10 percent extra cement was carried out by means of skip box of one cubic meter capacity which can discharge concrete at its base only as per IS 3955-1967. The skip box was attached to the crane and lowered into the dredge hole.

The bottom plugging operation is a continuous process and the concreting was done in equal quantity in both the dredge holes to ensure equal distribution of concrete in both the dredge holes. This was ensured by taking soundings at regular intervals.

Sand filling

Sand filling of the dredge holes was carried out after 48 hours of completion of concreting of bottom plug to ensure that the minute floating cement particles settle down on the top of the bottom plug concrete, since the floating particles travel with low velocity to reach the top of bottom plug level and deposit there.

Sand filling of the dredge holes was carried out either manually from the sand loaded in country boats or by pumping sand into the dredge holes with the help of dredgers. Care was taken to use approved quality of sand while filling the dredge holes.

Pumping of water into the dredge holes was carried out whenever the dredge holes dried during the process of sand filling with a view to get natural consolidation of the sand filled in the dredge holes. This problem did not arise where the sand filling was done with dredgers.

An extra height of 0.5 m sand filling was done in the dredge holes. As the silt, clay or floating debris normally accumulate on the top layers of the dredge hole during the process of sand filling the same was removed.

Top plugging

About one meter off-set in the inner side of the dredge hole on the top portion of the well was provided to accommodate about 2 in deep top plug concrete with M-10 grade.

After completion of 0.5 m deep concreting in the top plug portion bond rails were embedded at the rate of 9 rails of 90 "R" / 52 kg in each dredge hole and these rails were taken right upto the bottom of the bed block level. These rails were joined with fish plates and nuts. The idea of providing these rails is to arrest shearing of the piers due to heavy water current during high floods in the river.

Well cap

RC well cap were cast with M-15 grade of concrete. The locational details of the well cap are shown in the Figure 1.

Pier concreting

The piers of the third Godavari Bridge are of M-10 grade concrete upto 4.755 m height and balance 1.475 m height, concreting has been carried with M-15 grade. Peripheral reinforcement with 10 and 12 mm HYSD bars all around the pier has been provided. This reinforcement has been provided to cater for any thermal stresses.

Pier cap

RC pier cap, 1.2 m deep with M-42 grade of concrete was constructed to accommodate bow string arch prestressed concrete girder superstructure of 94.00 in effective span.

Method of concreting

Concreting of curb, steining, bottom plug, top plug, capping slab, pier and pier cap was carried out by the following methods or combinations thereof :

1. Feeding the raw materials into $1m^3$ capacity concrete mixer manually, conveying the mix by head loads and pouring.

2. Feeding the raw materials into concrete mixer manually, unloading the mix into bucket attached to the crane and pouring.

3. Mixing the concrete in mixers which were mounted on barges by feeding the fine and coarse aggregates, sand, and cement from the floating barges, mixing at the pier location itself and placing the mix with the help of bucket-operated by floating crane.

4. Mixing the raw materials in the concrete batching plant and mix filled in the bucket, transporting the bucket in the truck on the service roads available to the location required, and attaching to crane and finally pouring.

5. Mixing raw materials in the batching plant and filling the mix in the bucket kept on the pantoons and taking the pantoons to the required location in the river with launches, and thereafter attaching to the floating crane for pouring the concrete.

Savings

Pneumatic sinking of wells in soft sand strata with air lock equipment was contemplated originally. But sinking of the wells in soft sand stone strata was carried out by dewatering, chiselling and pneumatic drilling process by using divers. As a result, there is a saving to the extent of Rs 82.00 lakhs in the cost of execution of the work.

Apart from the savings in the cost, considerable time was saved in the execution of the well sinking. The rate of progress of well sinking with air-lock equipment is very low, to the extent of about 25 mm to 75 mm per day as was observed during the construction of second Godavari Bridge which is about 1050 m on the down-stream side of the third Railway Bridge. In contrast, the rate of well sinking on the third Godavari Bridge site was much faster.

Conclusion

The substructure work involved sinking of wells under varying conditions of water depth, soil strata etc. The sinking of well for pier no. 2 was done by pneumatic cassion method and use of air-lock was thus avoided. This way the work could be done in a safer and cheaper manner.

B. Deva Singh, Sr. Divisional Engineer (Co-ord.),
South Central Railway, Vijayawada.
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