UNIQUE FEATURES OF FOUNDATION NOS.17 & 18 - JOGIGHOPA BRIDGE

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SUMMARY

The river Brahmaputra is one of the mightiest water courses in India. Bridging the river has always been a great challenge to Engineers. Apart from variable river course with frequent changes, the construction working season is very short, about six months in a year. The 2.30 Km. long rail-cum-road bridge is situated at Jogighopa, 150 Km. downstream of Guwahati. The bridge has 17 spans of 125m + 1 span of 94.6m and 2 shore spans of 32.6m each. The superstructure consists of 18.5m deep open web steel girders with the roadway on the upper deck and railway line through the lower deck. Double `D' caissons have been adopted for all except two foundations on uneven sloping rock and as such, special consideration was given in the design and construction of foundation Nos. 17 and 18.

Detailed soil investigations indicated that barring foundations 17 and 18, the caissons could be founded on compact sand at a depth of about 75m below the HFL. At locations 17 & 18 investigations revealed presence of rock strata at various depths. As per the original configuration of 125m spans, foundation Nos. 16 to 19 would have been affected by the rock profile. The rock level was close to maximum scour level and as such, caissons with no grip during maximum scour were unsafe.

2 x 260m cable-stay spans were earlier considered in order to reduce the number of foundations in rock. On detailed techno economic analysis, this was not found attractive. It was decided to provide 18m diameter RC caissons with central vertical diaphragm. The spans were readjusted to ensure that only two foundations are thus affected. The paper describes the special features of these foundations which includes solutions adopted for the first time anywhere in the world.

CHOICE OF SOLUTION

At locations 17 and 18, the rock at founding level was steeply inclined. The following options were considered : (a) piles enclosed in sheet pile cofferdam, (b) piles with diaphragm wall, (c) caissons with rock anchors, (d) caissons with piles and (e) caissons protected by boulder apron. A high level technical advisory group, after deliberations advised Option(d). The 18m diameter caissons were anchored into the rock with 12 Nos. of 1500mm dia RC piles through the steining (Fig.1). At the base, the critical load combination consists of (a) Vertical loads : 21438 t ; (b) Base moment : 223183 tm., and (c) Horizontal base shear : 4865 t. About 76% of the base area is under tension. The maximum pile capacity under tension is about 1450 tonnes.

Prefabricated annular steel caisson fabricated on shore was floated to the location and grounded by concrete filling. The steining was progressively built in 2.5m lifts. A 60 cu.m. capacity floating batching plant in conjunction with concrete pump and placer boom was used for concreting. The sinking was done by open grabbing with a 75 t floating crane.

CONSTRUCTION OF ANCHOR PILES (Fig. 2)

Casings - For anchor piles, 1.65m dia. holes were provided in the steining during construction. (Fig. 3). Sets of 10mm thick casings were fabricated in the yard and assembled in 10m long modules. The first module was lowered in the pile opening using a crane and temporarily supported at the top. Successive modules were erected, joints welded and lowered progressively till entire length of 50m weighing about 25t. was assembled. Thereafter, it was driven close to the rock surface by use of swing head oscillator and air lift.

Drilling - Wirth Reverse Circulation Rig was used to drill through the rock below the base of the caisson (Fig.4). The drill string consisting of a 13m long bottom stiff assembly weighing 15t was lowered and thereafter 3m long drill pipes were lowered alongwith stabilizers at 9m intervals through the clamping and lowering/lifting arrangements in the rig. The average rate of drilling was about 50 cm/hr in weathered rock and 20 cm in hard rock. A positive head of 2m - 3m was maintained in the borehole during drilling to preclude any possibility of sand ingress from outside.

Rock is cut by rotary motion of the drill under the down-crowd varying from 50 - 120 bars. The rig is fitted with a low speed high torque hydraulic motor (Fig.5), and Tungsten carbide button cutters. The pulversied rock is airlifted through the 200mm drill pipe and a hydraulic power pack. Compressed air is fed to the bottom of the drill assembly through twin 40mm ID steel pipes fitted on opposite sides of the main drill pipe.

Reinforcement and Concreting - The 60m reinforcement cage was lowered in 7 modules (total weight 25t) and anchored into the well cap at top. The second cage segment was wrapped by 5mm thick liner as permanent formwork from rock level to the bottom of steining. A flapper arrangement was provided at the top of the liner, which opens out under the pressure of fresh concrete and close the annular gap between the reinforcement cage and the parent 1650mm diameter casing to prevent leakage of concrete through the gap. The temporary casing was then retracted with the help of hydraulic jacks and cranes. 125 cu.m. of 30 MPa grade concrete per pile with 40mm rounded aggregates and 180mm slump was pumped through 200mm dia. tremie.

JET GROUTING - SOILCRETE

The Process - Due to steep rock profile, the caisson could not be advanced to the rock level and seated evenly on rock. Attempts to excavate the caisson to full depth and to clean the rock surface failed because of the inflow of sand through the gap between the cutting edge and the rock. This was closed by installing soilcrete columns by jet grouting. The soil is eroded by a high energy jet. The eroded soil and the injected cement water grout is mixed insitu to form solid mass columns, 1.3m dia., spaced at one metre centre, into a secant profile. There are 121 columns consisting of two rings, installed from rock level to approx. 2m above the cutting edge.

Bore holes for jet grouting were drilled from working platforms on steining top. A high pressure pump was used to flush during drilling with a cement water grout (W/C 1.0). On reaching the rock level, the drill bit is shifted to jetting mode and the soilcrete process is started. The drill rods rotate at a constant speed which is determined by nature of the soil. The rods are gradually withdrawn at a steady rate. The rotating grout jet erodes a cylindrical soil mass which is mixed with the grout itself. Surplus material rises along the drill rods to the surface and is discharged into the river.

Quality Control - Prior to the actual jet grouting operations trials on the river bank were undertaken by constructing soilcrete columns in shallow depths to freeze operational and quality control parameters. The trials indicated that column diameters of 1.2 - 1.5 m could be achieved and the following operational parameters were fixed (Table 1) :

TABLE 1

Parameter	Drilling	Jetting
Benotonite pumping pressure	8 - 20 bars	-
Air pressure	2.5 - 4.5 bars	6 hours
Grout pressure	-	360 - 380 bars
Drill rod rotation	50 rpm	12 rpm
Retraction	-	25 cm/min.

The following data was observed and recorded during actual construction :

- grout and air pressure during jetting
- grout consumption during drilling and jetting
- rotation and withdrawal speeds of drilling rods during jetting
- final penetration depth and top elevation of column
- specific gravity of grout/mortar when returned from borehole. This value gives an indication of the column diameter.

Due to the large depth, drilling accuracy was a crucial parameter. Drilling rig was carefully set up over the location determined by accurate survey, taking into account the actual tilt of the caisson. Drilling was done in a controlled manner. On reaching the final depth, the exact location was surveyed using a special inclinometer. At few locations, where deviation was excessive, the boreholes were abandoned and redrilling was done. After the survey, the jetting was taken up. The drilling and survey operations required about one hour, before starting jet grouting. This was too long a period to keep drill rods in cement slurry and as such bentonite slurry was preferred.

BOTTOM PLUGGING

(a) Sink the caisson upto 1m above rock.
(b) Stabilize the soil around well kerb by soilcrete columns.
(c) Remove the sand in the dredge hole by grabbing and air lifting and clean the entire area below the well kerb.
(d) Construct the bottom plug, and lay a RC slab on top of the plug after complete dewatering of the dredge hole.

EXTERNAL ANCHOR PILES

In the original design, it was assumed that the bottom plug of the caisson will have 100% contact with the rock. Any local cavity was to be grouted from the top. During the bottom plugging at location 17, it was observed that either due to high flood level or some crevices in the rock, fine silt was deposited at the rock - plug interface just before or during the concreting. It was decided to construct 8 Nos. of 1.5 m diameter external piles integrated with the well cap at top. These external piles were taken up as parallel activity during erection of deck and anchored into hard rock for 5m.

The well cap was constructed in two stages. During the first stage part of the cap having the same diameter of the well was constructed with the reinforcement projecting out. The extended cantilever well cap/pile cap was constructed in the second stage keeping 1.8m dia, hole for the pile.

In the soil above the rock level, boring was done by using oscillatory hydraulic piling rig (Casagrande) with custom built 7.5m long casings. As the casings were progressively lowered, additional casings were installed and the joints welded. Thereafter the Wirth piling rig with drill bit, 1300mm diameter was used for boring 5m in rock. Reinforcement cage of total length of 48 m was lowered progressively in five segments, welded insitu. The concreting was done by using automated batching plant, placer boom and concrete pump placed on a floating pontoon. The piles were integrated with the top of pile/well cap by a suitable anchor system. To improve the stiffness, a tie beam was provided at low water level.

CONCLUSION AND CREDITS

Completion of wells 17 and 18 required adaptation of innovative techniques for overcoming complex problems encountered under very difficult working conditions. The use of jet grouting technique for tackling foundation problems was successfully attempted at such great depth in the river bed probably for the first time in the world. The bridge owned by the Indian Railways and constructed by Gammon India Limited, has been commissioned in May 1998.

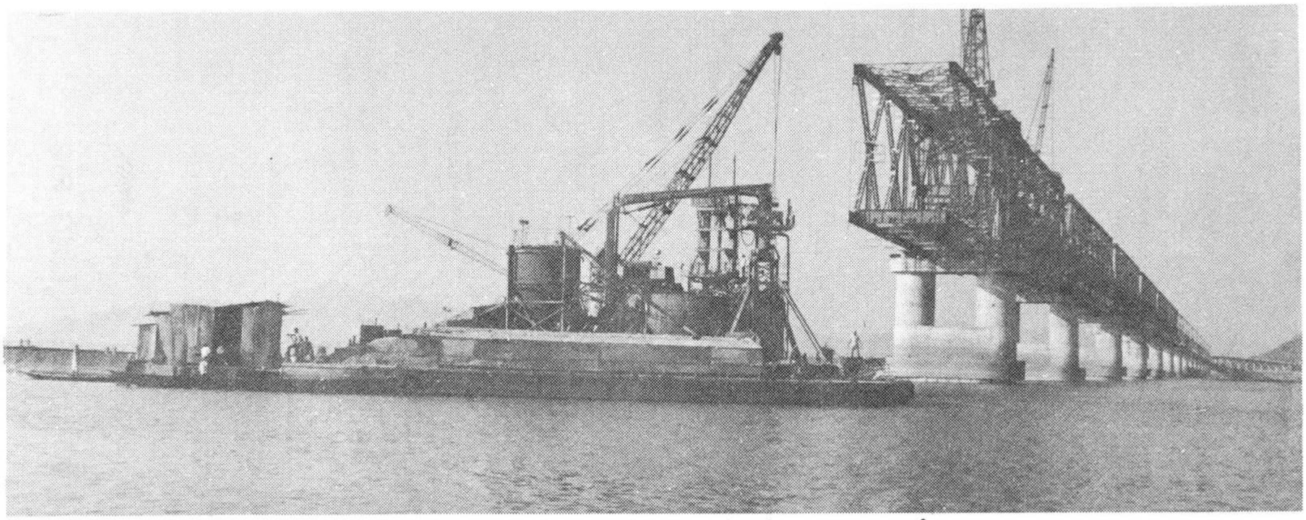

Fig.1 : Wirth Piling Rig in operation

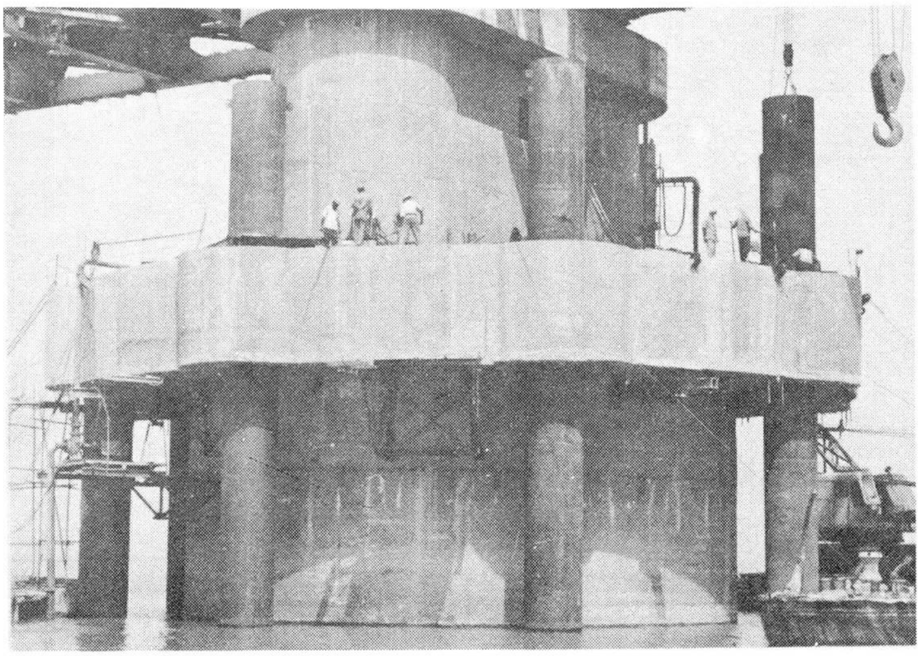

Fig.2 : External Piles

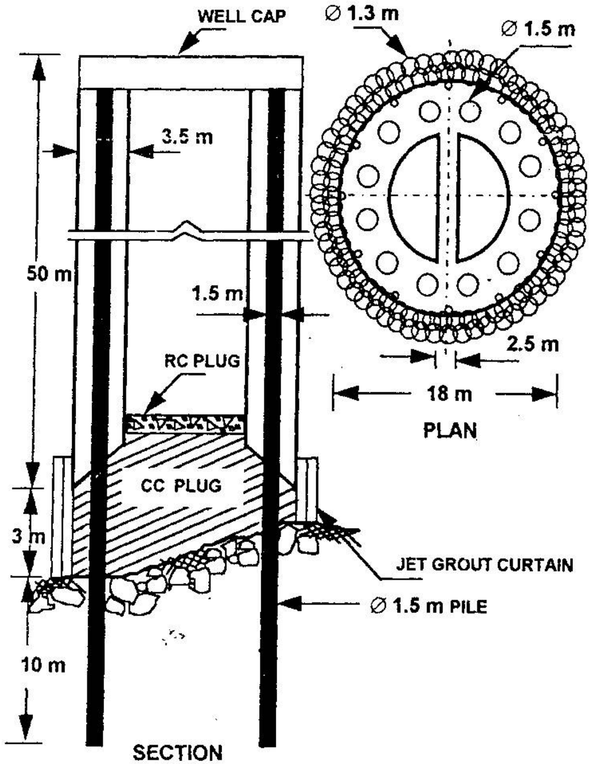

FIG. 3 JOGIGHOPA BRIDGE FOUNDATIONS 17, 18

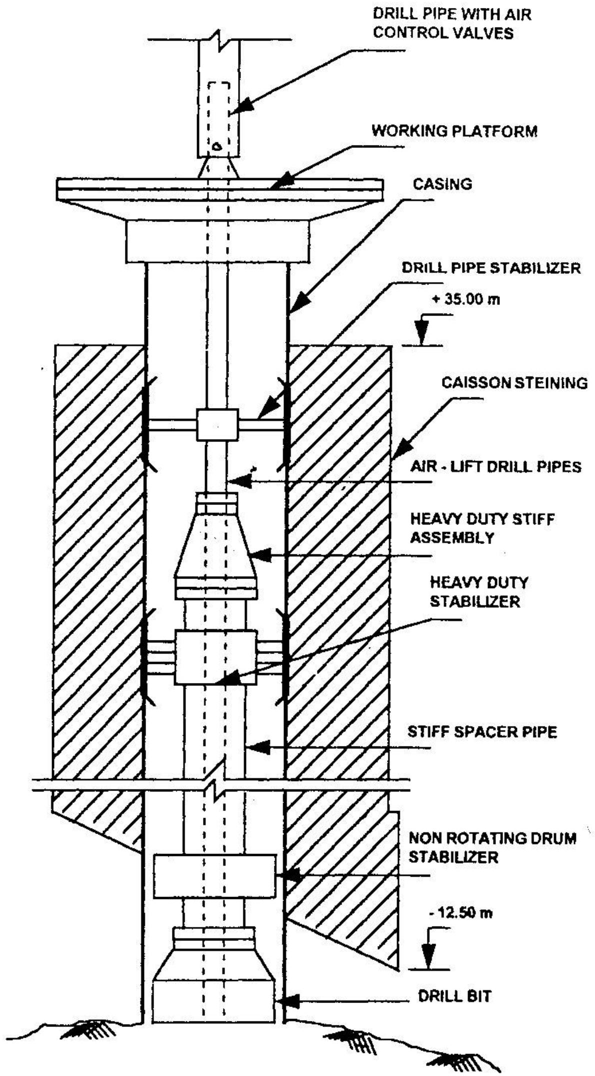

FIG. 4 WIRTH DRILLING RIG

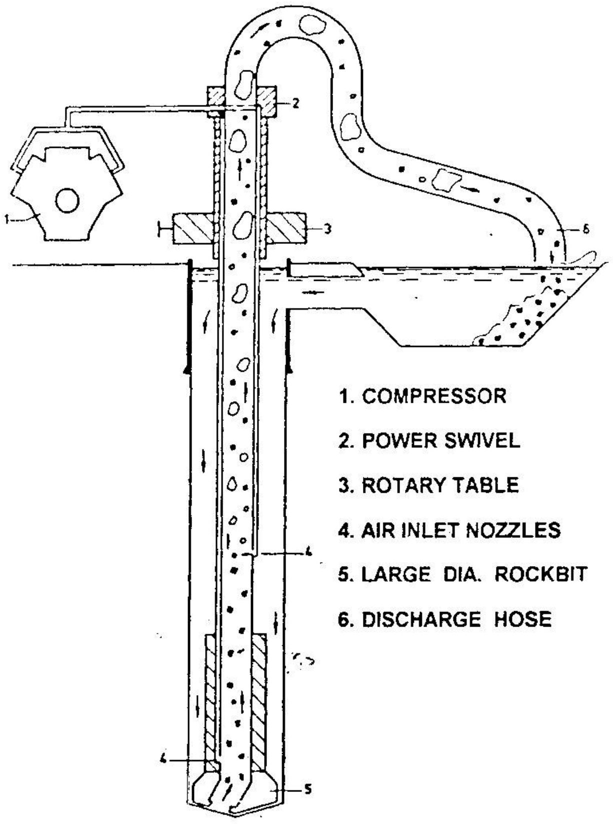

FIG. 5 AIRLIFTING MUCK