FOUNDATIONS FOR THATTA SUJAWAL ROAD BRIDGE

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1. INTRODUCTION

1. 1. A road bridge is being constructed across river Indus about 7 miles from Thatta. It is a very important bridge in many ways. In fact it is the first road bridge on the river Indus. When completed, it will open up the area irrigated by Ghulam Muhammad Barrage Project especially on the left bank Pinyari and Guni systems and will provide the shortest link with the main market *viz.* Karachi for the surplus produce of this area. The entire project is likely to cost Rs. 400 lacs, out of which the cost of the bridge structure is estimated at Rs. 155 lacs.

1. 2. It is designed to pass a peak discharge of 11 lacs cusecs in the river. The length of the bridge between abutments is 3,220 ft. There are 13 spans in all. The length of the 2 end spans is 171′—9″ each whereas each of the remaining 11 spans is 261′—6″ long. The main supports for the decking consist of tapering sections cantilevered out 92′—6″ on either side of the central line of the piers and the articulated units are 76′—6″, all in a 4-beam complex. The girders and decking of the 13 spans are carried on cellular concrete piers resting on well foundations. The substructure is in reinforced cement concrete while the superstructure is in prestressed concrete. The clear width of the roadway is 24′ with 4′ wide side walks on either side.

1. 3. The scope of this paper is limited to the method of construction of wells for foundations, their sinking, problems encountered during execution of work and the methods adopted to overcome these problems.

2. FOUNDATION STRUCTURE

2. 1. Each pier is carried on a single circular well with an internal diameter of 20 ft. The bottom of the pier wells is kept at 140′ below mean sea level and the top of the transom is 19 ft. above mean sea level. Each of the abutments is founded on 2 single wells with their bottom at 107 ft. below mean sea level and the top of the transom at 27 ft. above the mean sea level. The cutting edge consists of an 8″ X 5/8″ M.S. flat welded to a 4″ × 4″ × $\frac{1}{2}$″ M.S. angle over which the curb is laid. The reinforced cement concrete curb is 6 ft. in height and has a width of 6″ at the bottom and 3$\frac{1}{2}$ ft. at the top. The well steining over the curb is 3 ft. thick up to 59 ft. above the mean sea level above which level the thickness is reduced to 2½ ft. The steining is built of 3,000 p.s.i. concrete with main reinforcing bars of medium high tensile steel. The transom slab 4 ft. thick in reinforced cement concrete is ovalled out by 2 ft. transversally on either side of the well.

2. 2. The maximum scour calculated for the pier wells is up to 69 ft. below the mean sea level thus giving a permanent embedment of 71 ft. below the maximum scour to cater for the large moments due to long cantilevers and other factors. The wells are plugged at the bottom with 12 ft. thick colcrete, then sand-filled up to R. L. minus 69 over which a 3 ft. thick concrete slab is laid. Above this slab there is water in the well. A typical bore-log giving the nature of the substrata (fig. 1) and a drawing giving details of the well, the transom slab, the curb and the cutting edge (fig. 2) are enclosed.

3. CONSTRUCTION METHOD

3. 1. The well curbs were laid in two working seasons. During the first working season the river channel was on the left but during the next working season it shifted to the right thus making it possible to have dry bed for laying the curbs. This was most fortunate. However, in some cases sand islands had to be made to place the cutting edge and concrete the curb. Steining was not built until the curb was sunk.

3. 2. Formwork used for concreting well steining is the sliding type which is different from the conventional jumping type formwork. This sliding formwork has been rarely used in this country, particularly for such thickness of well steining. It consists of two concentric circular shutters kept apart by 12 equally spaced and suitably stiffened yokes. The height of the shutters is 3½ ft. After the formwork is mounted on the curb, a working platform is constructed inside to cover the well. This platform moves with the formwork. One screw jack is fitted with each yoke. The screw jacks move on a 1″ diameter M.S. rod which remains embedded in concrete. The operation of jacks is manual. One turn of a jack lifts the formwork by 1/2″. A drawing of the formwork along with a photograph is attached (see figs. 3 & 4).

3. 3. This formwork was used with great advantage inasmuch as the concreting was not interrupted for dismantling and re-erecting the formwork. This is not possible with jumping formwork. In one single operation, 25′ height of steining was concreted and even this limit was not imposed by the formwork but was due to other considerations. The formwork once fixed was not removed except for change of section of the steining. Only internal working platform was removed for sinking and refixed for further concreting in a matter of hours. Thus the time consumed in concreting a well by this method was about 20 days which is far too less than that required with conven-

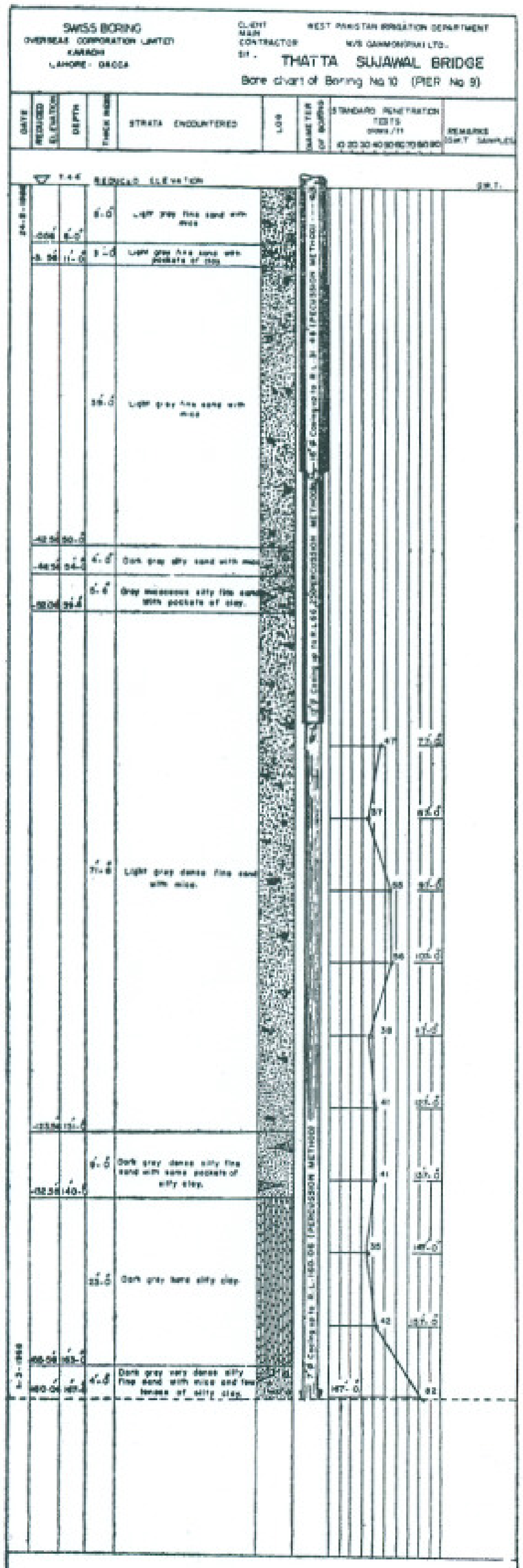

SWISS BORING
OVERSEAS CORPORATION LIMITED
KARACHI
LAHORE - DACCA
CLIENT WEST PAKISTAN IRRIGATION DEPARTMENT
MAIN CONTRACTOR M/S GAMMON(PAK) LTD.
THATTA SUJAWAL BRIDGE
Bore chart of Boring No 10 (PIER No 9)
DATE
REDUCED ELEVATION
DEPTH
THICKNESS
STRATA ENCOUNTERED
LOG
DIAMETER OF BORING
STANDARD PENETRATION TESTS
10 20 30 40 50 60 70 80 90
REMARKS
REDUCED ELEVATION
Light gray fine sand with mica
Light gray fine sand with pockets of clay
Light gray fine sand with mica
Dark gray silty sand with mica
Gray micaceous silty fine sand with pockets of clay
Light gray dense fine sand with mica
Dark gray dense silty fine sand with some pockets of silty clay
Dark gray hard silty clay
Dark gray very dense silty fine sand with mica and few lenses of silty clay
DATE 17-8-68
PLAN No

Fig. 1

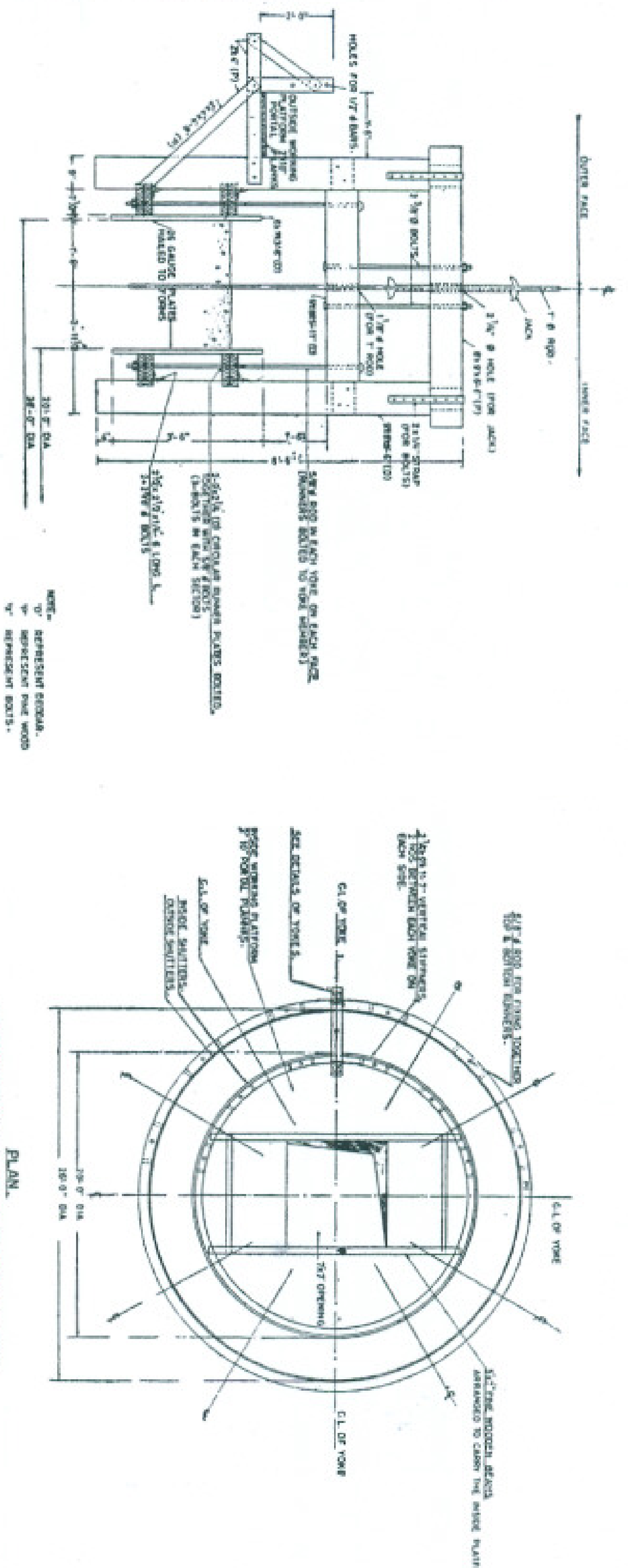

DETAILS OF YOKES
OUTER FACE
INNER FACE
JACK
HOLES FOR 1/2" φ BARS
NOTE
PLAN
(SHOWING ARRANGEMENT OF 12-NOS YOKES & RUNNERS)
SEE DETAILS OF YOKES
C.L. OF YOKE
INSIDE SHUTTERS
OUTSIDE SHUTTERS
7'-7" OPENING

Fig. 2

tional formwork. It is obvious that because the jacks were operated manually the labourers had to be trained to get uniform synchronized action. This only took a few days after which the operation was a treat to watch.

3. 4. Where the bed was dry, concreting was done with the help of cranes and bottom dump buckets. In other cases the plant such as mixer, weigh batcher etc. were carried on boats and concrete was placed in position by manual labour. Suitable concrete mix was designed beforehand and no effort was spared in the way of quality control.

3. 5. Analysis of some water samples at depths below R.L. minus 100 or so indicated the presence of sulphates but the percentage was such that use of sulphate resisting cement or other remedies was not necessary. Nevertheless, to play safe, cover to the reinforcing bars was increased to 8″.

4. SINKING OF WELLS

4. 1. Sinking was done by excavation from inside the well either by clam-shell bucket worked with the crane or by means of air-lift. Sinking through first 80 ft. or so did not present any major difficulties. In fact the rate of sinking over this depth was 1½′ to 2′ per hour. Below this depth, however, the rate of sinking slowed down considerably. Up to about 80 ft. or so the well would sink under its own weight, but at greater depths this was not possible on account of considerable frictional resistance. In such cases either the weight had to be increased to overcome friction, or the friction had to be reduced by other means. Actually the two methods used were:—

(*a*) creating difference in hydrostatic head, and
(*b*) increasing dead weight by kentledge.

Differential hydrostatic head was created by dewatering from inside the well. This reduces buoyancy and increases the weight of the well which helps in reducing friction and the well starts sinking. But this had to be done most carefully, sparingly and to a strictly limited extent of unwatering, because much differential hydrostatic head can cause blow-in which is not desirable. At times it was also found helpful to let a bucket-full of grabbed material fall freely inside the well from a height. This created shock vibration and enabled the well to sink. In the case of one well, which would not move because of a tree trunk under it, a mild charge of dynamite was exploded at the bottom. This well already had a kentledge of 700 tons. When the charge was exploded, the well shook and the cutting edge cut through the log of wood after which sinking was possible.

4. 2. As already stated, sinking was done either by means of grabbing with crane and clam-shell bucket or by air-lift. For shallow depths the crane is more efficient than the air-lift. The cranes used on this project were B.M. 43,

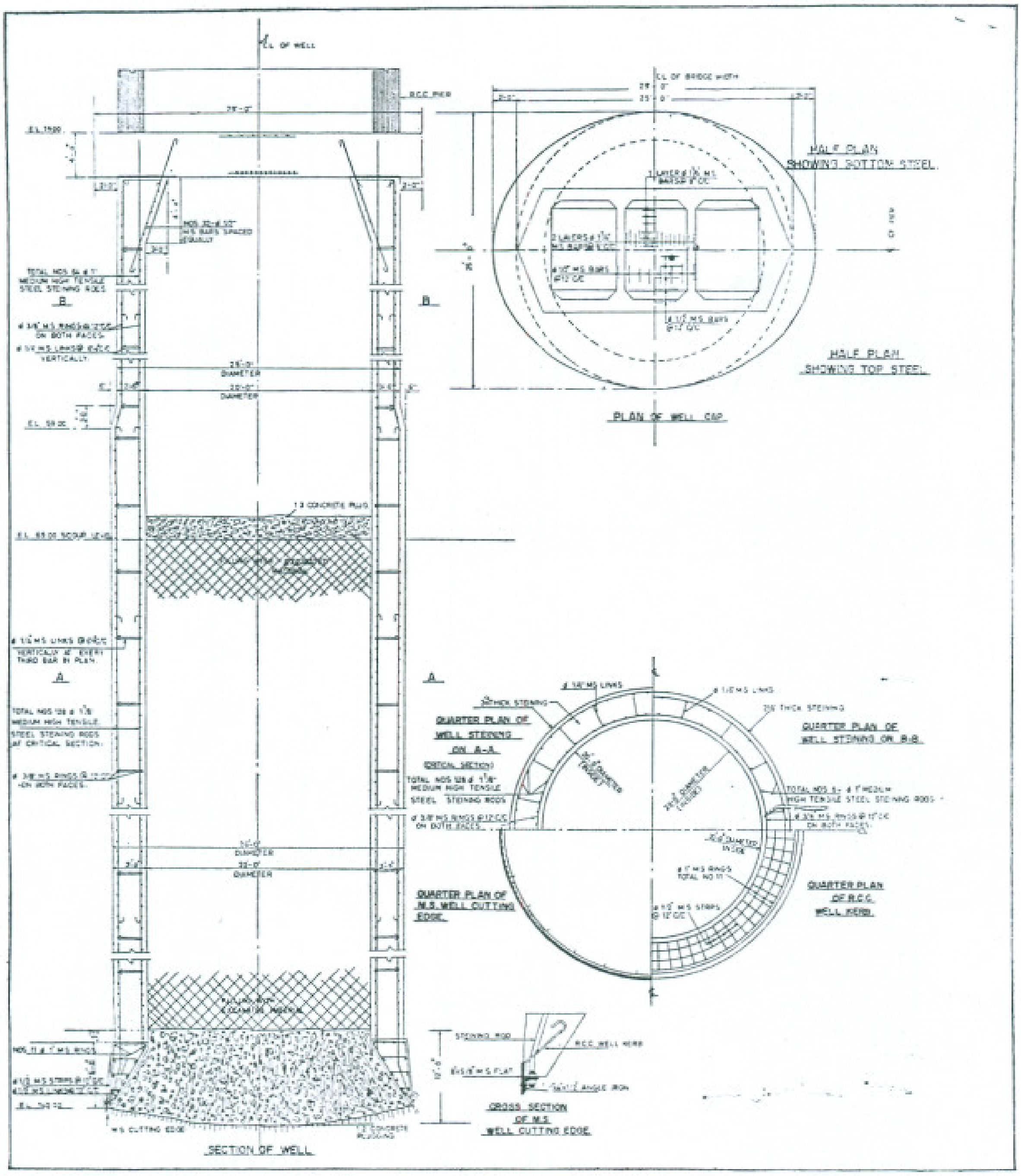
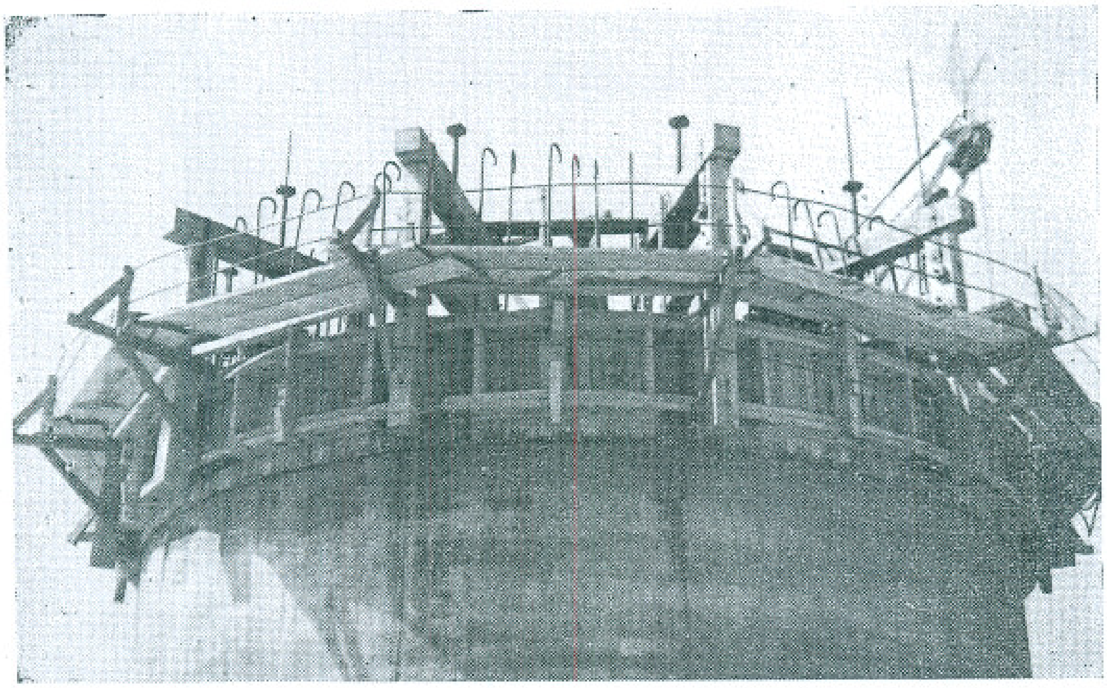

℄ OF WELL
R.C.C. PIER
E.L. 75.00
TOTAL NOS. 84 ø 1" MEDIUM HIGH TENSILE STEEL STEINING RODS
B
ø 3/8" M.S. RINGS @ 12" C/C ON BOTH FACES
ø 1/4" M.S. LINKS @ 6" C/C VERTICALLY
DIAMETER
E.L. 59.00
1:3 CONCRETE PLUG
E.L. 65.00 SCOUR LEVEL
ø 1/4" M.S. LINKS @ 6" C/C VERTICALLY AT EVERY THIRD BAR IN PLAN
A
TOTAL NOS. 128 ø 1 1/8" MEDIUM HIGH TENSILE STEEL STEINING RODS AT CRITICAL SECTION
ø 3/8" M.S. RINGS @ 12" C/C ON BOTH FACES
NOS. 11 ø 1" M.S. RINGS
M.S. CUTTING EDGE
1:3 CONCRETE PLUGGING
SECTION OF WELL
℄ OF BRIDGE WIDTH
HALF PLAN SHOWING BOTTOM STEEL
HALF PLAN SHOWING TOP STEEL
PLAN OF WELL CAP
ø 1/4" M.S. LINKS
QUARTER PLAN OF WELL STEINING ON A-A
(CRITICAL SECTION)
TOTAL NOS. 128 ø 1 1/8" MEDIUM HIGH TENSILE STEEL STEINING RODS
ø 3/8" M.S. RINGS @ 12" C/C ON BOTH FACES
QUARTER PLAN OF WELL STEINING ON B-B
TOTAL NOS. 84 ø 1" MEDIUM HIGH TENSILE STEEL STEINING RODS
ø 3/8" M.S. RINGS @ 12" C/C ON BOTH FACES
DIAMETER INSIDE
ø 1" M.S. RINGS TOTAL NO. 11
ø 1/2" M.S. STRIPS @ 12" C/C
QUARTER PLAN OF M.S. WELL CUTTING EDGE
QUARTER PLAN OF R.C.C. WELL KERB
STEINING ROD
R.C.C. WELL KERB
M.S. FLAT
ANGLE IRON
CROSS SECTION OF M.S. WELL CUTTING EDGE

Fig. 3



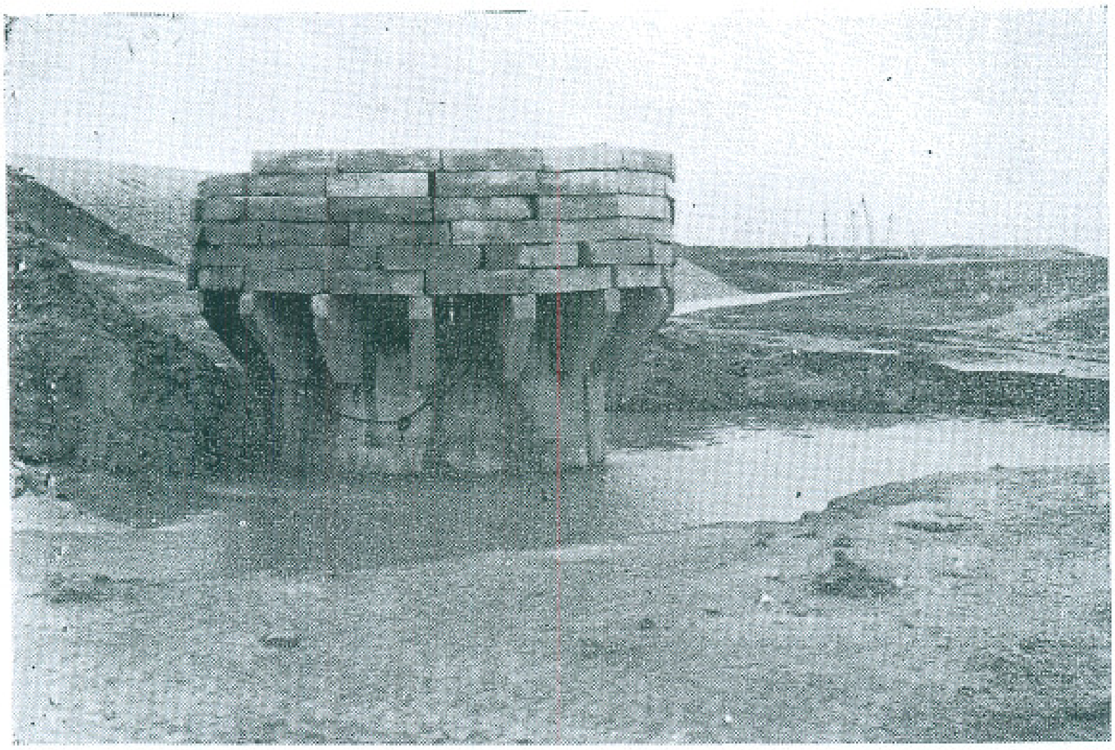


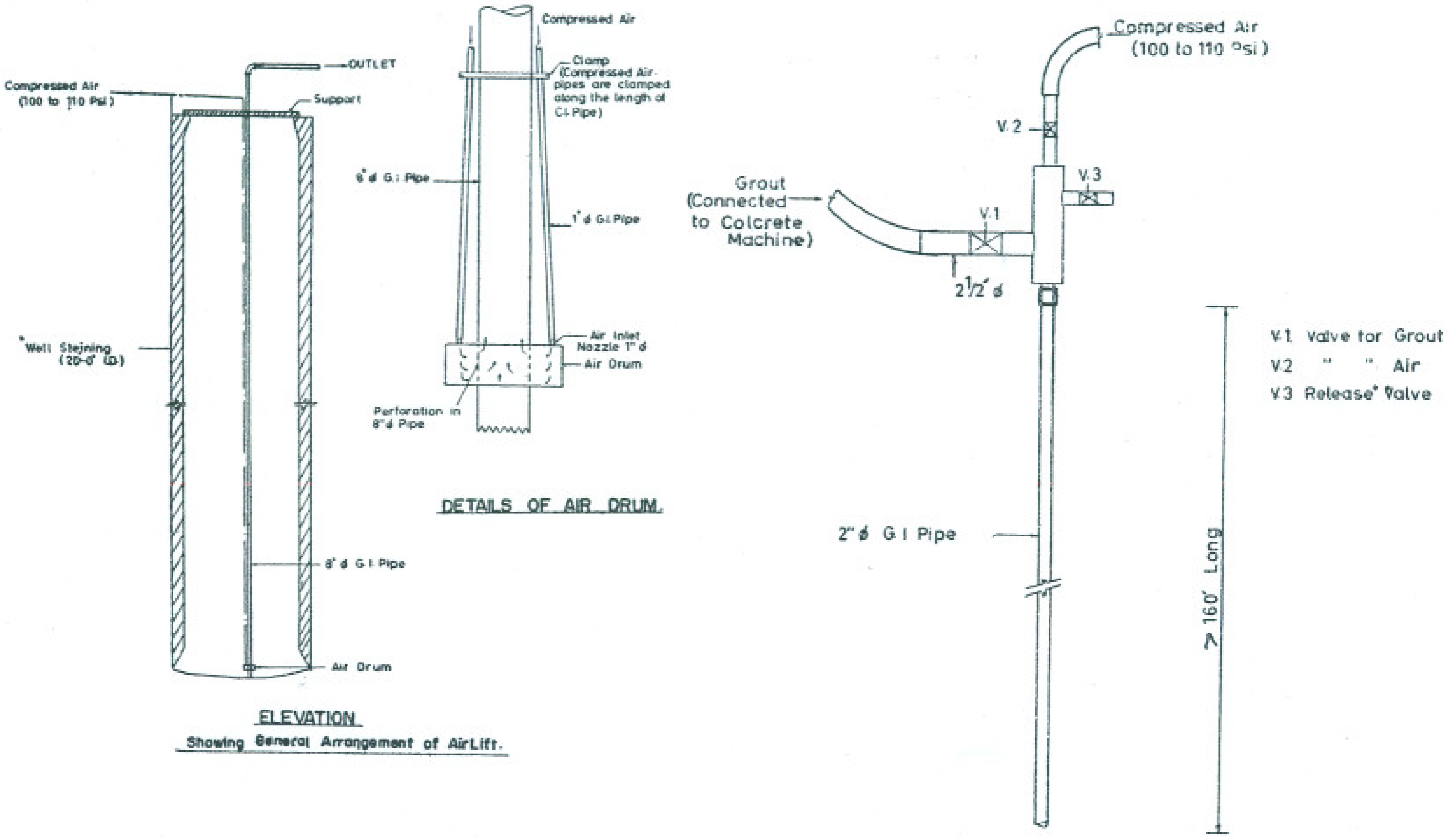
Fig. 4

M 47 and R.B. 38. There were, however, limitations to working by cranes which are as follows:—

- (*i*) Due to large depth and large diameter of the wells, large grab buckets were used for excavation. The usual size of 3/4 cu. yd. bucket would have been ineffective and uneconomical. The bucket actually used had a capacity of 1½ cu. yds. This bucket full of grabbed material weighed about 5 tons on account of which the boom of the crane had to be kept at an angle over 40 degrees with the horizontal. This limited the reach of the crane.
- (*ii*) During sinking the ground around the well caved in. Consequently the cranes which had limited reach could not work unless filling was done around the well. This was both expensive and time-consuming.
- (*iii*) The weight of the crane acted as surcharge on the soil which caused tilting of wells. The crane did not throw the excavated stuff very far from the well. This stuff unless rehandled and shifted away from the well, also caused the wells to tilt.
- (*iv*) The wells being very deep considerable difficulty was encountered due to spinning and unspinning of wire-ropes. Often the wire-ropes snapped and the buckets got trapped at the bottom of the well.
- (*v*) The wells which were started in the dry river bed before the floods, had water around them after the floods when the next working season started. This made the use of crawler cranes impossible.

4. 3. Excavation from inside the wells for sinking was found more practicable and economical with air-lift at depths below 80 ft. or so. It was found that with efficient working of the air-lift about 40 per cent of soil was pumped out with water. The air-lift equipment consisted of an 8″ diameter steel pipe with teeth at its lower end and a drum fitted near the bottom to receive compressed air. The length of the pipe inside the drum was perforated to allow air under pressure to get into the pipe. Compressed air was conveyed to the drum from air-compressor through two 1″ diameter G.I. pipes. This air rushed into the main pipe through the perforations thereby starting the process of air-lift pump and water gushed out with sand in suspension. For details of the air-lift see fig. 5. The air-lift pipe was moved around within the well to ensure uniform excavation. Some of the advantages of the use of air-lift experienced on this project are as under:—

- (*i*) This is the cheapest method of excavation as only a compressor to operate the air-lift and a pump to pump water into the well were required.



ELEVATION
Showing General Arrangement of AirLift.

DETAILS OF AIR DRUM.

Details of arrangement for
Grouting Sub-base.

Fig. 5

(*ii*) Air-lift was effectively used on wells surrounded by water. A large mounted crane in such cases would have had either insufficient water or its advantages would have been imbalanced by its exhorbitant cost.

(*iii*) With the use of the air-lift under strict supervision, excavation was carried out evenly which reduced the chances of tilt. It was also used effectively for removing tilts.

(*iv*) The use of air-lift eliminated or considerably reduced the chances of tilt because there was no heaping up of the excavated stuff close to the well.

4. 4. Some of the limitations to the use of air-lift noticed on this work are as follows:—

(*i*) Air-lift could not be used unless 2/3rd of its length was immersed in water. Constant pumping of water into the well was required to be done because the air-lift dewaters the well. If one is not careful, blow-in can take place.

(*ii*) It was very effective in pure loose sand. Its efficiency reduced with clay-like impurities in sand.

4. 5. The difficulties encountered during sinking of wells are as follows:—

(*i*) Caving-in of the ground around the outer periphery of the well was unavoidable. This caused quite a headache particularly when cranes were used and conditions were not favourable for the use of air-lift. Considerable time was lost in filling-in the caved area and making arrangements to resume sinking.

(*ii*) *Blow-in of soil.*—In spite of all the precautions such as ensuring uniform excavation inside the well, maintaining water level inside the well at least to the same level as that of water outside etc., blow-in did take place. When blow-in occurred it caused tilting. Sometimes it choked the air-lift pipes and trapped clam-shell buckets. One bucket was so badly trapped that it had to be abandoned under the well. Fortunately this occurred when the well had reached its final elevation.

(*iii*) *Obstructions due to buried tree trunks.*—During sinking, tree trunks were encountered under the cutting edge at various levels. This resulted not only in the stoppage of sinking but also in the tilting of wells. Interesting thing was that logs of semi-decomposed wood were encountered at elevations 120 to 130 feet below mean sea level.

5. KENTLEDGE

5. 1. After a well was sunk by about 80 ft. or so, further sinking became very slow on account of friction of the soil around the well steining. When sinking completely stopped, loading of the wells at the top had to be resorted to. The most common practice of loading the well is by means of rails and sand-filled gunny-bags. On this project, however, loading was done with specially made trapezoidal kentledge blocks of 1: 3: 6 cement concrete. With this shape of the blocks they could be well packed together and occupied as little space as practicable. These kentledge blocks were placed over kentledge beams made of R.C.C. The kentledge beams were so cast that the steining could be keyed into them when placed on top of the well. Hooks were provided in the beams and the blocks to facilitate lifting with crane (see figs. 6 and 7).

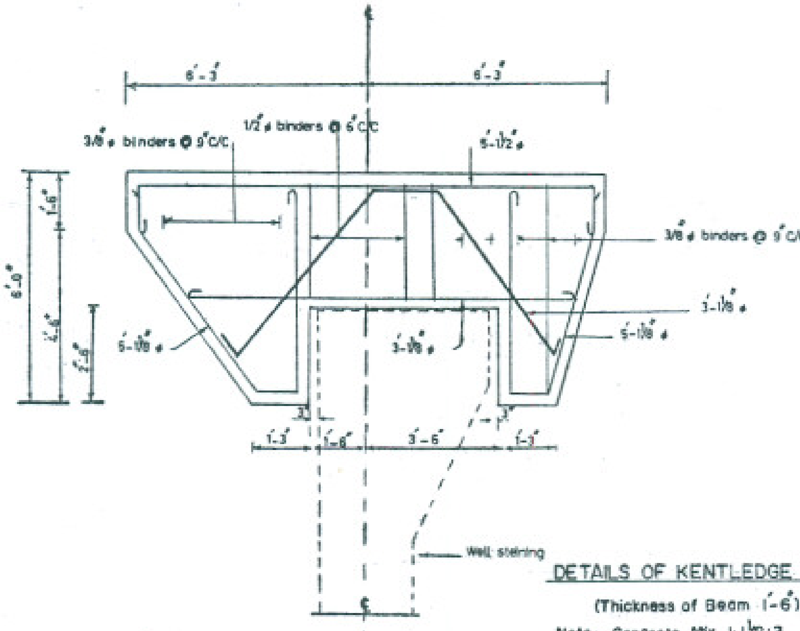


Fig. 6

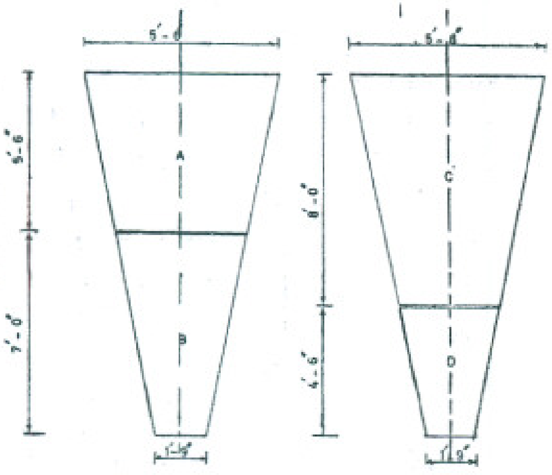


Fig. 7

5. 2. Loading by means of these kentledge blocks and kentledge beams was found most efficient and effective. The loading and unloading operations did not take much time as about 1000 tons could be placed and unloaded in about 3 days. Besides, they occupied minimum space leaving enough room for use of clam-shell bucket inside the well. On one particular well 900 tons of kentledge was placed and yet clear space of 15 ft. in diameter was available for excavation operations inside the well.

6. TILTING AND SHIFTING OF WELLS AND THEIR RECTIFICATION

6. 1. In spite of the best efforts to sink the wells plumb and in correct alignment there is not a single well which has not tilted or shifted from its true position. Fortunately, however, the allowance made in design has not been exceeded in any case. The design provides for a tilt of 1 in 96 and a shift of 1′. The causes of tilting were found to be as follows:—

(*i*) *None-uniform grabbing.*—If excavation for sinking is not done uniformally inside the well, it causes the well to tilt.

(*ii*) *Surcharge on the soil.*—Heaping of the excavated material on one side near the well or the weight of the crane itself exert a thrust from the side causing the well to tilt.

(*iii*) *Excavation below cutting edge.*—In comparatively compact strata, excavation below the cutting edge is possible but if it is not limited to about 5′ or so, the well would tilt.

(*iv*) *Abrupt sinking.*—This happens mostly in loose soil or in non-uniform strata.

(*v*) *Tree trunks under the cutting edge.*—Tree trunks or similar obstacles coming under the cutting edge would cause tilting and serious set-back to sinking.

6. 2. Of the five causes of tilting mentioned in para 6.1 above, the first three can be controlled to a considerable extent but the same does not apply to the last two. To keep the wells within the limits of design with regard to tilt and shift, strict watch had to be kept and the position and alignment of the wells were checked very frequently. The tilt was corrected as soon as it occurred and no sinking was allowed until the tilt was rectified. Some of the methods employed for rectification of tilt on this project are as follows:—

(*i*) *Providing holes in steining.*—12 No. equally spaced holes of 6″ diameter were left in the steining in its entire depth and opening on the outside at the bottom. If the well tilted on one side, air under pressure was passed through holes on the opposite side.

(*ii*) *By excavation.*—When tilt occurred, excavation was done either with grab or by means of air-lift from the side opposite to the tilted one. The air-lift proved more handy because of its greater manoeuvrability. Care had to be taken to see that a pit was not formed which would have caused blow-in. The excavation had to be uniform but slightly more from the side opposite to the tilted one.

(*iii*) *By Differential Kentledge.*—Eccentric loading also helped in correcting the tilt.

(*iv*) *By excavating and dumping soil outside.*—Excavating from the side opposite to the tilted one and heaping it on the outside of the well against the tilted side created a righting couple which helped correcting the tilt as sinking proceeded.

7. PLUGGING

7. 1. After a well was sunk to its final level, it was plugged with 12 ft. thick concrete. Before concreting, the well was cleaned and a pit 3 to 4 ft. in depth was formed below the cutting edge by means of grab or air-lift. After the formation of the pit, soundings were taken or sometimes even a diver was sent in to check the pit. After this, 7 Nos 3'' diameter pipes were suspended in the well (one in the centre and 6 along the periphery). The bottom of the pipe was kept 6'' higher than the bottom of the pit so that it did not get choked. Stone was then dumped in a depth of 12 ft. This stone was free of small sizes and fines. The quantity of stone required for a plug was 4100 cft. Colgrout in the ratio of 1 : 2 was then poured into the pipes by means of colgrout machine and the pipes lifted gradually until all the voids in the stone were filled with the grout. An air valve was fixed with grout pipe to clear it up in case it was choked.

7. 2. In two of the wells, formation of pit below the cutting edge was not possible. This was on account of flowing-in of the soil. To hold the soil at the bottom, water was pumped constantly into the well. False steining was also added and water level in the well was kept 12 ft. higher than the water level outside. But even then the bulb did not form. An attempt was also made to stabilise sub-soil by grouting it under pressure with neat cement slurry at 3 to 4 ft. below the cutting edge. This too proved unsuccessful in the sense that the pit could still not be formed below the cutting edge. Therefore the idea of forming the pit below cutting edge was given up and sub-soil was grouted as it was and plug placed over the same. The procedure adopted was as under:—

(*i*) A 2in. diameter pipe was inserted in the sub-base and sunk to a depth of 3 to 4 ft. with the aid of compressed air. The pipe used is shown in fig. 8.

(*ii*) Through this pipe a mixture of cement and water was poured by means of colgrout machine. By lifting the pipe gradually, the sub-base was grouted up to the top.

(*iii*) The entire sub-base was grouted to a depth of about 4 ft. below the cutting edge by inserting such pipes inside the well at 3 to 4 ft. intervals.

(*iv*) Next day, probing was done and a diver was also sent inside to find out if the sub-base had been properly grouted. A sample was also taken which was found to be pretty hard and therefore satisfactory.

(*v*) After satisfactorily grouting the sub-base, 14′ thick colcrete plug was laid on top of the grouted sand base.

8. CONCLUSION

8. 1. The well foundations for this project are perhaps the deepest in this continent. Due to the numerous difficulties as already described, sinking took much more time than was or could be estimated. From the experience gained it is felt that the following could have made actual execution easier at least to some extent:—

(*i*) The effective depth of the curb on the inside of the well is 5′—6″. If the curb were deeper the plug would get a better grip. Besides, the formation of the pit below the cutting edge would not have been so important.

(*ii*) Above the curb the thickness of the steining is 3 ft. This has been reduced to 2′—6″ above R. L. minus 59. This reduction in section was for reducing friction during sinking. In actual fact it aided caving in of the ground outside the well. Thus uniform thickness of steining might have proved better.