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CONSTRUCTION OF BORED CAST-IN-SITU CONCRETE PILES ON CHASHMA RIGHT BANK IRRIGATION PROJECT STAGE-II

BY

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1.0 GENERAL

The purpose of this article is to describe the almost indigenous methodology and techniques employed by the contractors for construction of the bored cast-in-situ concrete piles on CRBC Stage-II and to record difficulties encountered during this process with solutions devised. Discussion of the design aspects has been left out, being beyond the scope of the paper. The project was executed by WAPDA and construction was supervised by the National Development Consultants (NDC) in capacity as Engineer's representative.

Well-type spread foundations had originally been designed for arterial , district and village road bridges on the Main Canal . As a result of review of designs of the structures , the Consultants (NDC) suggested change over from well - type footings to pile foundations for the bridges . It was decided by WAPDA to switch over from spread to bored cast-in-situ concrete pile foundations. The design and drawings were furnished by the Central Design Office (W) WAPDA , Lahore . The Variation Orders and specifications were prepared by the Consultants. However, by then , the contractor had proceeded to construct village road bridges at RDs 266+517, 277+000 and 344+514 with spread foundation. For the remaining 7 bridges of three types , it was required to construct bored piles with a total pile length of over 2,600 ft.

Some time later, again on suggestion by the consultants the alignment of the main canal was changed between RDs 345+360 and 380+347. One of the objectives, for some good reasons, was to gain natural ground with higher elevation

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so as to pass flood waters of various nullahs and rodkohi flows over the canal, from its right to the left, enroute to the Indus river. Ten reinforced cement concrete (RCC) superpassages were ,therefore, provided from RD 345+360 to RD 385+425 including two of the Dove-tailing Proposal instead of the RCC syphons on the original alignment . These superpassages were also supported over pile foundations. The piles were placed at 10 feet intervals form centre to centre along the canal in four rows for each superpassage structure. Thus, additional 801 piles were bored in-situ in CRBC Stage-II and the Dove-tailing proposal involving a length of about 47,000 feet .

The important statistics of these bored cast-in-situ concrete piles are given structure-wise in Table-1. The designed diameter of all these piles was 30 inches. The bored cast-in-situ piles of this size come , under the category of large diameter piles (24 inch / 600 mm nominal diameter and above). Such percussion bored piles are very well suited to a large variety of sand strata including hard combined with un-stable ground conditions as were generally encountered on the CRBC Stage-II alignment.

2.0 OPERATION

Various steps involved in the process of installation of bored cast-in-situ piles are depicted in photographs 1 to 15 attached at the end of this paper. Excavation of the bore holes for the piles was achieved by either percussion or drilling at different sites. (Refer Table-1).

All percussion drilling rig assemblies were located at the field outfits. The Pakistani sub-contractor, had only one rotary rig which was deployed at AR Bridge RD 324+435 but it flopped as its cutting chisels failed at about 20 feet depth. This had to be replaced with a percussion rig. All other rigs used percussion method.

Two reverse rotary rigs were also used at bigger superpassages RD s 349+865, 378+756 and 382+500 which together accounted for 484 piles out of a total of 839 piles for all the structures. These were of Chinese make and

Messrs Chinageo, the lead partners of the Rakgeo J.V., had arranged them from their compatriots working in Baluchistan.

With both the percussion and rotary drills, the common purpose is to loosen soil in the bore-hole and then remove it to the surface by various methods as the bore-hole proceeds steadily down.

3.0 PERCUSSION METHOD

Cable Percussion Boring is successful for any type of soil. On CRBC, the soil strata were mostly firm, being clayey silt or silty clay with one or in some cases two layers of silt or fine sand one to two feet thick and then fine sand below 35 feet depth. As such no casing whether temporary or permanent was used.

In the Percussion or Cable-Tool drilling method, a heavy drilling bit, welded to a plunger pipe, acts as a cutting tool . It was weighted to improve penetration.

The top end of the plunger pipe is attached to one end of a drilling cable, the other end of which is fastened to a cable drum after passing over a system of sheaves. A mechanically operated spudding crank controlled by a spudding arm imparts movement to the drilling cable alternately in back and forward direction which makes the cutting drill rise and fall. This action cuts and pulverises the underlying soil in the bore hole. The hole is advanced by repeated dropping of the cutter drill and wrenching it to the surface with its burden of spoil.

Two methods were used to bring out this loosened spoil:-

At some sites, a dry method was used. In this method ,the plunger pipe had a valve at the lower end which opened upwards as the bit fell and pushed the material up. The pipe thus got filled up with thirty to forty strokes . When the pipe was pulled up the valve closed with the weight of the material. The plunger pipe was pulled out and cleaned and the operation was repeated. This method was not found to work well.

The other method of bore washing was, therefore, used at most of the sites. Here the heavy drilling bit attached to the plunger pipe had four jet nozzles fixed in it. A hose delivery pipe attached to the water pump at one end, had its other end fixed to top end of the plunger pipe through a water swivel. Water was forced under pressure through the plunger pipe jet nozzles which loosened and pushed the material out through the annular space available between the pipe and the bore surface.

The mechanical assembly used by the drilling contractor was one fixed on skids and cribbing as a base. Such assembly could even be mounted on a truck but no such percussion rig was available with him.

4.0 REVERSE ROTARY DRILLING METHOD

As already stated , for this type of drilling, rigs were deployed on the bigger superpassages needing a large number of piles at a single site such as at RDs 349+065, 378+065, 378+754 and 382+800. It is a more rapid method particularly for a more resistant medium. The borings were carried out by means of the Chinese reverse rotary drilling rig. Its power mechanism was mounted on a mobile platform. As at these structures, a large number of piles were to be installed in long rows, two steel rail lines were specially laid out along the row on sleepers placed at 5 feet intervals. A rig was then transferred from its mobile mounting onto these rails located on that row. Drilling was achieved by means of a rapidly rotated pipe, a hollow rod , to the lower end of which a hard steel cutting bit was attached. As the bore advanced, more pipe extensions in 10 feet lengths, were added and drilling continued till the required depth was achieved. The loosened material in the bore hole was removed by continuously circulating water in it. On the reverse rotary drill, this was accomplished by sucking out muddy water through the drilling pipe by means of a suction pump attached to and worked by the rig engine while an equal quantity of water moved from the main water pit into the bore hole under atmospheric pressure. The water moving down the bore hole proceeded very slowly because the area of the annular space was many times more than that of the drilling pipe through

which the water was sucked out. The velocity of the down-going water ,therefore, did not disturb the material of the bore hole. (On the ordinary rotary drill, the bore wash method already described above, is used as per demand of the strata).

The muddy water coming out of the bore was led in a watercourse of sufficient length so that the mud could settle enroute and the decanted water passed into the main water pit where further decapitation took place . This water was re-circulated. Water level in the pile-bore was always maintained. The watercourse was kept clean by continuously removing the settled mud. The bore surface was kept stable by the water pressure on its wall. On the other hand, with rotary and percussion drilling, the muddy or slushy water moving slowly up along the bore surface through the annular space for outflow protects the bore hole against caving in during the operation. It is imperative that a positive head of water is maintained in the bore hole to minimize loosening of granular or other non-cohesive material from the treacherous layers.

With the Chinese reverse-rotary rig, the bore depth advanced so fast that up to 8 bore-holes per day were accomplished depending upon nature of the soil strata encountered. The rig unit had got the facility of an air pump. Compressed air was blown at the bottom through the drilling pipe and the material pushed out.

4.1 Sequence of Operation

The following was the sequence of steps involved in the operation of casting bored concrete piles in-situ:-

4.1.1 a) Marking Control Points

The lay-out of the structure was marked with reference to the centre line of CRBC and an RD point marked by the Survey & Investigation Division of WAPDA. Control points were established around the area keeping clear of the ensuing activity expected in further sequence. The operation was carried out by the Contractor and checked by the Consultants.

4.1.2 b) Preparing Platform

The area of activity was raised & compacted to a level to which concreting of the pile was to be continued as per specifications; that was up to 2 feet above the designed bottom level of the future pile cap. The centre line of the canal was then marked on to this platform. Centre points of the piles were located with reference to the horizontal control points and secured by driving pegs with concrete placed round them.

For the reverse-rotary drilling, the crew again checked the centre line between the bed pile rows and laid on it a rail track 76 inch wide, fixed on wooden sleepers placed 5.0 ft centre to centre. A trench about 10 ft wide and 5 ft deep was excavated in middle of the bed pile rows, to act as a water storage and settling pit.

For percussion drilling, the water storage pits were placed at convenient points as per demand of the location. In both cases, the purpose was to lead water from the tank to the bore-hole and vice versa.

Water was brought to the site by pumping from CRBC through an earthen watercourse and then again pumped from it into the water pits.

The platforms were later used for on-ground shuttering for slabs of the bridges and the superpassage troughs.

4.1.3 c) Installation of Drilling Rigs

The pneumatic tyres of the reverse rotary rig were replaced with steel wheels before it was transferred onto the rail track. The position of its derrick with drill pipe was then adjusted to be in line with the center vertical axis of the pile and then drilling started.
Similarly the percussion drill assembly was moved to a convenient location near the pile site and the tripod centred over the centre peg of the pile.

To hold it in place soil of the top layer of these bore-hole sites which is generally weak and loose or gets disturbed with operational activity, a shallow mild steel casing pipe is inserted. To accomplish it, the crew of the reverse-rotary drilling rig excavated a hole at the target pile site, 3.25 ft in dia and 5.0 ft. in depth and placed in it a casing pipe 32 inches in dia and 5.0 ft long, having a side inlet hole near the top end for letting water in. At other sites, the crew of the percussion rigs hammer drove by the same casing 5.0 ft. at the pile site and then scooped out the earth from it by bore wash. This casing also acted as a starter for the bore-hole drilling and had its top kept at a level 20 feet higher than the design bottom level of the pile cap. The hole in the casing actually worked as an outlet for outflow of the muddy water expelled from the bore-hole by bore wash in case of a percussion or rotary rig and as an inlet for passing clean water into bore-hole to be sucked as muddy water by the pump through the drilling pipe.

As soon as the hole had been bored to the required depth, it was washed with clean water to remove any mud or muddy water present in it. Washing was continued till clear water started flowing out from the bore-hole.

4.1.4 d) Sampling of Material

Bore-logs one for each end piles of the four rows and eight in all at each structure were collected to know about the strata encountered. Also soil samples were taken for the last one foot of each bore hole and analysed to be ensure that piles would rest on suitable strata.

4.1.5 e) Fabricating and Lowering Steel Cage

Steel cages were fabricated in steel yards located close to the site to avoid transportation hazards. Steel hoops of # 6 size bars, were prepared with their outer circumference conforming to the inner circumference of the cage. Two hoops were for the two ends and one for its centre. Each hoop was secured in a vertical plan and square to a vertical rod, about 4 ft long the lower end of which was fixed in the ground. These rods

represented the two ends and the centre of the cage length. The circumferences of the hoops were divided with the number of rebars of the cage and marked. The rebars were fastened to the hoops with binding wire first at the bottom - most mark and then three trestles were placed underneath to provide support to the cage so that the cage might not sag by weight as more bars were added one by one. After securing the main bars with the hoops at required spacing, spiral bars of # 3 size and 3 or 6 inch pitch as designed were wrapped around the cage manually and fixed to the cage rebars with mild steel binding wire. Concrete spacers also were fastened to the outer face of the cage rebars to enable maintain specified concrete cover. The maximum length of the cage was 40 ft. the length of rebars normally available in the market. When it was completed, the three hoops were untied and removed. The cage was then shifted from the yard to the pile bore site by a front end loader and was lowered through the starter casing into the bore hole with the help of a crane or percussion drill tripod by operating the rope with its mechanical winch.

When more than one cage was to be lowered in the bore hole, there was a chance that the bottom cage would slide down more than planned and create difficulty before the next cage could be fastened securely on to it . To avoid such possibility, three hooks of #4 m.s. bar were tied with binding wire to the outer face of three re-bars round the cage at least six feet below its top. These hooks rested over the top edge of the starter casing and were strong enough to sustain the weight of the cage. The three hooks were at exactly the same level.

Two horizontal m.s. bars placed about one foot apart and exactly at the same level in the cage, and tied strongly at right angle to the vertical re-bars, about six feet below the top of the cage, also served the same purpose and were used at some piles.

With the lower cage held in place, with 6 ft of rebars left above the casing, the second cage was positioned and a lap of length equal to 50 bar diameters or as specified on the construction drawings was given. Alternate re-bars of the two

cages were then point welded to keep the cages in position. With lapping of all the re-bars completed, spiral reinforcement double the normal was added over the lapped length.

The cages were now ready for further lowering. Before that, the hooks were straightened and rods where used were removed because these could interfere with the movement of the tremie pipe while concreting.

Similar process was followed where more cage lengths were required to be lowered.

4.1.6 f) Pile Concreting

After placing reinforcement cages in position the depth of the bore hole was measured to make sure that no sliding of soil material had taken place. Wherever the depth was found less than specified, washing of the bore-hole was done again. As soon as washing was completed concreting was started.

First, a pit was excavated on one side of the bore hole and close to it. The pit dimension and shape were such as to accommodate a bucket shaped steel skip, bottom tapered conically with a 10 inch dia hole at the centre. The hole could be opened and closed by a flap and latch arrangement by manipulating it with a rope from distance.

A tremie pipe consisting of 8- inch dia 10 ft lengths, absolutely clean inside, was lowered into the bore hole to the bottom. A hopper, 3.5 feet in dia and 4 feet deep was fixed to the top length of the tremie. An arrangement existed which prevented the termite pipe to go down beyond the required depth but did not prevent it from being pulled freely upwards.

The skip was first placed in the pit and its bottom flap closed. The concrete mix was brought from the mixer in trollies and tipped over into the skip to fill it upto the fixed mark. At some pile sites, the concrete mixer was so placed that concrete mix from it was poured into the skip directly. The skip was then lifted by a rope and drum arrangement attached to a tripod

operated by a mechanical winch, or by a crane, and brought over the hopper. The flap was then opened by operating the latch with a rope attached to it. The concrete mix mass poured into the hopper and was guided down to the bottom of the hole through the tremie.

The tremie pipe was then given mild up and down jerks with the help of the mechanically operated winch so that the concrete in it moved down to the right place at the bottom. Care was taken that it was not moved so much as to make its bottom come out of the concrete mass in the bore hole. Infact; the bottom end of the tremie pipe was always kept minimum 10 feet in the concrete. As the filled concrete mass moved up in the bore hole, the upper most tremie pipe lengths were detached.

The Chinese reverse rotary rig did not have an arrangement to give a vertical jerk to the tremie pipe. To counter this shortcoming, a high slump self compacting concrete mix with a maximum slump of 7 inches was used and in addition, the tremie pipe used to be tapped. On other piles 5.5 inch slump was used. An air entraining agent(Fabricate) was used in dozes of 50 c.c per 100 Kg cement, to give 4-5% entrained air. To compensate for the loss of concrete strength resulting from the high water-cement ratio needed to attain the high slump concrete mix, the cement content was increased and 1:1.5:3 mix was used to give 3,000 psi compressive strength at 28 days. Also due to restriction of space between lapped lengths of the rebars, the size of the graded crush stone aggregate was kept as 3/4 inch down.

Concreting was continued to 2 feet above the designed top level of the pile. This length contained the thick layer of laitance and muddy concrete contaminated with bore detritus and was removed later. The Contractor was advised to remove this laitance and contaminated concrete when green but usually the action was delayed and difficulties were consequently experienced. The starter casing was also slowly removed immediately as the concreting was finished . Mild vibration was then allowed for compaction in the upper 5.0 feet length of the pile.

4.6 g) Raising columns

Technically as per design, the top of the bed pile rested at the bed level. The continuation of the pile above the bed level was treated as a column. The following three processes were followed in raising columns on the canal bed for the bridges and the superpassages:

i) Pile construction on all structures was carried out before excavation of canal prism there. For structures starting with V.R.Bridge RD 299+199 up to superpassage RD 358+236, the concreting of the bed piles was terminated in the bore hole at a level 2.0 ft above the design pay line of bed excavation. The part of the prism around bore hole was then excavated up to the bed pay line. The 2.0 feet extra length of the pile containing contaminated concrete was then removed and re bars exposed. After cleaning re-bars and making smooth the top surface of the pile, a concrete starter 30 inches in dia and 4 inches in depth was constructed over the pile. The reinforcing steel cage of the column was then fixed to the exposed rebars of the pile by giving proper lap and welding and by putting double the normal spiral bars. After plumbing of the steel cage with the help of concrete spacers, the form work was erected and column concerted.

ii) On structures starting with Superpassage RD 360+885 to A.R. Bridge RD 376+560, the Contractor lowered 18 ft long, i.e. design canal depth plus 2.0 feet, 30 inch dia 2 mm thick casing into the bore hole and secured its top at 2.0 feet above the design bottom level of the pile cap which is at the F.S.L of the canal at the site. The steel cage for the column was lapped and welded to the top pile steel cage and lowered into the bore hole alongwith and as continuation of the pile reinforcement. The concreting of the pile was then done upto the top of the steel lining which included that for the column. After about one hour, the casing was withdrawn in exactly vertical direction without disturbing the cast concrete and the contaminated concrete in top 2.0 feet pile removed and exposed rebars cleared.

iii) The same method with 2mm thick casing as at (ii) above was used at structures of the Dovetailing reach which included two V.R.Bridges at RDs 380+400 and 385+000 and the two superpassages RDs 378+754 and 382+800. Here however, the casing was in two pieces, the lower one about 16 feet and the top one, 2.0 feet. Instead of withdrawing the casing immediately after concreting was finished, it was left in place and was removed by cutting cautiously with acetylene flame torch later after completing construction of the structure.

The only drawback with the method at (ii) & (iii) above is that extra care has to be taken for ensuring verticality of the casing and consequently the column. Permission to go for method (iii) was given only when the result of a test column was found satisfactory.

5.0 PROBLEMS ENCOUNTERED DURING OPERATION AND SOLUTION THEREOF

a) Obstruction to Boring at A.R. Bridge RD. 324+435

The bore logs collected at various sites indicated mostly silty clay or clayey-silt soil at the top with one or more silt layers, 1 to 2 feet thick, sandwitched in between at varying depths, and fine sand below 35 feet or more. However, at the site of A.R. Bridge RD 324+435, a layer of hard material was encountered at about 20 feet depth. This reduced the bore progress drastically. Drilling then had to be switched on to percussion method.

b) Boring of a Pile Out-of-Position at A.R. Bridge RD.324+435

Specifications do not permit out-of-position tolerance of more than 2 inches in any direction. But at the site of AR Bridge RD 324+435, one of the left-side bed piles was found out of position by about 6 inches. The concrete of all the piles in the row was removed up to 2 feet depth below the bottom level of the bed line and the protruding re-bars of the piles were bent to anchor into a 3.5 ft x 2 ft RCC cap placed on top of the piles in the row at the Contractor's cost, to

provide a base for raising bridge columns on it in accordance with true position.

c) **Detachment of the Drilling Bit from Pulling Cable at A.R.Bridge RD.352+910**

At the site of AR Bridge RD 352+910, the heavy drilling bit detached itself from the main drilling cable at a depth of about 40 ft. All efforts to hook it out failed. Casing was lowered into the bore up to about 20 ft depth and earth around it was excavated manually in the form of an enlarged shaft. Still the effort to hook the drilling bit could not be successful. The excavation was then extended to 30 ft depth and the drilling bit was extracted. The over excavation was then refilled with sand and drilling operation re-started.

6.0 PRECAUTIONS

The following precautionary measures were adopted in addition to a few stated above, to avoid some expected difficulties.

- During installation of bored cast-in-situ concrete piles, the soil on the sides of the bore hole became soft due to a) migration of water b) absorption of water from wet concrete c) water used to expedite or facilitate boring operation. This reduces shear strength by skin friction. To minmise this minimum possible time lag should be allowed between boring and concreting.

- Initially about 20-25 Cft grout material of sand & cement ratio of 1:4.5 was used to avoid caving in of the bore surface, specially at the bottom of the hole. This action also kept the pile concrete free of mud mix.

- Well-graded aggregate 3/4 inch down was used to avoid interlocking in the bore hole particularly in view of the very high quantity of steel provided with poor space in between. The position at the joining points of the steel cages was particularly difficult.

- Bentonite was not used at all and it saved the hole from the settlement of bentonite particles.
- Vertical drop for concrete from concrete mixer / tip wagons into the skip or from skip into the hopper should not exceed 5.0 feet.
- Concreting rate was maintained at 20 to 50 ft length of the bore per hour and without any break.
- Time lag between completion of concrete mixing in the mixer to pouring into the bore hole should not exceed 30 minutes and temperature limits should be 32 °C maximum and 5°C minimum.
- Heavy jerks were avoided to avoid disturbance of the formation of soil of the bore-hole surface. Moderate impact, in addition to moving the concrete down the tremie pipe was enough to cause its compaction. Use of vibrators should be strictly disallowed except in the top 5.0 feet length of the finished pile.
- During concreting process no lateral movement or jerk should be imparted to tremie pipe.
- The diameter of the chisel should be equal to that required for the bore-hole.
- It is very important and worthwhile to reiterate that the lower end of the tremie pipe must always remain in concrete by about 10 feet.

7.0 LOAD- TESTING BORED CONCRETE PILES

The intended purpose of load-testing of the bored cast-in-situ concrete piles was stated as under:-

- Mainly to adjust in the field the penetration of piles actually required to obtain an ultimate load bearing capacity of the

piles of not less than 2 x (Dead load + Live load) or such higher factor of safety as the Engineer may stipulate at his direction.

- Secondly to establish whether any significant pile settlements are likely to occur up to the design load values.

- Load-testing of piles is quite expensive. It was initially envisaged to load-test two independent piles. Later, however, it was decided to carry out the test on a working pile. For this test the central one out of the three working piles at the right abutment of V.R. Bridge RD.309 + 134 was selected.

- The operation of boring and concreting in-situ piles at this structure was started on 21.05.1991 and completed on 13.06.1991. Although a minimum of 14 days was allowed as time lag between completion of concreting and commencement of the load test, yet here the load test was started on 11.07.1991 and completed on 15.07.1991. At the site of the test pile it was ensured that the application of compressive test loads to the central longitudinal axis of the pile correctly simulated, as far as possible, the actual ultimate condition of load to which the pile was expected to be subjected.

7.1 Test Arrangements

The Contractor was expected to use a non-destructive method of load-testing of the piles. He first outlined details of the method to be used by him for the test which was approved. The following sequence was followed:-

- An area about 30 feet long and 8 ft. wide around the test-pile and about 5 feet deep was excavated. The extra two feet of the pile length consisting of laitance and weak concrete was removed including the re-bars. The head of the pile was made smooth and level. A steel test plate about 2-inch thick and of the same size as the pile butt was centred on the latter and set in high strength quick setting grout, in

a plan perpendicular to the longitudinal axis of the pile. On it was centred a hydraulic jack , which had been prior tested and calibrated for pressure up to 4000 lbs per sq inch on 01.06.1991 at the Government of Pakistan, Central Testing Laboratories, Ferozepore Road, Lahore. The test report was produced and placed on record.

- A strong test beam, about 20 feet long and 21 inch in depth, was centred above the ram of the jack with ends resting on two concrete blocks 3 ft. x 3 ft. x 1.5ft so as to be strong enough to avoid any adverse settlement or tipping over of the weight platform. The lower flange of the beam was fixed to the blocks. The blocks themselves were just anchored in the ground in the pit to prevent their lateral movement. Bearing steel plates of the same size as the test plate were inserted between the top of the jack ram and bottom of the test beam such that their total thickness (bearing plates) was not less than 2 inches. The bearing plates also were centred on the jack ram precisely.

- On the test-beam and across it, were placed 20 feet long cross-beams, smaller in size, equally balanced about it with ends resting on a concrete base having top surface at ground level. These cross-beams were placed side by side to form a platform to accommodate weight material.

- The test-beam is ultimately subjected to high bending and buckling stresses and should be strong enough to carry the maximum load safely. Thus maximum safe load was marked clearly on the beam so that it was not exceeded inadvertently during the test.

- The jack was worked by a hydraulic pump placed at a distance beyond the platform and connected to it through a pressure pipe. The calibrated gauge was attached to the pump and read pressure in lbs/sq inch which when multiplied with the known area of the jack piston indicated the load coming on it.

- A clamp was tightened around the top of the test pile. To this clamp were fixed, by welding, three tips(angle iron) equidistant from one another. On these tips were placed three micro-meter gauges which could record even a minute movement of the test pile. These gauges were so fixed to a separate arrangement and secured as to be free of any extraneous influence or disturbance.

- Weight approximately equal to the final test load was carefully placed on the platform. The whole arrangement was watched closely for sufficient time to be sure that it was secure and there was no undue deflection in the test beam or settlement of the concrete blocks supporting it and also there was no possibility of the beam turning round when the jack was operated to apply load.

The arrangement then was complete to start applying load increments.

7.2 Loading and Unloading Piles

- The design load capacity of the pile had been intimated by C.D.O(W) WAPDA as 43 tons and it was required to test the pile against the test-load 2.5 times the design load i.e for 107.50 tons. The micro-meter gauges were set at zero. The load was transferred to the test pile by working up the hydraulic jack ram and making it react against the bottom of the test beam. The first load of 10.75 tons as 25% of the design load was applied at 1935 hrs on 11.07.1991. Further loads too were added in increments of 25% of the design load up to 250% of the design load i.e 107.5 tons as the ultimate test-load, with minimum two hours period intervening between the consecutive increments (Refer Table-2). During this intervening period, the pressure gauge corresponding to the total load transferred to the pile so far, was kept constant, and if the gauge strayed a little bit, the hydraulic jack was immediately worked to bring the gauge to read the applied load. The micrometer dial gauges which had been designated as M1, M2, & M3 were watched regularly and carefully. The indicated settlement was noted & recorded

at 15 minutes intervals and the average worked out. The next increment of load was added only when the rate of pile settlement had been found to be less than 0.125 mm or 0.005 inches during the last 15 minute interval and minimum 2 hours had elapsed since addition of the previous increment.

- The last increment had been added by 1,338 hrs on 12.07.1991. Full load was retained on the pile for the following 48 hours. During this period, the gauges were continued to be recorded, starting with short intervals and then increasing the interval as the gauge was noticed as almost steady.

- At 1338 hrs on 14.07.91, the first load decrement of 26.875 tons, i.e 25% of the total test load was made. Gauges were noted at 15 minutes intervals. Further load decrements @25% per hour of the total test load were made and completed by 1638 hrs on 14.07.91. Gauge continued to be observed for some further period till no further settlement was noticed.

- Total forward settlement noticed was 1.34 mm and the re-bound was of the order of 0.75 mm. The net settlement was therefore 1.34 - 0.75 = 0.59 mm, which was negligible compared to the permissible limit of 6.25 mm or 0.25 inches.

- A report was compiled and submitted to the Engineer for onward transmission to C.D.O (W) WAPDA, Lahore, alongwith: i) A Key Plan , ii) Bore Log, iii) Load-Settlement diagram (Figure-1), iv) Time-Settlement diagram (Figure-2) , v) Calculation and Information (Record of observations etc.), vi) Load increment schedule (Table-3), vii) Test Report of calibration of Pressure Gauge.

8.0 SAFETY REQUIREMENTS

Safety measures must be adopted during any construction activity to minimize loss of property and eliminate risk of

fatality or even an injury to the people involved and those around. The Contractors were advised to observe the safety requirements of various Building & Construction Codes including those of D-1143 for piles. More important of them are stated below:

- Work areas, walkways, platforms etc must be kept clear of debris, scrap, small tools and accumulations of mud, grease, oil and other slippery materials.
- All scaffolding, shuttering, shoring, timbers, blocking cribbing material should be strong enough to stand loads of quality material.
- Workers, technical staff, supervisors, inspectors, engineers should be provided with safety helmets, gum boots, rubber gloves, insulated tools as per demand of the situation. They also must not wear loose clothing.

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TABLE - 1

IMPORTANT STATISTICS OF IN-SITU BORED PILES

1. Diameter of Pile = 30 inches
2. Quantity of Concrete per foot run = 4.9 cft.

SR. NO.	DESCRIPTION OF STRUCTURE	PILE DATA				QUANTITY OF STEEL PER (kg.)		DATE OF		METHOD OF DRILLING
		NO. OF ROWS	NO. PER ROW	DEPTH (ft.) ABUTMENT	DEPTH (ft.) BED	ABUTMENT	BED	START	COMPLETION	
CONTRACT NO. CRBC - 62										
1	VR Bridge RD 299+199	3	3	67	51.5	2465	1638	05.04.1991	15.04.1991	Bore Wash
2	VR Bridge RD 309+654	3	3	67	51.5	2465	1638	21.05.1991	13.06.1991	Bore Wash
3	AR Bridge RD 324+433	4	5	80	68.5	2229	1317	16.06.1991	09.10.1991	Reverse Rotary Bore Wash
CONTRACT NO. CRBC - 63										
4	VR Bridge RD 346+814	4	3	67	53.5	1445	2231	13.08.1991	03.09.1991	Bore Wash
5	Super Passage RD 349+065	4	23	50	54.0	1233	1889	06.08.1991	28.11.1991	Reverse Rotary
6	Super Passage RD 351+767	4	5	50	54.0	1233	1889	05.09.1991	01.10.1991	Bore Wash
7	AR Bridge RD 352+913	4	5	75	68.5	1773	1889	23.11.1991	14.01.1992	Bore Wash
8	Super Passage RD 355+256	4	5	50	54.0	1233	1889	04.10.1991	25.10.1991	Bore Wash
9	Super Passage RD 358+236	4	5	50	54.0	1233	1889	27.10.1991	18.11.1991	Bore Wash
10	Super Passage RD 360+885	4	5	50	54.0	1233	1889	31.08.1991	17.09.1991	Bore Wash
11	Super Passage RD 365+609	4	25	55	54.2	1310	2385	28.09.1991	27.11.1991	Bore Wash
12	VR Bridge RD 370+918	4	3	62	53.7	1385	1543	26.11.1991	15.12.1991	Bore Wash
13	Super Passage RD 370+918	4	5	55	64.1	1310	2385	04.12.1991	25.12.1991	Bore Wash
14	Super Passage RD 372+835	4	11	55	64.1	1310	2385	02.01.1992	10.02.1992	Bore Wash
15	AR Bridge RD 376+560	4	5	88	78.6	1727	1790	23.02.1992	09.03.1992	Bore Wash
DOVE-TAILING PROJECT										
16	Super Passage RD 378+754 Tea Nullah	4	65	55	64.3	1310	2385	16.11.1992 16.11.1992	07.12.1992 25.02.1993	Pile R.Rotary for Balance 195 No. Piles
17	VR Bridge RD 380+400	3	2	72	66.0	1425	1703	29.04.1993	02.05.1993	Bore Wash
18	Super Passage RD 382+800 Gudh Nullah	4	33	55	64.3	1264	1803	23.01.1993 04.03.1993	10.02.1993 02.05.1993	Bore Wash for Abutment Piles Reverse Rotary for Balance Piles
19	VR Bridge RD 385+000	3	2	72	66.0	1425	1703	21.02.1993	21.02.1993	Bore Wash

DRILLING ENGINEERS (PVT) LTD.
NEW GARDEN TOWN LAHORE.

CALCULATIONS AND INFORMATIONS
PILE LOAD TEST NO. __1____

SITE: CONTRACT 62 CRBC D.I. KHAN V.R. BRIDGE RD 309+134
PROJECT: CHASHMA RIGHT BANK CANAL STAGE-2
CLIENTS: WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA)

Formula:- F=W/A

$$\frac{\text{Area of Jack Piston in Sq. inch} \times \text{Gauge Pressure ibs/Sq. Inch}}{2240} = \text{Load in tons}$$

1. Diameter of Jack Piston = 12.59" (Inch)
2. Cross sectional area of the Piston - 124.70 Sq. inch
3. Pressure of the Jack when the Gauge Pressure is 1-lbs per Sq. Inch = 124.70 lbs or 0.056 Tons
4. Pile No. 2/Right Abutment
5. Diameter of Pile: 30" (INCH)
6. Length of Pile: 63 Ft./(21.5.91)
7. Design Load of Pile: 43-TONS
8. Test Started on: 11.7.91 (1935 HRS)
9. Test Completed on: 15.7.1991 (1635 HRS)

Date	Time	Pressure of Jack lbs/Sq"	Load on Pile in Tons	Dial Gauges Reading in mm			Average	Remarks
				M1	M2	M3		
11.7.91	19.35	183	10.75	0.00	0.00	0.00	0.00	IST
	19.38	"	"	0.00	0.02	0.00	0.007	
	19.40	"	"	0.02	0.04	0.01	0.02	
	19.50	"	"	0.02	0.04	0.01	0.02	
	20.05	"	"	0.02	0.04	0.01	0.02	
	20.20	"	"	0.02	0.04	0.01	0.02	
	20.35	"	"	0.02	0.04	0.01	0.02	
	20.50	"	"	0.02	0.04	0.01	0.02	
	21.05	"	"	0.02	0.04	0.01	0.02	
	21.20	"	"	0.02	0.04	0.01	0.02	
	21.35	"	"	0.02	0.04	0.01	0.02	
	21.38	366	21.5	0.04	0.09	0.05	0.06	IIND
	21.40	"	"	0.04	0.09	0.05	0.06	
	21.50	"	"	0.04	0.09	0.05	0.06	
	22.05	"	"	0.04	0.09	0.05	0.06	
	22.20	"	"	0.04	0.09	0.05	0.06	
	22.35	"	"	0.04	0.09	0.05	0.06	
11.7.91	22.50	"	"	0.04	0.09	0.05	0.06	
	23.05	"	"	0.04	0.09	0.05	0.06	
	23.20	"	"	0.04	0.09	0.05	0.06	
	23.35	"	"	0.04	0.09	0.05	0.06	
	23.38	553	32.25	0.10	0.15	0.08	0.11	IIIRD
	23.40	"	"	0.14	0.17	0.08	0.13	
	23.50	"	"	0.14	0.17	0.08	0.13	
	24.05	"	"	0.14	0.17	0.09	0.13	
	24.20	"	"	0.14	0.17	0.09	0.13	
	24.35	"	"	0.14	0.17	0.09	0.13	
	24.50	"	"	0.14	0.17	0.09	0.13	

DRILLING ENGINEERS (PVT) LTD.

Date	Time	Pressure of Jack lbs/Sq"	Load on Pile in Tons	Dial Gauges Reading in mm			Average	Remarks
				M1	M2	M3		
12.7.91	1.05	"	"	0.14	0.17	0.09	0.13	
	1.20	"	"	0.14	0.17	0.09	0.13	
	1.35	"	"	0.14	0.17	0.09	0.13	
	1.38	768	43.00	0.17	0.22	0.03	0.17	4TH
	1.40	"		0.17	0.22	0.14	0.18	
	1.50	"		0.19	0.22	0.15	0.19	
	2.05	"		0.19	0.24	0.16	0.20	
	2.20	"		0.20	0.25	0.16	0.20	
	2.35	"		0.20	0.25	0.16	0.20	
	2.50	"		0.20	0.25	0.16	0.20	
	3.05	"		0.20	0.25	0.16	0.20	
	3.20	"		0.20	0.25	0.16	0.20	
	3.35	"		0.20	0.25	0.16	0.20	
	3.38	964	53.75	0.28	0.30	0.21	0.26	
	3.40	"		0.30	0.31	0.21	0.27	
	3.50	"		0.31	0.31	0.23	0.28	
	4.05	"		0.31	0.31	0.23	0.28	
	4.20	"		0.31	0.31	0.23	0.28	
	4.35	"		0.31	0.31	0.23	0.28	
	4.50	"		0.31	0.31	0.23	0.28	
	5.05	"		0.31	0.31	0.23	0.28	
	5.20	"		0.31	0.31	0.23	0.28	
12.7.91	5.35	964	53.57	0.31	0.31	0.23	0.28	
	5.38	1160	64.50	0.38	0.40	0.30	0.36	6TH
	5.40	"		0.40	0.41	0.32	0.38	
	5.50	"		0.41	0.41	0.32	0.38	
	6.05	"		0.47	0.44	0.34	0.42	
	6.20	"		0.48	0.44	0.34	0.42	
	6.35	"		0.48	0.45	0.36	0.43	
	6.50	"		0.50	0.45	0.36	0.43	
	7.05	"		0.50	0.45	0.37	0.44	
	7.20	"		0.50	0.45	0.37	0.44	
	7.35	"		0.50	0.45	0.37	0.44	
	7.38	1365	75.25	0.57	0.53	0.44	0.51	7TH
	7.40	"		0.57	0.53	0.44	0.51	
	7.50	"		0.57	0.56	0.46	0.53	
	8.05	"		0.57	0.56	0.46	0.53	
	8.20	"		0.59	0.58	0.47	0.55	
	8.35	"		0.60	0.60	0.48	0.56	
	8.50	"		0.60	0.60	0.49	0.56	
	9.05	"		0.62	0.61	0.49	0.57	
	9.20	"		0.63	0.61	0.49	0.58	
	9.35	"		0.63	0.61	0.49	0.58	
	9.38	1557	86.00	0.70	0.70	0.57	0.66	
	9.40	"	"	0.70	0.70	0.57	0.66	
	9.50	"	"	0.72	0.71	0.60	0.68	
	10.05	"	"	0.74	0.72	0.62	0.69	
	10.20	"	"	0.75	0.73	0.63	0.70	
	10.35	"	"	0.77	0.75	0.64	0.72	
	10.50	"	"	0.80	0.76	0.65	0.74	
	11.05	"	"	0.82	0.77	0.66	0.75	
	11.20	"	"	0.83	0.77	0.66	0.75	

DRILLING ENGINEERS (PVT) LTD.

Date	Time	Pressure of Jack lbs/Sq"	Load on Pile in Tons	Dial Gauges Reading in mm			Average	Remarks
				M1	M2	M3		
12.7.91	11.35	"	"	0.83	0.77	0.66	0.75	
	11.38	1748	96.75	0.90	0.85	0.73	0.83	
	11.40	"	"	0.90	0.85	0.73	0.83	
12.7.91	11.50	17.48	96.75	0.95	0.88	0.78	0.87	9TH
	12.05	"	"	0.95	0.88	0.78	0.87	
	12.20	"	"	0.97	0.88	0.80	0.88	
	12.35	"	"	0.99	0.88	0.80	0.89	
	12.50	"	"	1.00	0.90	0.81	0.90	
	13.05	"	"	1.00	1.92	0.82	0.91	
	13.20	"	"	1.02	1.94	0.83	0.93	
	13.35	"	"	1.02	1.94	0.93	0.93	
	13.38	19.44	107.50	1.10	1.01	0.93	1.01	10TH
	13.40	"	"	1.10	1.01	0.93	1.01	250% OF
	13.50	"	"	1.10	1.01	0.93	1.01	DESIGN
	14.05	"	"	1.10	1.01	0.93	1.01	LOAD
	14.20	"	"	1.10	1.01	0.93	1.01	
	14.35	"	"	1.10	1.03	0.93	1.03	
	14.50	"	"	1.11	1.05	0.95	1.04	
	15.05	"	"	1.12	1.06	0.97	1.05	
	15.20	"	"	1.13	1.07	0.98	1.06	
	15.35	"	"	1.15	1.08	0.99	1.09	
	16.35	"	"	1.17	1.09	1.03	1.10	
	17.35	"	"	1.20	1.09	1.05	1.12	
	18.35	"	"	1.20	1.09	1.06	1.12	
	20.35	"	"	1.20	1.10	1.07	1.12	
13.7.91	0.35	"	"	1.20	1.11	1.07	1.13	
	4.35	"	"	1.20	1.11	1.07	1.13	
	8.35	"	"	1.20	1.13	1.07	1.15	
	13.35	"	"	1.25	1.18	1.12	1.18	
	17.35	"	"	1.31	1.23	1.18	1.24	
	21.35	"	"	1.35	1.28	1.23	1.29	
14.7.91	1.35	"	"	1.41	1.32	1.27	1.33	
	5.35	"	"	1.42	1.33	1.28	1.34	
	9.35	"	"	1.42	1.33	1.28	1.34	
	13.35	"	"	1.42	1.33	1.28	1.34	

DRILLING ENGINEERS (PVT) LTD.

Date	Time	Pressure of Jack lbs/Sq"	Load on Pile in Tons	Dial Gauges Reading in mm			Average	Remarks
				M1	M2	M3		
14.7.91	13.38	1448	80.625	1.39	1.28	1.24	1.30	1ST
	13.40	"	"	1.37	1.28	1.24	1.29	
	13.50	"	"	1.37	1.28	1.24	1.29	
	14.05	"	"	1.37	1.28	1.24	1.29	
	14.20	"	"	1.37	1.28	1.24	1.29	
	14.35	"	"	1.37	1.28	1.24	1.19	2ND
	14.38	964	53.75	1.26	1.18	1.12	1.19	
	14.40	"	"	1.26	1.18	1.12	1.19	
	14.50	"	"	1.26	1.18	1.12	1.19	
	15.05	"	"	1.26	1.18	1.12	1.19	
	15.20	"	"	1.26	1.18	1.12	1.19	
	15.35	"	"	1.26	1.18	1.12	1.19	
	15.38	458	26.875	1.12	1.03	0.98	1.04	3RD
	15.40	"	"	1.12	1.03	0.98	1.04	
	15.50	"	"	1.12	1.03	0.98	1.04	
	16.05	"	"	1.12	1.03	0.98	1.04	
	16.20	"	"	1.12	1.03	0.98	1.04	
	16.35	"	"	1.12	1.03	0.98	1.04	
	16.38	ZERO	ZERO	0.82	0.70	0.65	0.72	4TH
	16.40	"	"	0.79	0.67	0.65	0.70	
	16.50	"	"	0.76	0.65	0.63	0.68	
	17.05	"	"	0.74	0.65	0.63	0.67	
	17.20	"	"	0.72	0.60	0.58	0.63	
	17.35	"	"	0.68	0.60	0.58	0.62	
	18.35	"	"	0.67	0.60	0.58	0.62	
	20.35	"	"	0.65	0.54	0.58	0.59	
15.7.91	0.35	"	"	0.65	0.54	0.58	0.59	
	4.35	"	"	0.65	0.54	0.58	0.59	
	8.35	"	"	0.65	0.54	0.58	0.59	
	12.35	"	"	0.65	0.54	0.58	0.59	
	16.35	"	"	0.65	0.54	0.58	0.59	
		TOTAL SETTLEMENT		=			1.34 mm	
		RABOUND		=			0.75 mm	
		NET SETTLEMENT		=			0.59 mm	

TABLE-3

LOAD INCREMENT SCHEDULE

PRESSURE GAUGE READING LBS/IN			LOAD IN TONS	DESIGN LOAD %	HOLDING TIME (HRS)
REQUIRED	DIFF +/- AS PER CALIB	ACTUAL			
190	-7	183	10.75	25	2
380	-14	366	21.50	50	2
570	-17	553	32.25	75	2
760	8	768	43.00	100	2
950	14	964	53.75	125	2
1140	20	1160	64.50	150	2
1330	26	1356	75.25	175	2
1520	32	1552	86.00	200	2
1710	38	1748	96.75	225	2
1900	44	1944	107.50	250	48

LOAD DECREMENT SCHEDULE

FOR TEST LOAD 107.5 TONS (%) =*

PRESSURE GAUGE READING LBS/IN			LOAD IN TONS	DESIGN LOAD %	HOLDING TIME (HRS)
REQUIRED	DIFF +/- AS PER CALIB	ACTUAL			
1425	23	1448	80.62	* 75	1
950	14	964	53.75	* 50	1
475	-18	457	26.87	* 25	1
ZERO	NIL	ZERO	ZERO	* ZERO	24

DRILLING ENGINEERS (PVT) LTD.

FIGURE . 1

V·R· BRIDGE R·D 309+134 (R/S ABUTMENT PILE)

LOAD SETTLEMENT DIAGRAM

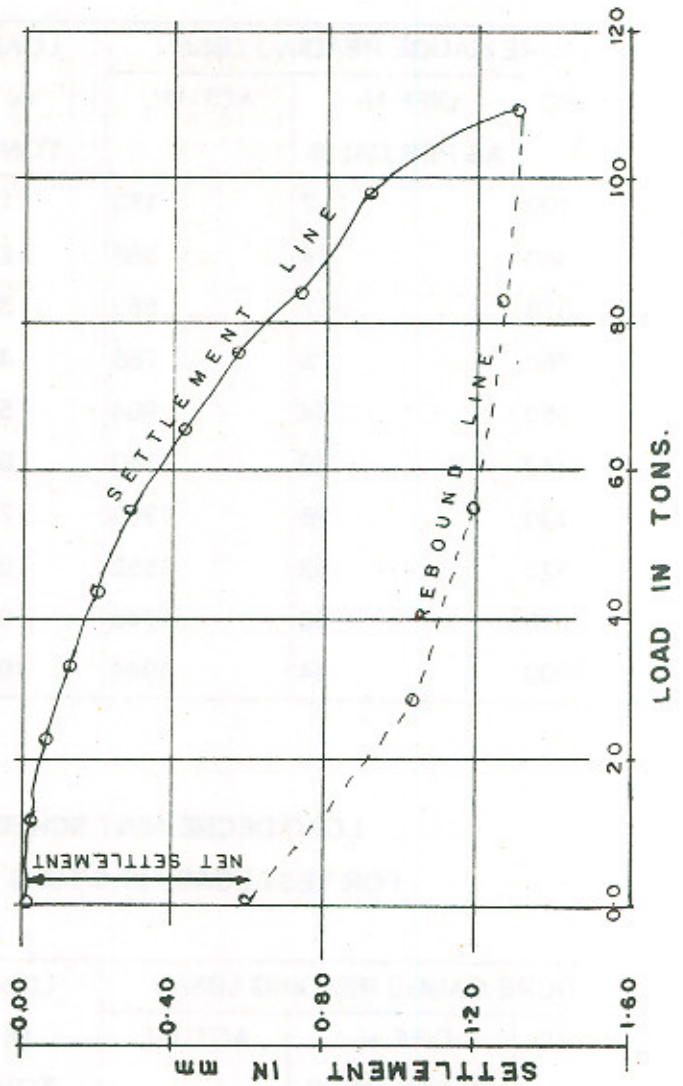
DESIGN LOAD = 43 TONS.

TOTAL LOAD APPLIED = 107·5 TONS.

GROSS SETTLEMENT = 1·34 mm

REBOUN = 0·75 mm

NET SETTLEMENT = 0·59 mm



FIGURE, 2

V.R. BRIDGE R.D 309+134 (R/S ABUTMENT PILE)

TIME LOAD SETTLEMENT DIAGRAM

DESIGN LOAD = 43 TONS.
APPLIED LOAD = 107·5 TONS.
GROSS SETTLEMENT = 1·34 mm
REBOUND = 0·75 mm
NET SETTLEMENT = 0·59 mm
TEST TIME = 93 Hours

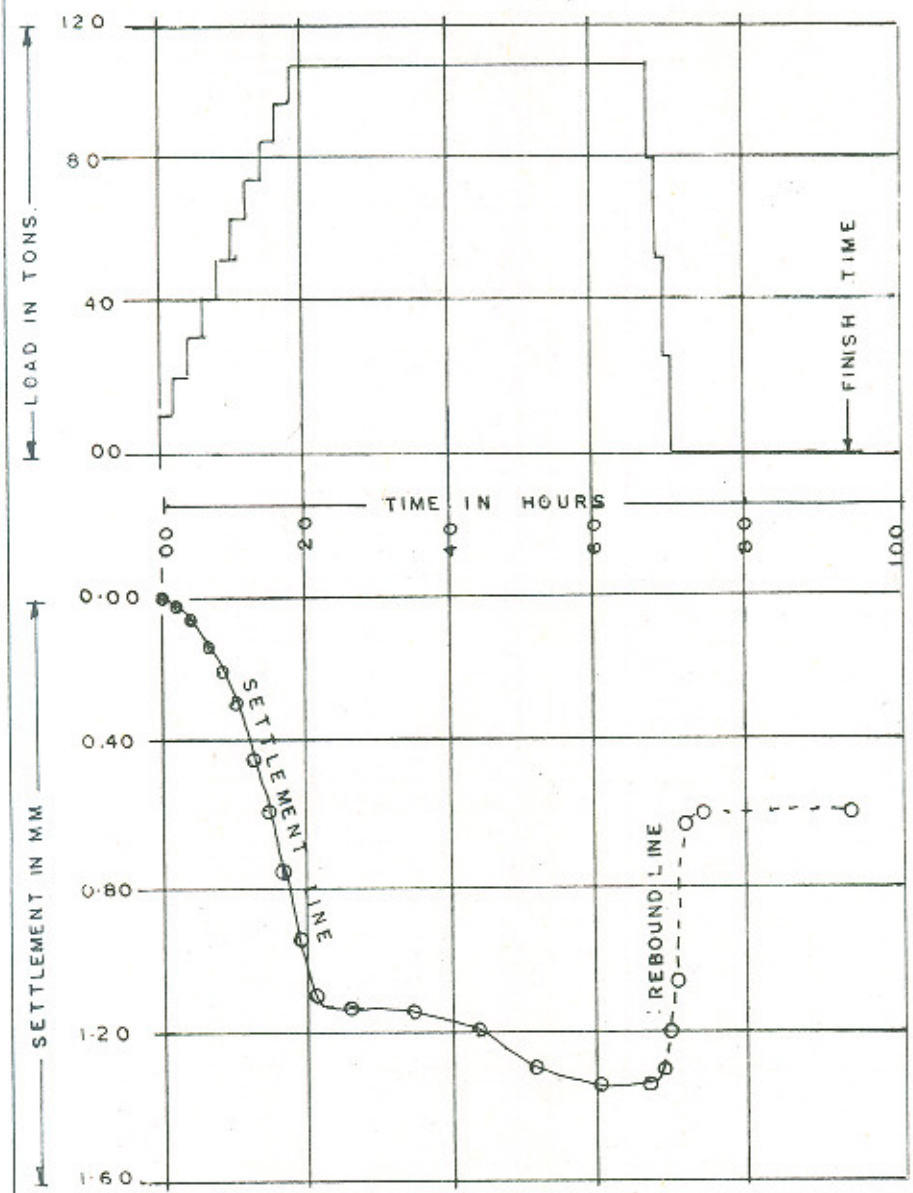
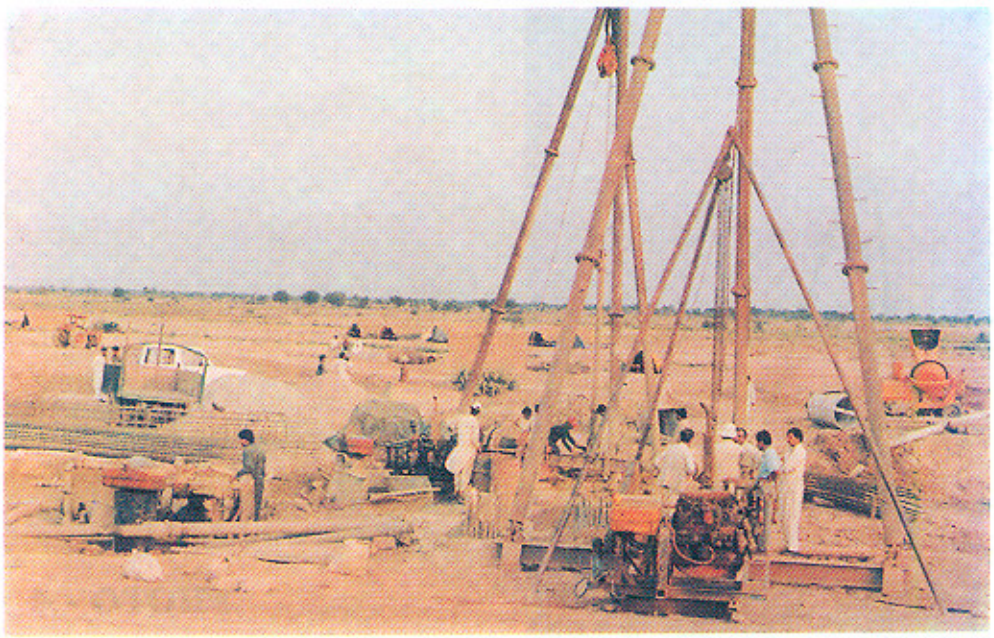
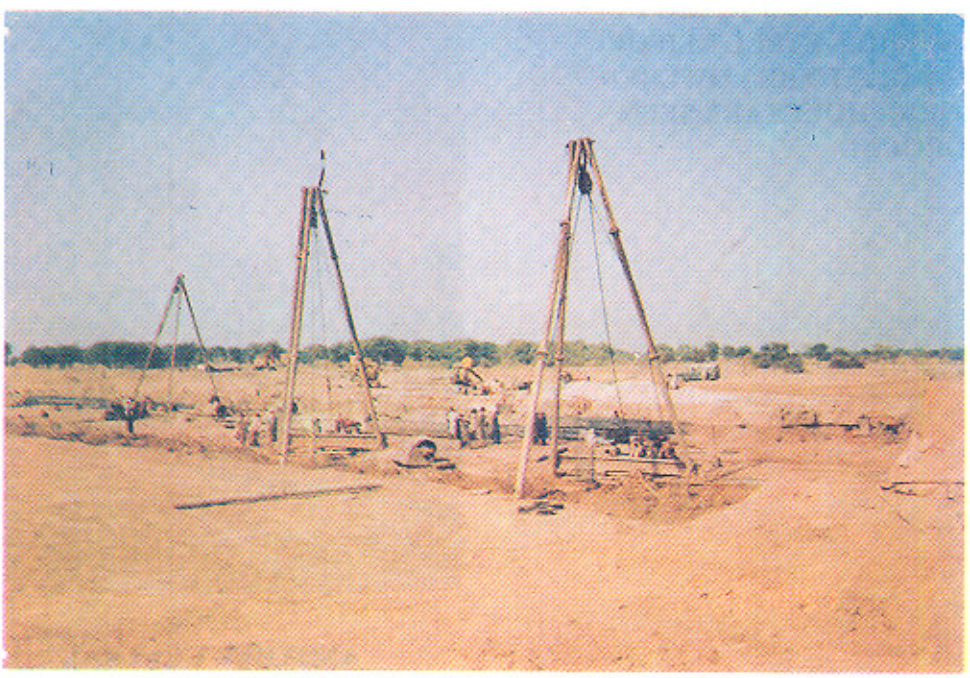


PHOTO - 1



A VIEW SHOWING PERCUSSION RIGS IN POSITION FOR BORING PILES WITH STEEL REINFORCEMENT CAGES, CONCRETE MIXERS AND OTHER IMPLEMENTS USED IN THE OPERATION

PHOTO - 2



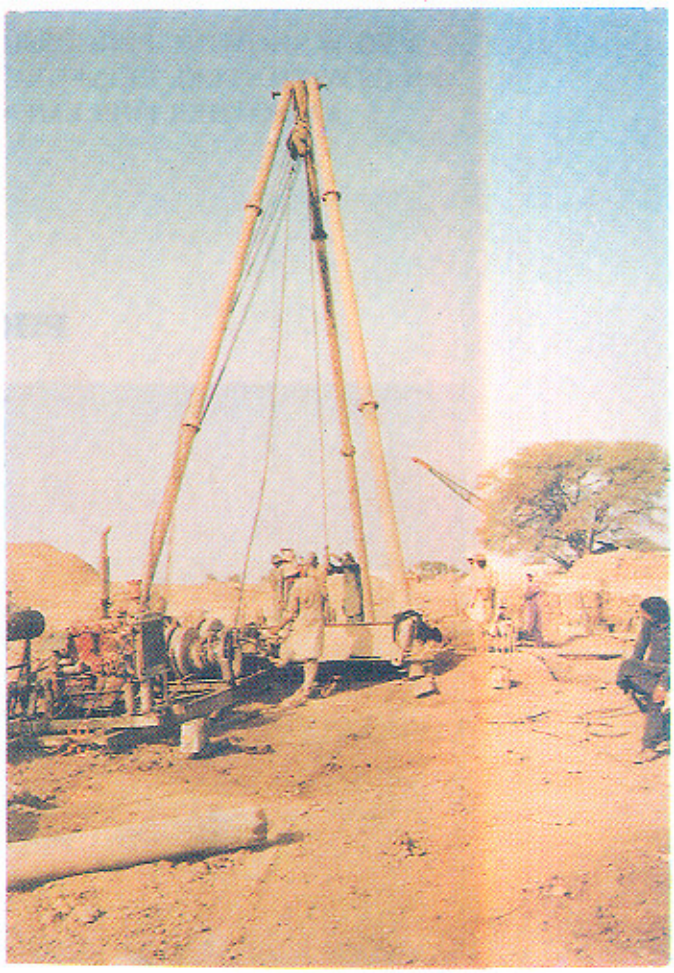
A GENERAL VIEW OF PERCUSSION DRILLING RIGS USED FOR BORING PILES FOR SUPERPASSAGE AND BRIDGE FOUNDATIONS.

PHOTO - 3



A PERCUSSION DRILLING RIG IN WORKING WHILE STEEL REIFORCEMENT CAGES TO BE LOWERED IN THE BORED HOLES ARE SEEN IN FOREGROUND

PHOTO - 4



ANOTHER GENERAL VIEW OF A PERCUSSION DRILLING RIG. A DRAGLINE SEEN WORKING IN THE BACKGROUND

PHOTO - 5



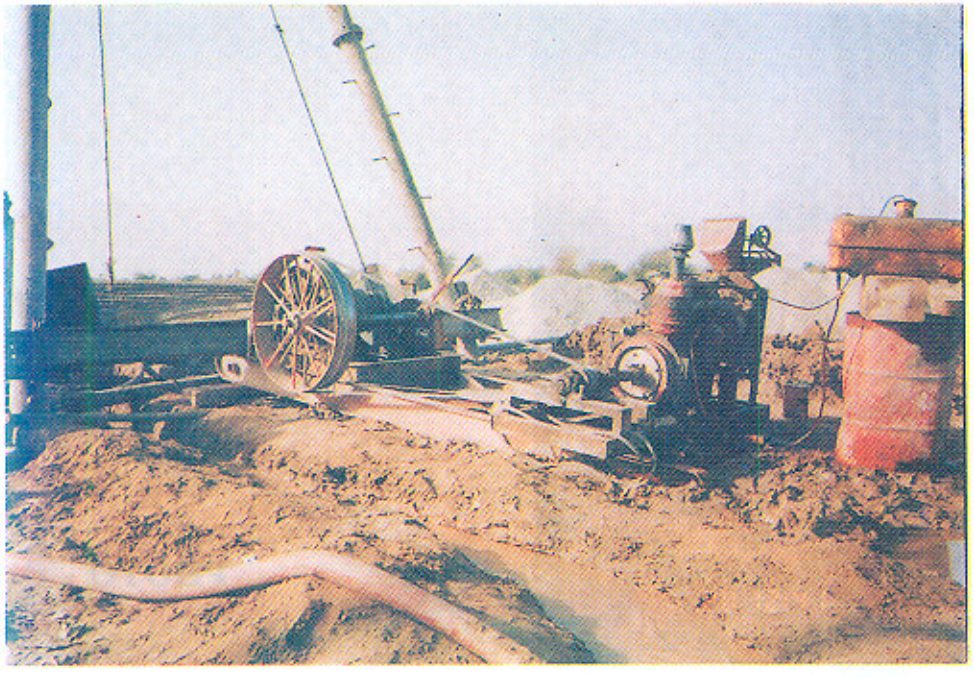
A WELDER IS SEEN WELDING HOOKS FOR SUPPORTING STEEL REINFORCEMENT CAGE. THE CASING PIPE FOR A COLUMN ALREADY LOWERED AT SITE OF A BED PILE IS ALSO SEEN AROUND THE STEEL CAGE.

PHOTO - 6



A STEEL LINER FOR COLUMN CAN BE SEEN LYING ALONG A REVISE ROTARY RIG. THESE LINERS WERE REMOVED BY CUTTING AFTER EXCAVATION OF THE CANAL.

PHOTO - 7



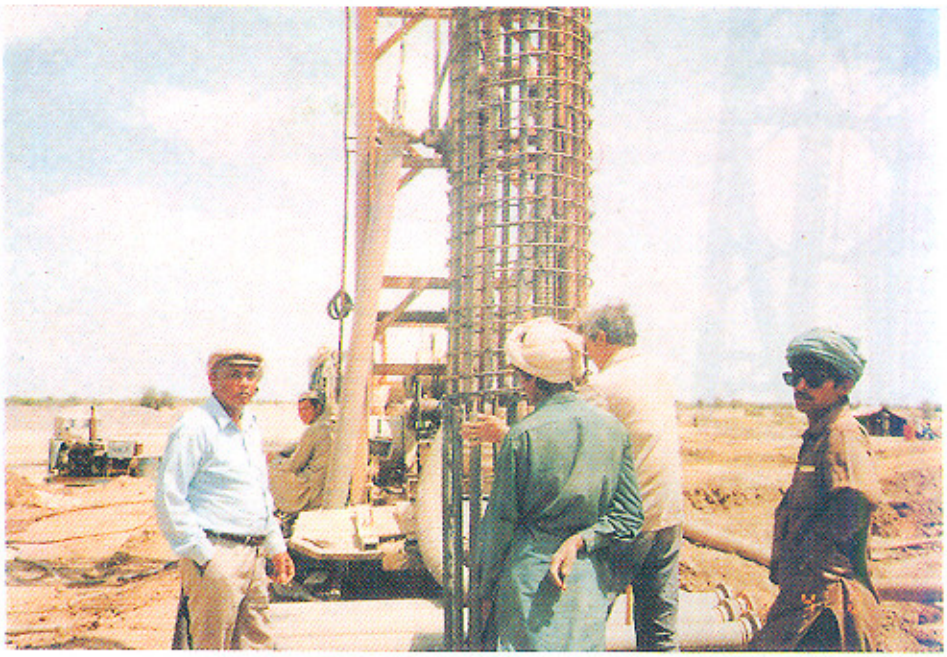
A VIEW OF A PERCUSSION RIG ENGINEER WITH SPUDDING ARM.

PHOTO - 8



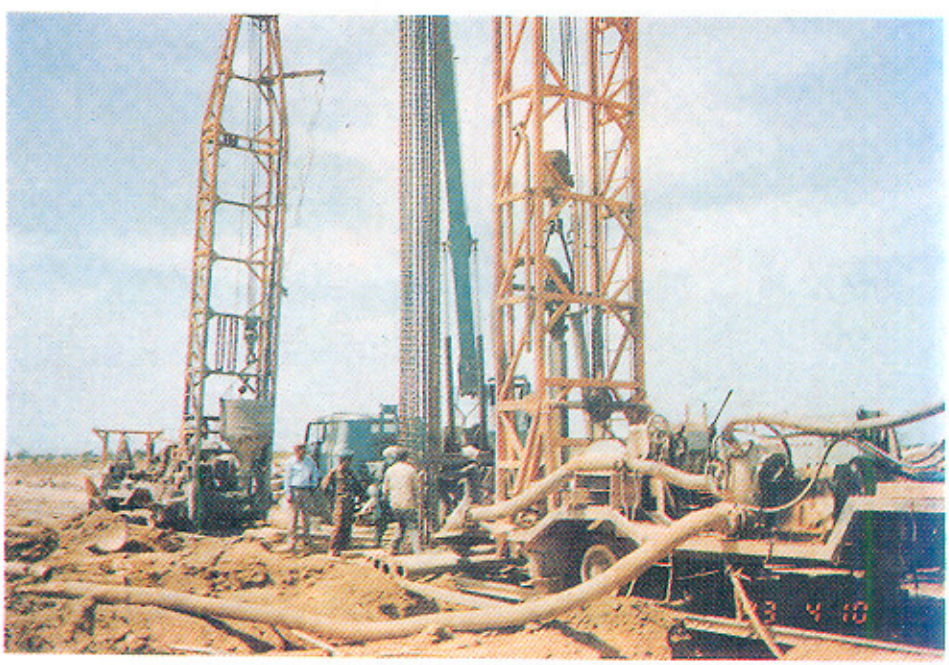
CAST - IN - SITU ENCASED CONCRETED BORED PILES READY FOR SHUTTERING TO BE LAID FOR CONCRETING CAP. ALSO PERCUSSION RIG WITH PLUNGER PIPE ATTACHED TO ONE END OF THE DRILLING CABLE.

PHOTO - 9



A REINFORCEMENT CAGE BEING LOWERED INTO THE BOREHOLE.

PHOTO - 10



A REVERSE ROTARY RIG SHOWING DETAILS OF THE ARRANGEMENTS FOR THE PILING PROCESS.

PHOTO - 11



WATER BEING PUMPED WITH THE BOREHOLE DURING DRILLING TO REMOVE LOOSENED MATERIAL OF THE UNDERLYING SOIL LAYERS. THE RIG MOVES ON RAILS.

PHOTO - 12



A GENERAL VIEW OF THE RAIL - MOUNTED REVERSE ROTARY DRILLING RIG AND ITS DERRICL. STEEL REINFORCEMENT CAGES CAN BE SEEN ON THE LEFT

PHOTO - 13



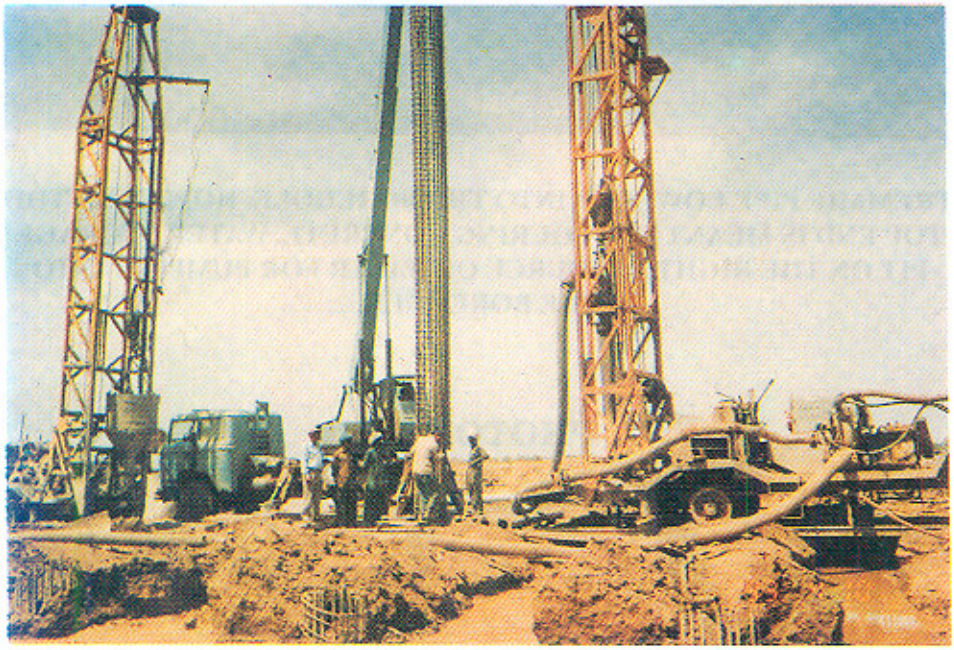
TREMMIE PIPE LOWERED INTO THE BOREHOLE. HOPPER AT THE TOP END IS MEANT FOR POURING CONCRETE. WATER STORAGE PIT ON THE RIGHT AS SOURCE OF WATER FOR PUMPING INTO THE BOREHOLE.

PHOTO - 14



TREMMIE PIPE IS BEING LOWERED INTO THE BOREHOLE. THE HOPPER IS FIXED TO THE TOP END OF THE TOP PIECE OF THE TREMMIE PIPE.

PHOTO - 15



TWO REVERSE ROTARY RIGS IN OPERATION. STEEL REINFORCEMENT CAGE IS BEING LOWERED AT ONE PLACE.