# Well Foundation Construction in Bouldery Bed Strata – A Case Study

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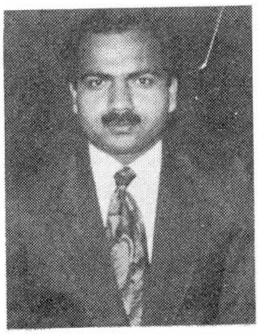


Graduated in Civil Engineering from Punjab Engineering College Chandigarh in 1986 and engaged in Bridge Construction with special experience of well foundation construction in boulderly bed using pneumatic sinking

## SUMMARY

Bridge construction in boulderly bed poses challenge for engineers firstly due to difficulties in finalization of design depth of foundation due to lack of reliable formulas in present literature, secondly during construction stage due to difficulties in sinking of well foundation even with the use of pneumatic technique as the soil strata underneath is of heterogeneous character. Construction problems faced specially during sinking of well foundation due to mismatch of soil strata anticipated by SS1 and actually encountered at site. Open grabbing, diving and pneumatic sinking is required at various location to sink the well to desired level. A case study of well foundation construction in boulderly bed has been discussed in this paper.

## Introduction

1. Bridge Construction in bouldery bed strata poses a challenge for the engineers for two basic reasons :

   (a) Due to non-availability of a proper formulae to calculate the scour depth.
   (b) Due to difficulties in construction while executing the work.

2. Most of the long span bridges are on well foundation specially, where there is a transition of the river from the hill area to the plains. Sinking of a well in such strata impedes the progress of execution due to the heterogeneous character of the soil and also due to the presence of large size boulders and wooden logs in the soil strata. A case study of well foundation construction in bouldery bed strata has been discussed in this paper.

## Well Foundation – An Overview

3. The speed of construction of a well foundation depends upon the shape of the well the soil strata available and the equipment/plant deployed for construction of a particular type of foundation. The depth of a well foundation is finalised based on the scour and structural criteria and the higher of either of the two is adopted.

## Essence of Design Parameters

4. The design parameters to be considered for a well foundation are hydraulics and soil parameters. The stratification of the soil below the proposed well foundation plays a major role while finalising the design and expediting the construction of the foundation. The hydraulic parameters considered are the silt factor, the bulk density, the angle of internal friction, the angle of wall friction and the cohesiveness of the soil. These are assessed based on the geological conditions of the strata. On assessing this data, the foundation levels are finalised. The correct assessment of the scour in soil is also very important. This is finalised based on available formulae and model studies as deemed fit and a judicious judgement of the Engineer, based on his past experience or similar structures.

## Scour Depth in Bouldery Bed Strata

5. A sample cross section of a river, as available at various locations near proposed bridge site in bouldery bed strata is indicated at Fig (1). Due to the heterogeneous character of the bed material, it is difficult to apply any formula to obtain the actual likely scour. The IRC code has also clarified, that in such situations, a judicious choice of the Engineer based on his experience on similar structures at such locations may be applied. Based on the ground conditions and the application of the formula as contained at clause 703.2.2.1 – IRC-78, the following results are generally obtained for a particular bridge scour.

| Depth of Water From HFL to LBL | Scour depth from HFL | Inference |
|---|---|---|
| H1 | DSM1 | (i) DSM 1 < H1 } Not a Practical<br>(ii) DSM 1 = H1 } case<br>(iii) DSM 1 > H1 } OK |
| DSM 1 – Mean Scour Depth | | |

6. It is further clarified that the results of DSM 1 and a silt factor have been indicated at Fig (2). Indicates that, after a silt factor `8', there is hardly any affect on DSM 1. The scour depth remains almost uniform even after an increase of the silt factor.

**Method of Well Sinking**

7. Well sinking in bouldery bed strata requires detailed planning which will vary from site to site. The soil strata obtained by the bore log must be examined. Basically, it is a guiding factor for the actual construction. A requirement for divers and pneumatic sinking can also be considered and necessary arrangements must be made to avoid any delay in the overall progress of the work.

**Conventional Sinking**

8. Conventional sinking is used for open wells. This is also known as grabbing. The material is taken out with the help of a grab. Progress in execution is expedited with kentledge if required and also with divers using jetting. Divers normally inspect the cutting edge and guide the crane operator Chiseling is also suggested if required. Explosives are also used in this technique, which results in shaking of the well and enhancing the rates of sinking. If the progress of sinking is very slow by this method, pneumatic sinking is restored to, to suit the site conditions and other related parameters.

**Pneumatic Sinking**

9. Pneumatic Sinking is resorted to in a situation, where dredging from an open well would cause loss of ground around the caisson or the soil underneath is full of boulders or the presence of clayey soil which poses problems for sinking the well. This technique is used for all types of soil, in case of bridges, where the progress of sinking by the conventional method is very very slow. This method is costlier but gives an output at a faster rate as compared to conventional sinking. Normally, on seeing the bore log details, the requirement of this technique is examined in advance and accordingly the design of the diaphragm or corbel slab and other necessary equipment for this technique are kept in readiness.

10. Penumatic sinking has the following advantages over the conventional method :

(a) The work is done in dry conditions and therefore control over the work on the foundation is better.

(b) Plumbness of the caission is easy to control as compared to the open caission method.

(c) Obstructions like boulders and logs can be removed. Excavation by blasting may be done, if necessary.

(d) Bottom plugging can be effectively done in pneumatic conditions.

## A Case Study

11. A case study of well foundation execution of a major permanent bridge over a perennial river on bouldery bed strata is now discussed. The foundation depth of this bridge was more and overall perspective of well sinking in this case was a difficult one. The subsoil consisted of large boulders of 2 to 3 mtrs in diameter in the upper strata, to a depth of about 25 mtrs and below that, the soil was of silt sand aggregate matrix. In the initial stage, open grabbing with a crane-grab was resorted to for a depth of about 12 mtrs and subsequently, the rate of sinking was 10 to 20 mm per day. To expedite the progress pneumatic sinking was adopted, which led to increase in the progress to 150-900 mm. Pneumatic sinking can only be used up to a pressure of 3.50 kg/cm2. It is difficult for a human being to work beyond this pressure as per codal provisions.

## Important Features of the Bridge

12. The important factors of the bridge were as follows :

| | | | |
|---|---|---|---|
| (a) | Length of the bridge | - | 704 Mtrs |
| (b) | Type of Bridge | - | Prestressed concrete single cell box girder of balanced cantilever construction. |

(c) <u>Foundation :</u>

| | | |
|---|---|---|
| (i) | Type | - Circular well |
| (ii) | Outer diameter | - 11.70 Mtrs |
| (iii) | Inside diameter | - 6.64 Mtrs |
| (iv) | Steining thickness | - 2.53 Mtrs |
| (v) | Well crub height | - 4.5 Mtrs |
| (vi) | Angle of cutting edge | - 33 degrees |
| (Vii) | Grade for Steining Concrete | - M25 |

## Set up of Equipment and Plant

13. The layout ensured minimum movement of material, equipment and personnel as well as proper drainage of the area. Wind conditions were taken into consideration in operation of some equipment, for example, the operation of the tower crane which was not possible in heavy winds. Supporting facilities such as generators, office stores etc. were located away from the path of the dusflow. Adequate space was provided for handling and storage of raw material as well as for finished products. Wherever practicable, a separte service road was provided for incoming material and outgoing products.

## Bore Log Details

14. Before starting the work at this location, bore log details of the location were examined and accordingly, the strategy for sinking the well foundaiton was planned. From the bore log details, it was obvious that sinking a well in the prevalent soil strata with open grabbing may not be possible due to packed bouldery strata as shown in the

Figs (3) & (4). Keeping in view, the likely strata, the bed well was designed for pneumatic pressure also.

## Conventional Sinking

15. The construction of the well foundation at location was started in Jan 1980 with the placing of the cutting edge at a ground RL of 160.735. Conventional sinking was adopted with the use of Tata Crane having a grab of 1.2 cum capacity and divers were also deployed, after reaching considerable depth, to expedite the rate of sinking. Whenever a sizeable sump was made and the cutting was cleared by divers, blasting was resorted to, which shook the well and finally led to sinking the well (Fig. 5). This work was continued till June 90 and an average rate of sinking observed during the period was approximately 7 cms per day. But the rate of sinking during the last month before suspending conventional sinking was 1 cm. It was felt that the further rate of sinking would be extremely slow and it was decided to start with pneumatic sinking.

## Pneumatic Sinking

16. Pneumatic sinking was attempted wef 4th Jul 90 at am RL of 145.360 mtrs. The steel diaphragm was placed at a gauge height of 14 mtrs. This technique was continued upto a design foundation level of 125 mtrs (Fig 6). During the course of sinking, boulders upto 2 mtrs size were encountered, which slowed down the rate of sinking, as boulders more than 50 cms size could not be taken out because of the limitation of the muck bucket. There was also a variation in the water level of the river from 153.500 mtrs to 163.00 mtrs during the year. It was obvious that the deeper the digging, grater was the pressure and progress reduced considerably which further led to increase in compression and decompression time. However, limited progress was assured in the technique. Out of a total sinking of 35.895 mtrs, 15.350 mtrs was executed through conventional means and the remaining 20.300 mtrs to 163.00 mtrs during the year. It was obvious that the deeper the digging, grater was the pressure and progress reduced considerably which further led to increase in compression and decompression time. However, limited progress was assured in this technique. Out of a tital sinking of 35.895 mtrs, 15.350 mtrs was executed through conventional means and the remaining 20.300 mtrs was by pneumatic sinking. The output of sinking depends upon various factors which include the size of the bucket, the depth of the well, the type of strata, the water head, the size of the shaft and the airlock. The team of personnel inside the working champer comprised of one Engineer, two supervisors and twenty labourers. One mtr of sinking resulted in required 110 m3 of material to be evacuated, which in turn required 440 buckets for dredging out the material, as the capacity of one bucket was 0.25 m3. The progress of work reduced with the depth of sinking. However, a percentage of acceptable progress was achieved within a specified time. The rate of sinking reduced with progressive sinking, as at an increased pressure, the progress of sinking reduced .

| SL NO. | Total Sinking achieved (Mtrs) | Average rate of sinking per day |
|---|---|---|
| 1. | Conventional Sinking : 15,350 mtrs | 7 Cms |
| 2. | Pneumatic Sinking : 20.455 mtrs | 4 Cms |
| | Total Sinking : 35.805 mtrs | |

**Bottom Plug**

17. The total sinking of 35.805 mtrs was completed and the position of the well was as under :

| | | | |
|---|---|---|---|
| (a) | Total steining from ground level | - | 35.805 mtrs |
| (b) | Total steining cast | - | 27.000 mtrs |
| (c) | Well crub height | - | 4.500 mtrs |
| (d) | Gauge height of well | - | 31/430 mtrs |

18. The last leg of sinking was completed in pneumatic sinking and it was planned to plug the well in the present condition only, as this would be helpful to remove the steel diaphragm placed inside over working chamber.

19. The concrete was transported to the airlock and subsequently to the working chamber, where it formed a part of the bottom plug. This process was repeated a number of times, as in one operation only one cubic mtr of concrete was possible. Out of total height of 5 mtrs., 2 mtrs was completed in pneumatic condition and the remaining was executed in open condition after removing the diaphragm.

**Sand Filling**

20. Sand was taken from the river and cleaned before transportation. This was finally lowered through a chute placed on the top of the steining and subsequently the top plug and the well cap were cast.

**Construction Problems**

21. The following problems were encountered during the construction of the bridge :

(a) The sinking of the well became very difficult due to the presence of large size of boulders in the strata. This led to a considerable slow down in the overall progress of the bridge.

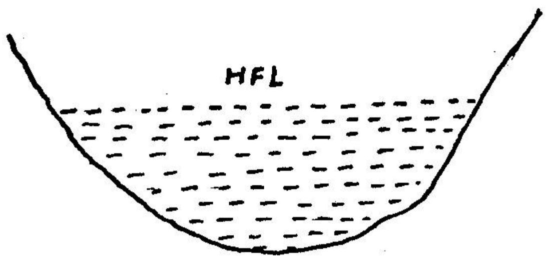
(b) Basically, there were difficulties in finally deciding the foundation level on such strata. This put the decision making body into a considerable dilemma and led to delay in progress.

(c) Due to heavy rainfall in the area, a considerably reduced working period was available in the region, which led to delay in overall completion of activities.

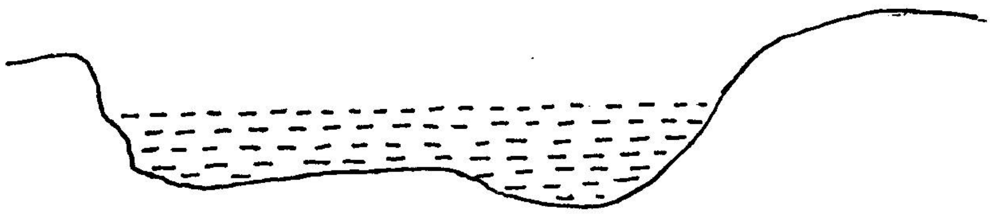
**Conclusion**

22. Construction of a well foundation in bouldery bed strata calls for a dedicated effort on the part of the executives. The data of the soil strata encountered at the site must be kept in detail for each meter and if required a review of the foundation must be carried out, based on actual soil parameters obtained during sinking.

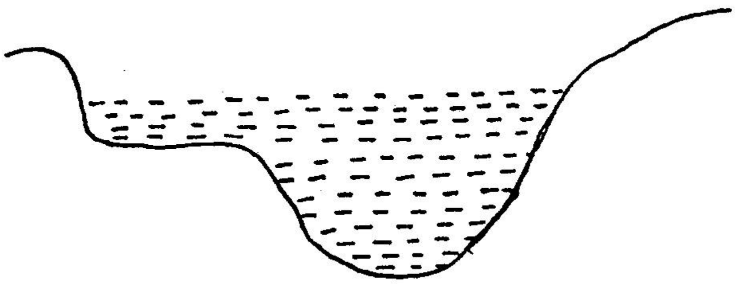
FIG 1




A. SEASONAL RIVER STEEP SLOPE NEAR HILLS



B. FLAT SLOPE



C. PERENNIAL RIVER WITH SIZABLE DISCHARGE

CROSS SECTION AVAILABLE IN BOULDERY BED

FIG 2

SILT FACTOR AND MEAN SCOUR DEPTH FOR A PARTICULAR DISCHARGE ($100\ m^3/sec/m$)

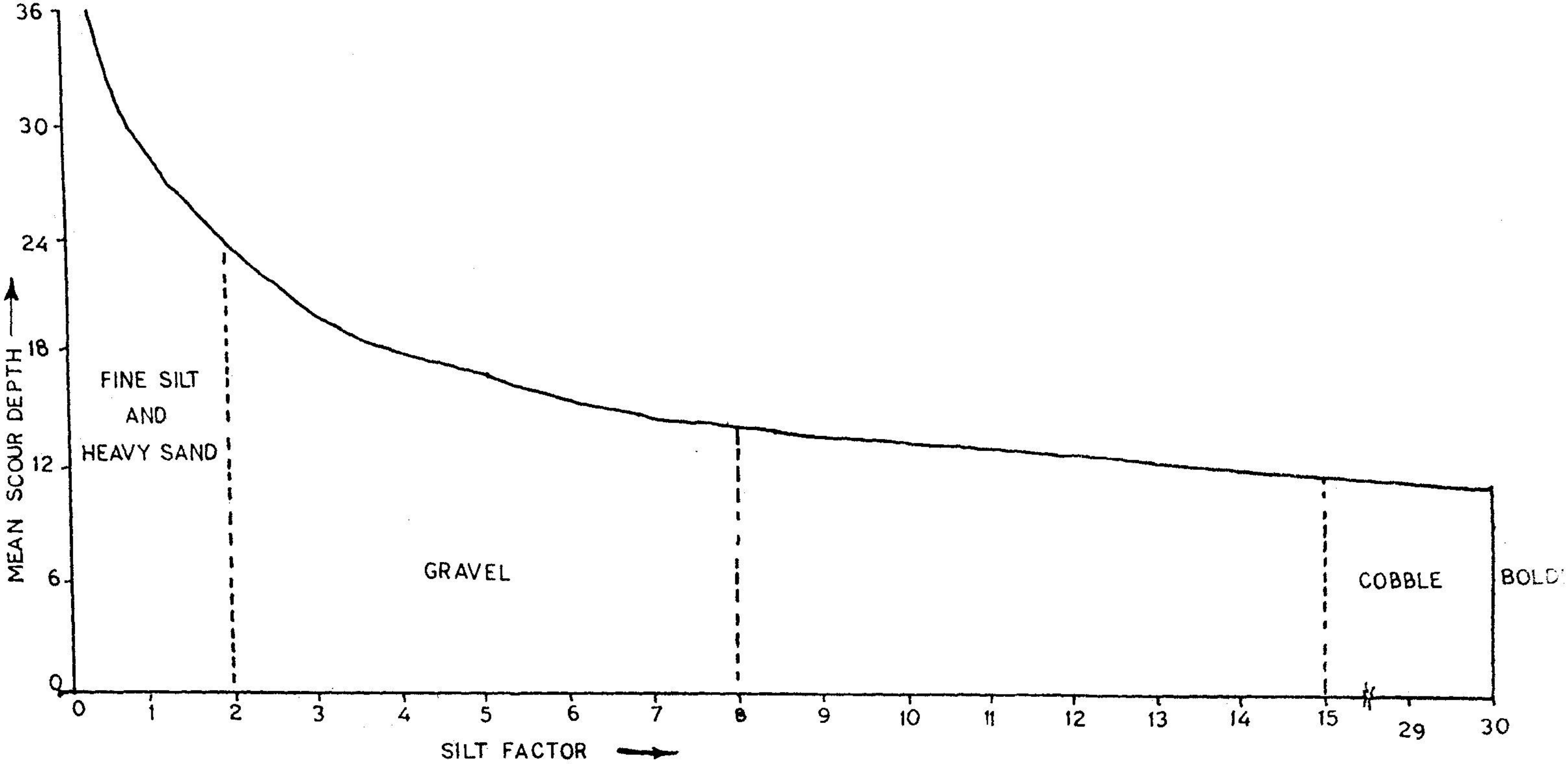


FIG 3

BORE LOG DATA

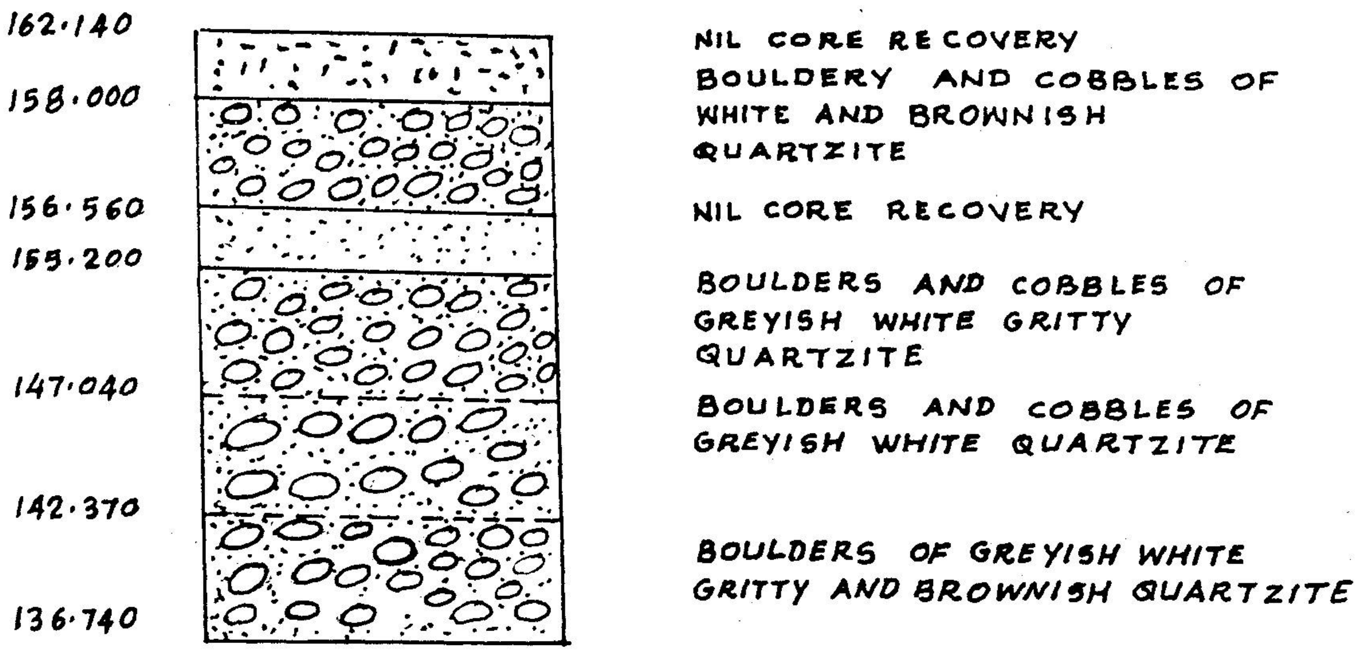


FIG 4

SOIL STRATA ENCOUNTERED

| RL | PICTORIAL DESCRIPTION | STRATA DESCRIPTION |
|---|---|---|
| 160·735 | | |
| 150·780 | | STRATA COMPRISING OF SAND SILT MIXED WITH 60% BOULDERS SIZE VARYING FROM 300 mm TO 600 mm |
| 145·360 | | SANDY SOIL MIXED WITH 60% BOULDERS SIZE VARYING FROM 300 mm TO 600 mm |
| 141·180 | | SANDY SOIL MIXED WITH BOULDERS VARYING FROM 300 mm TO 1500 mm. |
| 130·730 | | COMPACTED STRATA COMPRISING OF RED CLAYE SANDY SOIL : 40% BOULDERS UPTO 300 mm: 30% BOULDERS 300 mm TO 700 mm : 30% |

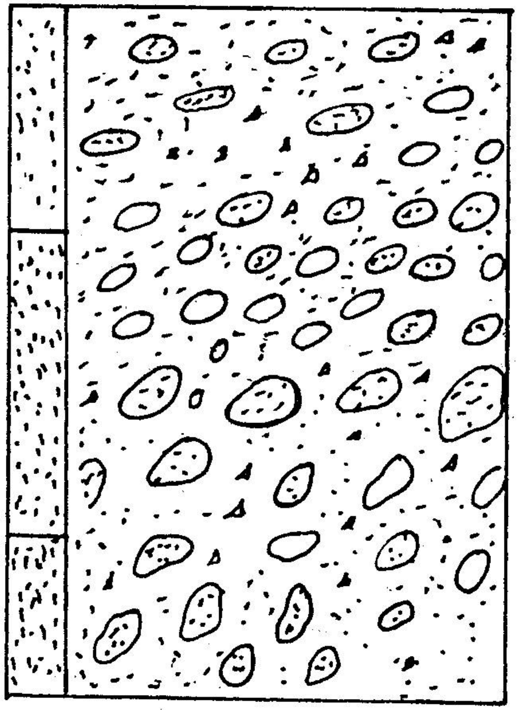
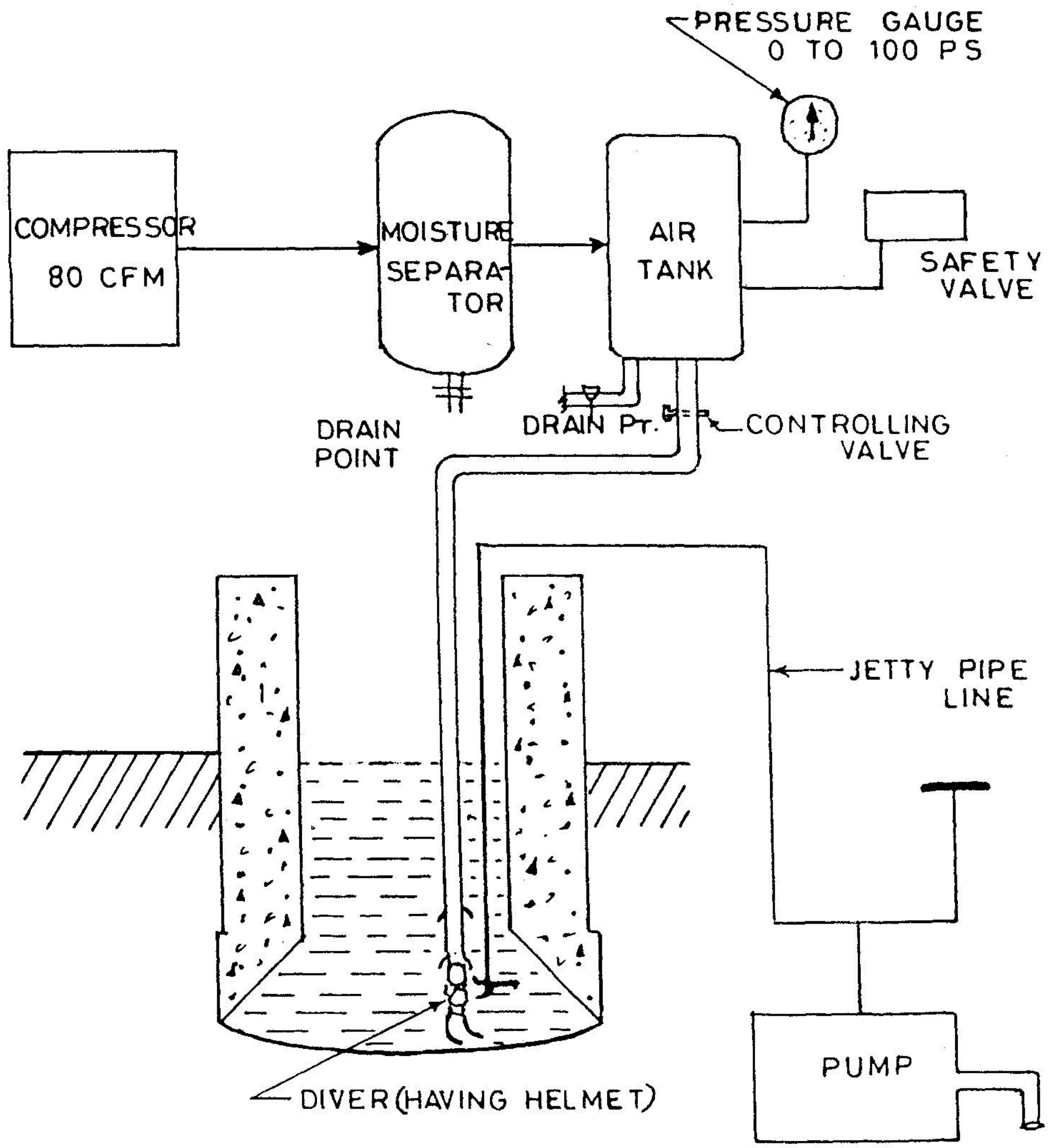
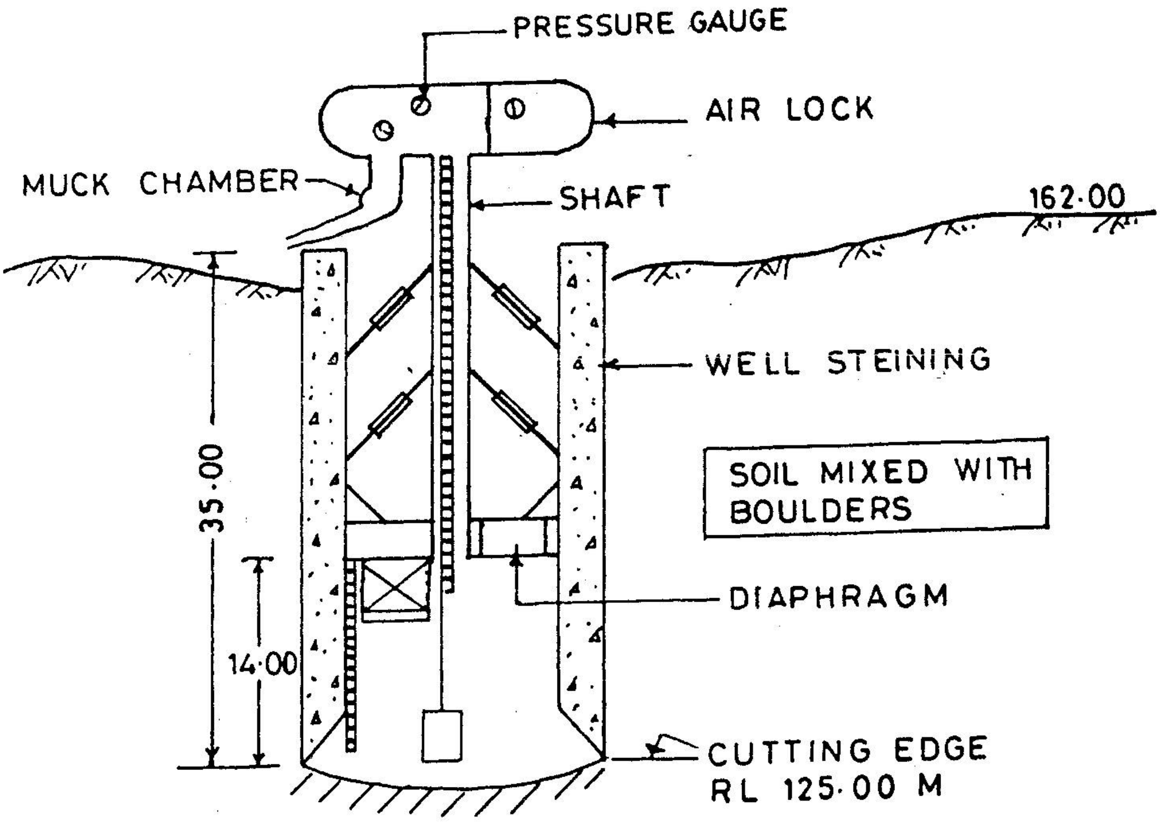


FIG 5




DIVING ACTIVITIES

FIG 6




FOUNDATION RL REACHED WITH PNEUMATIC SINKING