International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 3 March. 2024, pp: 664-669 www.ijaem.net ISSN: 2395-5252

Geotechnical Investigations in Gravelly-Bouldery Strata –A Case Study

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ABSTRACT

There are many technique which are used for geotechnical investigations into the ground. The use of different techniques for the subsurface investigations is governed by the strata type. Depending upon the project stage and strata, geophysical or geotechnical technique are used for the subsurface investigations. However, at the DPR/ construction stage, apart from the geophysical technique, geotechnical investigations is mandatory to confirm the study of the geophysical investigations. The geotechnical investigations involves drilling the bore holes in the ground and conducting various tests like Penetration tests (Standard Penetration tests, Dynamic Penetration tests, Static Cone Penetration tests), Pressuremeter tests etc, Plate load tests etc. Plate Load test are used at the surface or at shallow depths, but all these in-situ tests have limitations and application will depend upon the underground strata type.

The present papers presents a study on overburden material lying over the slopes of a hydroelectric projects. The strata contains particle sizes varying from clay to big boulders and characterizations of such strata by normal techniques was very difficult.

Key Words: Overburden Materials, Trial Pits, Direct Shear, Dry Density, Gravel and Boulders

Disclaimer: The views expressed in this paper are strictly individual views of the author and do not, in any way, represent the views of the department/organization where they are presently working.

I. INTRODUCTION

The construction of the large river valley projects results to heavy loads/stresses on the foundations. It is therefore necessary to determine foundation conditions for a safe and sound foundation design. A good foundation investigations should provide all the following information regarding the subsurface strata,

1) Sequence and extent of overburden soil underlain by boulder, gravel soil deposit which are to be affected by the proposed project.
2) Nature of matrix and boulders.
3) The amount and state of packing of the boulders, their nature (rounded or otherwise) and the size of the boulders present in the strata.
4) Whether the boulder-gravels is lying in the matrix of material or otherwise.
5) Nature of each stratum, ground water table and its possible effects on foundation material.
6) General information on geology and surface drainage, etc.
7) Location of faults, shear zone etc

In case of soil strata, the BIS: 1892-1979 describes the various techniques/methods which can be used for characterisation of the soil strata to collect all the data/information which are required for a safe and sound foundation design.

But in nature, sometime such a type of material found in river beds which neither falls in the class of soils nor in rocks but in the form of mix. of gravel -boulders. The strata may contain gravel-boulder mix in a matrix of soil in which the average size of the boulder is larger than 300 mm and it is generally mixed with fine (4.75 - 20 mm)

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to coarse (20 - 80 mm) gravels. Soils with a large quantity of gravel-boulders in soil matrix poses several problems in geotechnical investigations. The presence of large sized particles, gravel and boulders prevents the sampling by the usual methods of soil sampling. The normal method of geotechnical investigations like Penetration tests (Standard Penetration tests, Dynamic Penetration tests, Static Cone Penetration tests), Plate load tests etc. cannot be sued for characterisation the foundation strata due the limitations of these techniques. Further, the tests on disturbed samples will yield unreliable results as the natural arrangements of the grains and matrix materials disturbed. However, under such conditions the BIS: 10042–1981 describe certain methods to get the best results.

II. BEHAVIOUR OF GRAVEL-BOULDER STRATA UNDER LOAD

The behaviour of gravel-boulder deposits under load is very complex and normal method of testing generally leads to a conservative side which results in high cost of foundations. The behaviour of boulder deposits under high loads depends upon the size and quantity of gravel-boulder and also the nature and amount of the fine/filler material. If the fine/filler material exists only in the interstices/spaces of the boulder as shown in Figure-IA, the behaviour depends upon the state of packing of the boulders, their nature (rounded or suare) and the size of the boulders. On the other hand, if the boulder exists in the matrix of the fine/filler material as shown in Figure-IB, the behaviour will be governed by the size, quantity and distribution of the boulder in the fine/filler materials (IS 10042 – 1981).

When the fine/filler material is absent or lies in the interstices/spaces of the boulder, the load carrying capacity of starta will be high and the compressibility will be low. When boulders lies in the fine/filler material, there is an initial compression of strata which shall be followed by low compression. If only gravel lies in the matrix of the filler material, the behaviour is governed by the nature of the filler material (IS 10042 – 1981).
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The bouldery soil unlike ordinary soil shows certain peculiar characteristics when the boulder proportion is large (> 30 percent); the deposit shows an initial rapid compression followed by a stage where the compression is considerably low as the boulders take all the coming loads. Such kind of strata will carry the high loads with a initial compression but low compression in later stage of loading (IS 10042 – 1981).

(A) (B)

Figure 1- Gravel and Boulders in Fine Matrix/Filler Material

III. INFLUENCE OF FILLER MATERIAL

When the cobbles/boulders exist in the matrix of the fine/filler material, the properties of the matrix governs the overall behaviour of the strata although the presence of gravel/boulder shall reduce the compressibility of the matrix material to some extent as shown in Fig. 3. However when the filler material lies in the interstices/ spaces of boulders/gravels, the load carrying capacity shall be very high with a low value of compression (IS 10042 – 1981).

IV. THE PROBLEM

Geotechnical investigations was planned over the overburden material lying over the rock slopes of HRT Intakes of a hydroelectric project. The elevation of HRT was 540 m and above that, overburden material was lying over the rock slopes upto the elevation of 650 m. The overburden material contains gravels and boulders in the matrix. The percentage of gravel and boulders was more the 30 % of filler materials. The overburden materials lying over the slope material need to be characterised for the safe functioning of the HRT intake and the slope should be stable in the later stage of project.

V. METHODOLOGY ADOPTED

The overburden material lying over the rock slopes contained the gravels and boulders in the fine material/matrix. A typical grain size curve of the overburden material is presented in Figure 2. The various method of investigations were considered for the characterisation of the overburden materials per BIS: 1882 like drilling the bore holes, conducting the SPT and In-situ Permeability test, Pressuremeter tests, SCPT/DCPT were the few of options. But these methods could not be used due to the limitations of these methods, space limitations at the slopes and presence of the gravels and boulders in the matrix. Further, to perform the other tests as per BIS 10042 – 1981, the cutting of the slope and creating the space for the tests was also not the best possible option as further cutting the slope may destabilize the slope. Even Collection of the undisturbed soil samples was also not possible due to the presence of gravels and boulders in the strata. Finally it was decided that Ring and Water Displacement method should be used for the determination of the In-situ Dry Density and Moisture content and Direct Shear test shall be performed on the laboratory on the collected materials.

The Ring and Water Displacement tests was conducted at different locations of the slope from bottom to top of the slope and the material collected during the tests was graded for the laboratory investigations. The direct shear tests was conducted on the material passing 4.75 mm and 20 mm in two different sizes of shear box 60 mm x 60 mm and 300 mm x 300 mm respectively.

VI. RESULTS AND DISCUSSIONS

The Ring and Water Replacement test was conducted at various locations to determine the In-situ Dry Density test of the overburden materials. The Ring and Water Replacement test was conducted as per BIS: 2720-Part 39 and based upon the Ring and Water Replacement test results, the In-situ Dry Density and the Natural Moisture Content of the overburden materials was found to vary from 1.589 g/cc to 2.237 g/cc and 4.1 % to 13.8 % respectively.

The Direct Shear test was conducted in two different sizes of shear boxes. The materials passing through 4.75 mm was tested by shear box of size 60 mm x 60 mm and the materials passing through 20.0 mm was tested by shear box of size 300 mm x 300 mm. The Direct Shear test were conducted as per as BIS: 2720-13 and BIS: 2720-39 on the materials passing through 4.75 mm and 20.0 mm respectively.

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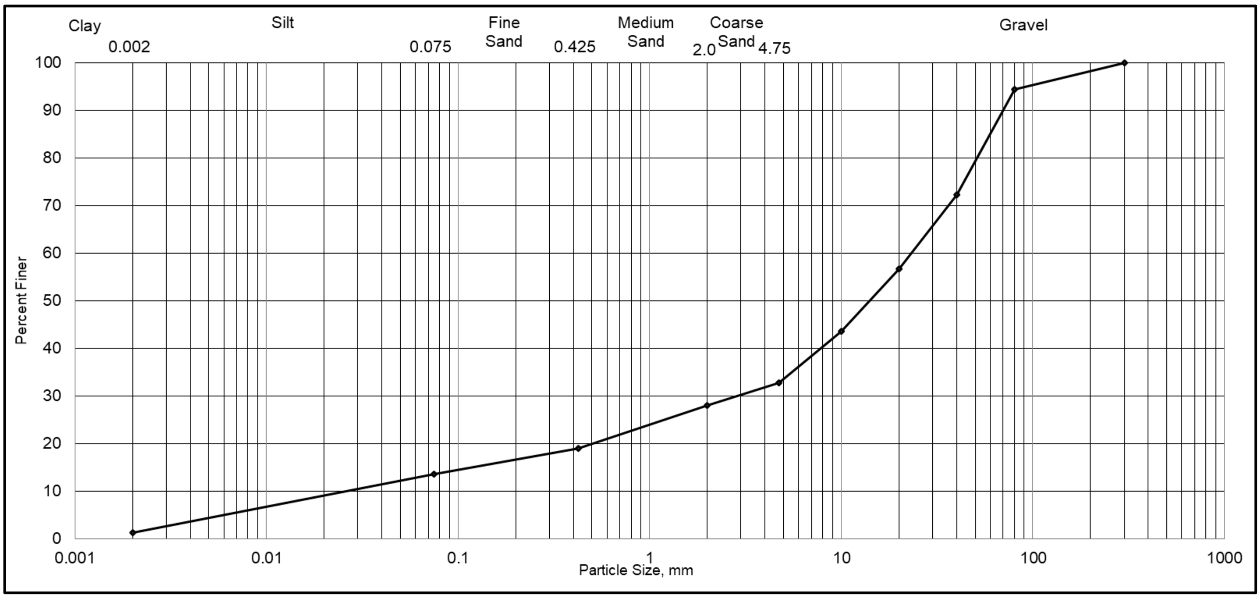

Figure 2 – Typical Grain Size Curve of the Overburden Material lying on the Rock Slopes

The soil samples were packed at the density arrived after exclusion of the particles larger than 4.75 mm in shear box of size 60 mm x 60 mm. In case of large size shear box of size 300 mm x 300 mm, the soil samples were packed at the density arrived after exclusion of the particles larger than 20.0 mm. The samples were tested under normal loads of 1, 2, 3 & 4 kg/cm^2 under saturated conditions. The typical stress-strain cures for small size shear box and large size shear box are presented in Figure 3 and Figure 4.

6.1 DIRECT SHEAR BY SMALL SIZE SHEAR BOX – 60 mm X 60 mm

The test results shows that when using the small size shear box (60 mm x 60 mm), the value of cohesion was observed nil and the angle of internal friction (ϕ) of tested materials vary from 31.2˚ to 31.9˚.

6.2 DIRECT SHEAR BY LARGE SIZE SHEAR BOX – 300 mm X 300 mm

The test results shows that when using the large size shear box (300 mm x 300 mm), the value of cohesion was observed nil and the angle of internal friction (ϕ) of tested materials vary from 33.4˚ to 33.8˚.

The test results shows that as the particle size in the matrix increases, the angle of internal friction (ϕ) also increases. The results obtained are in good agreement with the results of earlier researchers.

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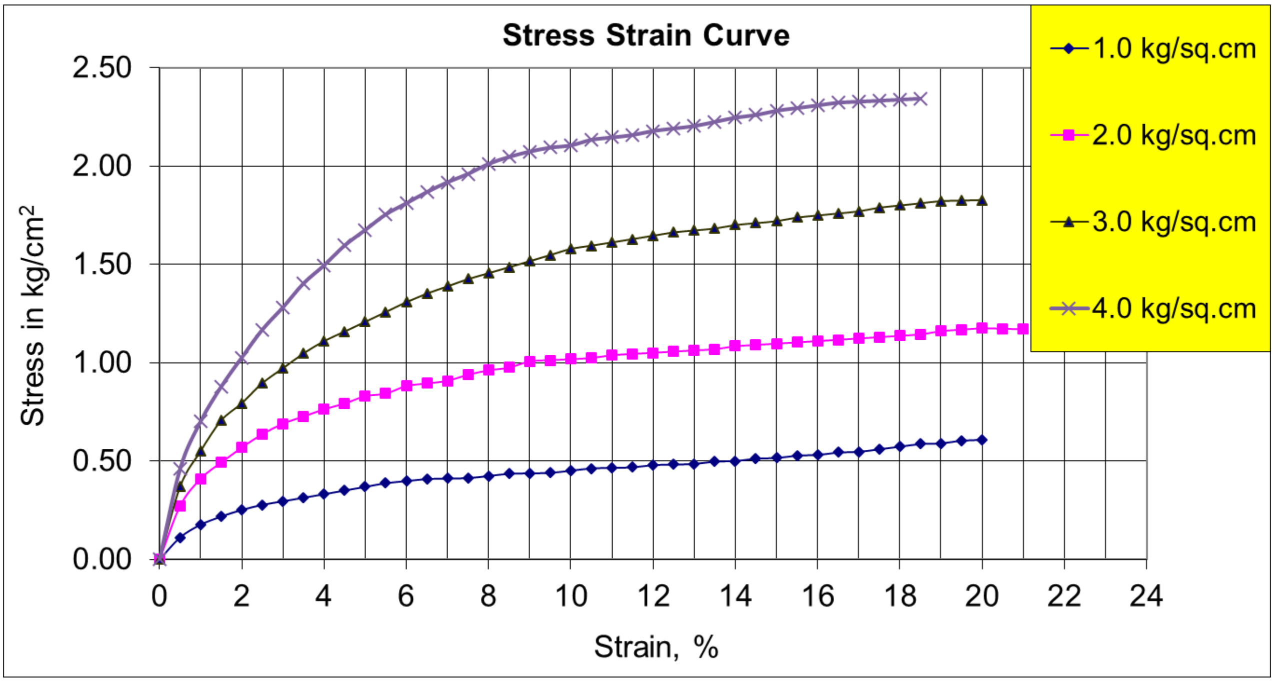

Figure 3 - Stress –Strain Curve by 60 mm x 60 mm size Shear Box

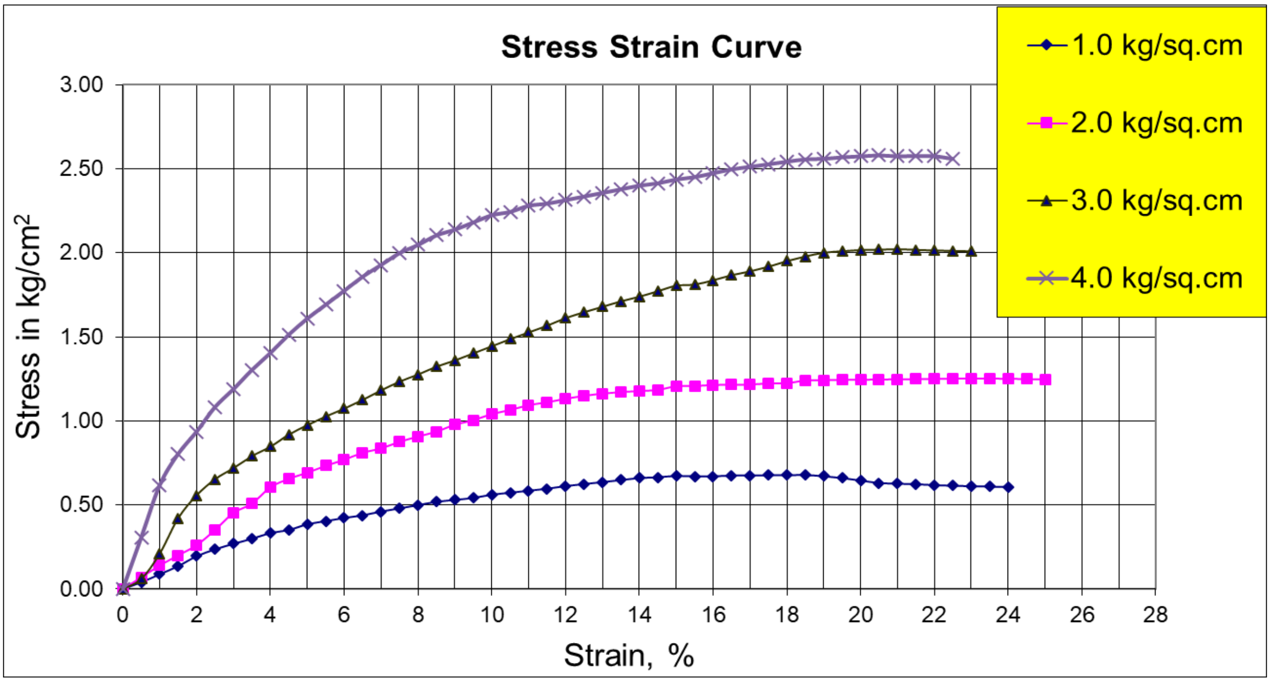

Figure 4 - Stress –Strain Curve by 300 mm x 300 mm size Shear Box

VII.CONCLUSIONS

The characterisation of foundation strata is utmost important for a safe and sound foundation design of the projects. In case of river valley projects, many a times such kind of strata is encountered which neither the soil nor the rock. The characterisation of such kind of strata with conventional technique is very difficult and the engineers need to device the special technique for characterisation of this kind strata which are good agreement of the established methods.

The present problem in which the overburden material was lying over the rock slopes of HRT Intakes of a hydroelectric project was one of the such kind of problem where the strata was neither the soil nor the rock. Efforts are made to characterise the strata with a combination of field and laboratory tests. The results obtained by the field and laboratory tests provided the input to check the stability of the overburden materials lying over the rock slopes.

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