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GEOTECHNICAL INVESTIGATIONS FOR FOUNDATION OFEARTHEN DAM OVER KAMSARATNALLAH FORWATER SUPPLY SCHEME AT ANDAMAN AND NICOBAR– A CASE STUDY

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ABSTRACT

The geotechnical investigations play an important role in economic viability and structural stability of a dam project. The geotechnical investigations for dam project involves the borrow area investigations and foundation investigations. The borrow area locations and characteristics decide the economic viability of earthen dam project. Borrow area investigations characterizes the construction material in the vicinity of dam site, depth of construction material, extent of construction material. The foundation investigations are carried out to decide the suitability of foundation and abutments for the dam project, treatment to be given to foundation and depth of excavation of foundation. The extent of foundation investigation depends upon the site conditions but it provide the information regarding type of the soil or rock strata in the foundation or abutment at dam site, depth of rock, water table and locations of buried channels, seams, joints and fissures etc. The foundation investigations decide the structural safety of a dam project.

The present paper presents the foundation investigations carried out for construction of earthen dam over Kamsarat Nallah at Wimberlygunj to supply the drinking water to near areas and villages in south Andaman.

KEY WORDS: Earthen Dam, Geotechnical Investigations, Borrow Area Investigations, Foundation Investigations, Trial Pits, Shear, Compaction, Consolidation

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.

INTRODUCTION

An earthen dam was proposed over Kamsarat Nallah near village Wimberlygunj in south Andaman to supply the drinking water to nearby areas and villages. The location of proposed earthen dam was 11°43'45" latitude and 92°43'30" longitude. The total reservoir area of proposed dam was 3851 hectare. The project envisages the construction of 18 m high and 96 m long earthen dam on Kamsarat Nallah. The Kamsart Nallah originatesfrom small hillocks and flows from east to west and takes almost right turn in the plains south of Wimberlygunj and flows almost southwest direction falling in the sea through swamp near Brigade creek. The proposed dam site is located at a U-shaped valley. The current geotechnical investigations were carried out for foundation investigations and construction materials of dam. The location of dam site is shown in Figure-1.

GEOLOGY OF THE RESERVOIR AREA

The reservoir area and area around the dam site was devoid of the rock exposures except the nallah bed and a few exposures on the slopes. The general hill slopes ranges from 30° to 45° with slight higher angle on the right bank, where as the underlying rocks shows high angle between 65° to 75°. The hill slopes were generally covered with slope wash material consisting of fragments of sandstone, siltstone and shale. In the upstream of dam, sandstone, siltstone, shale sequence of Mithakhari group of rocks was found exposed on nallah bed. The shales were black to greenish black, soft and splintery in nature. The silt stones were grey to brownish, fine grains and usually fresh. The sandstones range from fine to coarse, brownish, moderately hard and often stained on surface.

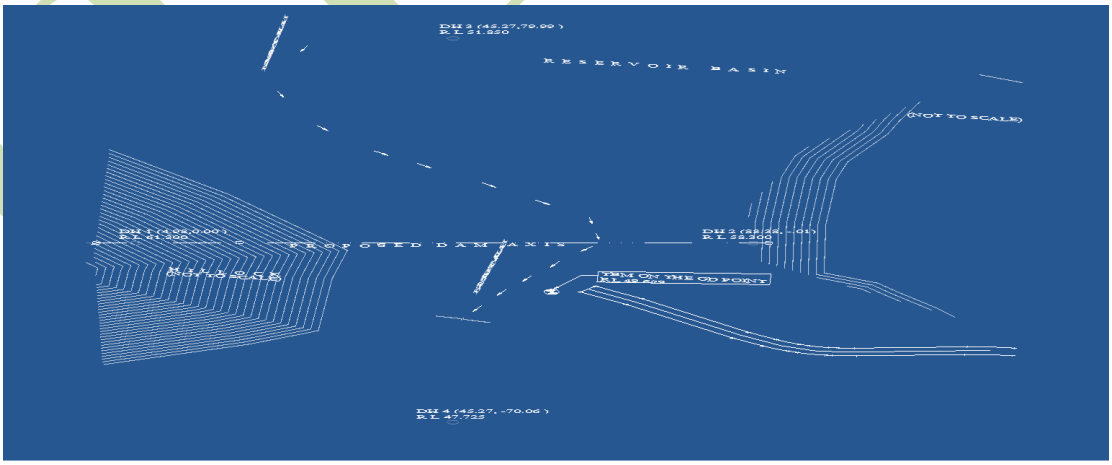


Figure -1: Location Plan showing dam axis

PLANNING OF GEOTECHNICAL INVESTIGATIONS FOR FOUNDATION INVESTIGATION OF EARTHEN DAM OVER KAMSARAT NALLAH

3.1 FOUNDATION INVESTIGATIONS

Foundation investigation is planned in such way to assess the overall foundation conditions along the dam axis, reservoir body and dam spillway. It was planned to drill the four bore holes, one bore hole each at left and right abutment and one bore in the dam body and other bore hole at the spill way location to assess the condition of foundation at the dam site. The depth of drill holes drilled varied from 12.6m to 18.0 m. The location of bore hole is shown in Figure 1. The geotechnical investigations for foundation involves conducting the Standard Penetration test and insitu permeability test at suitable interval in the drill holes and collection of disturbed and undisturbed soil samples at the various depth. The collected soil samples are tested in the laboratory to assess the foundation conditions.

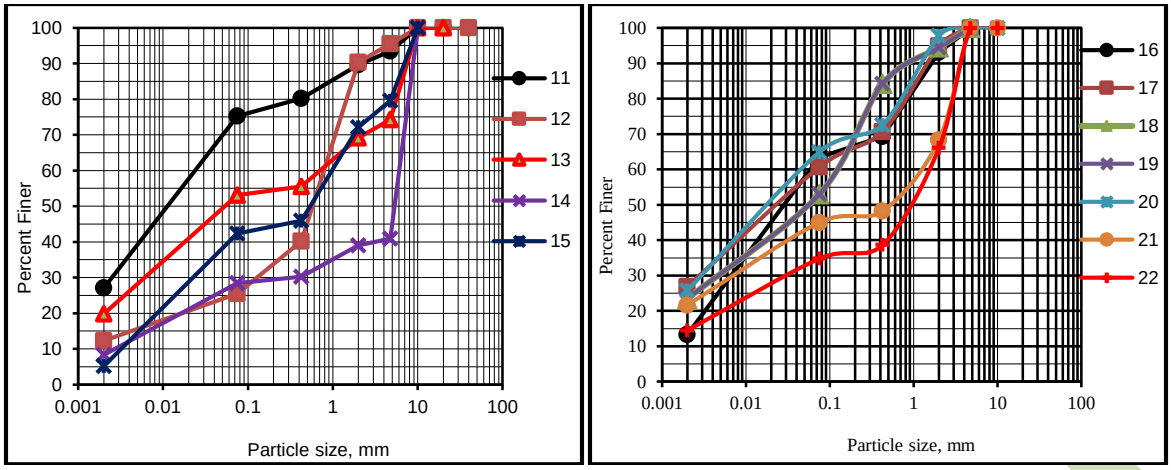
DISCUSSION OF RESULTS

4.1 Bore Hole-1

Bore hole 1 was drilled up to 12.6 m depth on the right abutment of the dam axis. The Standard Penetration Test (SPT)'N' values varied from 33 to 63 and are presented in Table 1and the value of insitupermeability varied from 1.01×10^{-3} to 5.32×10^{-3}cm/sec and the results of insitu permeability test are presented in Table 2. A total of 5 soil samples, one undisturbed and 4 SPT samples were collected from the bore hole. All the 5 soil samples were subjected to Mechanical Analysis and Atterberg's limit test. The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by medium sand sizes. The clay sizes varied from 5.2 % to 27.1 %, silt sizes varied from 13.2 % to 48.2 %, fine sand sizes varied from 1.8 % to 14.7 %, medium sand sizes varied from 8.8 % to 50.1 %, coarse sand sizes varied from 1.9 % to 7.5 % and gravel sizes varied from 4.5 % to 59.1 %. The grain size distribution of soil samples are presented in Figure 2(a). The plasticity index values of tested soil samples indicated that the tested soil samples in general possess the low to medium plasticity characteristics except two soil samples which exhibited non plasticity characteristics.

The insitu dry density of undisturbed soil samples was 1.70 g/cc and the results of insitu density test are presented in Table 3. The undisturbed soil sample was also subjected to triaxial shear test. The soil sample was sheared under four different constant effective confining pressures of 1, 2, 3 & 4 kg/cm^2 respectively after achieving the full saturation by back pressure. The value of total and effective cohesion (c & c') was observed 0.22 kg/cm^2 and 0.12 kg/cm^2 respectively and value of total and effective angle of shearing resistance (Φ & Φ')was observed 24.2° to 32.1° respectively and are presented in Table 4.

Based on the Mechanical Analysis and Atterberg limits tests, one soil samples each falls under CI (Clay of Medium Compressibility), CL (Clay of Low Compressibility), SM (Silty Sand), SC (Clayey Sand) and GM (Silty Gravel) group of Bureau of Indian Standard soil classification system. Figure 3(a) shows the log of bore hole 1.



(a) Bore Hole - 1 **(b) Bore Hole - 2**

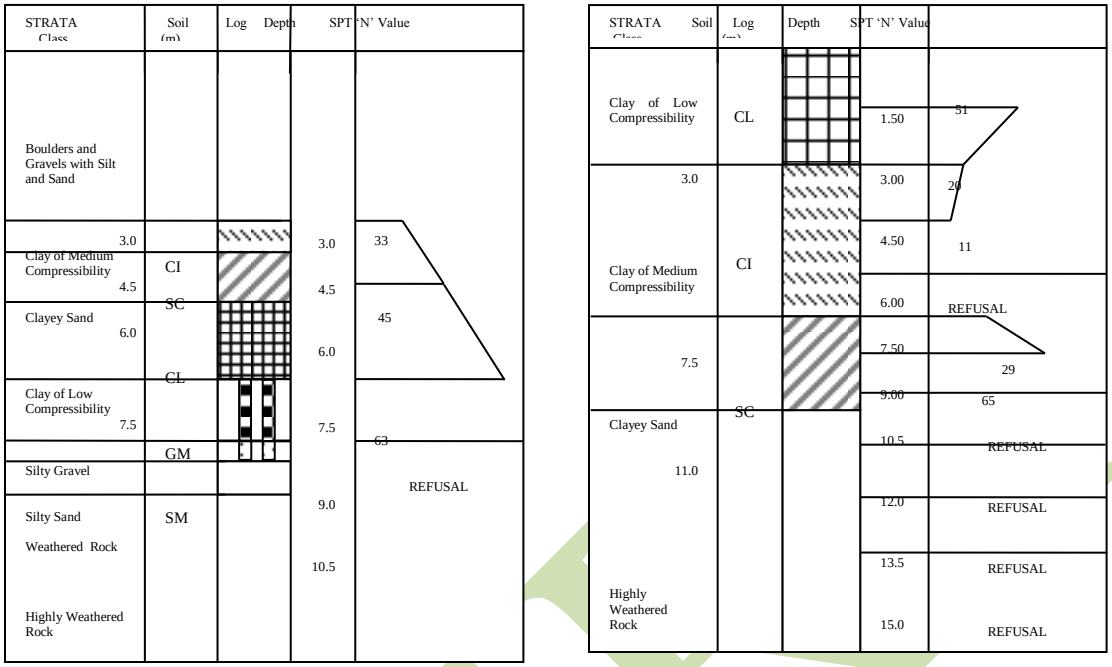
Figure 2: Grain Size Distribution Curve

BORE HOLE-2

Bore hole 2 was drilled upto 18.0 m depth on the left abutment of the dam axis. The SPT 'N' values varied from 11 to 65 and are presented in Table 1. The values of insitu permeability test varied from 2.02×10^{-2} to 5.32×10^{-5} cm/sec and the results of insitu permeability test are presented in Table 2. A total of 7 soil samples (2 undisturbed and 5 SPT samples) were collected from the bore hole. All the seven soil samples were subjected to Mechanical Analysis and Atterberg's limit test. The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by clay sizes. The clay sizes varied from 13.3 % to 31.7 %, silt sizes varied from 20.3 % to 50.1 %, fine sand sizes varied from 3.2 % to 31.2 %, medium sand sizes varied from 10.3 % to 50.4 %and coarse sand sizes varied from 2.2 % to 33.9 %. The gravel sizes were absent in the all soil samples. The grain size distribution of soil samples are presented in Figure 2(b). The plasticity index values of tested soil samples indicate that the tested soil samples in general possess the low to medium plasticity characteristics.

Based on the Mechanical Analysis and Atterberg limits tests, out of 7 tested soil samples, 4 soil samples fall under CI (Clay of Medium Compressibility), one soil sample falls under CL (Clay of Low Compressibility) and remaining 2 soil samples fall under SC (Clayey Sand) group of Bureau of Indian Standard soil classification system. Figure 3(b) shows the log of bore hole 2.

The insitu dry density of undisturbed soil samples varied from 1.89 g/cc to 2.07 g/cc and are presented in Table 3. Both the undisturbed soil samples were subjected to triaxial shear test. The soil samples were sheared under four different constant effective confining pressures of 1, 2, 3 & 4 kg/cm^2 respectively after achieving the full saturation by back pressure. The value of total and effective cohesion (c & c') varied from 0.32 $kg/cm^2$to 0.38 kg/cm^2 and 0.18 kg/cm^2 to 0.21 kg/cm^2respectively and value of total and effective angle of shearing resistance varied from (Φ & Φ') 23.6° to 24.5° and 31.2° to 31.8° respectively. The results of triaxial shear test are presented in Table 4.



(a) Bore Hole-1 **(b) Bore Hole-2**

Figure 3: Log of Bore Holes

Table 1: Standard Penetration Test Results

Depth (m)	Observed SPT 'N' Value			
	Bore Hole-1	**Bore Hole-2**	**Bore Hole-3**	**Bore Hole-4**
1.50	-	51	24	27
3.00	33	20	20	-
4.50	45	11	Refusal	Boulders encountered
6.00	63	Refusal	7	Boulders encountered
7.50	Refusal	29	56	29
9.00	-	65	13	35
10.5	-	Refusal	30	Boulders encountered
12.0	-	Refusal	24	Boulders encountered
13.5	-	Refusal	Refusal	-
15.0	-	Refusal	Refusal	-

Table 2: Insitu Permeability Test Results

Depth (m)	Coefficient of Permeability (cm/sec)			
	Bore Hole-1	**Bore Hole-2**	**Bore Hole-3**	**Bore Hole-4**
1.50	-	2.020×10^{-2}	4.040×10^{-3}	No loss
3.00	1.010×10^{-3}	No loss	8.979×10^{-4}	1.717×10^{-2}
4.50	2.056×10^{-3}	-	5.907×10^{-4}	1.772×10^{-4}
6.00	4.785×10^{-3}	2.658×10^{-4}	4.726×10^{-3}	No loss
7.50	5.316×10^{-3}	-	No loss	8.931×10^{-3}
9.00	2.835×10^{-3}	1.772×10^{-4}	2.954×10^{-3}	1.240×10^{-4}
10.5		5.316×10^{-5}	Artesian Flow	3.038×10^{-4}
12.0		4.023×10^{-3}	Artesian Flow	6.645×10^{-4}
13.5		4.785×10^{-3}	Artesian Flow	
15.0		1.152×10^{-3}	Artesian Flow	
16.5		6.202×10^{-4}	Artesian Flow	
18.0		1.772×10^{-4}	Artesian Flow	

Table 3: Insitu Density Test Results

Sample No.	Depth (m)	Insitu Bulk Density (g/cc)	Insitu Dry Density (g/cc)	Natural Moisture Content
Bore Hole - 1				
2	3.75-3.97	2.07	1.70	21.5
Bore Hole - 2				
9	5.25-5.70	2.15	1.89	13.9
10	6.75-7.20	2.39	2.07	15.3
Bore Hole - 4				
21	3.00-3.45	1.85	1.69	9.6

Table 4: Triaxial Shear Test – Consolidated Untrained with pore pressure measurement

Sample No.	Depth (m)	Triaxial Shear test – Consolidated Undrained with Pore Pressure Measurement			
		Total Shear Parameter		Effective Shear Parameter	
		c kg/cm^2	Φ Degrees	c' kg/cm^2	Φ' Degrees
Bore Hole - 1					
2	3.75-3.97	0.22	24.2°	0.12	32.1°
Bore Hole - 2					
9	5.25-5.70	0.32	24.5°	0.21	31.8°
10	6.75-7.20	0.38	23.6°	0.18	31.2°
Bore Hole - 4					
21	3.00-3.45	0.17	25.3°	0.08	32.7°

BORE HOLE-3

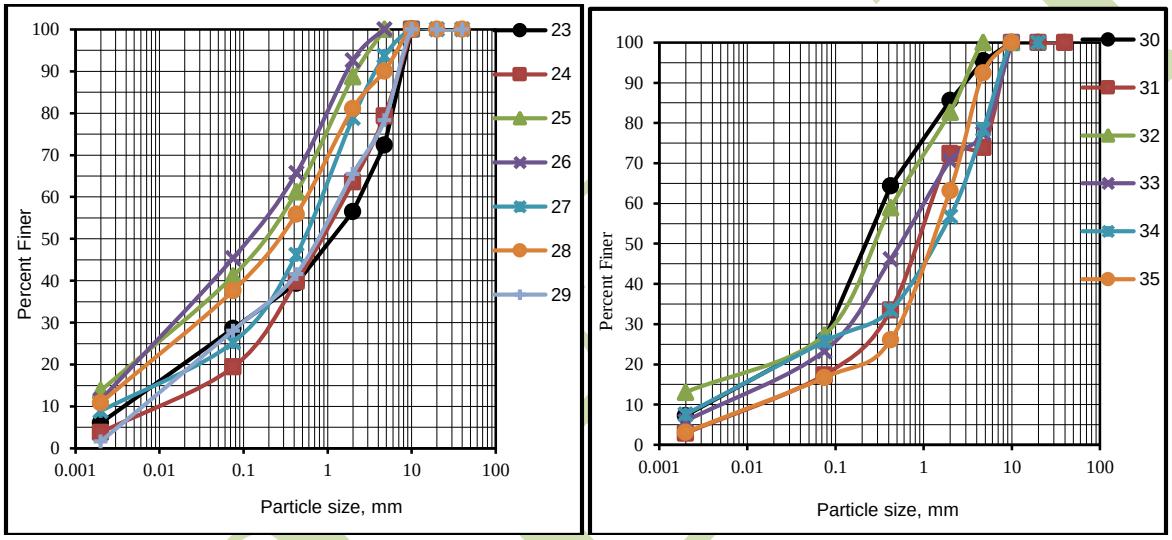
Bore hole 3 was drilled upto 15.50 m depth at the stilling basin. The SPT 'N' values varied from 7 to 56and are presented in Table 1. The values of insitu permeability varied from 4.73×10^{-3} to 5.91×10^{-4} cm/sec upto 9.0 m depth and beyond 9.00 m artesian flow was observed. The results of insitu permeability test are presented in Table 2. A total of 7 SPT soil samples were collected from the bore hole 3. All the seven soil samples were subjected to Mechanical Analysis and Atterberg's limit test. The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by medium sand sizes. The clay sizes varied from 1.6 % to 13.8 %, silt size varied from 15.6 % to 33.8 %, fine sand size varied from 10.8% to 20.9 %, medium sand sizes varied from 17.1 % to 32.7 % and coarse sand sizesvaried from 7.4 % to 15.9 %. The gravel sizes were absent in two soil samples and in remaining 5 soil samples varied from 6.3 % to 27.6 %. The grain size distribution of soil samples are presented in Figure 4(a). The plasticity index values of tested soil samples indicate that the tested soil samples in general possess the low plasticity characteristics except one soil sample which exhibit non plastic characteristics.

Based on the Mechanical Analysis and Atterberg limits tests, out of 7 tested soil samples, 6 soil samples fall under SC (Clayey Sand) and remaining one soil samples falls under SM (Silty Sand) group of Bureau of Indian Standard soil classification system. Figure 5 shows the log of bore hole3.

BORE HOLE-4

Bore hole 4 was drilled upto 15.0 m depth at the spillway location. The SPT 'N' values varied from 26 to 35 and are presented in Table 1. The values of insitu permeability varied from 1.72 ×

10^{-2} cm/sec to 1.77×10^{-5} cm/sec and the results of insitu permeability test are presented in Table 2. A total of 6 soil samples (1 undisturbed and 5 SPT samples) were collected from the bore hole 4. All the 6 soil samples were subjected to Mechanical Analysis and Atterberg's limit tests. The grain size analysis of tested soil samples indicate that tested soil samples possess predominately medium sand sizes followed by fine sand sizes. The clay sizes varied from 2.9 % to 13.1 %, silt sizes varied from 13.6 % to 18.8 %, fine sand sizes varied from 7.9 % to 38.3 %, medium sand sizes varied from 21.2 % to 38.9 % and coarse sand sizes varied from 1.5 % to 29.3 %. The gravel sizes was absent in one soil sample and in remaining 5 soil samples varied from 4.5 % to 26.1 %. . The grain size distribution of soil samples are presented in Figure 4(b). The plasticity index values of tested soil samples indicate that all the soil samples possess non plasticity characteristics except one soil sample which exhibits low plasticity characteristics.

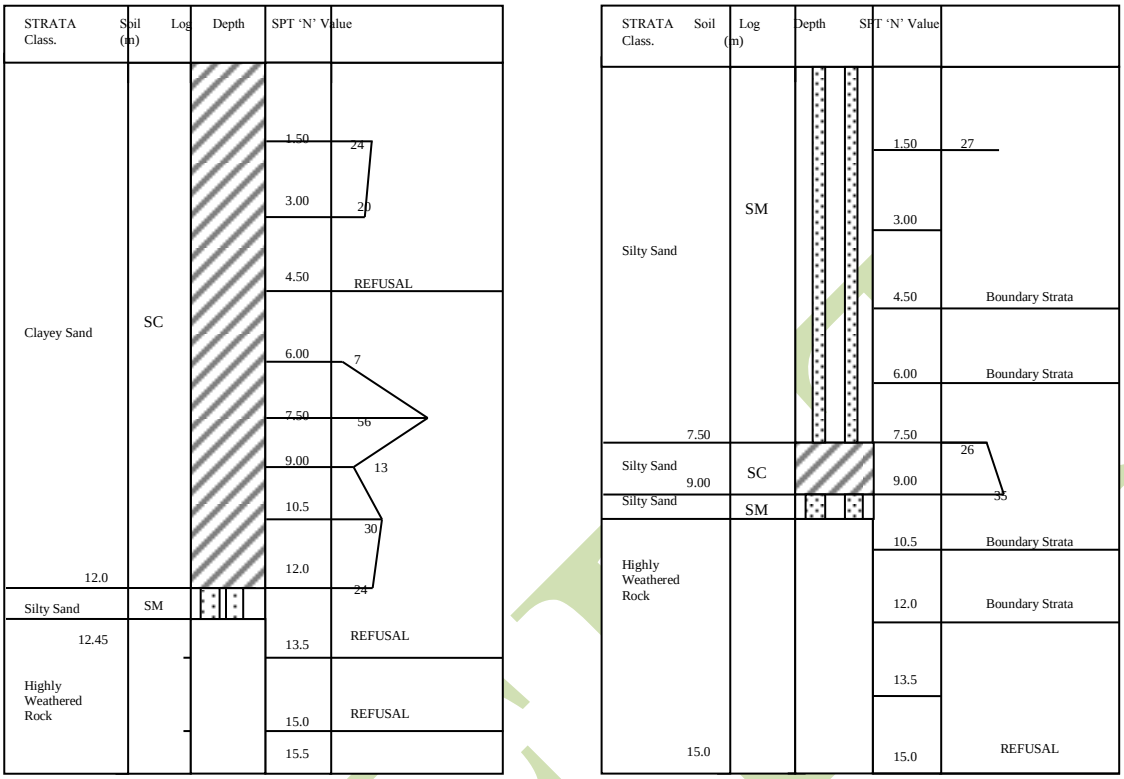


(a) Bore Hole - 3 **(b) Bore Hole - 4**

Figure 4: Grain Size Distribution Curve

Based on the Mechanical Analysis and Atterberg limits tests, out of 6 tested soil samples, 5 soil samples fall under SM (Silty Sand) and remaining one soil samples falls under SC (Clayey Sand) group of Bureau of Indian Standard soil classification system. Figure 5(b) shows the log of the bore hole - 4.

The insitu dry density soil sample collected from the bore hole 4 was 1.69 g/cc and results of insitu density test are presented in Table 3. One undisturbed soil sample was subjected to triaxial shear test.The soil samples was sheared under four different constant effective confining pressures of 1, 2, 3 & 4 kg/cm^2 respectively after achieving the full saturation by back pressure. The value of total and effective cohesion (c & c') was observed 0.17 kg/cm^2 and 0.08 kg/cm^2 respectively and value of total and effective angle of shearing resistance (Φ & Φ') was observed 25.3° to 32.7° respectively. The results of triaxial shear test are presented in Table 4.



(a)Bore Hole-3 **(b) Bore Hole-4**

Figure 5: Log of Bore Holes

CONCLUSIONS

Based upon the findings of geotechnical investigations carried out for foundation investigations for the proposed Earthen Dam over Kamsaat Nallah, Water Supply Scheme, Andaman, the following conclusions have been arrived at.

FOUNDATION INVESTIGATIONS

BORE HOLE-1

The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by medium sand sizes. The plasticity index values of tested soil samples indicate that the tested soil samples in general possess the low to medium plasticity characteristics except two soil samples which exhibits non plasticity characteristics. Based on the SPT 'N' values it may be inferred that the foundation strata in bore hole -1 posses medium to dense compactness. The value of insitu permeability tests indicates that foundation strata possess the semi pervious characteristics. The value of insitu dry density tests indicate that foundation

strata possess the medium compactness. The results of triaxial shear tests conducted on the soil samples indicate that soil samples are likely to exhibit the good shear strength characteristics.

BORE HOLE-2

The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by clay sizes. The plasticity index values of tested soil samples indicate that the tested soil samples in general possess the low to medium plasticity characteristics. Based on the SPT 'N' values it may be inferred that the foundation strata in bore hole -2 posses medium to dense compactness from the depth 1.0 m to 9.0 m and beyond 9.0 m, the foundation strata possess the very dense compactness. The value of insitu permeability tests indicates that foundation strata possess the semi- pervious characteristics. The value of insitu dry density indicates that foundation strata from 5.0 m depth to 7.50 m depth possess the medium compactness. The results of triaxial shear tests conducted on the soil samples indicate that soil samples are likely to exhibit the good shear strength characteristics.

BORE HOLE-3

The grain size analysis of tested soil samples indicate that tested soil samples possess predominately silt sizes followed by medium sand sizes. The plasticity index values of tested soil samples indicate that the tested soil samples in general possess the low plasticity characteristics except one soil sample which exhibit non plastic characteristics. Based on the SPT 'N' values it may be inferred that the foundation strata in bore hole -3 posses loose to medium compactness from the depth 0.0 m to 12.0 m and beyond 12.0 m depth, the foundation strata possess the very dense compactness. The values of insitu permeability tests indicate that foundation strata possess the semi- pervious characteristics.

BORE HOLE-4

The grain size analysis of tested soil samples indicate that tested soil samples possess predominately medium sand sizes followed by fine sand sizes. The plasticity index values of tested soil samples indicate that all the tested soil samples possess non plasticity characteristics except one soil sample which exhibit low plasticity characteristics. Based on the SPT 'N' values it may be inferred that the foundation strata posses medium to dense compactness. The values of insitu permeability tests indicate that foundation strata possess the semi- pervious characteristics. The values of insitu dry density indicate that foundation strata possess the medium compactness. The results of triaxial shear tests conducted on the soil samples indicate that foundation strata are likely to exhibit the good shear strength characteristics.

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