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Geophysical and Geotechnical Pre-Foundation Assessment of the proposed ICT center of the Olusegun Agagu University of Science and Technology, Okitipupa

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Abstract

A geophysical and geotechnical pre-foundation study on the proposed ICT center of the Olusegun Agagu University of Science and Technology (OAUSTECH), Okitipupa, was carried out to determine the suitability and competency of the subsurface soil and evaluate its engineering implications for infrastructural development. The Dipole-Dipole array, with a spacing of 5 meters, was used to investigate the subsurface lithology and its suitability for construction application in relation to the depth, thickness, and resistivity of subsurface materials. Three (3) traverses, 110 meters each, were employed. Four (4) soil samples randomly taken at depths of 0.5 meters were used to carry out geotechnical laboratory tests. The first layer resistivity ranges from 153 ohm-m – 1005 ohm-m with maximum thickness of approximately 2 meters, the second layers resistivity value ranges between 1162 ohm-m to 84965 ohm-m with corresponding thickness of 10 meters – 15 meters, and the third layer has resistivity values above 221486 ohm-m. Geotechnical analysis carried out on the soil samples obtained are Natural Moisture Content (NMC) with values between 14.1% to 14.3%, Grain Size Analysis with > 50% finer passing, Atterberg Limit Test with plastic limit ranging from 19.4% to 19.9%, Consolidation test ranging from 0.0131 – 0.0136m²/yr, Unconfined Compression (UC) Test revealing approximately 182.5Kla, Permeability test ranging from 1.33×10^{-5} cm/s to1.85×10^{-5} cm/s, and Specific Gravity (SG) of 2.648 - 2.654. Three geological layers were inferred namely; clayey sand, sandy clay and sand. From the geophysics and geotechnical it can be inferred that the study area is competent. But Excavation of soil to a depth of about 2 meter at which the soil is adequately competent (consolidated) is recommended.

Keywords: Assessment; Geophysical; Geotechnical; Dipole-dipole; Soil Competence.

I. INTRODUCTION

Geoscientists, engineers, and other professionals routinely conduct geophysical investigations and subsurface assessments for environmental remediation and other aspects of site characterization are used in engineering design and construction. [1]. In recent years, more structures have failed due to inadequate bedrock knowledge, incorrect top soil characterization, inability to determine groundwater levels, underground voids, and cavities in carbonate rocks, and soil strata competence [2]. This understanding will aid in the provision of adequate design data information as well as determining the likelihood of failure before design, and establishing the suitability of the location before building a safe, durable, and low-maintenance structure

All structures on the earth have foundations that are supported by rocks. The majority of structural failure issues are caused by a faulty foundation and poor-quality building materials. However, there is insufficient understanding of the physico-mechanical factors that determine the competency of soil-supporting engineering structures [3].

Geophysical methods are used to determine subsurface structures such as cavities, voids, sinkholes, fractures, faults, and other hazards in civil engineering structures [4]. Engineering geophysics provides detailed information on the subsoil's competence in foundation engineering [3].

Various methods of geophysical investigations/survey are frequently used to visualize the Earth's subsurface in support of subsoil investigations. Geophysical methods that are commonly used include seismic tomography, electrical resistivity, gravity, ground penetrating radar and electromagnetic [5], [6].

In the present study, geophysical and geotechnical methods of the survey were integrated into evaluating the competence of the subsoil at the proposed ICT building of the Olusegun Agagu University of Science and Technology (OAUTECH, formerly OSUSTECH), Okitipupa. The Integration approach involves geophysical investigation using the dipole-dipole array and geotechnical investigation by collecting soil samples to be analysed in a standard geotechnical laboratory. The objectives are to determine the geological parameters and nature of the lithology of the subsurface, delineate subsurface geological features and thus determine competent and incompetent layers in the subsurface.

The research area is on the permanent site of OAUTECH, Okitipupa, designated for the construction of the information technology (ICT) building with an area approximately 250 m x 145 m in size and is located between longitudes 4°3' E and 6°00' E and latitudes 5°42' N and 8°15' N. Okitipupa is located in Ondo State's Southern District, in south-western Nigeria, and it's within the Nigerian sector of the Dahomey basin. The basin is a marginal pull-apart basin formed during the early Cretaceous separation of the African and South American plates, and it is part of a network of West African pre-cratonic basins formed during the beginning of rifting [7], [8] and [9]. It stretches from South-eastern Ghana on the west to Benin Republic and Togo on the east to the Okitipupa ridge in southern Nigeria. The base map and geological map of Ondo State showing the study area is depicted in Fig. 1 and 2.

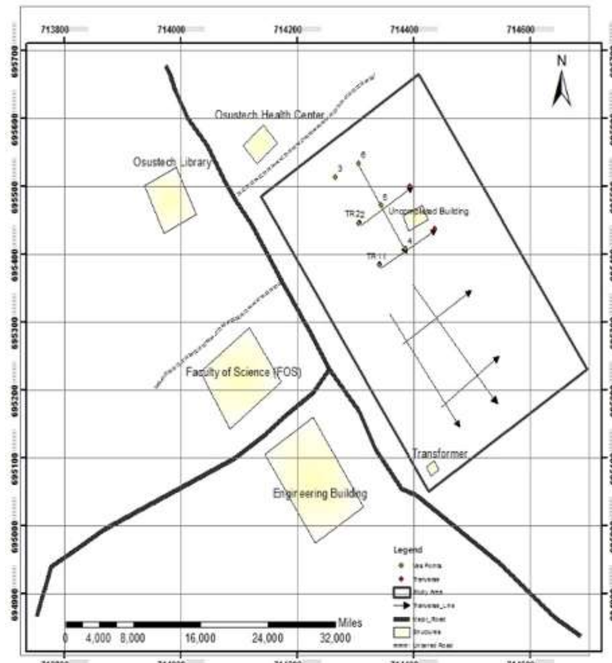


Fig. 1 Base Map of the Study Area

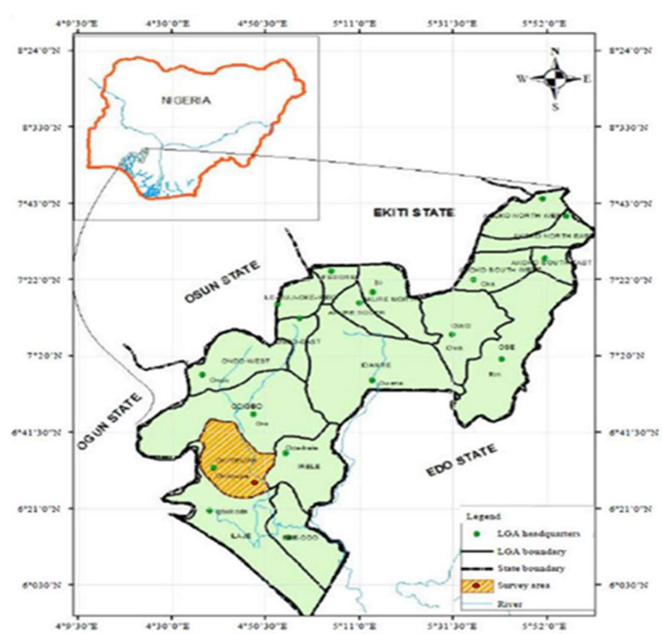


Fig. 2 Geological Map of Ondo State showing the Study Area [10].

The study area comprises undulating lowlands which characterizes the coastal sedimentary rocks of south-western

Nigeria. The drainage pattern observed in the study area is dendritic. They are characterized by irregular branching of tributary streams in many directions at almost any angle.

II. MATERIALS AND METHOD

A reconnaissance survey was carried out in the study area to acquire topographic information and the geology of the study area which is of an approximated dimension of 250 m x 145 m. The GPS reading was used to generate the base map of the study area. The electrical resistivity method of geophysical survey was carried out using the Dipole-Dipole array and three traverses were established, with a station interval of 5 meters with a Dipole level (n=5).

Soil samples obtained at four different locations within the study area were analyzed using geotechnical analysis in the laboratory.

A. Geophysical Measurements

The geoelectrical data was collected using a 12-electrode system, which allowed for automated measurements of near surface apparent resistivity using a dipole-dipole electrode array. This technique has a high horizontal resolution but suffers from a relatively low signal strength [11]. The dipoles were spaced 5m apart. Using the commercial software package DiproTM® [12], the resistivity data were processed and inverted [13]. The RMS errors were quite low due to the high quality of the processed data (less than 7 percent). The data output is used to make interpretations.

B. Geotechnical Study survey

The acquisition of soil samples for the geotechnical study involves the excavating of topsoil to a depth of 0.5m and the samples were taken randomly at these four positions, after which it was kept in a polythene bag to prevent them from being exposed to air to prevent it from losing water. The samples were later taken to the laboratory for analysis. The geotechnical tests conducted includes Natural Moisture Content (NMC), Grain size analysis, Atterberg limit tests and, Confined and Unconfined test.

1) Natural Moisture Content (NMC)

The Natural Moisture Content (NMC) of a soil is the ratio of the weight of water in a given sample to that of the dry weight of the sample. The soil mass was weighed, and a small amount of the soil sample was placed in two different cans. Each can was subsequently placed in the oven for 24 hours, and the weight was taken again to determine the dry mass of the soil sample. The NMC can be calculated as follows:

Weight of empty can = W_0 (g)

Weight of empty can + wet soil = W_1 (g)

Weight of empty can + dry soil = W_2 (g)

Weight of water in the pores of the soil = W_1- W_2 (g)

$$NMC = \frac{(W1-W0) - (W2-W0)}{(W1-W0)} \times 100 \quad (1)$$

2) Grain Size Analysis

A representative sample of oven-dried un-conglomerated soil weighing 250g was made to pass through a stack of meshes arranged according to sizes in descending order. The stack was placed in a shaker and the clamps were fixed and the time adjusted (10 to 20 minutes). The setup was left to shake and the mass of soil retained in each sieve was measured and analyzed.

3) Atterberg Limit Tests

I) Liquid Limit (LL)

A small amount of the sifted soil was mixed with distilled water, a penetrometer cup was filled with the wet sample, and a pallet was used to level the soil in the cup, the cone was later released on the soil for about five minutes and the penetration reading was taken from the gauge and recorded (in mm), the wet sample was taken using pallet knife inside the moisture content can, weighed and was placed inside the oven for 24 hours to know the mass of the dry soil, so that the moisture content can be calculated. This method was repeated three times.

The number of penetration was plotted against the moisture content and a curve is drawn through the plotted points. The curve is called the flow curve, in which the straight line is drawn to the moisture content to determine the value of the liquid limit for each sample.

4) Plastic Limit (PL)

A small quantity of soil was taken and the sample was sieved through a 425µm sieve. It was thoroughly mixed with distilled water and subsequently moulded into a ball. The soil was moulded between the palm, finger, and glass plate until the soil's heat was sufficient to cause minor cracks then the sample was divided into two subsamples was later roll between the tip of the finger and with a glass plate into 3mm diameter and was weighed immediately before it was placed inside the oven for 110^{o}C, It was weighed after dryness. The moisture content was then calculated.

5) Linear Shrinkage (LS)

The brass mould is rub with grease, after it is filled with wet soil and placed inside an oven for 48hours to determine the shrinkage which occur to the soil, which will now be measured by a meter rule after it dryness. Mathematically linear shrinkage is calculated by this expression

$$L.S\,\% = \frac{L_s}{L} \times 100 \quad (2)$$

6) Compaction Test

The soil was pulverized and sieved through the 20mm sieve and 3kg of the sample was weighed and poured into a large tray. The base plate was fixed to the mold, weighed, and recorded as M_1, later the extension collar was attached, while the mold was rubbed using oil, 8% water of the soil sample was mixed with it and was divided into 3 equal parts, then the mold was filled with the first part and 25kg hammer was used to blow at a count of 25 blows. The hammer was always in contact with the soil surface as the blow was distributed over the surface, the second and third part was done the same way but the third part was compacted very well so that it will not extend above the mold, later the extension collar was removed and straight was used to trim the soil compacted above 6 mm until is perfectly leveled with the top of the mold. The weight of the mould along with the compacted soil was taken and recorded. A portion of the soil that had been compacted and extruded from the mould was taken as a sample from both the top and the bottom for moisture content determination. To raise the water content, 2% of water was added to it. The same step was repeated about four times till the weight of the mold plus compacted soil dropped.

7) Consolidation test

When subjected to different vertical pressures, the Consolidation test is used to ascertain the magnitude and rate of volume decrease in a laterally confined soil sample. Using the measured data, the consolidation curve (pressure-void ratio relationship) can be plotted. This data can further be used to estimate the compression, recompression index and pre-consolidation pressure of the soil. Furthermore, the data can be used to calculate the soil's consolidation and secondary compression coefficients

8) Unconfined Compression (UC) Test

The soil sample was compacted into a mold and later extruded. An exact diameter of the soil at the top at three locations at an angle of 1200 apart at exact length; was also average and recorded as length. The mass of the sample was weighed. The sample was positioned and centered on the device's bottom plate, the upper plates were adjusted to make contact with the sample, and the deformation dial was set to zero. The load was applied until the load dial was decreased, and the apparatus produced axial strain at a rate between 0.5 - 2.0 percent per minute. The load and deformation dial readings were recorded. The sample was then extracted from the compression apparatus, and its moisture content was measured.

9) Specific Gravity (SG)

In the laboratory, a Pycnometer is utilized to determine the specific gravity of a soil sample. The specific gravity of a soil is utilized to determine the phase relationship between air, water, and solids within a given volume of soil.

10) Permeability Test

Permeability test (or hydraulic conductivity) is a test used to determine the rate at which water flows through a soil. It is a function of grain size, shape and voids.

III. RESULTS AND DISCUSSION

A. Geophysical field result

The Dipole-Dipole data was acquired from resistivity values taken in the South – North direction for traverse 1 and traverse 2. And the third traverse was perpendicular to them at the center (East-West direction). The inverted 2D resistivity structure sections correlated along with the current density sections along the traverses (Fig. 3-5).

Traverse 1, the 2-D resistivity structure beneath Traverse images (Fig. 3) 25m below the surface sequence. The topsoil (in blue color) has variable resistivity values of between 245 and 448 Ωm. The second layer (in green/yellow color) corresponds to the lateritic layer with resistivity values ranging from 1162 – 19949 Ωm and a depth of about 4 m. The third layer (red /purple color) corresponds to resistivity values ranging from 53745 Ωm – 412218 Ωm which is termed to be the most competent layer. It should be noted that at 35m to 50m across the traverse 1 and at a depth of 20- 30 m, a conductive body was observed which was noted for further investigation.

Traverse 2 (Fig. 4), the topsoil has a resistivity ranging from 153 Ωm – 851 Ωm showing that it is a competent bed for foundation structure. The second layer (in green/yellow color) corresponds to the lateritic layer with resistivity values ranging from 5049 Ωm – 76634 Ωm and a depth of about 3m.

Traverse 3 (Fig. 5), the resistivity values ranging from 405 Ωm -1005 Ωm at the topsoil were interpreted as clayey sand. The second layer having resistivity values ranging from 6276 Ωm – 82584 Ωm was interpreted as a competent layer.

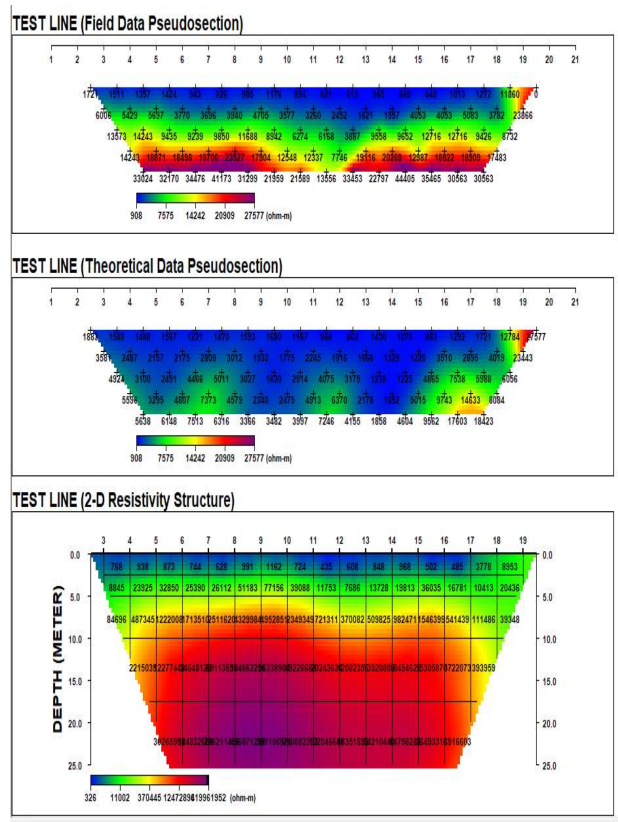


Fig. 3 2D Resistivity Section for Traverse 1 along S – N Direction

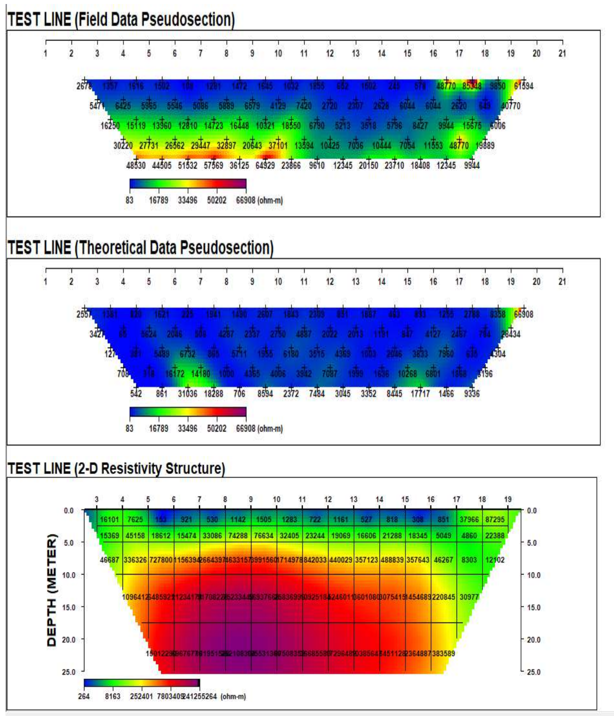


Fig. 4 2D Resistivity Section for Traverse2 along S – N Direction

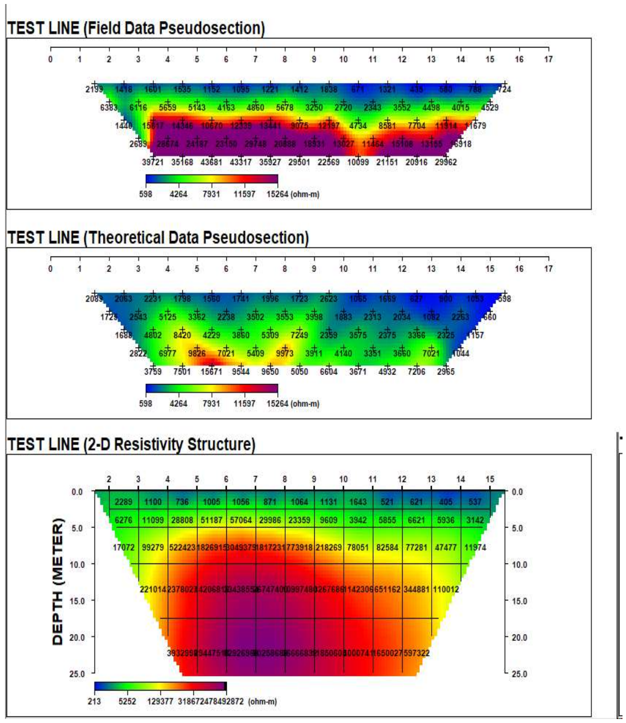


Fig. 5 2D Resistivity Section for Traverse 3 along E – W Direction

B. Geotechnical result

A geotechnical analysis was carried out so as to gain insight into the types and properties of soil materials present in the near-surface of the study area and to compare results obtained with the geophysical results. The outcomes of the geotechnical analysis conducted on the collected soil samples are displayed in tables and graphs and used as a basis of interpretation.

1) Natural Moisture Content (NMC) Results

The water content of many soils may be a fundamental index for establishing the relationship between the properties of soils and how they behave. The moisture content of fine-grained soil greatly influences its consistency. The natural moisture content of the soil sample tested in the study area ranges between 14.1% - 14.3% (Table I). The values indicates that the NMC of the soils in the area is moderately low. When the rainfall is heavy, the soil beneath the study area will not be greatly affected.

2) Consistency Limit Results

On the four soil samples, the Atterberg limits tests were performed to establish and describe their consistency, providing useful information about their strength, behavior, stability, type, and degree of consolidation [14]. As observed from Fig. 6-9, the liquid limit value ranges from 30.2 percent to 32.0 percent. The plastic limit ranges from 19.4% - 19.9%. The soil samples have low liquid and plastic limits indicating their sandy or silt nature (AASHTO classification system, 1945). The values obtained for the liquid limit and Plastic Limit of the collected samples are in the medium range (<30%) and indicate low plasticity of the soil samples. It is generally believed that soils having high values of liquid and plastic limits are not good as construction materials. The plastic index of all soil samples in the area ranges from 10.80–12.10 which is less than 20%, hence it is suitable for engineering construction [15]. The higher the Plasticity Index, the lower the competence of the soil for civil engineering construction [16]. The linear shrinkage values of the samples range from 11.0 – 12.0%. They are therefore good as construction materials.

3) Compaction Test Results

As observed from Fig. 10-13, the compaction test results of the subsoil give the Maximum Dry Density and Optimum Moisture Content of the soil samples to range from 1923 kg/cm^3 - 1946 kg/cm^3 and 14.0 % - 14.6 % respectively. The moisture-density relationship, i.e. the compaction curves, indicates the maximum bulk density to which a given force can compact the soil and the water content of the soil that is optimal for maximum compaction. According to the Unified Soil Classification System (USCS) on moisture-density relationships, the study area's soil samples fall into sandy clay and gravelly clay, which correlates with the Atterberg Limit classification and grain size distribution. This demonstrates that compaction has a gradual effect on the soil.

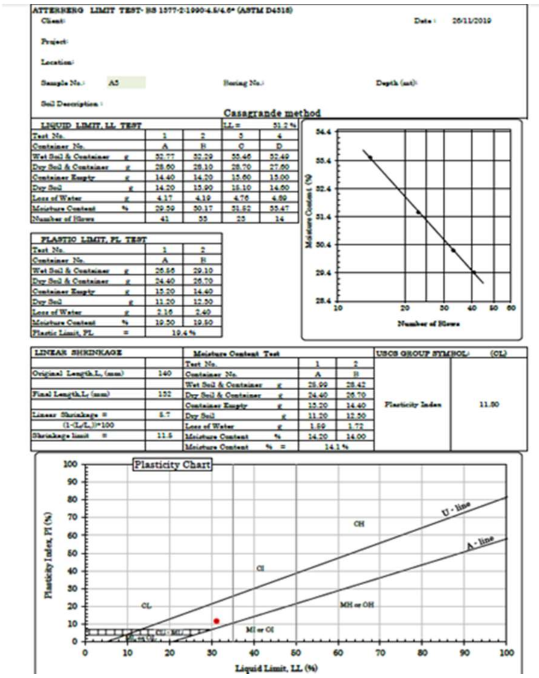


Fig. 6 Atterberg limit result for sample 1

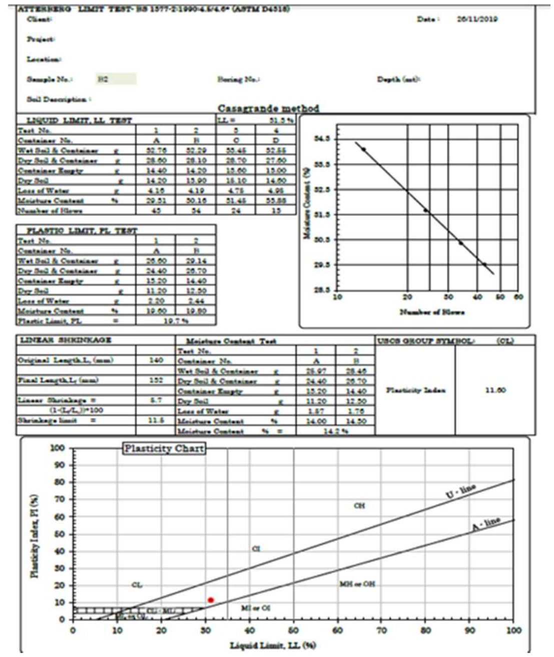


Fig. 8 Atterberg limit result for sample 3

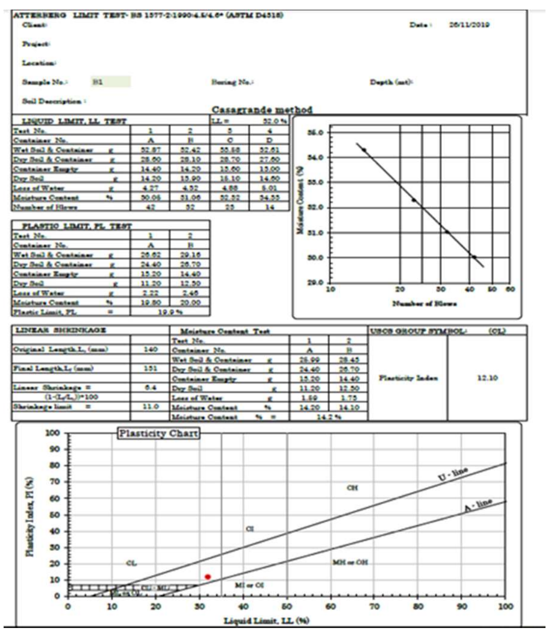


Fig. 7 Atterberg limit result for sample 2

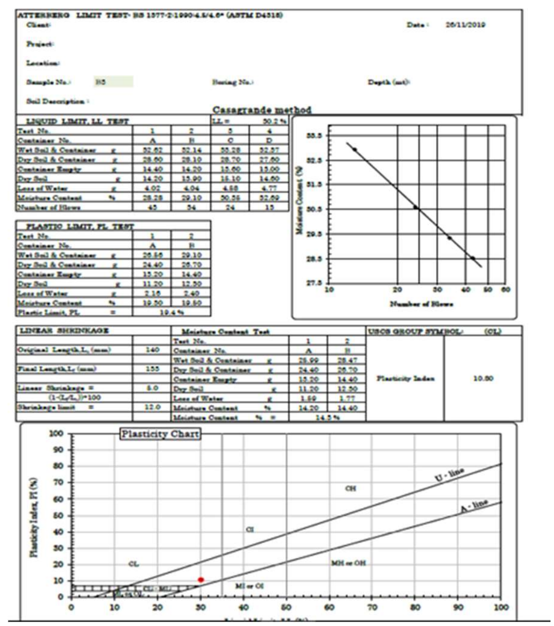
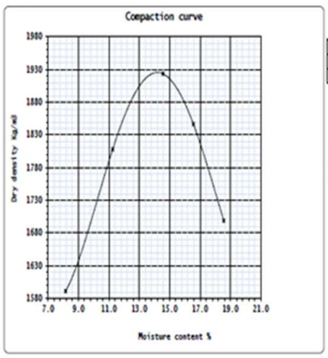


Fig. 9 Atterberg limit result for sample 4

Compaction Test										
Date: 22/11/2019										
Project:					Client:					
Sample No.: A3					Borehole No.:				Depth.:	
Compaction Method: Standard Proctor					ASTM 698					
Mould			Hammer							
Diameter: 10.16 cm			height of drop: 30.48 cm			No. Of layers: 3				
Height: 11.643 cm			weight: 2.5 kg			No. Of blows per layer: 25				
Volume: 944 cm³										
Test number	1		2		3		4		5	
Mass of Mould (g)	1525		1525		1525		1525		1525	
Mass of Mould+Compacted Soil (g)	3150		3424		3606		3558		3427	
Mass of Compacted Soil (g)	1625		1899		2081		2033		1902	
Wet Density (kg/m³)	1721		2011		2204		2152		2014	
Mass of can (g)	16.0	12.9	13.0	14.2	14.3	14.1	13.2	14.6	15.1	15.6
Mass of can+wet soil (g)	65.4	59.8	65.8	65.7	69.4	68.7	66.5	68.4	71.5	70.9
Mass of can+dry soil (g)	61.7	56.3	60.5	60.4	62.5	61.7	58.9	60.8	62.7	62.2
Mass of moisture (g)	3.7	3.5	5.3	5.3	6.9	7.0	7.6	7.6	8.8	8.7
Mass of dry soil (g)	45.7	43.4	47.5	46.2	48.2	47.6	45.7	46.2	47.6	46.6
Moisture content,%	8.2	8.1	11.1	11.4	14.4	14.7	16.7	16.4	18.4	18.7
Average moisture content,%	8.2		11.3		14.6		16.6		18.6	
Dry Density (kg/m³)	1591		1808		1923		1847		1699	

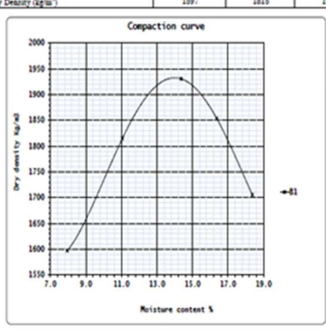


A3		Units
OMC	14.6	%
MDD	1923	kg/m³

OMC = Optimum moisture content
MDD = Maximum dry density

Fig. 10 Compaction test for sample 1

Compaction Test										
Date: 22/11/2019										
Project:					Client:					
Sample No.: B1					Borehole No.:				Depth.:	
Compaction Method: Standard Proctor					ASTM 698					
Mould			Hammer							
Diameter: 10.16 cm			height of drop: 30.48 cm			No. Of layers: 3				
Height: 11.643 cm			weight: 2.5 kg			No. Of blows per layer: 25				
Volume: 944 cm³										
Test number	1		2		3		4		5	
Mass of Mould (g)	1529		1529		1529		1529		1529	
Mass of Mould+Compacted Soil (g)	3157		3432		3614		3566		3435	
Mass of Compacted Soil (g)	1628		1903		2085		2037		1906	
Wet Density (kg/m³)	1724		2016		2208		2157		2019	
Mass of can (g)	16.0	12.9	13.0	14.2	14.3	14.1	13.2	14.6	15.1	15.4
Mass of can+wet soil (g)	65.4	59.7	65.7	65.6	69.3	68.6	66.5	68.3	71.4	70.6
Mass of can+dry soil (g)	61.7	56.3	60.5	60.4	62.5	61.7	58.9	60.8	62.7	62.0
Mass of moisture (g)	3.7	3.4	5.2	5.2	6.8	6.9	7.6	7.5	8.7	8.6
Mass of dry soil (g)	45.7	43.4	47.5	46.2	48.2	47.6	45.7	46.2	47.6	46.6
Moisture content,%	8.0	7.9	10.9	11.2	14.2	14.5	16.5	16.2	18.2	18.5
Average moisture content,%	8.0		11.1		14.4		16.4		18.4	
Dry Density (kg/m³)	1597		1815		1931		1884		1706	

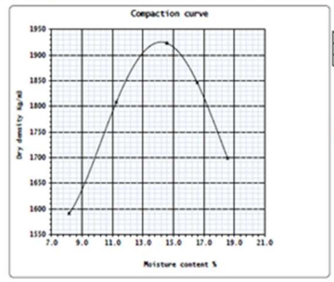


B1		Units
OMC	14.4	%
MDD	1931	kg/m³

OMC = Optimum moisture content
MDD = Maximum dry density

Fig. 11 Compaction test for sample 2

Compaction Test										
Date: 22/11/2019										
Project:					Client:					
Sample No.: B2					Borehole No.:				Depth.:	
Compaction Method: Standard Proctor					ASTM 698					
Mould			Hammer							
Diameter: 10.16 cm			height of drop: 30.48 cm			No. Of layers: 3				
Height: 11.643 cm			weight: 2.5 kg			No. Of blows per layer: 25				
Volume: 944 cm³										
Test number	1		2		3		4		5	
Mass of Mould (g)	1529		1529		1529		1529		1529	
Mass of Mould+Compacted Soil (g)	3154		3428		3610		3562		3431	
Mass of Compacted Soil (g)	1625		1899		2081		2033		1902	
Wet Density (kg/m³)	1721		2011		2204		2152		2014	
Mass of can (g)	16.0	12.9	13.0	14.2	14.3	14.1	13.2	14.6	15.1	15.6
Mass of can+wet soil (g)	65.4	59.8	65.8	65.7	69.4	68.7	66.5	68.4	71.5	70.9
Mass of can+dry soil (g)	61.7	56.3	60.5	60.4	62.5	61.7	58.9	60.8	62.7	62.2
Mass of moisture (g)	3.7	3.5	5.3	5.3	6.9	7.0	7.6	7.6	8.8	8.7
Mass of dry soil (g)	45.7	43.4	47.5	46.2	48.2	47.6	45.7	46.2	47.6	46.6
Moisture content,%	8.2	8.1	11.1	11.4	14.4	14.7	16.7	16.4	18.4	18.7
Average moisture content,%	8.2		11.3		14.6		16.6		18.6	
Dry Density (kg/m³)	1591		1808		1923		1847		1699	

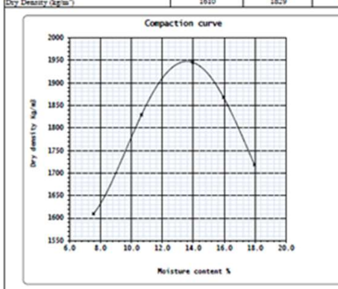


B2		Units
OMC	14.6	%
MDD	1923	kg/m³

OMC = Optimum moisture content
MDD = Maximum dry density

Fig. 12 Compaction test for sample 3

Compaction Test										
Date: 22/11/2019										
Project:					Client:					
Sample No.: B3					Borehole No.:				Depth.:	
Compaction Method: Standard Proctor					ASTM 698					
Mould			Hammer							
Diameter: 10.16 cm			height of drop: 30.48 cm			No. Of layers: 3				
Height: 11.643 cm			weight: 2.5 kg			No. Of blows per layer: 25				
Volume: 944 cm³										
Test number	1		2		3		4		5	
Mass of Mould (g)	1529		1529		1529		1529		1529	
Mass of Mould+Compacted Soil (g)	3164		3440		3623		3574		3443	
Mass of Compacted Soil (g)	1635		1911		2094		2045		1914	
Wet Density (kg/m³)	1731		2024		2217		2166		2027	
Mass of can (g)	16.0	12.9	13.0	14.2	14.3	14.1	13.2	14.6	15.1	15.6
Mass of can+wet soil (g)	65.2	59.6	65.5	65.4	69.2	68.4	66.3	68.1	71.2	70.6
Mass of can+dry soil (g)	61.7	56.3	60.5	60.4	62.5	61.7	58.9	60.8	62.7	62.2
Mass of moisture (g)	3.5	3.3	5.0	5.0	6.7	6.7	7.4	7.3	8.5	8.4
Mass of dry soil (g)	45.7	43.4	47.5	46.2	48.2	47.6	45.7	46.2	47.6	46.6
Moisture content,%	7.6	7.5	10.5	10.8	13.8	14.1	16.1	15.8	17.8	18.1
Average moisture content,%	7.6		10.7		14.0		16.0		18.0	
Dry Density (kg/m³)	1610		1829		1946		1868		1718	



B3		Units
OMC	14.0	%
MDD	1946	kg/m³

OMC = Optimum moisture content
MDD = Maximum dry density

Fig. 13 Compaction test for sample 4

4) *Grain Size Analysis Results*

The results obtained from the soil samples (Fig. 14-17) reveals that the percentage of soil passing for sieves 10, 40, and 200 range from 22.4 – 25.7%, 20.8 – 22.5%, and 51.1 – 53.3% respectively. It was observed that each soil sample exhibited >50% finer passing (sieve 200) and according to the USCS (Unified Soil Classification System), these samples are classified as clay of high plasticity (CH) and are all considered fair engineering material. There is a correlation between these results and the resistivity distribution of the topsoil within which these samples are taken. This indicates a direct relationship between the resistivity of a material and its competence to sustain the structural load [15].

GRAIN SIZE ANALYSIS

Client: Date: 26/11/2019

Project:

Location:

Borehole No. Sample No. A3 Depth, mt.:

Sieve Analysis

Particle Description		Particle Diameter (mm)	Mass Retained (g)	Retained (%)	Percent Passing (%)
		100.000			100.0
	Cobbles	75.000			100.0
GRAVEL		63.000			100.0
		37.500			100.0
		19.000			100.0
		14.000			100.0
	Coarse	9.500			100.0
		4.750	0.00	0.00	100.0
	Fine	2.360	6.20	1.42	98.6
SAND		1.180	15.60	3.56	95.0
	Coarse	0.600	27.40	6.26	88.8
		0.425	54.80	12.52	76.2
	Medium	0.300	80.40	18.36	57.9
		0.150	66.40	15.17	42.7
	Fine	0.075	32.40	7.40	35.3
FINES	Clay & Silt	<0.075	154.63	35.32	
		Sum	283.20		
		Initial wgt	437.83		

Gravel = 1.4% Gravel = 1.4%
Coarse Sand = 9.8%
Medium Sand = 30.9% Sand = 63.3%
Fine Sand = 22.6%
Fines = 35.3% Fines = 35.3%

Silt = 14.2% Clay = 21.1%

Moisture Content % = 14.2 %

Bulk weight = 500.0 g

Dry weight = 437.8 g

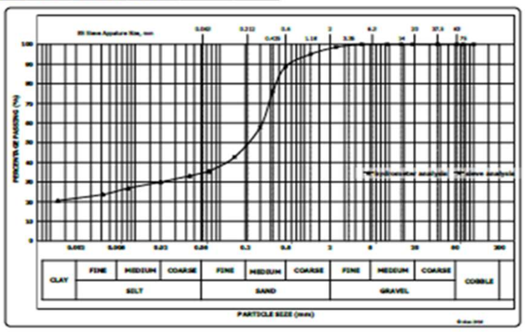


Fig. 14 Grain Size Analysis Result for Sample 1

GRAIN SIZE ANALYSIS

Client: Date: 26/11/2019

Project:

Location:

Borehole No. Sample No. B1 Depth, mt.:

Sieve Analysis

Particle Description		Particle Diameter (mm)	Mass Retained (g)	Retained (%)	Percent Passing (%)
		100.000			100.0
	Cobbles	75.000			100.0
GRAVEL		63.000			100.0
		37.500			100.0
		19.000			100.0
		14.000			100.0
	Coarse	9.500			100.0
		4.750	0.00	0.00	100.0
	Fine	2.360	5.60	1.28	98.7
SAND		1.180	16.60	3.79	94.9
	Coarse	0.600	29.20	6.67	88.3
		0.425	69.40	15.85	72.4
	Medium	0.300	76.80	17.54	54.9
		0.150	56.60	12.93	41.9
	Fine	0.075	32.80	7.49	34.4
FINES	Clay & Silt	<0.075	150.83	34.45	
		Sum	287.00		
		Initial wgt	437.83		

Gravel = 1.3% Gravel = 1.3%
Coarse Sand = 10.5%
Medium Sand = 33.4% Sand = 64.3%
Fine Sand = 20.4%
Fines = 34.4% Fines = 34.4%

Silt = 16.2% Clay = 18.3%

Moisture Content % = 14.2 %

Bulk weight = 500.0 g

Dry weight = 437.8 g

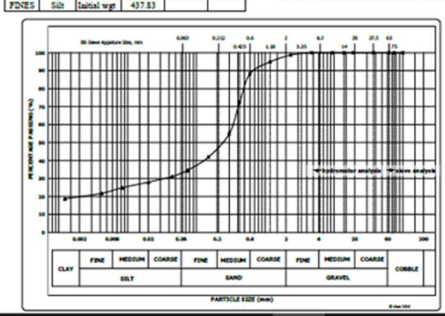


Fig. 15 Grain Size Analysis Result for Sample 2

GRAIN SIZE ANALYSIS

Client: Date: 26/11/2019

Project:

Location:

Borehole No. Sample No. B2 Depth, mt.:

Sieve Analysis

Particle Description		Particle Diameter (mm)	Mass Retained (g)	Retained (%)	Percent Passing (%)
		100.000			100.0
	Cobbles	75.000			100.0
GRAVEL		63.000			100.0
		37.500			100.0
		19.000			100.0
		14.000			100.0
	Coarse	9.500			100.0
		4.750	0.00	0.00	100.0
	Fine	2.360	5.40	1.23	98.8
SAND		1.180	15.60	3.56	95.2
	Coarse	0.600	24.80	5.65	89.6
		0.425	55.00	12.54	77.0
	Medium	0.300	80.20	18.29	58.7
		0.150	63.00	14.36	44.4
	Fine	0.075	32.60	7.43	36.9
FINES	Clay & Silt	<0.075	162.00	36.94	
		Sum	276.60		
		Initial wgt	438.60		

Gravel = 1.2% Gravel = 1.2%
Coarse Sand = 9.2%
Medium Sand = 30.8% Sand = 61.8%
Fine Sand = 21.8%
Fines = 36.9% Fines = 36.9%

Silt = 15.8% Clay = 21.2%

Moisture Content % = 14.0 %

Bulk weight = 500.0 g

Dry weight = 438.6 g

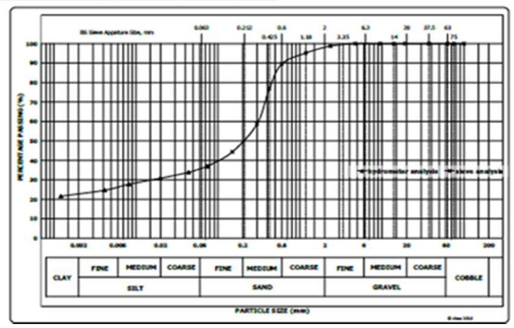


Fig. 16 Grain Size Analysis Result for Sample 3

GRAIN SIZE ANALYSIS

Client: Date: 26/11/2019

Project:

Location:

Borehole No. Sample No. B3 Depth, mt.:

Sieve Analysis

Particle Description		Particle Diameter (mm)	Mass Retained (g)	Retained (%)	Percent Passing (%)
		100.000			100.0
	Cobbles	75.000			100.0
GRAVEL		63.000			100.0
		37.500			100.0
		19.000			100.0
		14.000			100.0
	Coarse	9.500			100.0
		4.750	0.00	0.00	100.0
	Fine	2.360	5.40	1.23	98.8
SAND		1.180	14.60	3.33	95.4
	Coarse	0.600	25.20	5.76	89.7
		0.425	50.40	11.51	78.2
	Medium	0.300	82.80	18.91	59.3
		0.150	63.00	14.39	44.9
	Fine	0.075	36.60	8.36	36.5
FINES	Clay & Silt	<0.075	159.83	36.50	
		Sum	278.00		
		Initial wgt	437.83		

Gravel = 1.2% Gravel = 1.2%
Coarse Sand = 9.1%
Medium Sand = 30.4% Sand = 62.3%
Fine Sand = 22.7%
Fines = 36.5% Fines = 36.5%

Silt = 15.3% Clay = 21.2%

Moisture Content % = 14.2 %

Bulk weight = 500.0 g

Dry weight = 437.8 g

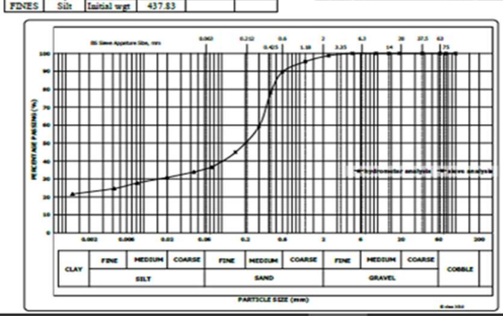


Fig. 17 Grain Size Analysis Result for Sample 4

5) Hydrometer Analysis Result

Hygrometer analysis is the process by which fine-grained soil, silts, and clay, are graded. The buoyoucous Hydrometer analysis performed on the samples to assess textural classification reveals the samples, as revealed from the results in Fig. 18-21, classified as silty sand.

Sample No. A3

Hydrometer Analysis

Composite correction, C_T = 1.0 % Passing sieve No. 200 = 35.3 % 2.65

Elapsed Time, (*T*) minutes	Actual Hydrometer Reading	Corrected hydrometer Reading	Temp. (°C)	Temperature & Specific gravity Constant, (*K*)	Effective Depth (*L*)	Particle Diameter (*D*), mm	Percent Finer (%)
0							
0.5	21.00	22.00	29	0.0123	12.69	0.0621	34.68
1	20.00	21.00	29	0.0123	12.86	0.0442	33.11
2	19.00	20.00	29	0.0123	13.02	0.0315	31.53
5	18.00	19.00	29	0.0123	13.19	0.0200	29.95
15	17.00	18.00	29	0.0123	13.35	0.0116	28.38
30	16.00	17.00	29	0.0123	13.51	0.0083	26.80
60	15.00	16.00	29	0.0123	13.68	0.0059	25.22
120	14.00	15.00	29	0.0123	13.84	0.0042	23.65
240	13.00	14.00	29	0.0123	14.01	0.0030	22.07
1440	12.00	13.00	29	0.0123	14.17	0.0012	20.50

Ws = 63.7 g

Fig. 18 Hydrometer Analysis Result for Sample 1

Sample No. B1

Hydrometer Analysis

Composite correction, C_T = 1.0 % Passing sieve No. 200 = 34.4 % 2.65

Elapsed Time, (*T*) minutes	Actual Hydrometer Reading	Corrected hydrometer Reading	Temp. (°C)	Temperature & Specific gravity Constant, (*K*)	Effective Depth (*L*)	Particle Diameter (*D*), mm	Percent Finer (%)
0							
0.5	20.00	21.00	29	0.0123	12.86	0.0626	32.65
1	19.00	20.00	29	0.0123	13.02	0.0445	31.09
2	18.00	19.00	29	0.0123	13.19	0.0317	29.54
5	17.00	18.00	29	0.0123	13.35	0.0202	27.98
15	16.00	17.00	29	0.0123	13.51	0.0117	26.43
30	15.00	16.00	29	0.0123	13.68	0.0083	24.87
60	14.00	15.00	29	0.0123	13.84	0.0059	23.32
120	13.00	14.00	29	0.0123	14.01	0.0042	21.77
240	12.00	13.00	29	0.0123	14.17	0.0030	20.21
1440	11.00	12.00	29	0.0123	14.33	0.0012	18.66

Ws = 64.6 g

Fig. 19 Hydrometer Analysis Result for Sample 2

Sample No. B2

Hydrometer Analysis

Composite correction, C_T = 1.0 % Passing sieve No. 200 = 36.9 % 2.65

Elapsed Time, (*T*) minutes	Actual Hydrometer Reading	Corrected hydrometer Reading	Temp. (°C)	Temperature & Specific gravity Constant, (*K*)	Effective Depth (*L*)	Particle Diameter (*D*), mm	Percent Finer (%)
0							
0.5	22.00	23.00	29	0.0123	12.53	0.0617	35.42
1	21.00	22.00	29	0.0123	12.69	0.0439	33.88
2	20.00	21.00	29	0.0123	12.86	0.0313	32.34
5	19.00	20.00	29	0.0123	13.02	0.0199	30.80
15	18.00	19.00	29	0.0123	13.19	0.0116	29.26
30	17.00	18.00	29	0.0123	13.35	0.0082	27.72
60	16.00	17.00	29	0.0123	13.51	0.0059	26.18
120	15.00	16.00	29	0.0123	13.68	0.0042	24.64
240	14.00	15.00	29	0.0123	13.84	0.0030	23.10
1440	13.00	14.00	29	0.0123	14.01	0.0012	21.56

Ws = 65.2 g

Fig. 20 Hydrometer Analysis Result for Sample 3

Sample No. B3

Hydrometer Analysis

Composite correction, C_T = 1.0 % Passing sieve No. 200 = 36.5 % 2.65

Elapsed Time, (*T*) minutes	Actual Hydrometer Reading	Corrected hydrometer Reading	Temp. (°C)	Temperature & Specific gravity Constant, (*K*)	Effective Depth (*L*)	Particle Diameter (*D*), mm	Percent Finer (%)
0							
0.5	22.00	23.00	29	0.0123	12.53	0.0618	35.46
1	21.00	22.00	29	0.0123	12.69	0.0440	33.91
2	20.00	21.00	29	0.0123	12.86	0.0313	32.37
5	19.00	20.00	29	0.0123	13.02	0.0199	30.83
15	18.00	19.00	29	0.0123	13.19	0.0116	29.29
30	17.00	18.00	29	0.0123	13.35	0.0082	27.75
60	16.00	17.00	29	0.0123	13.51	0.0059	26.21
120	15.00	16.00	29	0.0123	13.68	0.0042	24.67
240	14.00	15.00	29	0.0123	13.84	0.0030	23.12
1440	13.00	14.00	29	0.0123	14.01	0.0012	21.58

Ws = 65.2 g

Fig. 21 Hydrometer Analysis Result for Sample 4

6) Specific Gravity Result

From the soil sample obtained (Fig. 22-25), Sample number one has a specific gravity of 2.652, sample number two has a specific gravity of 6.52, sample number three has a specific gravity of 2.654, and sample number four has a specific gravity of 2.648. The sample has a specific gravity range of 2.648 - 2.654, indicating that it is a silty-sand.

SPECIFIC GRAVITY, SG TEST

		A3		
Test Number		1	2	3
Mass of empty jar + lid,	M_1	495.00	495.00	495.00
Mass of jar + lid + oven dry soil,	M_2	548.20	540.90	553.60
Mass of jar + lid + soil + water,	M_3	1044.25	1039.73	1047.69
Mass of jar + lid + water only,	M_4	1011.14	1011.14	1011.14
Mass of soil,	$(M_2 - M_1)$	53.20	45.90	58.60
Mass of equivalant Vol. Of water,		20.09	17.31	22.05
	$(M_4 - M_1) - (M_3 - M_2)$			
Specific gravity, SG =		2.648	2.652	2.657
	$[(M_2 - M_1)/((M_4 - M_1) - (M_3 - M_2))]$			
Average specific gravity SG =		2.652		

Fig. 22 Specific Gravity analysis for sample 1

SPECIFIC GRAVITY, SG TEST

		B1		
Test Number		1	2	3
Mass of empty jar + lid,	M_1	495.00	495.00	495.00
Mass of jar + lid + oven dry soil,	M_2	548.20	540.90	553.60
Mass of jar + lid + soil + water,	M_3	1044.30	1039.74	1047.61
Mass of jar + lid + water only,	M_4	1011.14	1011.14	1011.14
Mass of soil,	$(M_2 - M_1)$	53.20	45.90	58.60
Mass of equivalant Vol. Of water,		20.04	17.30	22.13
	$(M_4 - M_1) - (M_3 - M_2)$			
Specific gravity, SG =		2.655	2.653	2.648
	$[(M_2 - M_1)/((M_4 - M_1) - (M_3 - M_2))]$			
Average specific gravity SG =		2.652		

Fig. 23 Specific Gravity analysis for sample 2

SPECIFIC GRAVITY, SG TEST

	B2		
Test Number	1	2	3
Mass of empty jar + lid, M_1	495.00	495.00	495.00
Mass of jar + lid + oven dry soil, M_2	548.20	540.90	553.60
Mass of jar + lid + soil + water, M_3	1044.28	1039.75	1047.65
Mass of jar + lid + water only, M_4	1011.14	1011.14	1011.14
Mass of soil, $(M_2 - M_1)$	53.20	45.90	58.60
Mass of equivalant Vol. Of water,	20.06	17.29	22.09
$(M_4 - M_1) - (M_3 - M_2)$			
Specific gravity, SG =	2.652	2.655	2.653
$[(M_2 - M_1)/((M_4 - M_1) - (M_3 - M_2))]$			
Average specific gravity SG =	2.654		

Fig. 24 Specific Gravity analysis for sample 3

SPECIFIC GRAVITY, SG TEST

	B3		
Test Number	1	2	3
Mass of empty jar + lid, M_1	495.00	495.00	495.00
Mass of jar + lid + oven dry soil, M_2	548.20	540.90	553.60
Mass of jar + lid + soil + water, M_3	1044.23	1039.71	1047.64
Mass of jar + lid + water only, M_4	1011.14	1011.14	1011.14
Mass of soil, $(M_2 - M_1)$	53.20	45.90	58.60
Mass of equivalant Vol. Of water,	20.11	17.33	22.10
$(M_4 - M_1) - (M_3 - M_2)$			
Specific gravity, SG =	2.645	2.649	2.651
$[(M_2 - M_1)/((M_4 - M_1) - (M_3 - M_2))]$			
Average specific gravity SG =	2.648		

Fig. 25 Specific Gravity analysis for sample 4

7) *Permeability Results*

The results obtained from the permeability test, as revealed in Fig. 26-29, on the samples show that the permeability rates range from $1.33 \times 10^{-5}\ cm/s$ to $1.85 \times 10^{-5}\ cm/s$, indicating a very low rate of water flow through the soil.

COEFFICIENT OF PERMEABILITY (Falling Head)

Project: Sample No.: A1

Soil Description :

Tested by: Date : 26/11/2019

Sample Dimensions: Diam. 10.2 cm; Area,A 81.75 cm² Vol. 915.55 cm³ Ht.L 11.2 cm

Standpipe = Burette (50 ml) Diam. 1.06 cm Area,a 0.883 cm²

Test no.	h_1, cm	h_2, cm	t, s	Q_{in} cm³	Q_{out} cm³	T, °C	Test no.	h_1, cm	h_2, cm	t, s	T, °C
1	80	60	1734		17.66	28	1	80	60	1734	28
2	80	60	1740		17.66	28	2	80	60	1740	28
3	80	60	1746		17.66	28	3	80	60	1746	28
4	80	60	1740		17.66	28	4	80	60	1740	28
						Average		80	60	1740	28

$\alpha = \eta_T/\eta_{20} =$ 0.8287

$k_T = (aL/At)\ln(h_1/h_2) =$ 2.00E-05 = 0.0000199983 cm/s

$k_{20} = \alpha k_T =$ 1.66E-05 = 0.0000165723 cm/s

Degree of Permeability: Low (Soil testing for Engineerers by T. William Lambe, 1951)

Fig. 26 Permeability test for sample 1

COEFFICIENT OF PERMEABILITY (Falling Head)

Project: Sample No.: B1

Soil Description :

Tested by: Date : 26/11/2019

Sample Dimensions: Diam. 10.2 cm; Area,A 81.75 cm² Vol. 915.55 cm³ Ht.L 11.2 cm

Standpipe = Burette (50 ml) Diam. 1.06 cm Area,a 0.883 cm²

Test no.	h_1, cm	h_2, cm	t, s	Q_{in} cm³	Q_{out} cm³	T, °C	Test no.	h_1, cm	h_2, cm	t, s	T, °C
1	80	60	1554		17.66	28	1	80	60	1554	28
2	80	60	1560		17.66	28	2	80	60	1560	28
3	80	60	1566		17.66	28	3	80	60	1566	28
4	80	60	1560		17.66	28	4	80	60	1560	28
						Average		80	60	1560	28

$\alpha = \eta_T/\eta_{20} =$ 0.8287

$k_T = (aL/At)\ln(h_1/h_2) =$ 2.23E-05 = 0.0000223058 cm/s

$k_{20} = \alpha k_T =$ 1.85E-05 = 0.0000184845 cm/s

Degree of Permeability: Low (Soil testing for Engineerers by T. William Lambe, 1951)

Fig. 27 Permeability test for sample 2

COEFFICIENT OF PERMEABILITY (Falling Head)

Project: Sample No.: B2

Soil Description :

Tested by: Date : 17/10/2019

Sample Dimensions: Diam. 10.2 cm; Area,A 81.75 cm² Vol. 915.55 cm³ Ht.L 11.2 cm

Standpipe = Burette (50 ml) Diam. 1.06 cm Area,a 0.883 cm²

Test no.	h_1, cm	h_2, cm	t, s	Q_{in} cm³	Q_{out} cm³	T, °C	Test no.	h_1, cm	h_2, cm	t, s	T, °C
1	80	60	2154		17.66	28	1	80	60	2154	28
2	80	60	2160		17.66	28	2	80	60	2160	28
3	80	60	2166		17.66	28	3	80	60	2166	28
4	80	60	2160		17.66	28	4	80	60	2160	28
						Average		80	60	2160	28

$\alpha = \eta_T/\eta_{20} =$ 0.8287

$k_T = (aL/At)\ln(h_1/h_2) =$ 1.61E-05 = 0.0000161097 cm/s

$k_{20} = \alpha k_T =$ 1.33E-05 = 0.0000133499 cm/s

Degree of Permeability: Low (Soil testing for Engineerers by T. William Lambe, 1951)

Fig. 28 Permeability test for sample 3

COEFFICIENT OF PERMEABILITY (Falling Head)

Project: Sample No.: B3

Soil Description :

Tested by: Date : 17/10/2019

Sample Dimensions: Diam. 10.2 cm; Area,A 81.75 cm² Vol. 915.55 cm³ Ht.L 11.2 cm

Standpipe = Burette (50 ml) Diam. 1.06 cm Area,a 0.883 cm²

Test no.	h_1, cm	h_2, cm	t, s	Q_{in} cm³	Q_{out} cm³	T, °C	Test no.	h_1, cm	h_2, cm	t, s	T, °C
1	80	60	2094		17.66	28	1	80	60	2094	28
2	80	60	2100		17.66	28	2	80	60	2100	28
3	80	60	2106		17.66	28	3	80	60	2106	28
4	80	60	2100		17.66	28	4	80	60	2100	28
						Average		80	60	2100	28

$\alpha = \eta_T/\eta_{20} =$ 0.8287

$k_T = (aL/At)\ln(h_1/h_2) =$ 1.66E-05 = 0.0000165700 cm/s

$k_{20} = \alpha k_T =$ 1.37E-05 = 0.0000137314 cm/s

Degree of Permeability: Low (Soil testing for Engineerers by T. William Lambe, 1951)

Fig. 29 Permeability test for sample 4

8) *Consolidation Results*

The consolidation properties determined from the consolidation test (Fig. 30-33) show the rate at which the volume of the soil decreases laterally over time. The rate of consolidation of the soil samples ranges from 0.0131 – 0.0136 m²/yr indicating that there is a low decrease in volume of the soil and showing that it can withstand the load of the structure erected on it.

Consolidation test data analysis

Sample code:	A3
Test date:	23/11/2019
Sample description:	
Initial sample height, h_0 =	2.0 cm
Sample diameter, d_0 =	5.0 cm
Initial sample weight, W_{w0} =	86.5 g
Final sample weight, W_w =	85.9 g
Final weight of dry sample, W_d =	75.5 g
Initial dial reading, d_i =	0.000 cm
Final dial reading, d_f =	0.08848 cm
Initial water content, w_o =	14.57%
Initial dry unit weight, γ_{do} =	19.23 kN/m³
Initial void ratio, e_o =	0.489
Initial degree of saturation, S_{io} =	85.29%
Assumed final degree of saturation, S_f =	100.00%
Estimated specific gravity, G_S =	2.86
Final water content, w =	13.79%
Final dry unit weight, γ_d =	20.13 kN/m³
Final void ratio, e =	0.421
Liquid limit, LL =	31.20
Plastic limit, PL =	19.40
Coefficient of compressibility, a_v =	0.40014 MPa⁻¹
Coefficient of vol. compressibility, m_v =	0.28150 MPa⁻¹
Preconsolidation pressure, σ_p =	0.0400 MPa
Compression index, C_C =	0.0541
Swelling index, C_S =	0.02362
Recompression index, C_r =	0.032

Load number	Vertical stress (MPa)	Dial reading (cm)	System deflection (cm)	Vertical strain (%)	H for C_v (mm)	Void ratio	Coefficient of consolidation, C_v (mm²/min)	Elapsed time (min)
		d	hc	eps				
1	0.02	0.05569	0.00800	2.38	0.9008	0.454	2.93E-02	1440
2	0.04	0.07271	0.01220	3.03	0.8792	0.444	2.79E-02	1440
3	0.08	0.09815	0.01780	4.02	0.8436	0.429	2.64E-02	1400
4	0.16	0.12827	0.02400	5.21	0.7993	0.412	2.31E-02	1440
5	0.08	0.11253	0.01780	4.74	0.8077	0.419	2.36E-02	1440
6	0.04	0.09717	0.01220	4.25	0.8181	0.426	2.42E-02	1440
7	0.02	0.08848	0.00800	4.02	0.8188	0.429	2.49E-02	1400
		Total Settlement (mm)	m_v (MPa⁻¹)					
1	0.02	0.5569	1.43225					
2	0.04	0.1702	0.44153					
3	0.08	0.2544	0.33437					
4	0.16	0.3012	0.20118					
5	0.08	0.1575	0.10429					
6	0.04	0.1535	0.20173					
7	0.02	0.0870	0.22744		Sample Settlement	=	0.88 mm	

Coefficient of consolidation (C_v) =	**2.31E-02**	**to**	**2.93E-02**	**Average =**	**2.56E-02**	**(mm²/min)**
C_v	**1.21E-02**	**to**	**1.54E-02**	**Average =**	**1.35E-02**	**(m²/year)**

Fig. 30 Consolidation Test Analysis Result for Sample 1

Consolidation test data analysis

Sample code:	B1
Test date:	23/11/2019
Sample description:	
Initial sample height, h_0 =	2.0 cm
Sample diameter, d_0 =	5.0 cm
Initial sample weight, W_{w0} =	86.7 g
Final sample weight, W_w =	86.1 g
Final weight of dry sample, W_d =	75.8 g
Initial dial reading, d_i =	0.000 cm
Final dial reading, d_f =	0.08630 cm
Initial water content, w_o =	14.37%
Initial dry unit weight, γ_{do} =	19.31 kN/m³
Initial void ratio, e_o =	0.480
Initial degree of saturation, S_{io} =	85.55%
Assumed final degree of saturation, S_f =	100.00%
Estimated specific gravity, G_S =	2.86
Final water content, w =	13.57%
Final dry unit weight, γ_d =	20.18 kN/m³
Final void ratio, e =	0.414
Liquid limit, LL =	32.00
Plastic limit, PL =	19.90
Coefficient of compressibility, a_v =	0.38491 MPa⁻¹
Coefficient of vol. compressibility, m_v =	0.27215 MPa⁻¹
Preconsolidation pressure, σ_p =	0.0400 MPa
Compression index, C_C =	0.0521
Swelling index, C_S =	0.02251
Recompression index, C_r =	0.030

Load number	Vertical stress (MPa)	Dial reading (cm)	System deflection (cm)	Vertical strain (%)	H for C_v (mm)	Void ratio	Coefficient of consolidation, C_v (mm²/min)	Elapsed time (min)
		d	hc	eps				
1	0.02	0.05433	0.00800	2.32	0.9042	0.446	2.95E-02	1440
2	0.04	0.07093	0.01220	2.94	0.8837	0.436	2.82E-02	1440
3	0.08	0.09574	0.01780	3.90	0.8497	0.422	2.68E-02	1400
4	0.16	0.12512	0.02400	5.06	0.8072	0.405	2.35E-02	1440
5	0.08	0.10976	0.01780	4.60	0.8146	0.412	2.40E-02	1440
6	0.04	0.09478	0.01220	4.13	0.8240	0.419	2.45E-02	1440
7	0.02	0.08630	0.00800	3.92	0.8242	0.422	2.52E-02	1400
		Total Settlement (mm)	m_v (MPa⁻¹)					
1	0.02	0.5433	1.39607					
2	0.04	0.1660	0.43028					
3	0.08	0.2481	0.32574					
4	0.16	0.2938	0.19590					
5	0.08	0.1536	0.10157					
6	0.04	0.1498	0.19653					
7	0.02	0.0848	0.22160		Sample Settlement	=	0.86 mm	

Coefficient of consolidation (C_v) =	**2.35E-02**	**to**	**2.95E-02**	**Average =**	**2.60E-02**	**(mm²/min)**
C_v	**1.24E-02**	**to**	**1.55E-02**	**Average =**	**1.36E-02**	**(m²/year)**

Fig. 31 Consolidation Test Analysis Result for Sample 2

Consolidation test data analysis

Sample code:	B2
Test date:	23/11/2019
Sample description:	
Initial sample height, h_0 =	2.0 cm
Sample diameter, d_0 =	5.0 cm
Initial sample weight, W_{w0} =	86.5 g
Final sample weight, W_w =	85.9 g
Final weight of dry sample, W_d =	75.5 g
Initial dial reading, d_i =	0.000 cm
Final dial reading, d_f =	0.09253 cm
Initial water content, w_o =	14.57%
Initial dry unit weight, γ_{do} =	19.23 kN/m³
Initial void ratio, e_o =	0.494
Initial degree of saturation, S_{io} =	84.79%
Assumed final degree of saturation, S_f =	100.00%
Estimated specific gravity, G_S =	2.87
Final water content, w =	13.78%
Final dry unit weight, γ_d =	20.17 kN/m³
Final void ratio, e =	0.422
Liquid limit, LL =	31.30
Plastic limit, PL =	19.70
Coefficient of compressibility, a_v =	0.42516 MPa⁻¹
Coefficient of vol. compressibility, m_v =	0.29901 MPa⁻¹
Preconsolidation pressure, σ_p =	0.0400 MPa
Compression index, C_C =	0.0574
Swelling index, C_S =	0.02547
Recompression index, C_r =	0.034

Load number	Vertical stress (MPa)	Dial reading (cm)	System deflection (cm)	Vertical strain (%)	H for C_v (mm)	Void ratio	Coefficient of consolidation, C_v (mm²/min)	Elapsed time (min)
		d	hc	eps				
1	0.02	0.05825	0.00800	2.51	0.8944	0.456	2.89E-02	1440
2	0.04	0.07605	0.01220	3.19	0.8709	0.446	2.74E-02	1440
3	0.08	0.10265	0.01780	4.24	0.8324	0.430	2.57E-02	1400
4	0.16	0.13415	0.02400	5.51	0.7846	0.411	2.22E-02	1440
5	0.08	0.11768	0.01780	4.99	0.7948	0.419	2.28E-02	1440
6	0.04	0.10162	0.01220	4.47	0.8069	0.427	2.35E-02	1440
7	0.02	0.09253	0.00800	4.23	0.8087	0.430	2.43E-02	1400
		Total Settlement (mm)	m_v (MPa⁻¹)					
1	0.02	0.5825	1.49984					
2	0.04	0.1780	0.46256					
3	0.08	0.2660	0.35051					
4	0.16	0.3150	0.21105					
5	0.08	0.1647	0.10936					
6	0.04	0.1606	0.21147					
7	0.02	0.0909	0.23837		Sample Settlement	=	0.93 mm	

Coefficient of consolidation (C_v) =	**2.22E-02**	**to**	**2.89E-02**	**Average =**	**2.50E-02**	**(mm²/min)**
C_v	**1.17E-02**	**to**	**1.52E-02**	**Average =**	**1.31E-02**	**(m²/year)**

Fig. 32 Consolidation Test Analysis Result for Sample 3

Consolidation test data analysis

Sample code:	B3
Test date:	23/11/2019
Sample description:	
Initial sample height, h_0 =	2.0 cm
Sample diameter, d_0 =	5.0 cm
Initial sample weight, W_{w0} =	87.1 g
Final sample weight, W_w =	86.5 g
Final weight of dry sample, W_d =	76.4 g
Initial dial reading, d_i =	0.000 cm
Final dial reading, d_f =	0.09253 cm
Initial water content, w_o =	13.96%
Initial dry unit weight, γ_{do} =	19.46 kN/m³
Initial void ratio, e_o =	0.476
Initial degree of saturation, S_{io} =	84.27%
Assumed final degree of saturation, S_f =	100.00%
Estimated specific gravity, G_S =	2.87
Final water content, w =	13.21%
Final dry unit weight, γ_d =	20.40 kN/m³
Final void ratio, e =	0.405
Liquid limit, LL =	30.20
Plastic limit, PL =	19.40
Coefficient of compressibility, a_v =	0.42006 MPa⁻¹
Coefficient of vol. compressibility, m_v =	0.29901 MPa⁻¹
Preconsolidation pressure, σ_p =	0.0400 MPa
Compression index, C_C =	0.0567
Swelling index, C_S =	0.02517
Recompression index, C_r =	0.033

Load number	Vertical stress (MPa)	Dial reading (cm)	System deflection (cm)	Vertical strain (%)	H for C_v (mm)	Void ratio	Coefficient of consolidation, C_v (mm²/min)	Elapsed time (min)
		d	hc	eps				
1	0.02	0.05825	0.00800	2.51	0.8944	0.439	2.89E-02	1440
2	0.04	0.07605	0.01220	3.19	0.8709	0.429	2.74E-02	1440
3	0.08	0.10265	0.01780	4.24	0.8324	0.413	2.57E-02	1400
4	0.16	0.13415	0.02400	5.51	0.7846	0.394	2.22E-02	1440
5	0.08	0.11768	0.01780	4.99	0.7948	0.402	2.28E-02	1440
6	0.04	0.10162	0.01220	4.47	0.8069	0.410	2.35E-02	1440
7	0.02	0.09253	0.00800	4.23	0.8087	0.413	2.43E-02	1400
		Total Settlement (mm)	m_v (MPa⁻¹)					
1	0.02	0.5825	1.49984					
2	0.04	0.1780	0.46256					
3	0.08	0.2660	0.35051					
4	0.16	0.3150	0.21105					
5	0.08	0.1647	0.10936					
6	0.04	0.1606	0.21147					
7	0.02	0.0909	0.23837		Sample Settlement	=	0.93 mm	

Coefficient of consolidation (C_v) =	**2.22E-02**	**to**	**2.89E-02**	**Average =**	**2.50E-02**	**(mm²/min)**
C_v	**1.17E-02**	**to**	**1.52E-02**	**Average =**	**1.31E-02**	**(m²/year)**

Fig. 33 Consolidation Test Analysis Result for Sample 4

9) Unconfined Compression Test

UCT is a straightforward laboratory testing method for determining the mechanical properties of rocks and fine-grained soil such as clay and silt. It measures the undrained strength and stress-strain properties of the rock or soil being investigated. Unconfined compressive strength is approximately 182.5Kla. The unconfined compressive strength of soil is expressed in terms of consistency. The result (Fig. 34-37) shows that the soil is very stiff.

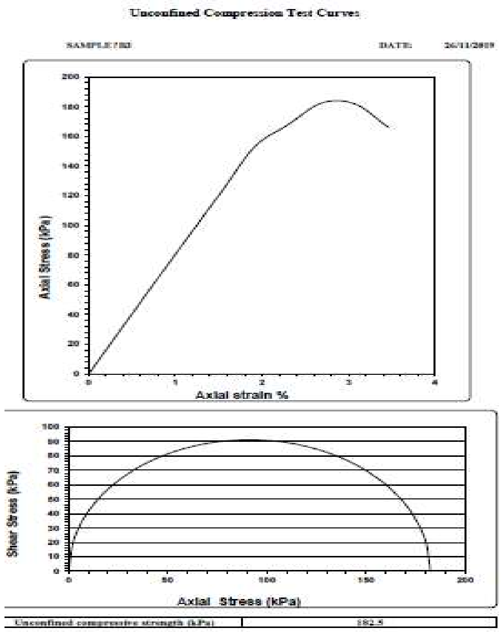


Fig. 34 Unconfined Compression Test Result for Sample 1

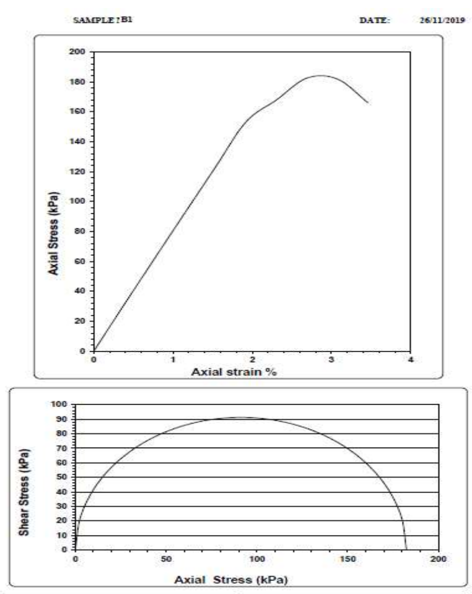


Fig. 35 Unconfined Compression Test Result for Sample 2

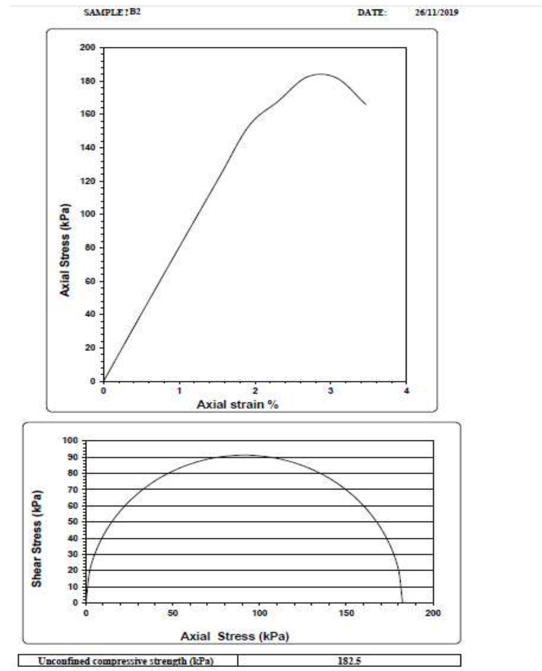


Fig. 36 Unconfined Compression Test Result for Sample 3

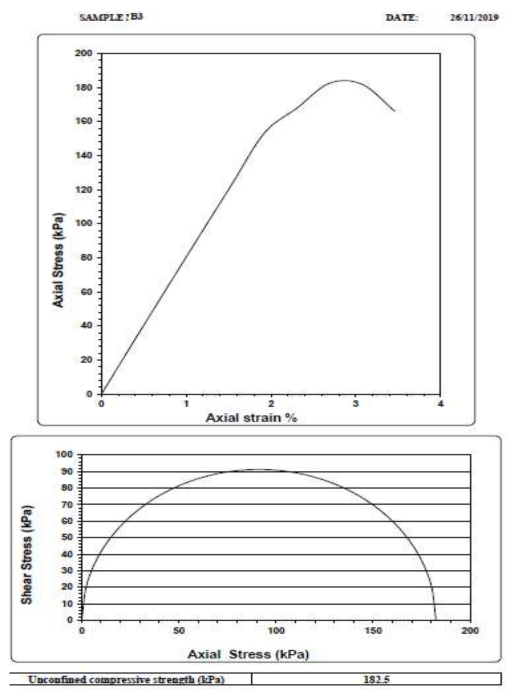


Fig. 37 Unconfined Compression Test Result for Sample 4

The summary of the geotechnical analysis carried out on the soil samples obtained from the study area is as displayed in Table I.

Table I. Summary of Geotechnical Analysis Result

Samples	Atterberg Limits (%)				NMC	Permeability	Compaction		SG	Consolidation	Hydrometer Analysis			
	LL	PL	LS	PI		CM/S	OMC (%)	MDD (kg/m^3)		m^2/yr	Sand	Silt	Clay	Tex class
Sample 1	31.2	19.4	11.5	11.8	14.1	1.60×10^{-5}	14.6	1923	2.652	0.0135	64.7	14.2	21.1	Clayey sand
Sample 2	32.0	19.9	11.0	12.10	14.2	1.85×10^{-5}	14.4	1931	2.659	0.0136	65.5	16.2	18.3	Clayey sand
Sample 3	31.3	19.7	11.5	11.60	14.2	1.33×10^{-5}	14.6	1923	2.654	0.0131	63.0	15.8	21.2	Clayey sand
Sample 4	30.2	19.4	12.0	10.80	14.3	1.37×10^{-5}	14.0	1946	2.648	0.0131	63.7	15.3	21.2	Clayey sand

IV. Conclusion

A geophysical investigation was carried out on the proposed ICT center of the Olusegun Agagu University of Science and Technology, Okitipupa using the Dipole-Dipole array. The geophysical data were processed and interpreted qualitatively and quantitatively to image subsurface. Pseudo sections were generated as related to the objectives of the study. The second layer with resistivity value ranging from 1162 – 84965 Ωm was recommended as a competent bed for foundation structure.

The interpretation of the geophysical data and the geotechnical analysis from the study area revealed that three major layers were delineated which comprise the topsoil which is mainly clayey sand, sandy clay, and sand.

Geotechnical analysis was carried out on the four (4) soil samples collected, at a depth of 0.5m. Tests conducted include Natural Moisture Content, grain size analysis, the Atterberg limit, permeability, compaction tests, specific gravity, and Unconfined Compression Test, consolidation, and hydrometer analysis.

Generally, there was no evidence of any major linear structures or discontinuities such as faults and shear zones that could impact the proposed structure's stability. Similarly, the topsoil is free of aggressive soil that can cause corrosion failure in the structure's steel reinforcement, consequently the subsoil can house metallic pipes. The weathered layer, observed at a depth of 20-30 m down the subsurface and hosts a conductive body, should be sought for adequate grounding operation to protect installed electrical materials in the event of lightning or thunderstorms.

In conclusion the subsurface layer can be considered to be fit as foundation material, however its clayey nature should be considered in designing the foundation. In a case whereby the proposed structure might be a superstructure, it is advisable to excavate the topsoil up to a depth of about 2 meters thereby placing the foundation on the competent bedrock.

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