GEOTECHNICAL AND GEOPHYSICAL INVESTIGATION INTO THE CAUSES OF CRACKS IN BUILDING: CASE STUDY OF SOME BUILDINGS IN SCHOOL OF ENGINEERING KOGI STATE POLYTECHNIC, ITAKPE CAMPUS, KOGI STATE NORTH CENTRAL NIGERIA

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ABSTRACT: *The aim of study is to investigate the major cause of cracks observed in majority of the buildings in school of engineering Itakpe campus of Kogi State Polytechnic, Kogi state. To achieve this aim, both geotechnical and geophysical approaches were adopted to study the soil properties and subsurface formations respectively. Soil samples were collected around the area of the affected building for laboratory study. The properties determined were natural moisture content, particle size distribution, Atterberg limits, proctor compaction, and specific gravity. The results of the tests show that the site is dominated with poorly graded soil with specific gravity (2.2 - 2.7), liquid limit (25.8 % - 39.0 %), plastic limit (18.8 % - 35.1 %), Natural moisture content (3.89 % - 27.91 %) and maximum dry Density (620 kg/m^3 - 825kg/m^3). Geophysical survey involving the electrical resistivity method utilizing the Vertical Electrical Sounding (VES) techniques conducted around the crack walls of some building with the aim of studying the causes of crack in the walls and characterizing the soil conditions of the area. A total of 8 Vertical Electrical Sounding (VES) stations were occupied using Schlumberger Configuration with AB/2 varying from 1 to 65 m. Three geoelectric sequences were delineated within the study area. These include the topsoil, weathered layer, and fresh basement. Results identified differential settlement resulting from incompetent subsoil materials are the possible causes of the failure.*

KEYWORDS: Geotechnical, Geophysical, Cracks in Building, Structural & Non-Structural Cracks, Nigeria

INTRODUCTION

Crack in engineering structure is a common failure that occurs in most building in our environment. When this failure is notice there will be need for amendment of the structure to avoid total failure of the structure with time. Structural failures do not only damage properties and endangers the lives of Human and animals in the environment, it can also suspend the economics activity that takes place within and around the building.

Crack in building are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Cracks are classified into structural and non-structural cracks. The structural crack is due to faulty design; faulty construction or overloading which may endangers Safety of buildings. The non-structural cracks are due to internal induced stress depending on the width of crack; these are classified into thin less than 1 mm, medium 1 mm – 2 mm, and wide is more than 2 mm.

Geotechnical engineering practice require investigation of soil and subsurface of the chosen site for Engineering construction. This is done to ascertain the suitability of the earth materials at such site for Structure in terms of bearing capacity and hoisting fitness.

If assumptions in structural design are not incorporate into preconstruction investigation, the result of this omission is usually failed structures.

Location and Access of the study Area

The study area is Kogi State Polytechnic Itakpe Campus which is located in Okehi Local Government Area of Kogi State in North Central Nigeria. It lies within latitudes $7^0$36'N to $7^0$39'N and Longitudes $6^0$17'E to $6^0$22'E. Itakpe is located Northeast of Okene and is about 10 km along the Okene – Lokoja road. Fig.1. shows the location map of Kogi state showing Itakpe and important towns.

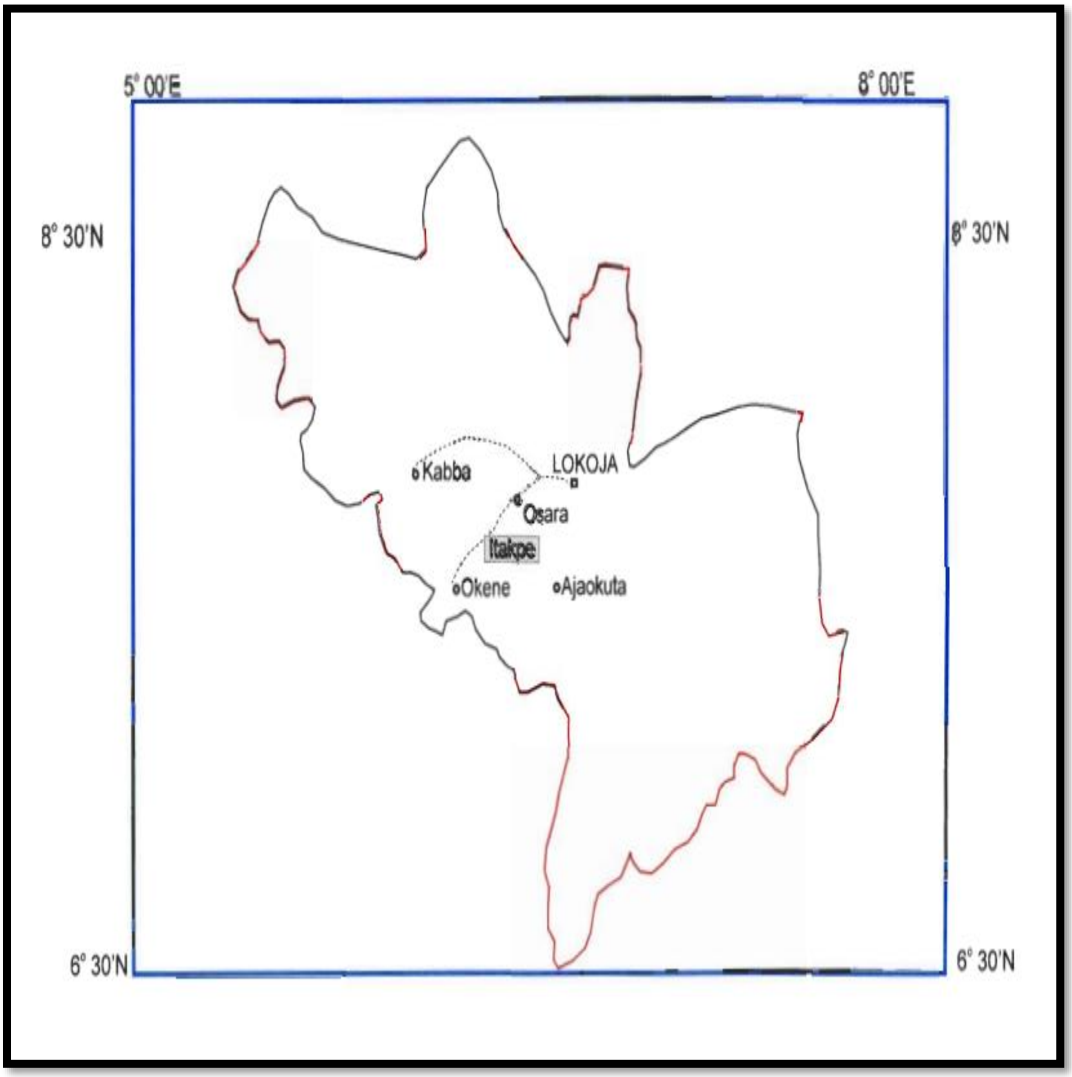

Figure 1: Map of Kogi State Showing Itakpe and Some Towns

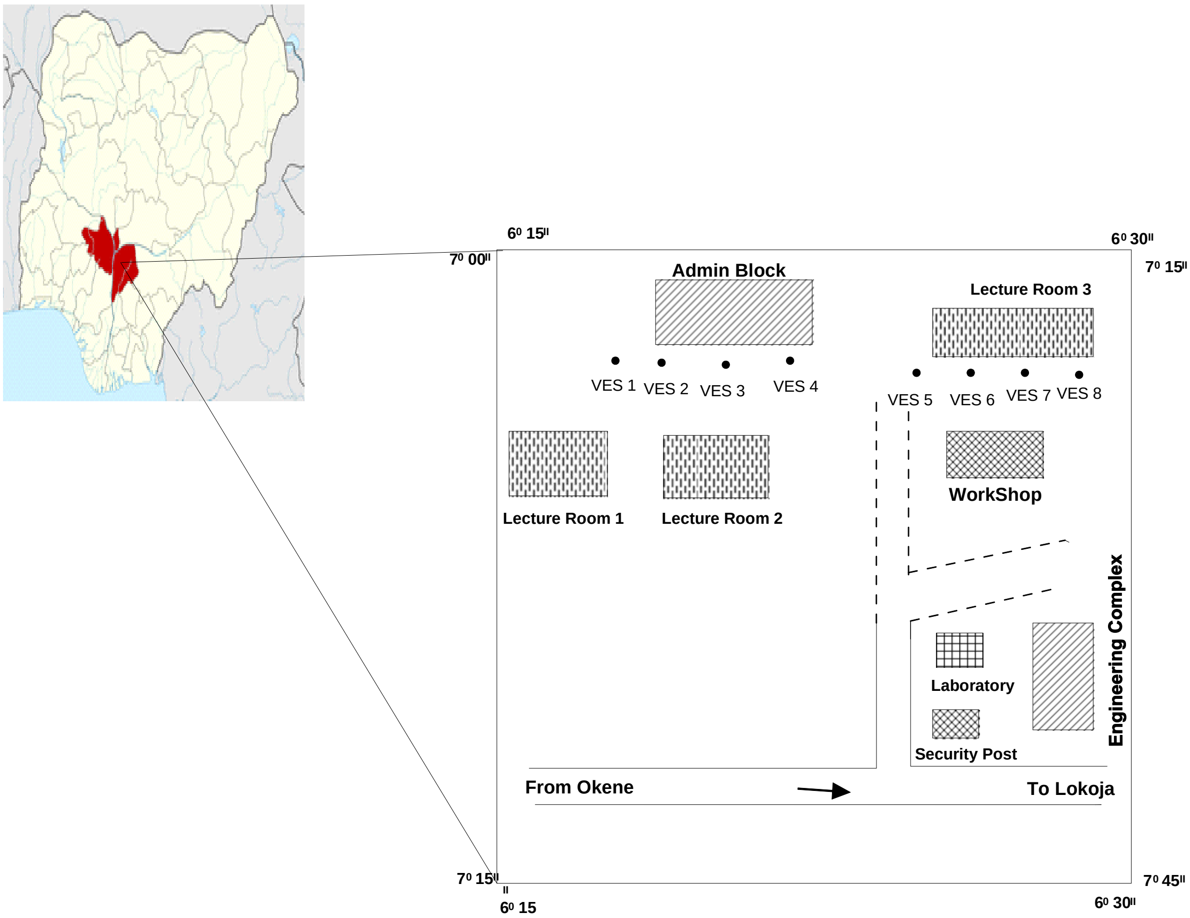

Figure 2: An Inset Map of the Study Area in Nigeria

Plate 1: Section of the Cracks Wall in the Study Area

Plate 2: Section of the Cracks Wall in the Study Area

Geology of the Study Area

The study area is underlain by rocks of Gneiss, Migmatite Gneiss, Biotie Gneiss and Granie Gneisses and these rocks are parts of Basement complex. The Nigerian basement complex is part of the Pan African mobile belt and lies within the West African Craton and South of the Tuareg Shield (Black 1980). The basement complex of Nigeria includes those of the North Central Nigeria, the Southwestern Nigeria and the Eastern province (Fig. 2.). The three broad lithological groups within the Nigerian basement complex are the migmatite gneiss complex made up largely of migmatite and gneisses of various compositions, the low-grade sediment dominated schist belt and the granitic rocks which cut both the migmatite gneiss complex and the schists belt (Ajibade and Woakes, in Kogbe 1980).

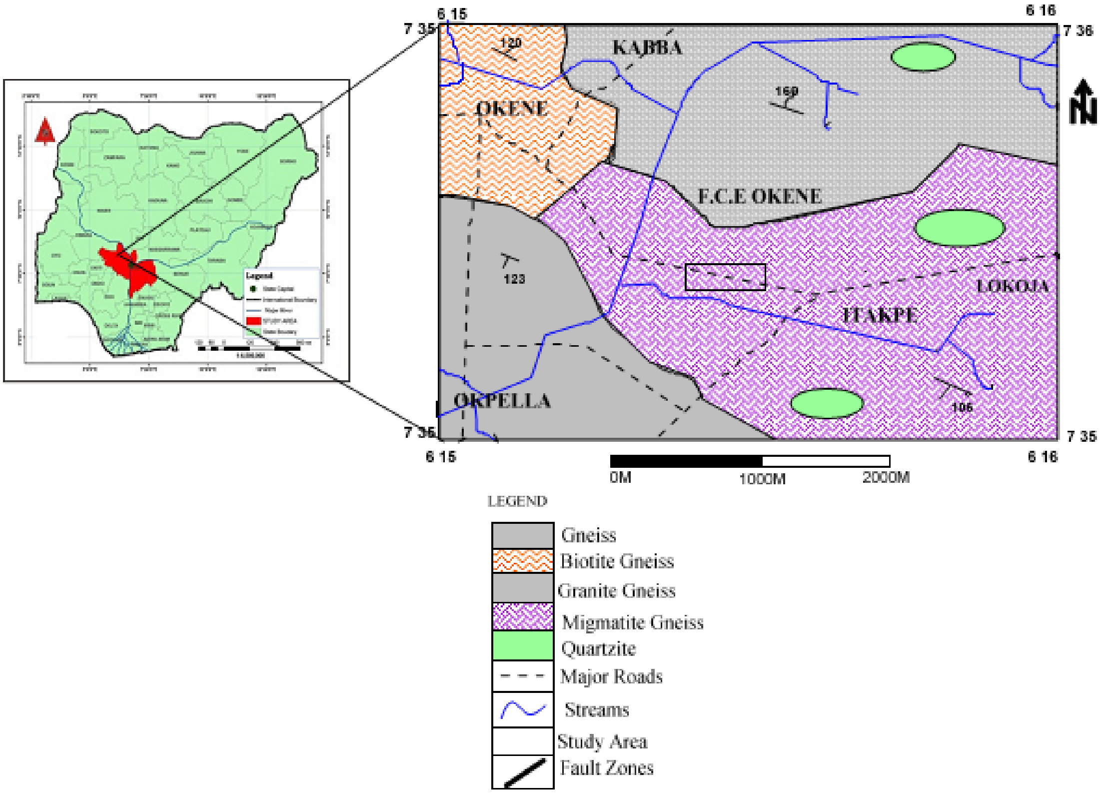

Figure 3: Geological Map of the Study Area

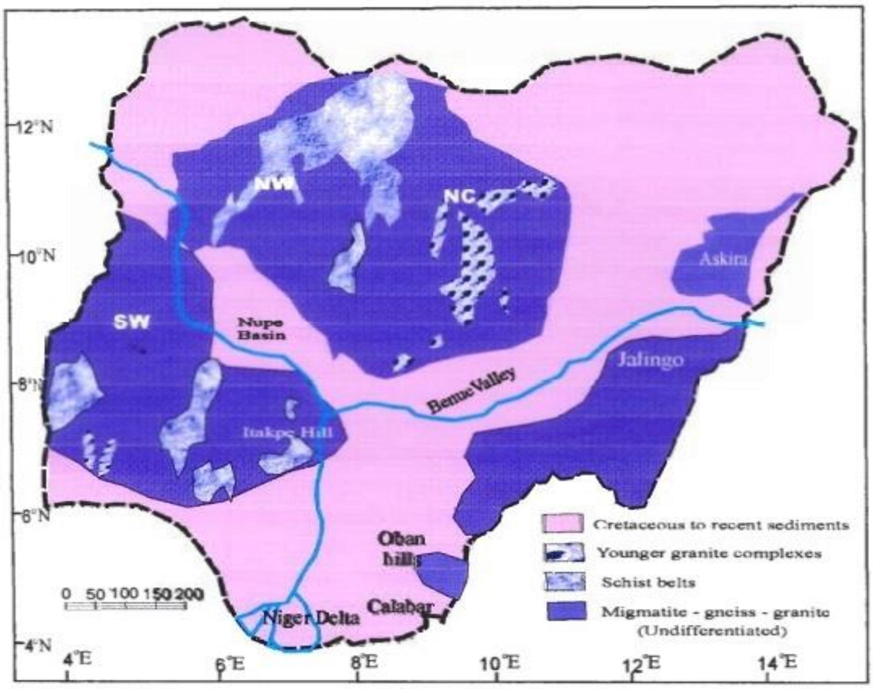

Fig 4: Geological Map of Nigeria Showing The Schist Belt(modifield fron Kogbe, 1980)

MATERIALS AND METHOD

The materials used for the study are as follows:

Geographical position system (GPS), sampling bag, marker, spatula, masking tape, measuring tape, proctor rammer, scoopels, Desiccators, Sieve, Mortal, Pestle, Density bottle, measuring cylinder, weighing balance, oven, terrameter and electrodes

Field Observations

Tables below shows the result of the various field's observations on the soil samples.

Table 1: Sample Acquisition for Geotechnical Data in the Study Area

S/N	Name of building	Longitude (E)	Latitude (N)	Elevation above sea level (ft)	Observation
1	Old Admin Block	006°21′577″	07°39'469″	469	The crack is as wide as 0.8cm, sample at about 1.5m depth and above contain high organic matter.
2	R A. C Block	006°21′546″	07°39′469″	512	The cracks are less than 0.5cm wide, Sample at about 1.5m depth and above have no organic matter but contains medium grain size of laterite.
3	No mercy hall block	006°21′651″	07°39′453″	559	The cracks in this location are about 0.5-1cm wide, the soil is rich in brown clay.
4	New ongoing construction laboratory block	006°21′661″	07°21′766″	564	No crack is observed, sample at about 1.5m depth and above contain about 1.5cm large grain size also rich in laterite
5	Engineering complex	006°21′661″	07°39′409″	568	The crack is less than0.5cm, sample at about 1.5m depth and above contain large grain size solid formation

RESULTS

The result of the research are presented in table 2- 31 and the figure 5 – 20.

PARTICLE SIZE DISTRIBUTION

Table 2: Sieve Analysis L1

sieve No.	Sieve size	wt of sieve	wt of sieve +soil	Wt Retained	Wt Passing	% Retained	% Passed
	10			0	500	0	100
1	4.75 mm	414.1	425.8	11.7	488.3	2.34	97.66
2	2.36 mm	443.7	480.8	37.1	451.2	7.42	90.24
3	1.18 mm	355.4	419.4	64	387.2	12.8	77.44
4	600 m	379.1	498.4	119.3	267.9	23.86	53.58
5	300 µm	350.7	509.8	159.1	108.8	31.82	21.76
6	200 µm	325.9	381.5	55.6	53.2	11.12	10.64
7	150 µm	304.4	324.9	20.5	32.7	4.1	6.54
8	75 µm	327.4	344.8	17.4	15.3	3.48	3.06
9	Receiver	281.2					

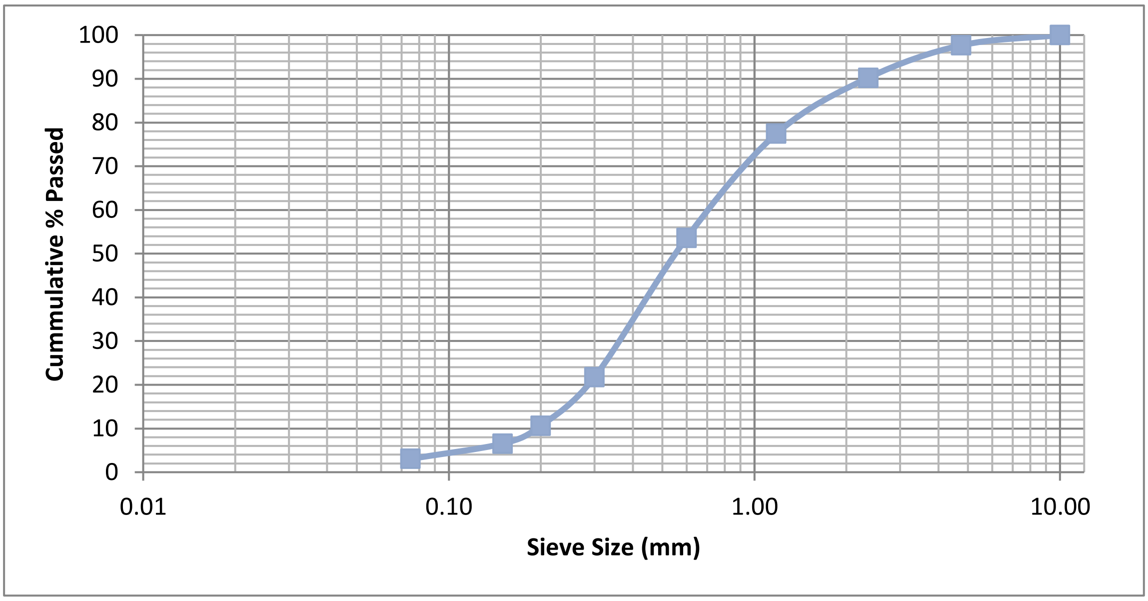

Figure 6: Particles Size Distribution of Location L1

Table 3: Sieve Analyses L2

	Sieve size	wt of sieve	Wt of sieve + soil	Wt Retained	Wt Passing	% Retained	% Passed
1	4.75 mm	414.1	450.5	36.4	463.6	7.28	92.72
2	2.36 mm	443.7	529.9	86.2	377.4	17.24	75.48
3	1.18 mm	355.4	408.6	53.2	324.2	10.64	64.84
4	600 □m	379.1	.6	59.5	264.7	11.90	52.94
5	300 µm	350.7	460.2	109.5	155.2	21.90	31.04
6	200 µm	325.9	396.3	70.4	84.8	14.08	15.92
7	150 µm	304.4	338.2	33.8	51	6.76	9.16
8	75 µm	327.4	361	33.6	17.4	6.72	2.44
	Receiver	281.2			0	0	

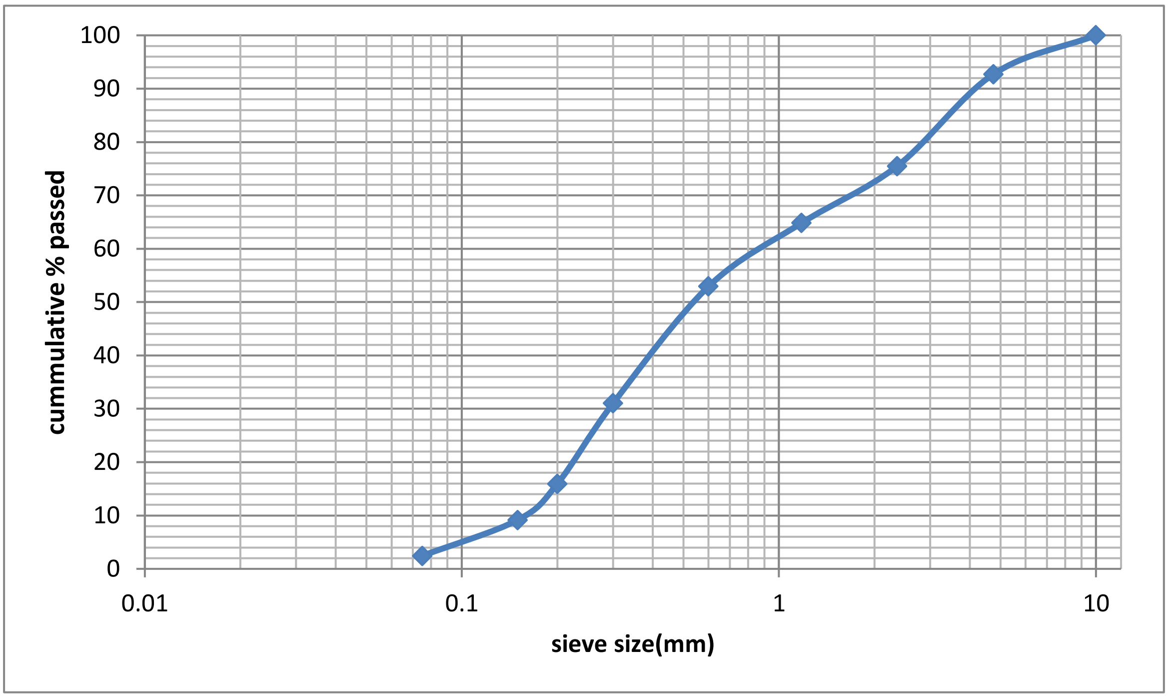

Figure 7: Graph of Particle Size Distribution L2

Table 4: Sieve Analysis L3

	Sieve size	wt of sieve	wt of sieve +soil	Wt Retained	Wt Passing	% Retained	% Passed
1	4.75 mm	414.1	430.8	16.7	483.3	3.34	96.66
2	2.36 mm	443.7	483.5	39.8	443.5	7.96	88.70
3	1.18 mm	355.4	440	84.6	358.9	16.92	71.78
4	600 □m	379.1	496.8	117.7	241.2	23.54	48.24
5	300 µm	350.7	487	136.3	104.9	27.26	20.98
6	200 µm	325.9	382.1	56.2	48.7	11.24	9.74
7	150 µm	304.4	324	19.6	29.1	3.92	5.82
8	75 µm	327.4	346.5	19.1	10	3.82	2.00
	reciever	281.2			0	0.00	

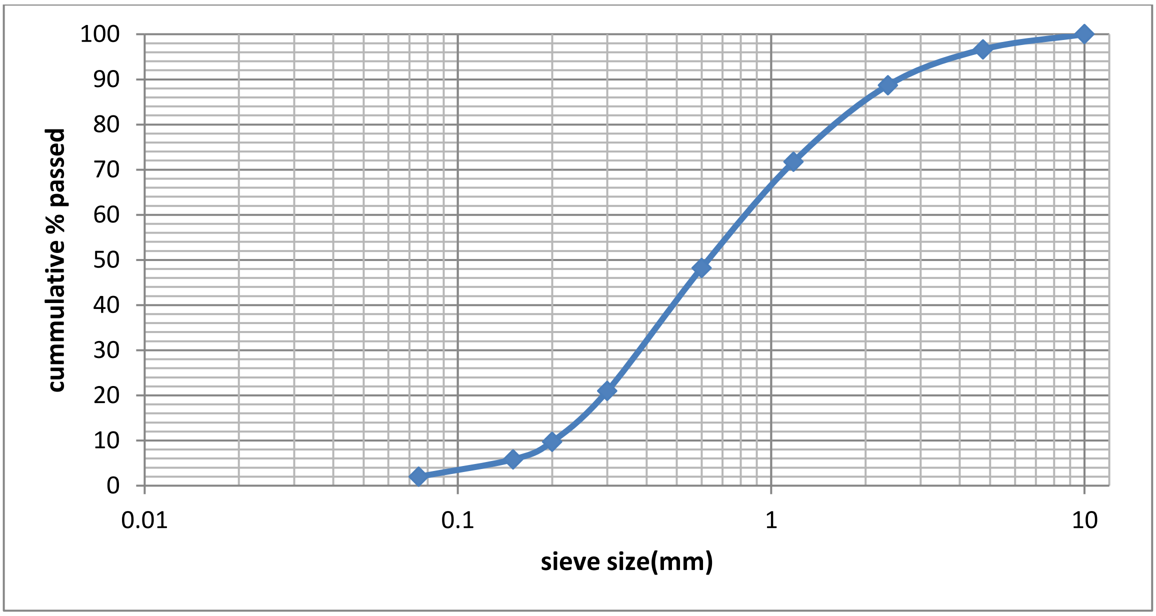

Figure 8: Graph of Particle Size Distribution L3

Table 5: Sieve Analysis L4

sieve No.	Sieve size	wt of sieve	wt of sieve + soil	Wt Retained	Wt Passing	% Retained	% Passed
1	4.75 mm	414.1	517.1	103	397.0	20.60	79.40
2	2.36 mm	443.7	562	118.3	278.7	23.66	55.74
3	1.18 mm	355.4	414.4	59	219.7	11.80	43.94
4	600 □m	379.1	437.6	58.5	161.2	11.70	32.24
5	300 µm	350.7	422.7	72	89.2	14.40	17.84

6	200 µm	325.9	364.1	38.2	51.0	7.64	10.20
7	150 µm	304.4	322.6	18.2	32.8	3.64	6.56
8	75 µm	327.4	348.8	21.4	11.4	4.28	2.28
	receiver	281.2	299.1	17.9	0	0	0

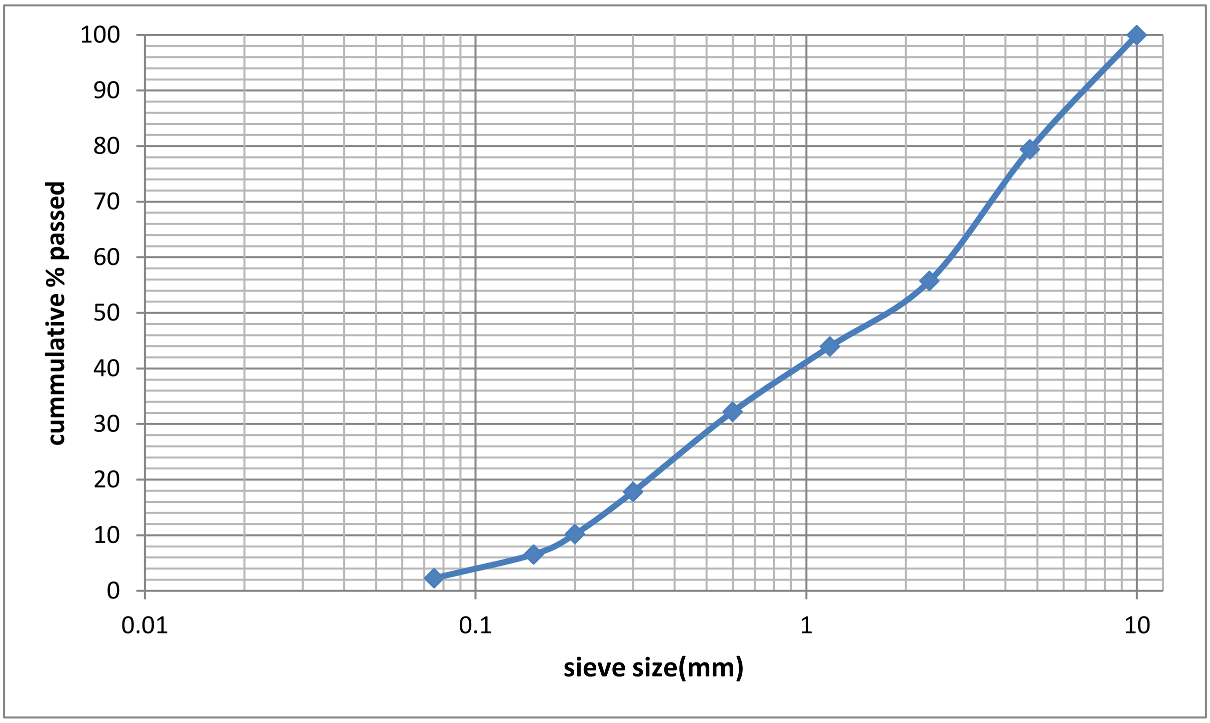

Figure 9: Graph of Particle Size Distribution L4

Table 6: Sieve Analysis L5

sieve No.	Sieve size	wt of sieve	wt of sieve + soil	Wt Retained	Wt Passing	% Retained	% Passed
1	4.75 mm	414.1	497.3	83.2	416.8	16.64	83.36
w2	2.36 mm	443.7	554.8	111.1	305.7	2.92	80.44
3	1.18 mm	355.4	421	65.6	240.1	13.12	67.32
4	600 □m	379.1	432	52.9	187.2	10.58	56.74
5	300 µm	350.7	414.9	64.2	123	12.84	43.90
6	200 µm	325.9	358.4	32.5	90.5	6.50	37.40
7	150 µm	304.4	317.1	12.7	77.8	2.54	34.86
8	75 µm	327.4	341.4	14	63.8	2.80	32.06
	reciever	281.2	294.7	13.5	0	0.00	0.00

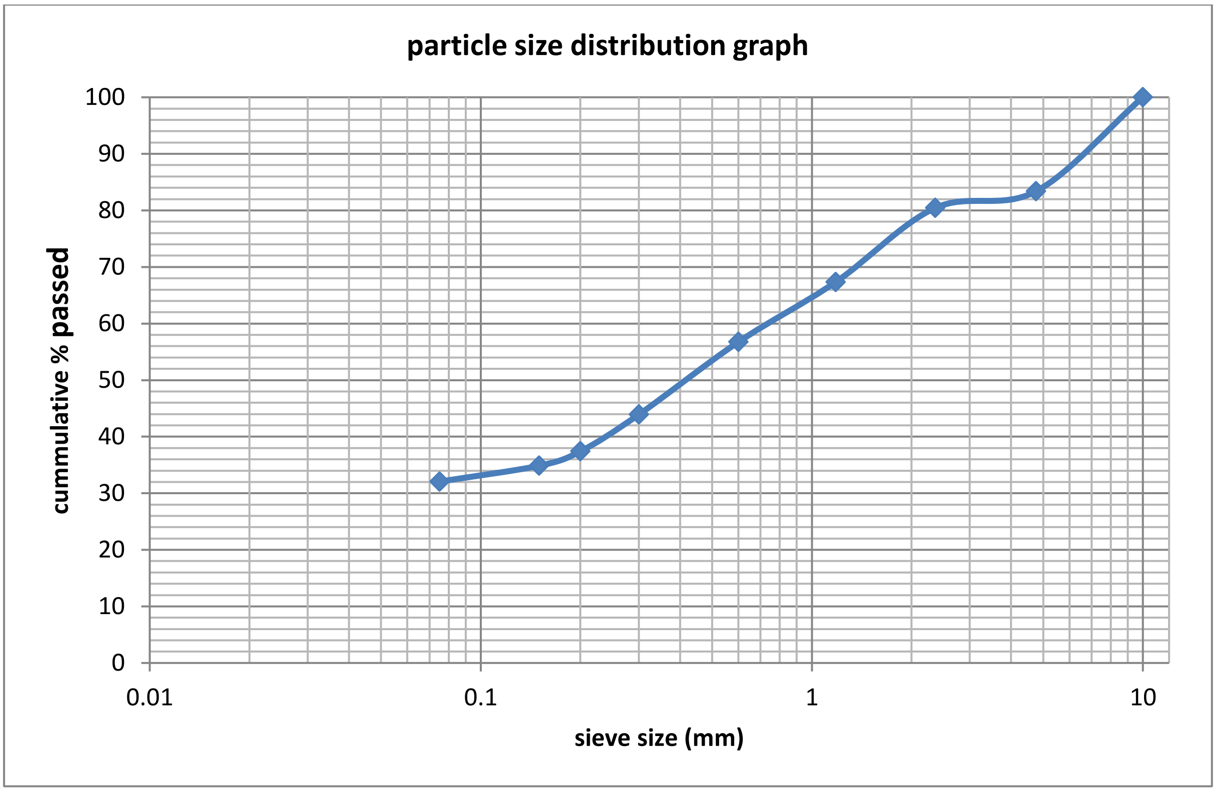

Figure 10: Graph of Particle Size Distribution L5

NATURAL MOISTURE CONTENT

The tables below show the results of the natural moisture content test conducted on the soil samples.

Table 7: Natural Moisture Content L1

S/No	**Description**	**A**	**B**
1	Weight of empty container (g)	14.7	**15.4**
2	Weight of empty container + wet soil (g)	34.1	**32.9**
3	Weight of empty container + dry soil (g)	31.5	**30.8**
4	Moisture content (%)	15.48	**13.6**
5	Average moisture content (%)	14.56	

Table 8: Natural Moisture Content L2

S/No	Description	A	B
1	Weight of empty container (g)	15	**13.9**
2	Weight of empty container + wet soil (g)	41.5	**41.2**
3	Weight of empty container + dry soil (g)	39.50	**39.2**
4	Moisture content (%)	8.16	**7.91**
5	Average moisture content (%)	**8.03**	

Table 9: Natural Moisture Content L3

S/No	Description	A	B
1	Weight of empty container (g)	15.5	**14.6**
2	Weight of empty container + wet soil (g)	37.2	**33.4**
3	Weight of empty container + dry soil (g)	32.70	**29.1**
4	Moisture content (%)	26.16	**29.66**
5	Average moisture content (%)	27.91	

Table 10: Natural Moisture Content L4

S/No	Description	A	B
1	Weight of empty container (g)	14.7	15.4
2	Weight of empty container + wet soil (g)	36.6	40.1
3	Weight of empty container + dry soil (g)	35.50	39.5
4	Moisture content (%)	5.29	2.49
5	Average moisture content (%)	3.89	

Table 11: Natural Moisture Content L5

S/No	Description	A	B
1	Weight of empty container (g)	15	13.9
2	Weight of empty container + wet soil (g)	46	39.4
3	Weight of empty container + dry soil (g)	43.60	37.6
4	Moisture content (%)	8.39	7.59
5	Average moisture content (%)	7.99	

ATTERBERG LIMIT TEST

The atterberg limit tests conducted on the soil samples were liquid limit (LL) and plastic limit (PL), the table below shows the result of the atterberg limit tests conducted on the soil samples.

Table 12: Atteberg Limit (Liquid and Plastic) L1

Atterberg Limit (Liquid and Plastic Limits)						
Type of Test	**Liquid Limit (LL)**			**Plastic Limit (PL)**		
Container No	1	2	3	1	2	3
No. of Blows	12	17	27			
Moisture can and lid number						
Mass of Empty can, m1 (g)	14.1	14.2	14.9	15.8	14.5	14.1
Mass of can + Moist Soil, m2 (g)	15.8	16.6	17.1	17.3	18.8	18.1
Mass of can + Dry Soil, m3 (g)	15.3	16.2	16.7	16.8	18.4	17.8
Mass of Soil (g)	1.2	2	1.8	1.0	3.9	3.7
Mass of Water (g)	0.5	0.4	0.4	0.5	0.4	0.3
Moisture Content (%)	41.7	20.0	22.2	50.0	10.3	8.1
5.2	**28.0**			**22.8**		

Table 13: Atteberg Limit (Liquid and Plastic) L2

Atterberg Limit (liquid and Plastic Limits)						
Type of Test	**Liquid Limit (LL)**			**Plastic Limit (PL)**		
Container No	1	2	3	1	2	3
No. of Blows	19	38	26			
Moisture can and lid number						
Mass of Empty can, m1 (g)	14.5	15.4	14.1	15.8	14.5	14.1
Mass of can + Moist Soil, m2 (g)	18.1	18.8	18.3	17.5	19.5	17.7
Mass of can + Dry Soil, m3 (g)	17.4	18.1	17.4	17	19	17.2
Mass of Soil (g)	2.9	2.7	3.3	1.2	4.5	3.1
Mass of Water (g)	0.7	0.7	0.9	0.5	0.5	0.5
Moisture Content (%)	24.1	25.9	27.3	41.7	11.1	16.1
Pl=2.8	**25.8**			**23.0**		

Table 14: Atteberg Limit (Liquid and Plastic) L3

Atterberg Limit (Liquid and Plastic Limits)						
Type of Test	**Liquid Limit (LL)**			**Plastic Limit (PL)**		
Container No	1	2	3	1	2	3
No. of Blows	40	21	19			

Moisture can and lid number						
Mass of Empty can, m1 (g)	15.8	15.4	15.8	15.8	14.5	14.1
Mass of can + Moist Soil, m2 (g)	17.2	17.9	17.8	17.7	17.5	17.3
Mass of can + Dry Soil, m3 (g)	16.9	17	17.3	17.1	17	16.4
Mass of Soil (g)	1.1	1.6	1.5	1.3	2.5	2.3
Mass of Water (g)	0.3	0.9	0.5	0.6	0.5	0.9
Moisture Content (%)	27.3	56.2	33.3	46.2	20.0	39.1
Pl=3.9	**39.0**			**35.1**		

Table 15: Atteberg Limit (Liquid and Plastic) L4

Type of Test	**Liquid (LL)**		**Limit**	**Plastic (PL)**		**Limit**
Container No	1	2	3	1	2	3
No. of Blows	16	23	28			
Moisture can and lid number						
Mass of Empty can, m1 (g)	15.8	15.4	15.8	15.8	14.5	14.1
Mass of can + Moist Soil, m2 (g)	18.3	18.4	20.1	19.1	19	18.3
Mass of can + Dry Soil, m3 (g)	17.6	17.7	19.3	18.4	18	17.5
Mass of Soil (g)	1.8	2.3	3.5	2.6	3.5	3.4
Mass of Water (g)	0.7	0.7	0.8	0.7	1	0.8
Moisture Content (%)	38.9	30.4	22.9	26.9	28.6	23.5
PI=4.4	**30.7**			**26.3**		

Table 16: Atteberg Limit (Liquid and Plastic) L5

Type of Test	**Liquid (LL)**		**Limit**	**Plastic (PL)**		**Limit**
Container No	1	2	3	1	2	3
No. of Blows	16	20	36			
Moisture can and lid number						
Mass of Empty can, m1 (g)	15.8	15.4	15.8	15.8	14.5	14.1
Mass of can + Moist Soil, m2 (g)	18.6	18.5	18	16.4	17.2	16.6
Mass of can + Dry Soil, m3 (g)	17.7	17.7	17.6	16.3	16.8	16.2
Mass of Soil (g)	1.9	2.3	1.8	0.5	2.3	2.1
Mass of Water (g)	0.9	0.8	0.4	0.1	0.4	0.4
Moisture Content (%)	47.4	34.8	22.2	20.0	17.4	19.0
Pl=16.0	**34.8**			**18.8**		

SPECIFIC GRAVITY TEST

The tables below show the result of the specific gravity test conducted on the soil samples.

Table 17: Specific Gravity for L1

S/No	Descriptions	
1	Weight of density + cork (g)	23.4
2	Weight of density + cork + dry soil (g)	39.6
3	Weight of density + cork + dry soil + water (g)	83.7
4	Weight of density + cork + full water (g)	73.5
5	Weight of sample	16.2
6	Weight of water	6.0
7	Specific gravity	2.7

Table 18: Specific Gravity for L2

S/No	Descriptions	
1	Weight of density + cork (g)	23.4
2	Weight of density + cork + dry soil (g)	47.4
3	Weight of density + cork + dry soil + water (g)	88.1
4	Weight of density + cork + full water (g)	73.5
5	Weight of sample	24.0
6	Weight of water	9.4
7	Specific gravity	2.6

Table 19: Specific Gravity for L3

S/No	Descriptions	
1	Weight of density + cork (g)	23.4
2	Weight of density + cork + dry soil (g)	49.6
3	Weight of density + cork + dry soil + water (g)	89.6
4	Weight of density + cork + full water (g)	73.5
5	Weight of sample	26.2
6	Weight of water	10.1
7	Specific gravity	2.6

Table 20: Specific Gravity for L4

S/No	Descriptions	
1	Weight of density + cork (g)	23.4
2	Weight of density + cork + dry soil (g)	64.3
3	Weight of density + cork + dry soil + water (g)	99
4	Weight of density + cork + full water (g)	73.5
5	Weight of sample	40.9
6	Weight of water	15.4
7	Specific gravity	2.7

Table 21: Specific Gravity for L5

S/No	Descriptions	
1	Weight of density + cork (g)	23.4
2	Weight of density + cork + dry soil (g)	50.1
3	Weight of density + cork + dry soil + water (g)	88.2
4	Weight of density + cork + full water (g)	73.5
5	Weight of sample	26.7
6	Weight of water	12.0
7	Specific gravity	2.2

PROCTOR COMPACTION TEST

The tables below show the result of the compaction test conducted on the soil sample.

Table 22: Compaction Test for L1

Parameter	Values									
Water Added (%)	4		6		8		10		12	
Compacted Soil + Mould (kg)	3.500		3.591		3.818		3.864		3.909	
Wt. of Mould (kg)	3.250		3.250		3.250		3.250		3.250	
Wt. of Compacted Soil in Mould (kg)	0.250		0.341		0.568		0.614		0.659	
Wet Density (kg/m3)	266		363		604		653		701	
Bowl No.	T	B	T	B	T	B	T	B	T	B
Wt of Bowl + Wet Soil (g)	20.7	19.3	21.9	21.6	21.1	22.4	18.9	23.1	18.9	18.0

Wt. of Bowl + Dry Soil (g)	20.3	19.3	21.4	21.2	20.8	21.8	18.5	22.5	18.6	17.4
Wt. of Water (g)	0.4	0.4	0.5	0.4	0.3	0.6	0.4	0.6	0.3	0.6
Wt. of Bowl (g)	15.8	14.5	15.4	13.8	15.8	14.1	15.8	14.5	15.4	13.8
Wt. of Dry Soil (g)	4.5	4.8	6	7.4	5	7.7	2.7	8	3.2	3.6
Water Content (%)	8.9	8.3	8.3	5.4	6.0	7.8	14.8	7.5	9.4	16.7
Average Water Content (%)	8.6		6.9		6.9		11.2		13.0	
Dry Density(kg/m3)	245		339		565		588		620	

Table 23: Compaction Test for L2

Parameter	**Values**									
Water Added (%)	4		6		8		10		12	
Compacted Soil + Mould (kg)	3.636		3.727		3.864		3.955		4.045	
Wt. of Mould (kg)	3.250		3.250		3.250		3.250		3.250	
Wt. of Compacted Soil in Mould (kg)	0.386		0.477		0.614		0.705		0.795	
Wet Density (kg/m3)	411		507		653		750		846	
Bowl No.	T	B	T	B	T	B	T	B	T	B
Wt of Bowl + Wet Soil (g)	20	19.2	20.2	18	22.1	20.3	22.3	21.6	21	22.0
Wt. of Bowl + Dry Soil (g)	19.7	19	19.9	17.8	21.8	20	21.5	21.3	20.4	21.0
Wt. of Water (g)	0.3	0.2	0.3	0.2	0.3	0.3	0.8	0.3	0.6	1.0
Wt. of Bowl (g)	15.8	14.5	15.4	13.8	15.8	14.1	15.8	14.5	15.4	13.8
Wt. of Dry Soil (g)	3.9	4.5	4.5	4	6	5.9	5.7	6.8	5.0	7.2
Water Content (%)	7.7	4.4	6.7	5.0	5.0	5.1	14.0	4.4	12.0	13.9
Average Water Content (%)	6.1		5.8		5.0		9.2		12.9	
Dry Density(kg/m3)	387		479		622		687		749	

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Table 24: Compaction Test for L3

Parameter	Values									
Water Added (%)	4		6		8		10		`12	
Compacted Soil + Mould (kg)	3.591		3.682		3.727		3.682		3.591	
Wt. of Mould (kg)	3.250		3.250		3.250		3.250		3.250	
Wt. of Compacted Soil in Mould (kg)	0.386		0.477		0.614		0.705		0.795	
Wet Density (kg/m3)	411		507		653		750		846	
Bowl No.	T	B	T	B	T	B	T	B	T	B
Wt of Bowl + Wet Soil (g)	19.2	19.9	19.5	20	20.7	19.9	20	22.2	24.8	23.9
Wt. of Bowl + Dry Soil (g)	18.8	19.6	19.1	19.4	20.2	19.3	19.3	21.4	23.4	22.6
Wt. of Water (g)	0.4	0.3	0.4	0.6	0.5	0.6	0.7	0.8	1.4	1.3
Wt. of Bowl (g)	15.8	14.5	15.4	13.8	15.8	14.1	15.8	14.5	15.4	13.8
Wt. of Dry Soil (g)	3	5.1	3.7	5.6	4.4	5.2	3.5	6.9	8.0	8.8
Water Content (%)	13.3	5.9	10.8	10.7	11.4	11.5	20.0	11.6	17.5	14.8
Average Water Content (%)	9.6		10.8		11.5		15.8		16.1	
Dry Density(kg/m3)	375		458		586		648		728	

Table 25: Compaction Test for L4

Parameter	Values									
Water Added (%)	4		6		8		10		12	
Compacted Soil + Mould (kg)	3.864		4.000		4.045		4.091		4.136	
Wt. of Mould (kg)	3.250		3.250		3.250		3.250		3.250	
Wt. of Compacted Soil in Mould (kg)	0.614		0.750		0.795		0.841		0.886	
Wet Density (kg/m3)	653		798		846		895		943	
Bowl No.	T	B	T	B	T	B	T	B	T	B

Wt of Bowl + Wet Soil (g)	22.1	23	21.5	21.7	27	24.4	28.4	30.1	29.8	25.7
Wt. of Bowl + Dry Soil (g)	21.7	22.6	20.9	21	25.9	23.3	27	28.3	27.9	24.3
Wt. of Water (g)	0.4	0.4	0.6	0.7	1.1	1.1	1.4	1.8	1.9	1.4
Wt. of Bowl (g)	15.8	14.5	15.4	13.8	15.8	14.1	15.8	14.5	15.4	13.8
Wt. of Dry Soil (g)	5.9	8.1	5.5	7.2	10.1	9.2	11.2	13.8	12.5	10.5
Water Content (%)	6.8	4.9	10.9	9.7	10.9	12.0	12.5	13.0	15.2	13.3
Average Water Content (%)	5.9		10.3		11.4		12.8		14.3	
Dry Density(kg/m3)	617		723		759		793		825	

Table 26: Compaction Test for L5

Parameter	**Values**									
Water Added (%)	4		6		8		10		12	
Compacted Soil + Mould (kg)	3.818		3.909		4.045		4.091		4.091	
Wt. of Mould (kg)	3.250		3.250		3.250		3.250		3.250	
Wt. of Compacted Soil in Mould (kg)	0.568		0.659		0.795		0.841		0.841	
Wet Density (kg/m3)	604		701		846		895		895	
Bowl No.	T	B	T	B	T	B	T	B	T	B
Wt of Bowl + Wet Soil (g)	21.8	22.9	23.6	23.8	25.4	24.2	27	23.9	24.5	26.7
Wt. of Bowl + Dry Soil (g)	21.6	22.4	23	23.7	24.7	23.6	25.8	23.3	23.3	25.5
Wt. of Water (g)	0.2	0.5	0.6	0.1	0.7	0.6	1.2	0.6	1.2	1.2
Wt. of Bowl (g)	15.8	14.5	15.4	13.8	15.8	14.1	15.8	14.5	15.4	13.8
Wt. of Dry Soil (g)	5.8	7.9	7.6	9.9	8.9	9.5	10.0	8.8	7.9	11.7
Water Content (%)	3.4	6.3	7.9	1.0	7.9	6.3	12.0	6.8	15.2	10.3
Average Water Content (%)	4.9		4.5		7.1		9.4		12.7	
Dry Density(kg/m3)	576		671		790		818		794	

Table 27: Summary of Compaction Test Result of the Study Area

S/N	location	Soil description	Max dry density(kg/m3)	Optimum moisture content (%)	Specific density S.G
1	L1	High organic matter.	620	13.0	2.7
2	L2	Medium grain size of soil	749	12.9	2.6
3	L3	Rich in brown clay	728	16.1	2.6
4	L4	Large grain size Of soil	825	14.3	2.7
5	L5	Large grain size solid formation.	818	9.4	2.2

ELECTRICAL RESISTIVITY DATA OBTAINED

The table below shows the result of the geophysical survey carried out in the study area using the electrical resistivity method.

Table 28: Summary of VES data interpretation

N						
VES	Layers	Apparent Resistivity(Ω/m)	Thickness	Dept(m)	Lithographic unit	Curve type
1	1	67.1	0.3	0.3	Top soil	
	2	26.7	4.1	4.4	Weathered layer	
	3	1707.8	-	-	Fresh basement	H
2	1	58.5	0.4	0.4	Top soil	
	2	18.8	3.5	3.9	Weathered layer	
	3	2115.2	-	-	Fresh basement	H
3	1	90.8	0.3	0.3	Top soil	
	2	22.2	3.5	3.8	Weathered layer	
	3	438.5	-	-	Fresh basement	H
4	1	101.4	0.2	0.2	Top soil	
	2	19.7	3.3	3.5	Weathered layer	
	3	1253.3	-	-	Fresh basement	H

5	1	81.4	0.2	0.2	Top soil	
	2	15	3.2	3.4	Weathered layer	
	3	1399.3	-	-	Fresh basement	H
6	1	84.4	0.3	0.3	Top soil	
	2	8.5	1.6	1.9	Weathered layer	
	3	2269.2	-	-	Fresh basement	H
7	1	64.8	0.4	0.4	Top soil	
	2	13.5	2.5	2.9	Weathered layer	
	3	1448.6	-	-	Fresh basement	H
8	14	94.5	0.4	0.4	Top soil	
	2	14.7	2.8	3.2	Weathered layer	
	3	2012.1	-	-	Fresh basement	H

Table 29: Type of Soil and Mean Resistivity Values

Soil	**Mean value of resistivity (Ωm)**
Clay, compacted	100-200
Clay, soft	50
Clay sand	50-500
Humus, leaf mold	10-150
Granite	1500-10000
Granite, modified	100-600
Jurassic marl	30-40
Limestone, Fissured	500-1000
Marl	100-200
Mica, schist	800
Peat turf	5-100
Sandstone	1500-10000
Sandstone, modified	100-600
Shist, shale	50-300

Siliceous, sand	200-300
Soil, chalky	100-300
Soil, swampy	1-30
Stony sub-soil, grass-covered	300-500

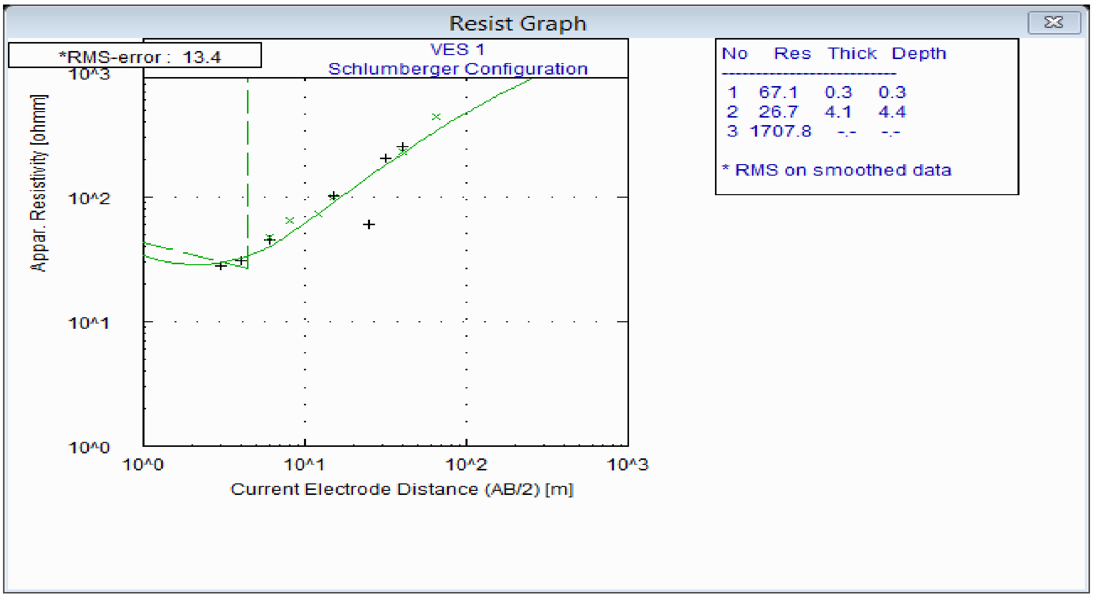

Figure 11: Resistivity Graph of Verse 1

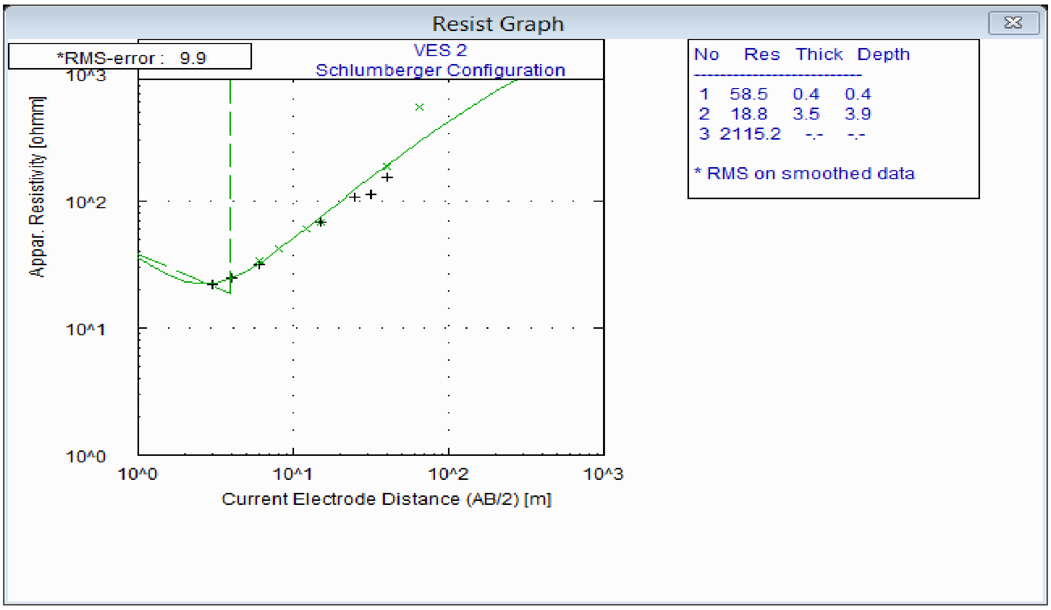

Figure 12: Resistivity Graph of Verse 2

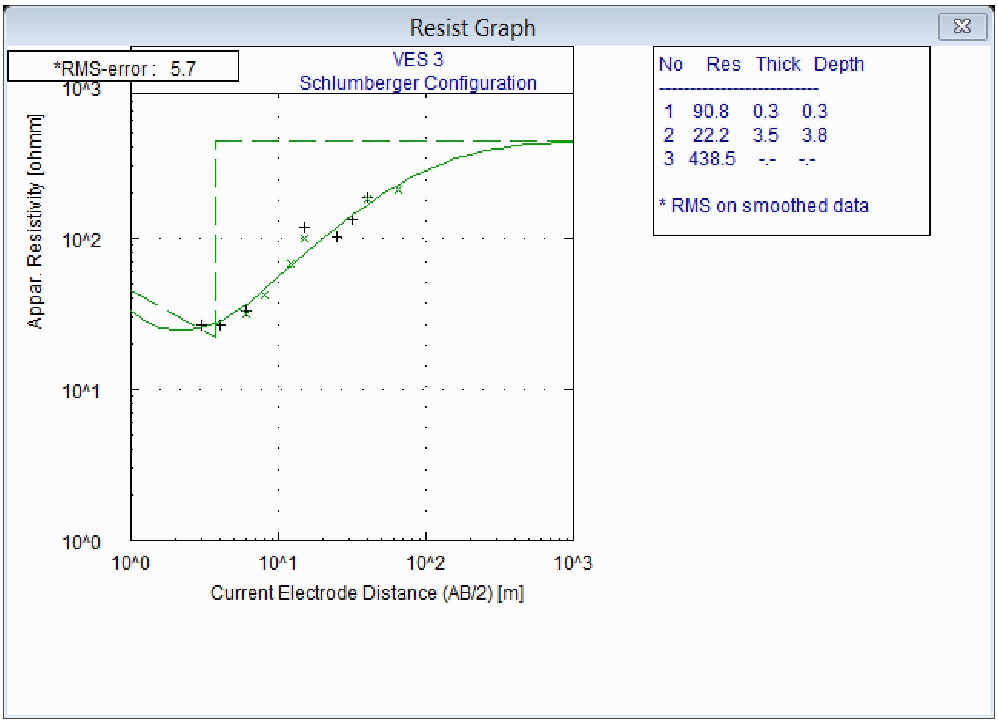

Figure 13: Resistivity Graph of Verse 3

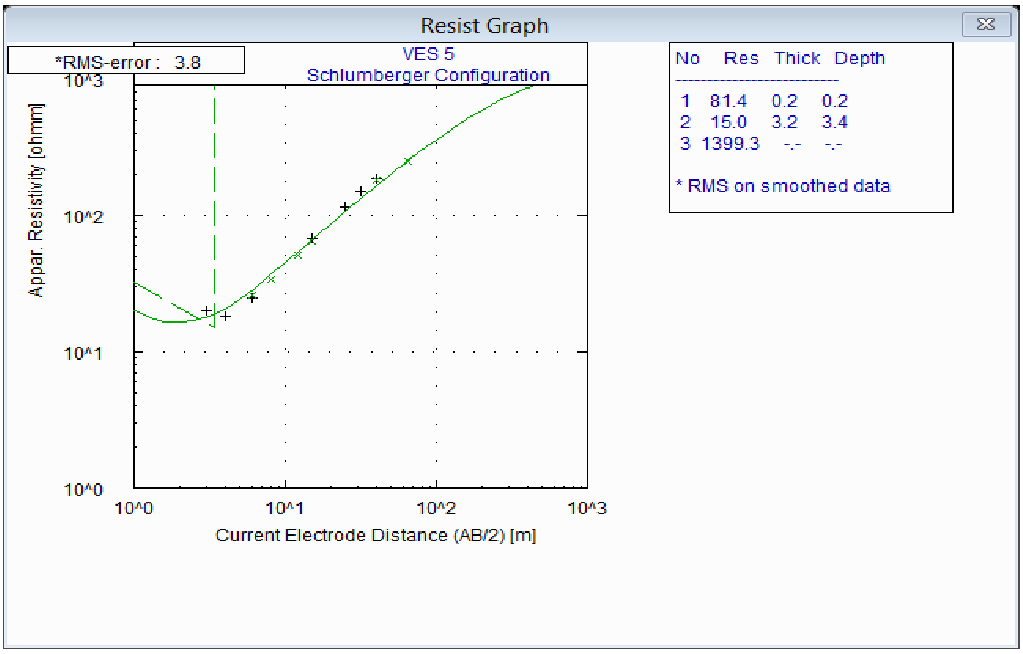

Figure 14: Resistivity Graph of Verse 4

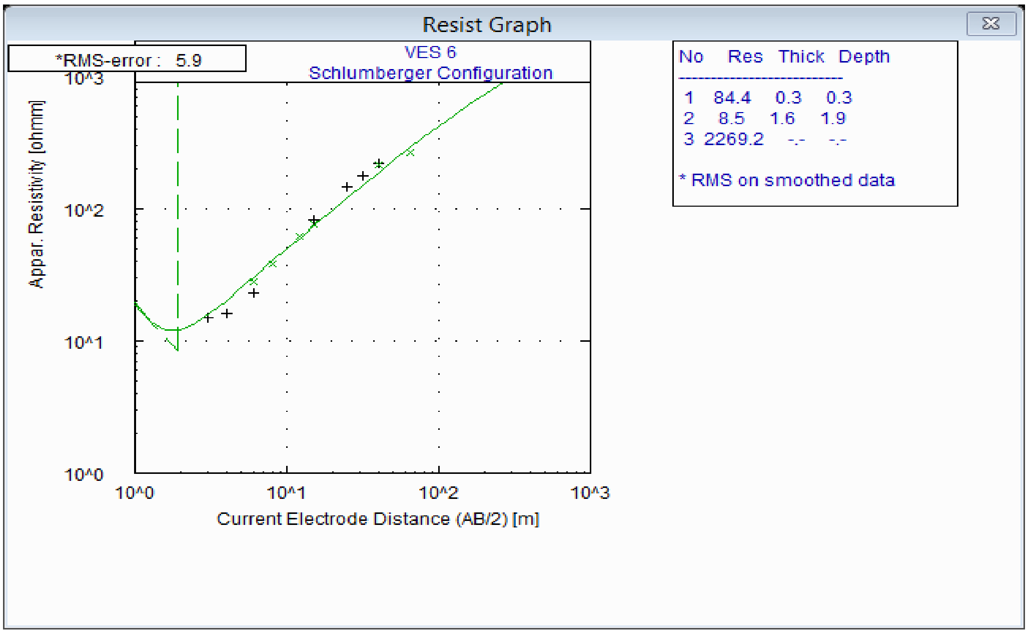

Figure 15: Resistivity Graph of Verse 5

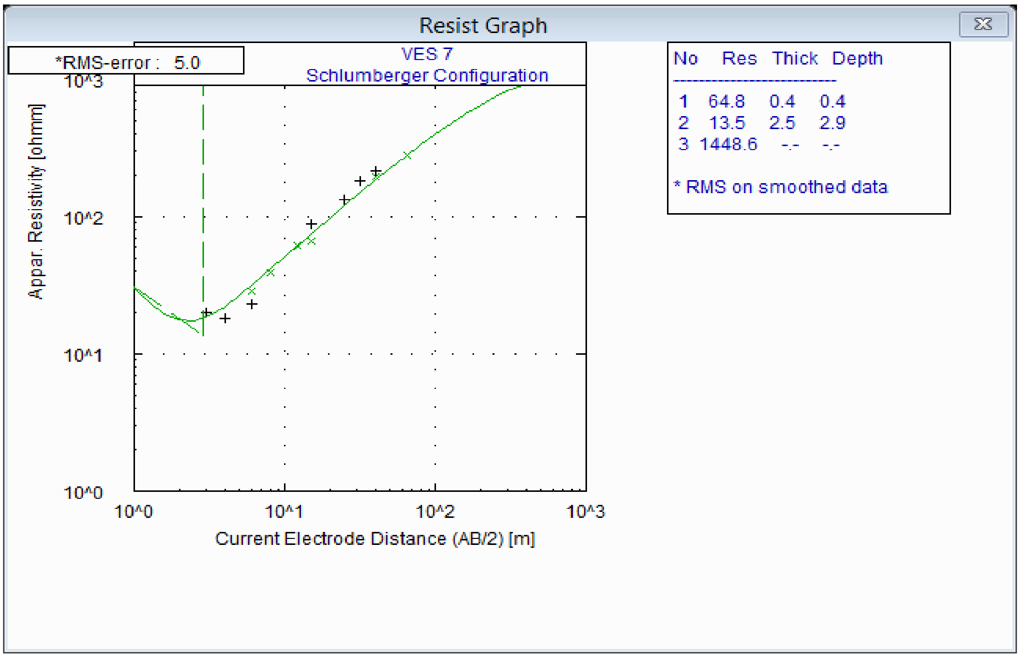

Figure 16: Resistivity Graph of Verse 6

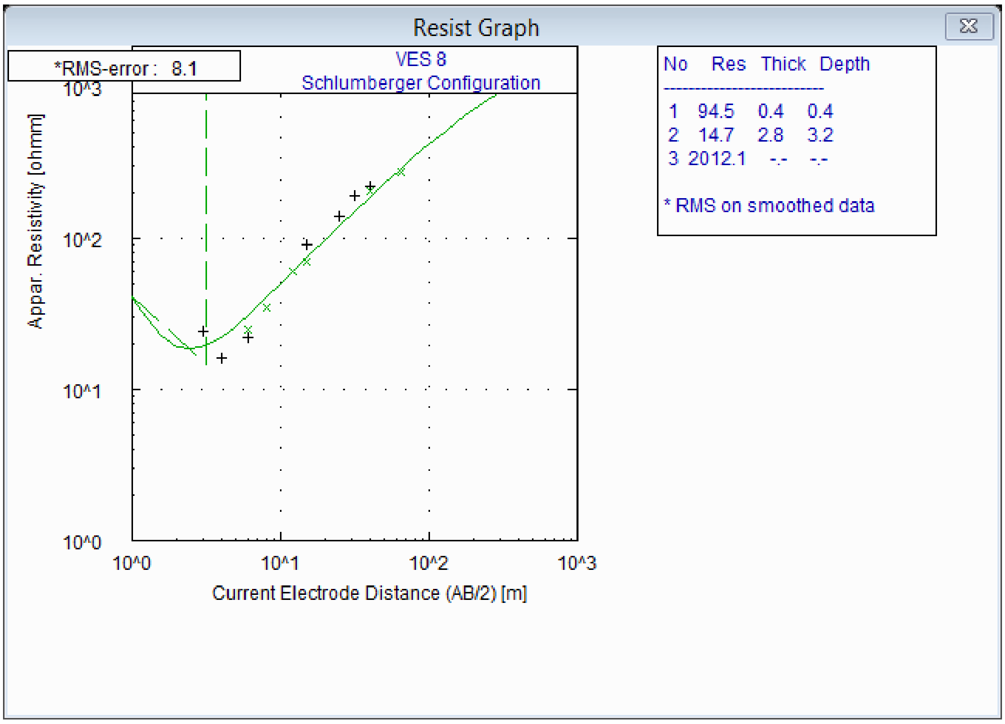

Figure 17: Resistivity Graph of Verse 7

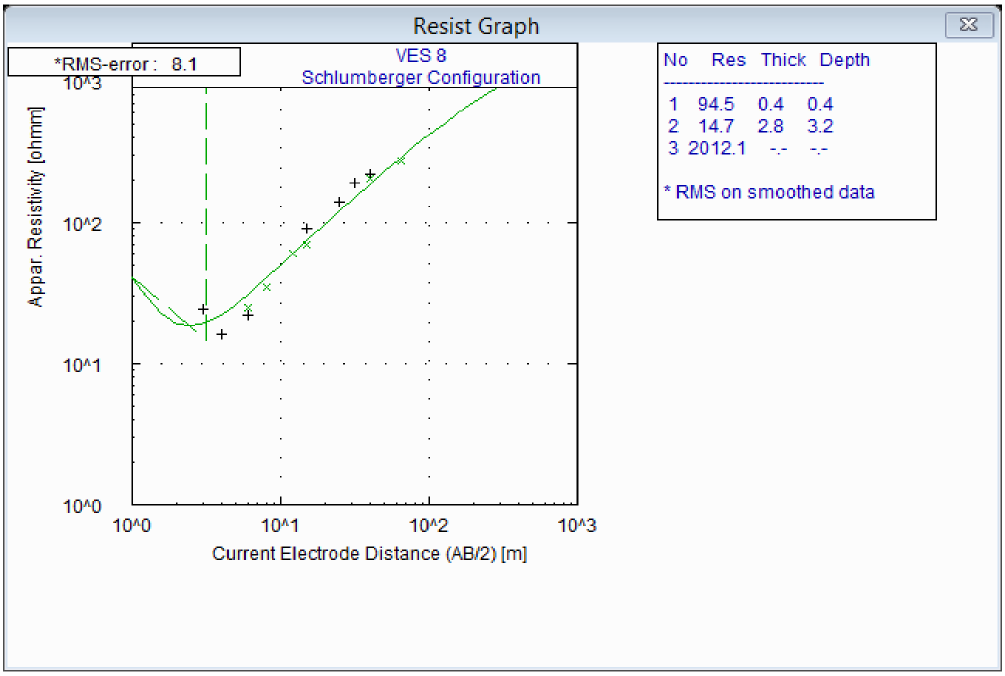

Figure 18: Resistivity Graph of Verse 8

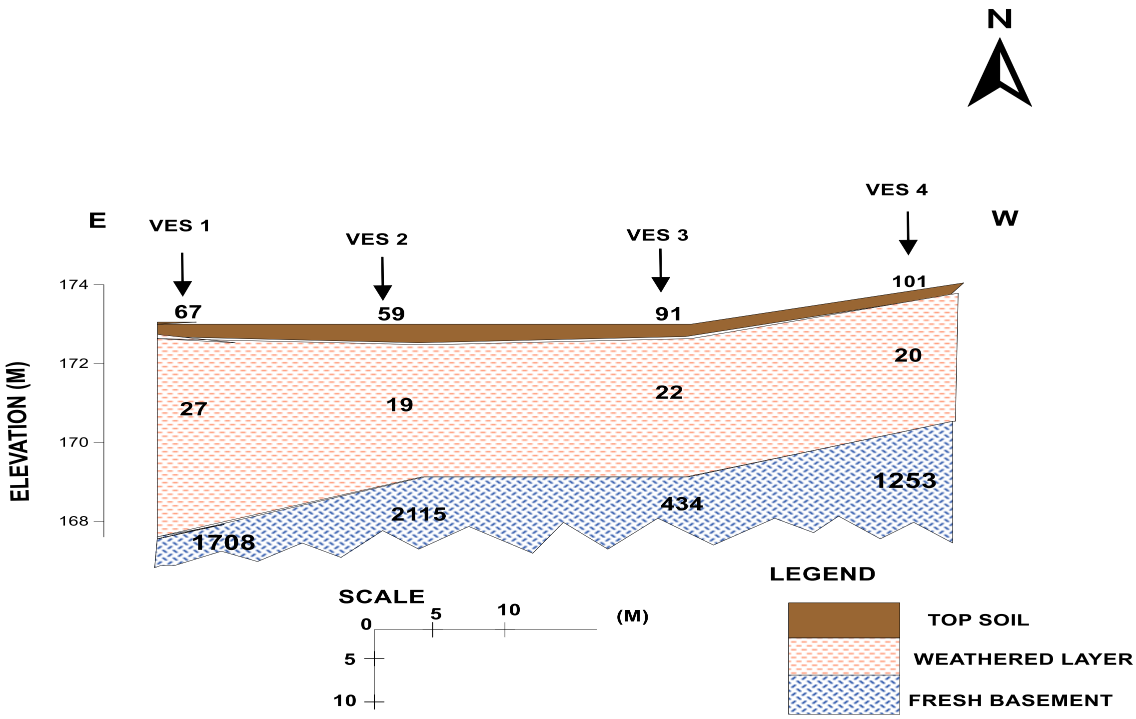

Figure 19: Geoelectric Section Across VES Stations 1-4

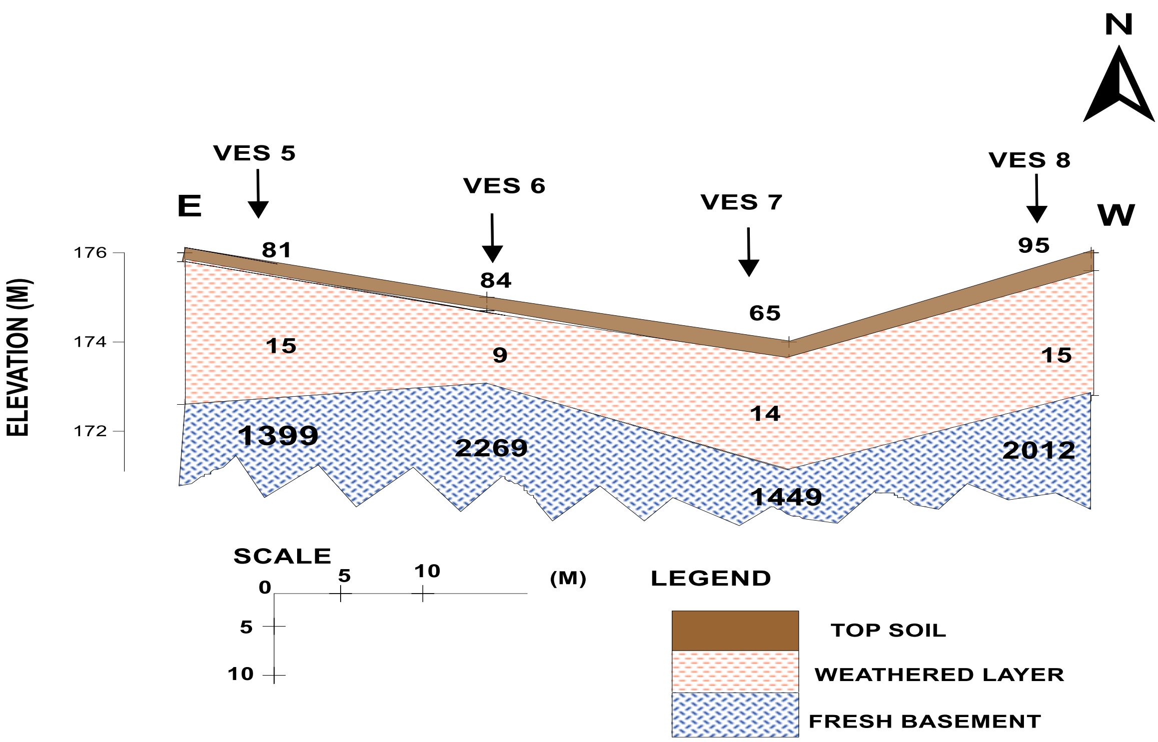

Figure 20 : Geoelectric Section Across VES Stations 5

DISCUSSION

Particle Sizes Distribution

The distribution of particles in the soil are presented by grading curves on a particle size distribution charts, as shown in fig 4.2- 4.6 more than 50% of samples fall within medium to coarse grained sand from the rounded nature of the grains, it shows that it is well sorted and graded.

Natural Moisture Content

The natural moisture content of the soil sample as shown in table 7-11 ranges from 3.89 % - 27.9 %. These results suggested that the soil has high ability to hold water during wet season which when losses during the dry season could cause serious shrinkage.

The Atterberg Limit Test

The summary of the plasticity index result in table 12 - 16 which range from 2.8 % to 16 %, soil sample in this study area have low to medium plasticity and will not posses problem when use in any engineering construction as stated by burnister(1947). This indicated that the soil can be further classified as sandy clay soil of low to medium plasticity

Liquid limit is the minimum water that a soil will contain before it begin to flow as a liquid. The liquild limit as shown in table 12 - 16 is range from 25.8 % to 39 % which are not suitable for any engineering construction

The plastic limit of the soil sample is range from18.8 % to 35.1 % which are not suitable for any engineering construction.

Table 30: Plasticity Characteristic After Burnister (1947)

Plastic index (%)	Plasticity
0	Non plastic
1-5	Slight
6-10	Low
11-20	Medium
21-40	High
>40	Very high

Table 31: Department of Scientific Industrial Reseach (1965)

Average value		Maximum dry density from standard compaction test kgm3	Suitability of soil for construction of embankments
LL	PL		
>65	>22	<1600	Not suitable to very poor
65-50	22-19	1600-1730	Poor

49-32	18-16	1731-1920	Fair good
31-24	15-14	1921-2060	Excellent
<24	<14	>2060	

Specific Gravity

Specific gravity is the ratio of density of a substance to the density of reference substance. This reference substance is always water. The specific gravity of soil sample obtain from the study are range from 2.2 to 2.7

Maximum Dry Density

The maximum dry density of the sample collected from the study ranges from 620 kg/m^3 to 825 kg/m^3, they are less than 1000 kg/m^3 on average and are not good to be used as construction material.

Electrical Resistivity

The result of the geophysical survey are presented in Sounding Curves, Geo-electric sections and Maps. The layer model interpretations of all the VES points are presented in figure 11 - 18. The results of the interpretation in figure 11 - 18 show a system of three geo-electric layers for VES1- 4 and VES 5-8 . All the curves show an H curve pattern. A summary of the VES interpretation is presented on Table 4.28. From the Table, it is quite evident that the resistivity of the first layer is high. The resistivity values range from 58.5 – 101.4 Ohm-m . The thickness of this layer ranges from 0.2–0.4 m. The second-layer layer has low resistivity value ranging 8.5 – 26.7 Ohm-m and the thickness of this layer ranges from 1.6 – 4.1 m.

CONCLUSION

The causes of crack in the buildings are as follow:

Low specific gravity of the foundation soil surporting the buildings.

Poor plasticity of the soil in all the location.

The heterogeneity of the subsurface layer

The foundation soil contains soil with humus, clay and swampy soil.

The cracks could be attributed to expansive soil supporting the foundation of the building. The soil foundation contains a considerably high amount of clay with high plasticity index

Recommendation

Base on these studies, it is therefore recommeded that:

1. The design of subsequent buildings should include more colum base at the DPC level up to a minimum depth of 5m or more.

2. The foundation soil may require significant improvement through engineering reinforcement in the form of raft/pile foundation to enhance their bearing capacities.

3. Timely repairs of cracks should be ensured. This will prevent continuous effect of any further shaking of the building.

4. The usage of the building should be put under monitoring to avoid any overloading of the structure.

5. A good drainage system should be constructed around the buildings to prevent continuous washing away of the building's foundation foot.

6. A more detail geotechnical and geophysical invetigation should be carried out on study area for further studie

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