SUB - SURFACE SOIL PROPERTIES IN THE WESTERN NIGER DELTA REGION

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Abstract
This research work seek is to determine the physicochemical, stratigraphy and engineering geological properties of the underlying subsoils in Delta state, which can be used as reference database for future infrastructural and environmental development. Soil samples where obtained from Oleh, Ozoro, Olomoro, Obiaruku and Abraka township areas of Delta State. Secondary data comprising of geotechnical and electrical resistivity properties of the subsoil were obtained from consultancy firms. The result of the study reveals that the soils are acidic in nature poorly graded sand with low proportion of fines. The water table was found close to the ground surface decreasing with depth. Deep footing or raft foundation is considered appropriate for building design.

Introduction

The knowledge of the geotechnical characteristics of sub soil properties in Delta State, Nigeria is very desirable for design and construction of foundation for civil engineering structures. This will minimize adverse effects and prevention of post construction problems. There have been much efforts towards understanding and quantifying the geology and properties of reservoir and source rocks following the discovery of oil in the area. In contrast, little effort has been made in understanding the engineering geological properties of sub-surface soils. Adeyemi (2002), buttressed the importance of a complete assessment of any soils before its utilization for any engineering works. This is because of the peculiar set of engineering, chemical and physical properties the soils exhibit in response to the climatic, geological and geomorphologic conditions of their origin. Therefore, the need for accurate information and adequate understanding of the geotechnical properties of the soils in precise locations in the region has necessitated various works by researchers (Nwankwaola et al., 2014; Udo and Uko, 2014; Ekeng et al., 2016; Onyebuolise and Akpokodje, 2008; Youdeowei and Nwankwoala ,2012). The western Niger Delta is the area that lies west of the Nun River and is geographically defined by Delta, Edo, and parts of Bayelsa States. Delta state lies within the Niger delta region of southern Nigeria. The region is over 70% riverine and is acknowledged to be on the surface apparently underlain by different soil types all covering the *coastal plain sand* of the Benin formation (Short and Stauble, 1967). This formation consists of sandy silt, brownish clayey/silty sand, and fine-medium/coarse grained unconsolidated sands. Overlying the formation are several quaternary alluvial deposits consisting largely of recent deltaic sand, silt and clay of variable depth and spatial spread (Abam,2016). The soil lithology is relatively uniform or an alternating sequence of sand silt, clay-peat or sand-silt clay mixture (Akpokodje, 1989) and that the depositional environment determines the nature and properties of the sediments formed (Akpokodje,1987). Most construction projects are founded in the quaternary deposits and based on similar characteristic in geotechnical, geological, geomorphological and drainage propertie., Akpokodje (1987) described the quaternary deposits into four major soil types in the region namely; reddish brown sandy clay loam; brown sandy clay; organic fine sand and silty clay and dark organic/peaty clay. In this work, the physicochemical, stratification and geotechnical properties of subsoils for several localities in Delta State are characterized to provide information for future development in these areas.

Data Collection

Disturbed soil samples were obtained at Oleh, Ozoro, Olomoro, Obiaruku and Abraka for physicochemical tests. While secondary soils data comprising of cone penetrometer, Soil borehole log and electrical resistivity at Udu, Oghara, Warri and Sapele were obtained from consultancy firms.

Physico-Chemical Properties of Soils

The test results for the physico-chemical properties of soils in several localities in Delta State is presented in Table 1

Table 1: Physico-Chemical Properties of Soils

S/N	Paramaters	Units	Oleh	Ozoro	Olomoro	Obiaruku	Abraka
1	pH		5.9	4.7	5.1	6.37	6.9
2	EC	µs/cm	87	587	376	86	143
4	Cl-	mg/Kg	27	29.35	7.52	26.7	44.3
5	SO_4^{2-}	mg/Kg	3.57	9.7	2.44	3.53	5.86
6	NO_3^-	mg/Kg	1.91	19.02	5.24	1.89	3.15
7	PO_4^{3-}	mg/Kg	2.61	24.72	3.65	2.58	4.29
8	Na+	mg/Kg	4.35	38.04	14.62	15.42	8.57
9	Fe	mg/Kg	3.09	62.76	10.96	6.02	10.01
10	Ca^{2+}	mg/Kg	1.91	24.72	8.53	5.47	7.26
11	Mg^{2+}	mg/Kg	1.41	32.64	6.84	11.02	14.25
12	K	mg/Kg	0.96	55.15	21.20	14.20	13.11
14	Zn^{2+}	mg/Kg	0.37	24.72	3.65	0.37	0.61
15	Mn^{2+}	mg/Kg	0.18	6.28	1.46	0.18	0.3
16	Cu^{2+}	mg/Kg	0.44	13.31	6.09	0.43	1.14
17	Ni^{2+}	mg/Kg	0.06	3.80	2.44	0.06	0.3
18	Cd^{2+}	mg/Kg	0.03	2.13	0.76	0.03	0.04
19	V^{2+}	mg/Kg	0.07	6.92	4.43	0.07	0.26
20	Cr^{6+}	mg/Kg	0.06	7.96	3.15	0.06	0.07
21	Pb^{2+}	mg/Kg	0.04	2.39	1.37	0.04	0.07
22	Org. Carbon	%	1.76	3.93	0.91	0.76	1.35
23	Organic Matter Content	%	3.08	6.88	1.59	1.33	2.36
24	Clay	%	1.43	7.32	4.68	5.14	6.25
25	Silt	%	9.34	6.97	6.48	6.00	7.42
26	Sand	%	89.23	85.71	88.84	89.14	87.24

The soils are acidic based on the pH value ranged of 4.7 to 6.9. The acidic nature of the soils may be as a result of the high percentage of sand with the low holding capacity of the soil (low clay content). This give rise to a higher amount of water that is infiltrated in the ground increasing the humidity and the acidifying process of the soil. (Eriksson et.al., 2005). Also this trend is in agreement with the work of Mustapha and Alhassan (2012), who reported neutral to acidic medium ($pH \leqslant 7$) for lateritic soil medium. Tropical soils are intensively weathered and all nutrients are found in the organic matter (Troeh and Thompson; 2005.). The organic matter content (1.33-6.88%) is low in these soils. Also, the acidic nature of the soils encourages the growth of pest within the soil. This may be the reason, nutrients such as K, Ca, Mg etc are less available in the soil. The high level of humidity also has a great effect on the leaching of anions and cation. (Eriksson et al.; 2005). pH value less than 5.5 (acidic soils) are associated with excess of Cu, Fe, Mn and Zn (Landon; 1991). Hence Ozoro and Olomoro with the lowest pH have the highest values of metal of Fe, Mn, Zn, and Cu.

The soil texture here indicates a range for clay of 1 - 7%, silt 6 - 9% and sand 87 - 89%. The low value of clay present in the soil will result in the high porosity and low cohesion within the soil mass. Electrical conductivity (EC) is a measure of ionic concentration in the soils. It is closely related to the total dissolved solid. The significantly higher electrical conductivity values obtained for Ozoro and Olomoro could be as a result of the high accumulated values of the various ions (anions, metallic ions, cations) present in the soils.

Soil Stratigraphy.

The subsoil soil stratigraphy for a point at Oghara is presented in Table 2;

Table 2. Soil Properties at Various Depths at Oghara

S/N	Depth (m)	Specific Gravity	% Passing Sieve No.			Moisture Content (%)
			1.18mm	0.425mm	0.075mm	
1	1.0	2.39	98.85	75.86	32.05	20.32
2	4.0	2.44	99.22	73.9	43.17	14.95
3	7.0	2.45	97.29	79.56	34.80	29.13
4	10.0	2.49	96.31	78.33	36.52	18.09

The sieve analysis shows that the soils consist of 32.05 to 43.17% of fines. The fines increase with depth up to 4m and decreases downward. The soil group consist of alternate layers of A-2 and A-7 subgroup. The soil layers can be classified as sandy clay of medium and high plasticity. The specific gravity increase with depth, the lower value may be due to the presence of organic matter (Garg, 2009).

The subsoil soil stratigraphy for a point at Sapele is presented in Table 3 .

Table 3. Soil Properties at Various Depths at Sapele

S/N	Depth (m)	Specific Gravity	% Passing Sieve No.			Moisture Content (%)
			1.18mm	0.425mm	0.075mm	
1	1.5	2.68	94.15	79.86	11.12	20.32
2	3.0	2.58	89.36	69.56	4.93	14.95
3	4.5	2.49	95.48	87.03	5.83	29.13
4	6.0	2.63	99.68	95.96	12.2	18.09
5	7.5	2.64	99.70	89.8	8.04	20.88
6	9.0	2.62	99.71	94.72	3.7	20.35
7	10.5	2.64	99.99	96.06	6.53	22.32
8	12.0	2.71	97.95	83.8	1.76	15.28
9	13.5	2.64	98.6	85.64	1.2	22.00
10	15.0	2.66	98.51	63.35	0.12	18.98
11	16.5	2.65	90.18	50.30	6.24	13.04
12	17.25	2.51	95.66	48.42	2.66	25.33
13	18.0	2.59	95.25	56.37	1.43	15.11
14	19.5	2.55	96.32	41.49	1.55	18.44
15	21.0	2.59	97.06	51.73	0.9	16.93

The sieve analysis results show the soils consist of 0.9% to 12.2% of fines. dominance of sand over fines indicate a non-uniform distribution of grain sizes which implies poor grading. The fines tend to decrease downward indicating that the top soil might be sandy silt or sandy clay up to a depth of 10.5m. While the soils beyond the depth of 20m might be sandy soils The soil can be classified as poorly graded medium size sand (SP). The soil profile is shown in Figure 1.

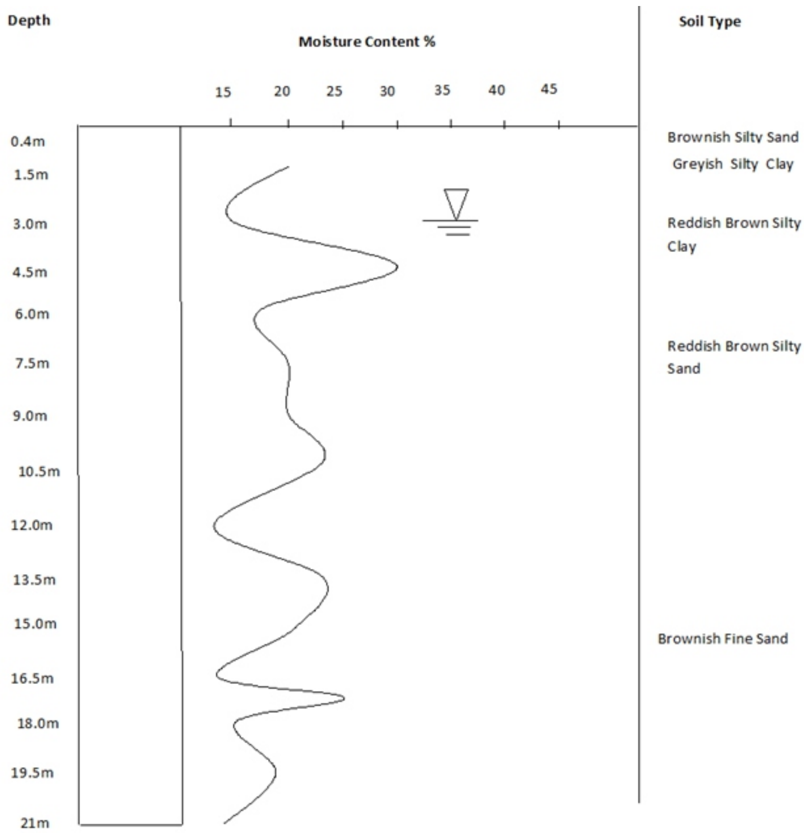

Figure 1. Soil borehole log at Sapele

The water table was found to be at a depth of 3.40m, which accounts for the high values of moisture content. The water table fluctuates during rainy and dry seasons (i.e groundwater levels may vary depending on the time of year and climatic events). The specific gravity ranges from 2.49 to 2.68. The lower limit of the specific gravity could be an indication of silt with organic matter (Garg, 2009).

The subsoil soil stratigraphy for a point at Warri is presented in Table 4.

Table 4. Soil Properties at Various Depths at Warri

S/N	Depth (%)	Specific Gravity	% Passing Sieve No.			Moisture Content (%)
			1.18mm	0.425mm	0.075mm	
1	1.0	2.34	93.26	79.07	12.05	53.32
2	2.0	2.35	61.67	37.16	4.93	56.73
3	3.0	2.47	88.76	76.80	14.19	59.80
4	4.5	2.65	99.15	94.74	5.19	36.08
5	6.0	2.62	99.86	97.11	5.69	31.41
6	7.5	2.65	100	99.15	2.38	33.22
7	9.0	2.62	99.87	99.17	5.41	33.80
8	10.5	2.65	99.79	98.77	2.21	29.98
9	12.0	2.66	99.95	99.09	3.26	26.64
10	13.5	2.66	94.76	82.96	2.51	27.80
11	15.0	2.66	99.95	99.09	3.26	28.37
12	16.5	2.65	99.77	97.34	8.21	43.50
13	19.5	2.64	97.56	94.96	9.77	27.17
14	21	2.66	93.09	88.19	10.94	27.51
16	24.0	2.65	98.8	96.87	8.81	24.07
17	25.5	2.67	98.71	96.76	6.42	27
18	27.0	2.68	99.51	97.34	6.10	23.21
19	28.5	2.66	99.36	97.03	8.31	26.23

The specific gravity of the soil samples from the various depth lies between 2.34 and 2.68 and increases with depth. The greyish colour and the low value of specific gravity may be an indication of organic matter. The percentage of soil passing the 0.075mm sieve lies in the range of 2.51 to 14.19%. The soil profile is shown in Figure 2.

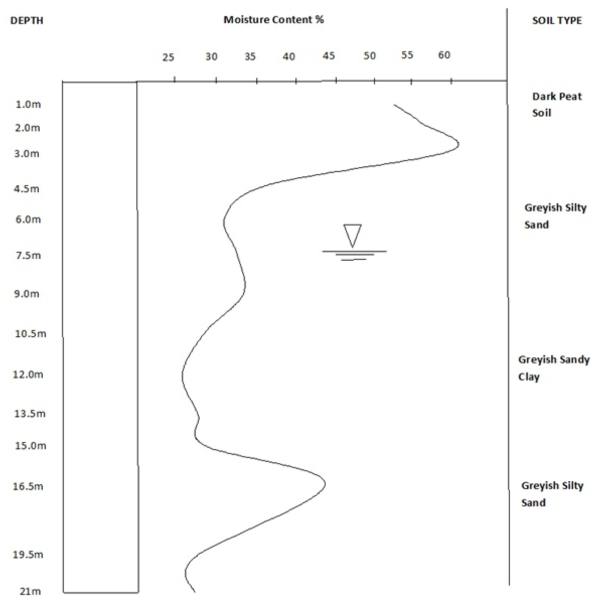

Figure 2. Soil borehole log at Warri

There is water table is at a depth of 7.50m, which accounts for the high values of moisture content. The moisture content of the soils reduces as the depth increases. This may be due to the presence of coarser aggregate materials in the soil mix. The actual moisture content of the soils at various depth lies between 23.21 and 59.50%

The electrical resistivity test (Vertical Electrical Sounding) carried out at a location in Warri, Delta State to study the pattern of variation of the soils at various depth. The geoelectric parameters and inferred lithology is in Table 5, while the soil log profile is shown in Fig. 4.8

Table 5. Geoelectric Parameters and Inferred Lithology

Layers	Resitivity[Ohm-m]	Thickness[m]	Depth [m]	Lithology
1	3048	1.74	1.74	Compacted sandy topsoil
2	1093	4.04	5.78	Subsoil (saturated)
3	116	19.24	25.02	Sandy aquifer
4	1268	19.13	44.15	Resistive sandy clay/ clayey sand
5	89	-	-	Sandy clay aquifer

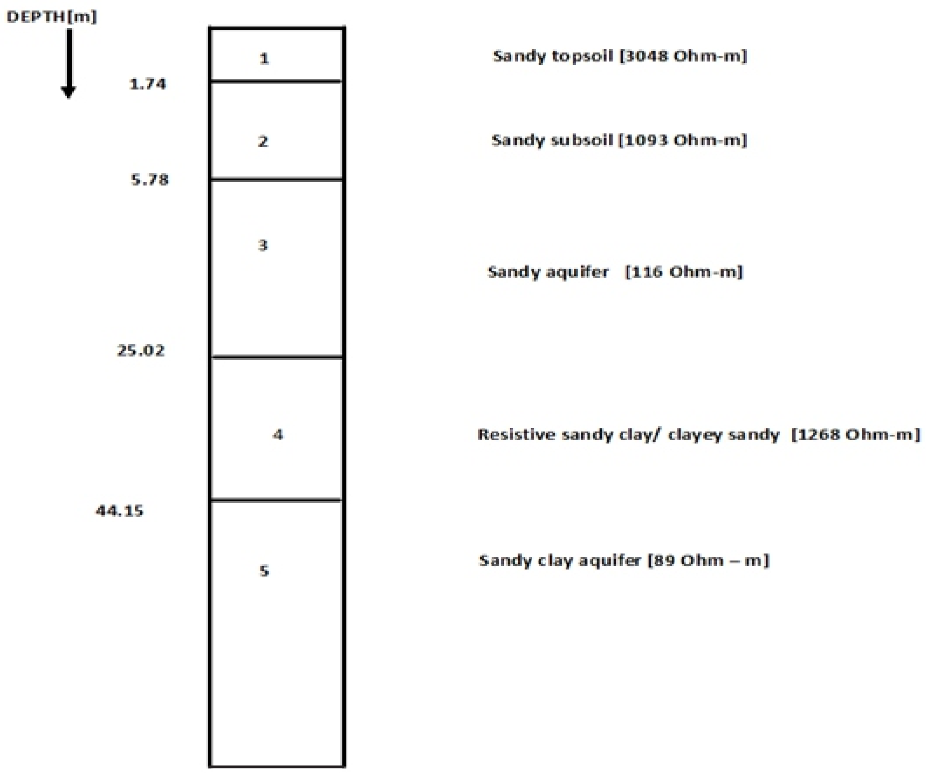

Figure 5. Soil log profile at Warri

Five geoelectric layers were delineated. Layer 1 is designated as compacted sandy topsoil with a thickness of 1.74m. Layer 2 is a partly saturated sandy subsoil, 4.04m thick. The third layer with a relatively low resistivity is designated as saturated sandy horizon (sandy phreatic aquifer). The fourth layer is the resistive sandy clay/clayey sand horizon. Layer 5 is another conductive strata, designated as the saturated sandy clay/clayey sand unit (sandy clay confined aquifer).

The subsoil stratigraphy for a point at Udu is presented in Table 6.

Table 6. Soil Properties at Various Depths at Udu

S/N	Depth (m)	Specific Gravity	% Passing Sieve No.			Moisture Content (%)
			1.18mm	0.425mm	0.075mm	
1	1.5	2.12	61.82	51.8	21.9	30.68
2	3.0	2.52	70.82	39.94	2.05	19.57
3	3.5	2.46	87.12	61.44	17.86	21.76
4	4.5	2.49	90.33	53.83	3.01	19.21
5	6.0	2.48	86.52	56.18	3.10	18.29
6	7.5	2.62	89.80	65.61	11.86	18.43
7	9.0	2.46	96.13	70.96	0.53	19.22
8	10.5	2.61	95.64	66.86	1.81	16.54
9	12.0	2.61	85.71	52.89	1.16	14.84
10	13.5	2.58	98.19	77.08	10.69	18.42
11	15.0	2.57	92.16	76.40	0.8	19.30
12	16.5	2.63	99.84	94.27	0.11	20.48
13	18.0	2.53	98.29	88.07	5.28	19.59
14	19.5	2.66	98.78	94.93	3.63	20.10
15	20.25	2.53	79.27	48.53	23.16	27.29
16	21.0	2.58	91.77	55.82	5.64	15.50
17	22.5	2.13	96.9	51.33	2.13	15.31
18	24.0	2.54	99.37	88.99	5.13	17.07
19	25.5	2.58	83.97	33.57	1.96	15.15
20	27.0	2.32	87.82	38.10	2.09	14.03
21	28.5	2.56	90.04	45.96	4.69	14.40
22	30.0	2.53	84.25	33.01	1.71	17.96

The sieve analysis shows the soils consist of 0.11% to 23.16% of fines. The dominance of sand over fines indicate a non-uniform distribution of grain sizes which implies poor grading. The soil profile is shown in Figure 6.

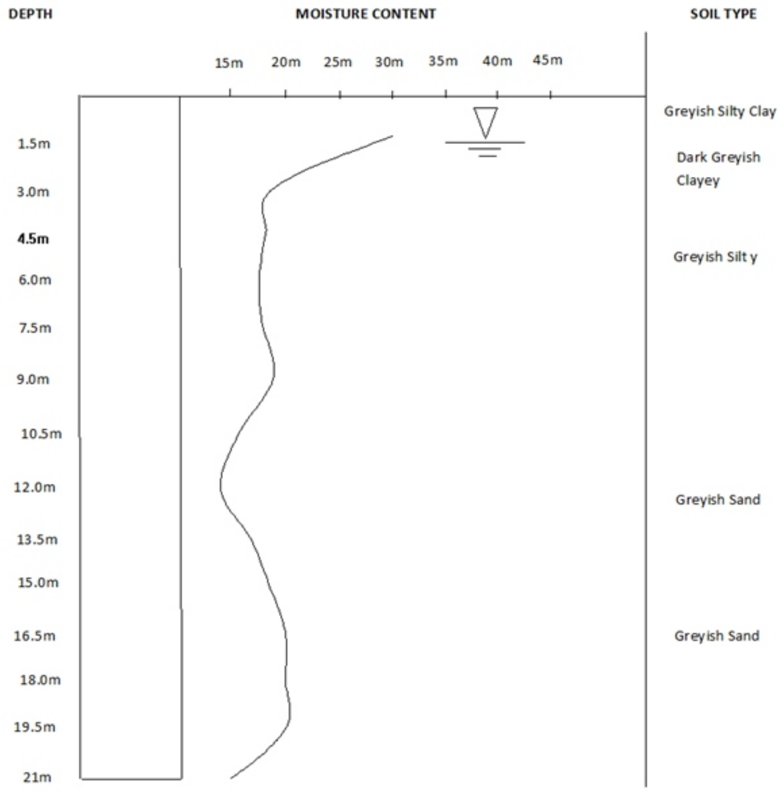

Figure 6. Soil log profile at Udu

The soil can be classified as poorly graded medium size sand (SP). The specific gravity ranges from 2.12 to 2.66. The grey colour may be an indication of the presence of organic matter. The water table is at about 1.5m below ground level. The moisture content of the soil reduces as the depth increases. This may be due to the presence of coarser aggregate materials with depth. The moisture content of the soils at various depth lies between 23.21 and 59.50%.

Conclusion

The lithology of the sub-soil in the area reveals that the soil is predominantly sandy with low proportion of fines particles. The water table is close to the existing ground surface and decreases with depth, this may be an indication of the presence of coarse particle. The homogenous uniformity is an indication of deposition under similar energy conditions. The greyish colouration of the soils may be due to the presence of organic matter.

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