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SUBSOIL CONSTITUENTS VARIATIONS AND DISTRIBUTIONS ACROSS THE NIGER DELTA STATES OF NIGERIA

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ABSTRACT

The geotechnical properties of sub-soils strata of States in the Niger Delta, which include SPT-N, grain size and natural moisture content, were investigated. The average SPT-N value across the States varies in randomly, but generally increased with soil. The average SPT-N values ranged from 5.20±1.13 to 32.40±2.05 blows for Rivers State, 4.50±2.89 to 28.75±3.10 blows for Bayelsa State, 5.00±2.35 to 27.33±3.09 blows for Akwa-Ibom State and 5.00±2.44 to 26.00±2.92 blows for Delta State. These variations are due to soil characteristic behaviour as its depth increases. Additionally, the SPT-N values across the States are not significantly different. Similarly, natural moisture content of the various sites varies randomly and generally decreased with increase in soil depth. The average natural moisture content ranged from 10.32±1.13 to 26.70±0.97% for Rivers State, 12.43±0.35 to 29.15±0.18% for Bayelsa State, 0 to 28.77±1.01% for Akwa-Ibom State, and 0 to 28.35±1.71% for Delta State. There were high variability and fluctuations in grain size of the different soil composition due to the soils' characteristic properties. However, the grain size generally increases in sandy region especially, above 25m depth, but for silt, the grain size generally increased with depth from its initial values to certain depths and then, reduced gradually. Whereas, in some locations, there was no detectable grain size in clay, gravel and even silt and sand at certain depths. The variations recorded from the various geotechnical properties were as a result of the distinct soil characteristics exhibited across the different layers. Based on the observations, it can be said that there is possibility of liquefaction occurrence in the Niger Delta soil, however, it may not result to excessive disaster

1. INTRODUCTION

Landslide particularly has been one of the major hazards resulting from an earthquake in Africa, which had destroyed resources worth several millions of dollars annually (Ige *et al*., 2016). In 2005, 2011 and 2013, landslide was recorded in Umuchiani community, Awgu and Oji-River and Oko Community respectively in Anambra and Enugu States of Nigeria (Ige *et al*., 2016). Also, in 2013, no fewer than nine persons were buried alive and many others sustained injuries in a landslide that occurred at Edim Otop community of Calabar metropolis (Ige *et al*., 2016). Tremor, a type of wave energy movement that starts in constrained locale and afterward spreads from the wellspring of unsettling influence was experienced in Rivers and Bayelsa States in 2016. The cause of structural tremors is clarified with the assistance of a 'flexible bounce back hypothesis'. Tremor can trigger occurrence of earthquake, which will be disastrous if at high magnitude. Earthquake is a form of energy propelled by wave motion, and originates in a limited region spreading to several directions from the source of the disturbance. It usually lasts for a few seconds to a minute (Pratt and Johnson, 1926).

This recent tremor incidents in the Niger Delta region and series of earth tremors in various parts of the country, made the Nigerian seismologists conclude that Nigeria is no longer an earthquake-free zone as previously thought. The use of explosives as seismic exploration energy source in the Niger Delta over the years has also generated fears and concerns to the inhabitants as it affects roads, buildings and the environment (Eze and Okara, 2014). Seismic induced activities such as blast-induced ground vibrations have been studied via geological formation and surface soil characteristics (Adeoti et al., 2012; Eze and Okara, 2014). Eze and Okara (2014) noted that the guidelines applied to the use of explosives by the exploration companies were based on standards developed in countries whose soil types and geology are different from what obtains in the Niger Delta.

Research shows that Nigeria is not situated on any active known seismic belt, yet tremendous tremors had been recorded (Adeoti et al., 2012). Therefore, it is important to identify the geological formations of area with high seismic activities like the Niger Delta region of the country, which is essential for determining the seismic sources and also for establishing earthquake hazard models. From this analysis, the causes of failures and sudden change in soil properties which triggered the actions of earth tremor will be known. The geotechnical description of subsoil is imperative as it will generate relevant data inputs for engineering design and construction, which will minimize post construction problems (Nwankwoala and Oborie, 2014). Most of the Niger Delta areas can be described as coastal zone, which comprises of beach ridges and mangrove swamps, underlain by alternating sequence of sand and clay with high frequency of occurrence of clay within 10m below the ground surface (Nwankwoala and Oborie, 2014). The impact of imposed load on such soil can be exacerbated by the thickness and consistency of compressible layer, which in addition to other intrinsic factors may contribute to failure of engineering structures (Youdeowei and Nwankwoala, 2013; Amadi *et al,* 2012). For the purpose of generating relevant data inputs for the design, construction and averting earthquake disasters, it is essential that geotechnical properties of soil are known. Therefore, this study aims at establishing significant subsoil profile of selected Niger Delta States.

2. METHODOLOGY

2.1 Study Area

The soil samples were collected from four (4) States of the Niger Delta Region of Nigeria. The sampling locations are in Rivers State (Akinima and Mbiama Towns in Ahoada West Local Government, Ogbogu Town in Ogba/Egbema/Ndoni Local Government Area, Tombia Town in Degema Local Government Area and Bori Town in Khana Local Government Area; Bayelsa State (Igbogene and Agudama Towns in Yenagoa Local Government Area, Otuasega Town in Ogbia Local Government Area and Nembe Town in Nembe Local Government Area), Akwa-Ibom State (Ikot Abasi Town in Ikot Abasi Local Government Area, Ibagwa Town in Abak Local Government Area and Ibiaku Offot Town in Uyo Local Government Area) and Delta State (Aboh Town and Afor Ogbodigbo Town in Ndokwa East Local Government Area).

2.2 Soil Sample Collection

Soil samples were collected by subsurface exploration activities at the sites which included drilling and deep boring by standard penetration test (SPT). In-situ field test and laboratory test were adopted in this research work. The tests were conducted to estimate the dynamic soil properties.

2.3 Test Procedures

Detailed laboratory tests were carried out on the representative samples recovered from the explored holes for basic geotechnical properties of sub-soils and classification tests. The laboratory exercise was carried out in accordance with BS 1377 (1995) – Methods of Tests for Soil for Civil Engineering Purposes. Laboratory procedures on the tests are given below:

2.4 Moisture Content

The water content was determined by drying selected wet soil material for at least 12 hours to a constant mass in 1100C drying oven. The difference in mass before and after drying was used as the mass of the water in the test material. The mass of material remaining after drying was used as the mass of the solid particles. The ratio of the mass of water to the measured mass of solid particles was the water content of the material. This ratio can exceed 1 (or 100%). Reference test standard: BS 1377: Part 2: 1990.

2.5 Grain Sizes Analysis

Laboratory tests were carried out on soil samples according to British Standards (BS) 1377 and ASTM (1975) standards. The particle size distribution was determined by washing a known weight of oven-dried sample through ASTM sieve No.4 (4.75mm), vibrated with a shaker until no fines were retained. The percentage passing through the successive sizes were found from the difference between the initial weight and the weight retained by each sieve.

2.6 Standard Penetration Test (SPT)

To identify the soil stratification and engineering properties of soil layers, the Standard Penetration Test (SPT) was performed. Thus, holes were drilled down to 30m depth with 250mm, 200mm and 150mm diameter steel casings. The borings were conducted using a Percussion motorised Shell and Auger rig employing light cable percussion boring techniques. In the cohesionless materials, Standard Penetration Test (SPT) was carried out at intervals not more than 1.5m, and the disturbed samples recovered from the SPT sampling tool. A 50mm diameter split spoon sampler is then driven into the soil using a 63.5kg hammer with a 760mm drop. The penetration resistance is expressed as the number of blows (SPT-N value) required to obtaining a 300mm penetration below an initial 150mm penetration. The SPT-N values, the borehole data, penetration resistance, and sample data were recorded.

3. RESULTS AND DISCUSSION

The geotechnical properties of sub-soils strata of the sites located in Rivers, Bayelsa, Akwa-Ibom and Delta States of Niger Delta region have been studied and they include SPT-N, grain size, and natural moisture content.

3.1 SPT-N Variation

The average SPT-N values of the sites in the various States of the Niger Delta region have been studied and shown in Figure 1. Thus, the trends in SPT-N variation do not assume a definite pattern or shape as it varies in a zigzag manner with depth across all the States. However, as depth increased, the average SPT-N values can generally be said to increased despite the decline experienced at some region of the soil layers (i.e. the SPT-N values tends to decrease after a certain depth, while in some sites, the values initially increased to a certain depth and then, decreased before increasing again). The average SPT-N values ranged from 5.20±1.13 – 32.40±2.05 blows for Rivers State, 4.50±2.89 – 28.75±3.10 blows for Bayelsa State, 5.00±2.35 – 27.33±3.09 blows for Akwa-Ibom State and 5.00±2.44 – 26.00±2.92 blows for Delta State. These variations are due to soil characteristic behaviour as its depth increases. Additionally, the SPT-N values across the States are not significantly different.

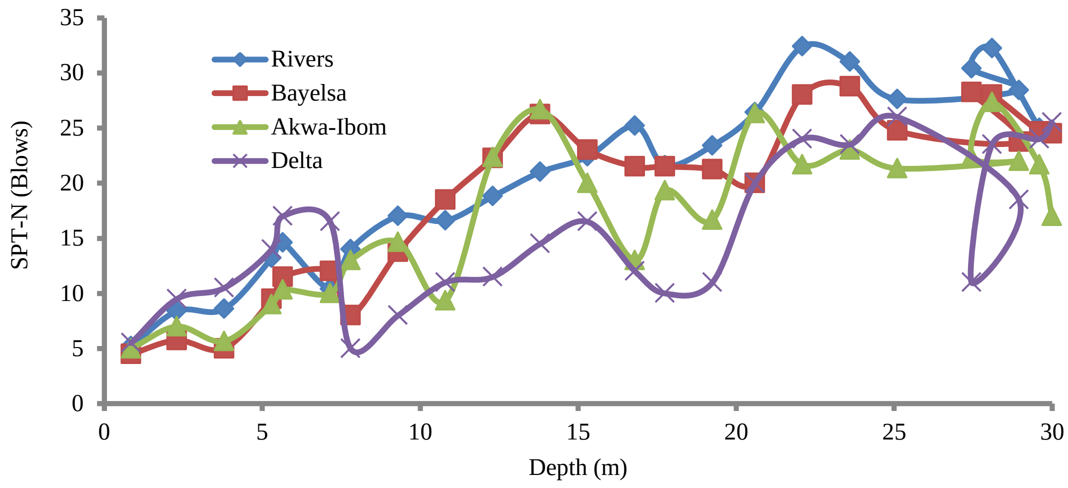

Figure 1: Variation in SPT-N with depth across the States

However, the average of SPT-N values below 20 blows was recorded between 0.85 and 12.3m depth and 0.85 and 13.8m depth in Rivers and Bayelsa States respectively, while for Akwa-Ibom and Delta States, there was a mix of SPT-N values below and above 20 blows as soil depth increases. The average SPT-N above 30 blows count was recorded only in Rivers State. According to Seed *et al*. (1985), soil with SPT-N range of 0-20 blow counts will tends to liquefy and thus, causes more damage upon disaster incident, while with range of 20-30 blow counts, the possibility of liquefaction occurring will be low, and if it occurs, it will only cause slight damage. They continued that if the SPT-N value is above 30 blow counts, liquefaction may not occur, and hence, no damage will occur as a result. Therefore, it can be said based on the SPT blow counts that there is possibility of liquefaction occurrence in the Niger Delta soil, however, it may not result to excessive disaster.

3.2 Natural Moisture Content Variation

Like SPT-N, the natural moisture content in the soil obtained from the various sites varies randomly with increase in soil depth as shown in Figure 2. Generally, when there is increase in soil depth, the soil natural moisture content tends to decrease. Thus, as recorded from the analysis, the average natural moisture content ranged from 10.32±1.13 - 26.70±0.97% for Rivers State, 12.43±0.35 - 29.15±0.18% for Bayelsa State, 0 - 28.77±1.01% for Akwa-Ibom State, and 0- 28.35±1.71% for Delta State. Natural moisture content was not recorded between 20.6 and 30m depth in Akwa-Ibom State, while in Delta State, 0% natural moisture content was not recorded at 30m depth.

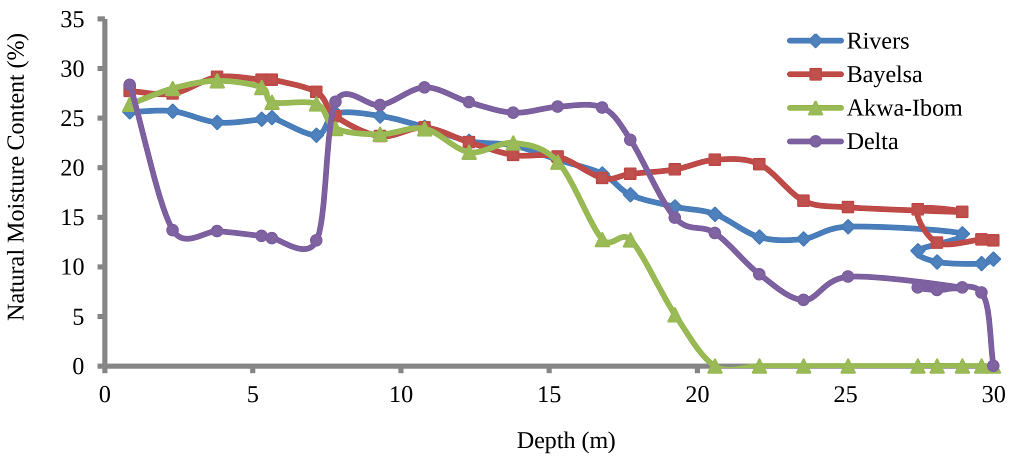

Figure 2: Variation in Natural Moisture Content across the States

However, a range of 21 – 32% moisture content was reported by Nwankwoala and Oborie (2014) while investigating the geotechnical properties soil in Bayelsa State. The study also acknowledged the fluctuation in moisture content, which was attributed to persistent heavy rainfall throughout the year. However, it has been reported that soil moisture increases soil pore pressure, which minimizes material stability upon loading, thereby triggering the occurrence of landslide (Ngecu and Mathu, 1999; Knapen et al., 2006; Ige et al., 2016).

3.3 Grain Size Analysis of Sub-Soil Strata

The grain size analysis was performed along the soils' depth as shown in Figure-3 through to Figure-6. There was high variability in grain size of the different soil compositions, which could be attributed to the soils' characteristic properties. Thus, the percentage grain size along the depth of the soil showed high fluctuation regarding its uniformity, either towards increasing or decreasing trends as depth increases. However, the grain size tends to generally increase in sandy region especially, above 25m depth. Meanwhile, for silt, the grain size generally increased with depth from its initial values to a certain depth and then, reduced gradually. Whereas, in some locations, there was no detectable grain size in clay and gravel at certain depths. The average grain size obtained across the sites is presented in Table 1.

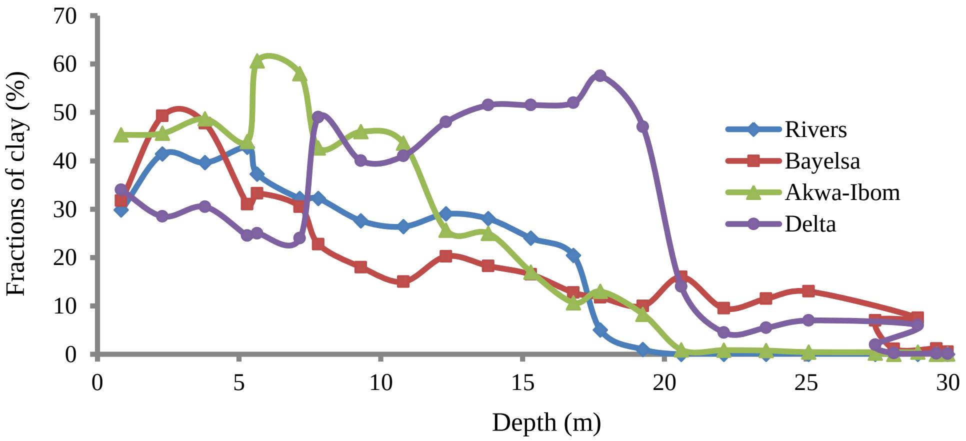

Figure 3: Grain size analysis of clay across the States

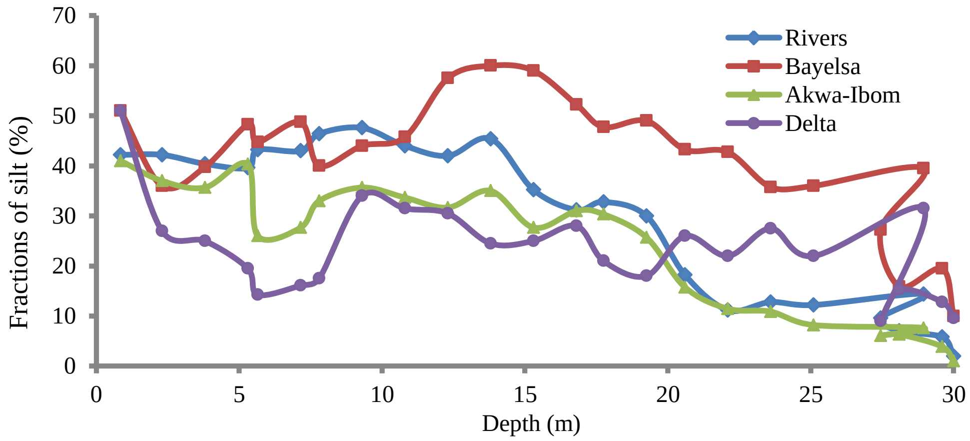

Figure 4: Grain size analysis of silt across the States

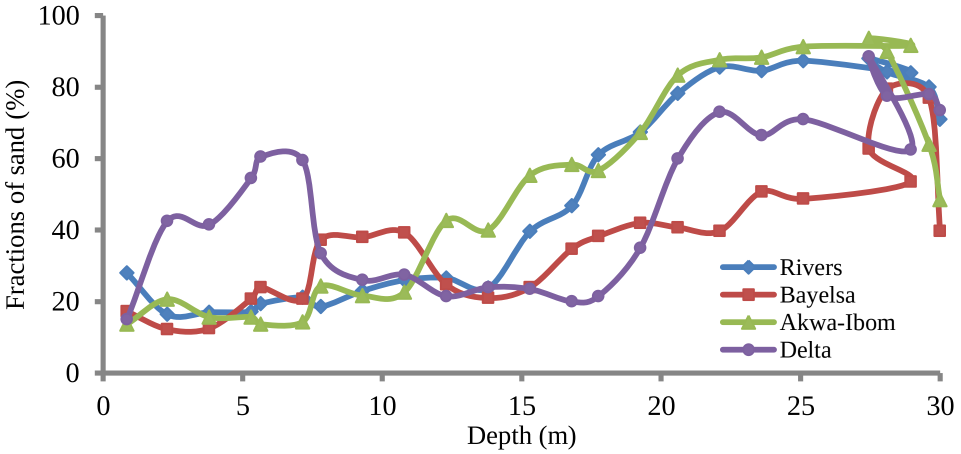

Figure 5: Grain size analysis of sand across the States

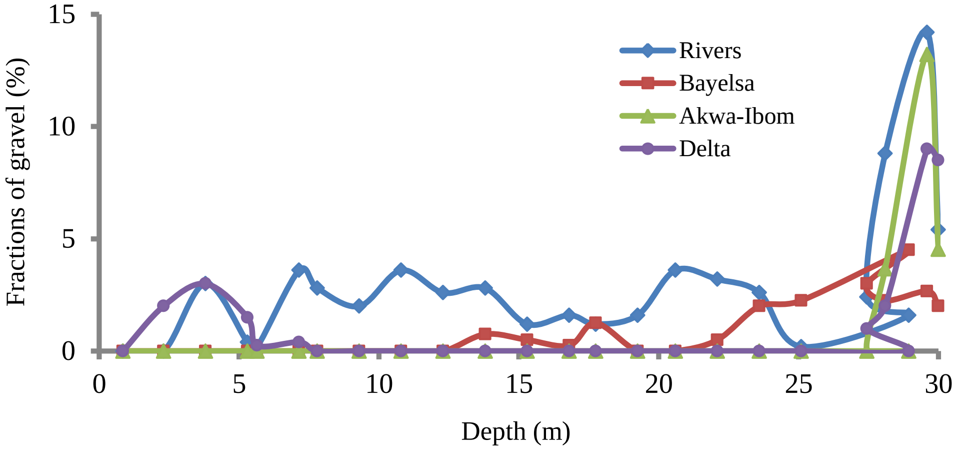

Figure 6: Grain size analysis of gravel across the States

Table 1: Ranges of the average grain fractions of Niger Delta Soils

Soil	State	Fractional Ranges (%)
Clay	Rivers	0 – 42.8±4.67
	Bayelsa	0.5±2.87 – 49.25±2.38
	Akwa Ibom	0.01±3.08 – 60.67±1.33
	Delta	0.10±2.22 – 57.50±2.75
Silt	Rivers	2±0.54- 47.6±2.31
	Bayelsa	8.00±0.34 - 56±1.16
	Akwa Ibom	10.00±0.13 - 60±1.91
	Delta	9±2.95 - 51±1.36
Sand	Rivers	16.40±2.05 – 88.00±2.60
	Bayelsa	12.25±3.34 – 79.50±1.51
	Akwa Ibom	13.67±3.11 – 93.67±1.07
	Delta	15.00±0.99 - 88.50±2.16
Gravel	Rivers	0 – 14.2±4.01
	Bayelsa	0 – 4.50±2.04
	Akwa Ibom	0 – 13.21±4.11
	Delta	0 – 9.00±3.82

From the result analysis, it was also observed that clay and silt layers are most dominant within 0.85 to about 19m soil depths, while beneath the soil strata of about 20 to 30m depth, sand has higher percentage in the soils. Again, Niger Delta soil, irrespective of location, share similar characteristic behaviour in regard to grain size. Therefore, an occurrence of any earthquake disaster in one of the States means a warning to the other States because of these resemblance characteristics. Generally, the composition of the soils is most dominated by sand. In a report by the National Research Council in Washington D.C., liquefaction of sands can cause failure of embankments, natural slopes, earth structures and foundations (National Research Council, 1985). Ige *et al*. (2016) also reported that the high percentage of sand recorded in soil obtained from Anambra State and Lokoja in Kogi State of Nigeria can trigger the occurrence of landslide, and could be reason for the previous cases of landslide occurrence in these areas. In Karim *et al*. (2010), it was said that soil with very high content of sand is more likely to liquefy than soil with more of clay and silt. Therefore, the high percentage of sand in the soil implied that the liquefaction occurrence in the Niger Delta region is possible.

4. CONCLUSION

The geotechnical properties of sub-soils strata of States in the Niger Delta as investigated, shows that the trends in SPT-N variation with depth do not assume a definite pattern or shape. However, it generally increased with depth, and the range of blows recorded for all the sites are identical. The variation of natural moisture content with soil depth has no defined pattern like SPT-N, but it decreases generally with increase in soil depth. Similarly, there was high variability in grain size of the different soil composition. However, the grain size tends to generally increase in sandy region especially, above 25m depth. Whereas, for silt region, the grain size generally increased with depth initially, before declining. There was no detectable grain size at certain depths for the different soil types in some of the site location. Although, in the various individual site analysis, it was observed that some of the sites are mostly clayed, while others soil was dominated by silt. Also in few of the sites that the soil was majorly characterized by sand, there was no detectable coarse aggregate within 30 meters depth. Hence, based on the observations, it is suggested that more studies be carried out in other locations and other States within the region that were not considered in this study. This would enable the collation of more results for comparison and understanding of the geotechnical properties of sub-soils strata of Niger Delta soils, as well as to justify the susceptibility of the region to earthquake occurrence in the near future.

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