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Assessment of Geologic Effect of Road Submergence Depths on Soil Subgrade Strength in Eket, South-South Nigeria

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Abstract
Road submergence is a common occurrence in Eket, South-South Nigeria, resulting in massive outlays for road construction and alimony. Fundamentally, the delineation of roadway structures is based on the strength of consolidated soil avowed as the subgrade. Consequently, the subgrade is the in situ material upon which the roadway structure is placed. It is necessary to know the modes of damage to roads caused by submergence. This study assesses the effect of road submergence depths and the extent of submergences on the subgrade strength of soil samples carried out on the Uquo Eket road that was intensely defective by the deluge. Coherent and frictional soil material types were tested for California Bearing ratio (CBR), mechanical analysis, Atterberg limit determination, and moisture density tests, respectively. CBR tests were done at various elevations of submersion, including common drenching limit, elongated deluge, and resoluteness of its suitability. Atterberg limit determination and mechanical analysis tests categorized and determined the applicability of studious soil as subgrade substantial. For elongated duration deluges, the depth and extent of submergence of subgrade strength show a lower value. Moreover, mechanical and Atterberg limit determination tests indicate a rapid and high-resolution occurrence of delegation for the elongated duration.

Keywords: **C**ompaction Test, Permeability, Resilient Modulus, Soil Strength,

1.0 Introduction

Effective risk management appropriately allocates financial resources to minimize the negative consequences of a potential event such as road submergence as a consequence of flooding (Dawson et al., 2018; Adebayo, 1987). A better understanding of flood impacts can aid in more informed decision-making. Hence, much research has been dedicated throughout the ages to flood impact appraisal. Although flood impacts have been modeled for decades, there is a lot of room for innovation (Afolabi, 2005). Floods' impacts on road transportation are still not explored in Eket and its environment, where flooding impartations are a recurrent occurrence and succeeding apiece phenomenon, leaving a massive mark on public and indigenous thrift as shown in Fig. 2. This leads to persistent flooding in the research area and no required depths of road submergence on soil subgrade to describe the involved processes. In facing this perforation, the current research aspires to develop novel approaches to assessing the effect of submergence depths and the extent of submergence on the subgrade strength of soil samples. Flood consequence types were first classified by Penning-Rowell et al. (1980) into both uninterrupted and incidental, and, conversely, a combination of both. Uninterrupted destruction significantly increases the display of structure, humans, and domain to deluge reservoirs. Incidental destructions are sheath deluge regions and usually take a long time to become distinguishable (Merze et al., 2010). Transportation disturbances as a consequence of submerging are considered incidental impacts because they evaluate the knock-on effect of submergence continuously throughout the whole transportation system. Its consequences are impalpable: dally, exasperation, and degeneration owing to carbonic acid gas discharge, but it can also have a monetary dimension (Pregnolato et al., 2017). However, exploring an area of science that has not been previously studied is always tempting and challenging. Assessing deluge collisions along roadway carriageways is not an abstract topic of research, and it can affect many road users and motorists on the way to their destinations. Transportation difficulties are everyday experiences for many, and it is not hard to imagine that a flood with a large geographical scope may lead to devastating consequences for transport (Hossain and Davis, 2007). Even though this problem is recognized, it is surprising how little we know about it. Flooding is often a result of a complex combination of various causes (coastal, fluvial, and pluvial). Further, transportation systems are susceptible to external disturbances which disrupt many aspects: traffic delays, additional travelled distance, additional greenhouse gas emissions, and frustration. Perpetual flooding of roadways has yielded destruction to the highway foundation. Hence, this destruction distresses the strength and durability of tarry materials on road thicknesses (Adedeji and Salami, 2008; Ayoade and Akintoda, 1980). Persistence modifies roadway construction as a result of deluge occurrences routinely creating massive roadway workings (Deshpande et al., 2008; Bowoputro, 2009). Recently, Akwa Ibom State Management has assigned bulk money for the overhaul of the embankment of Eket roadways that service the Mobil Oil Company that was damaged by deluging as shown in Fig. 4. Moreover, whenever roadways are overloaded for a lengthy period, their bearing strength layer, together with the roadway surface flatter soaked with groundwater void, starts to decrease and its soil subgrade starts to soften. This unrestrained reservoir is void toward the foundation, reducing its load-bearing efficiency. Thus, this condition roots the stability of the roadway concrete structures and leaves them imperiled.

1.1 Subgrade

Subgrades are unmoved by matters operating at a certain road construction setup. Within the shipment stage, subsoil acts as the original substance beneath structures (Deshpande et al., 2008). Despite shear failure or severe distortion, the subgrade must have sufficient strength and stiffness to support the road construction and related traffic load. The shear strength of the soil is not typically expected to be a major component in road thickness design due to the nature of pressures produced on-road roadways and their comparatively modest magnitude. The main foundation factors that must be considered are the subgrade's elastic qualities. Nevertheless, because they are highly difficult features to quantify, and given the heterogeneity of soils over short distances, using them directly to evaluate subgrade properties may not be economically practical. In addition, it refers to finding strength that is made up based on the original topsoil, especially antiquated compressed to stability as shown in Fig 3. The subgrade is mainly subject to load-bearing capacity, moisture content, and distortion in the company of concrete roadbed constraint, auxiliary settlement, thickness, and stability with rigidity in subsoil (Tanfedar et al., 2008). The attributes of subgrade soil are stability, incompressibility, longevity, void, capability, and adroitness to compression. Its edge sustains effective bearing capacity within its foundation. However, topsoil holding high-rise wetness ensues loosely (Fair-weather and Yeoman, 2014). Simple test techniques that are linked to structural qualities through experimentation are required whether roads are to be developed empirically based on historical performance and experience records or fundamentally by utilizing the elastic theory analysis. Atterberg limit, compaction, and California Bearing Ratio (CBR) tests are some common basic soil identification and classification tests routinely performed on subgrade soils, as well as some empirical tests specifically developed for subgrade evaluation for road design purposes specified by the Nigerian Federal Ministry of Work Highway specification (FMWHS). The soil sample's coefficient of elasticity can also be determined using the Resilient Modulus (Mr) test.

2.0 Geological Setting

The site attributed to the research study is Eket, South-South Nigeria. Eket is the second-largest city in the Gulf of Guinea, Nigeria. The name also refers to the indigenous ethnic group of its terrain with their language. It lies allying latitudes 4°33’N and latitudes 4°45’N and longitudes 7°52 ’E and 8°02’E, 153 m elevation above the sea level with about 214 km^2 covering an area as illustrated using and ArcGIS software program in Fig.1. It has the watercourse flowing through the area, bounded on the north by Nsit Ubium, on the east by Esit Eket, on the west by Onna, and on the south by Ibeno Local Government Areas. Geographically, the actual ease of the region breathes primarily smooth in the company of swampy inlet scrub throughout its edge above the rivulet. It gravitates in an equatorial bed in which other fallow flora greenish verdure undergrowth along with Elaeis Guineensis shrub zone. The region possesses duo timeliness: rainy and dried. The rainy timeliness amounts to warm and clouded while dried timeliness amounts to hot and mostly overclouded as well as brutal age globular. The regional climate characteristic ranges from 68°F to 90°F and is scarcely beneath 62°F or above 93°F. Based on the beach /pool score, the prime period to sojourn the terrain for hot-weather activities is from early December to late January. Its atmospheric averages weather series of the region are: The hot season lasts for 2.6 months, from January 15 to April 3, with an average daily high temperature above 88°F, hottest month of February with an average high of 90°F and low of 72°F. The cool season lasts for 3.9 months, from June 25 to October 21, with an average daily high temperature below 83°F with the chilliest season about August, with an average low of 71°F and a high of 82°F. The region experiences extreme periodic variance within regular precipitation. The month with the most rain is August, with an average rainfall of 358.14 mm. The month with the least rain is January, with an average rainfall of 17.78 mm. The resources of the region are: natural and forest resources. A natural resource is the abundant deposit of crude oil and clay, and the oil mining activities of local and multinational oil companies contribute immensely to the economic development of the area. It is the hub of Mobil Producing Nigeria operations with more than 250 companies providing support services such as catering, flights, and exports. Forest resources include timber, and palm products to boot nourishment management. Traditionally, Eket people are fishermen, hunters, farmers, and weavers. Geologically, the parent rock materials within the area are mainly sedimentary rocks which have resulted in the prevalence of sandy, clayey-silt soils.

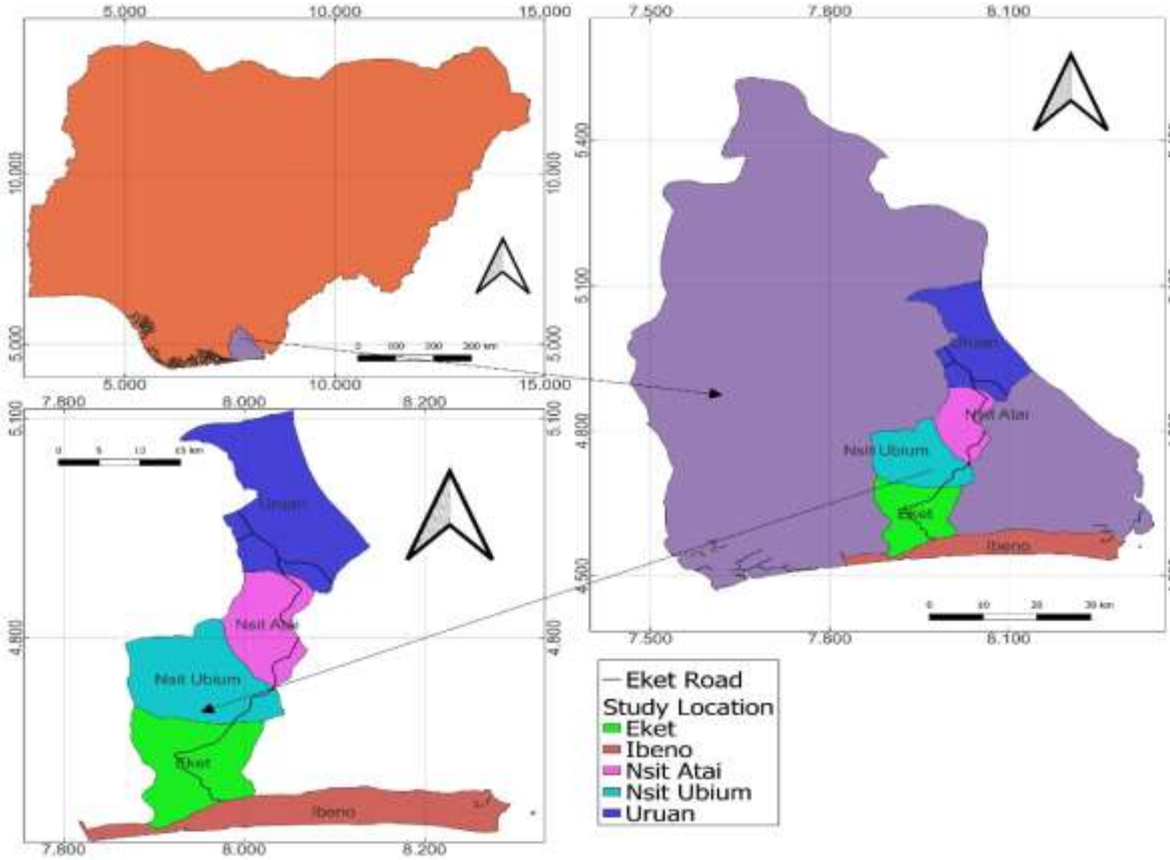

Fig 1: Map of Eket, showing Eket Uqua road and its terrain

Fig 2: Submergence on Eket Uqua road

Fig.3. Submergence effect on topsoil foundation in Eket

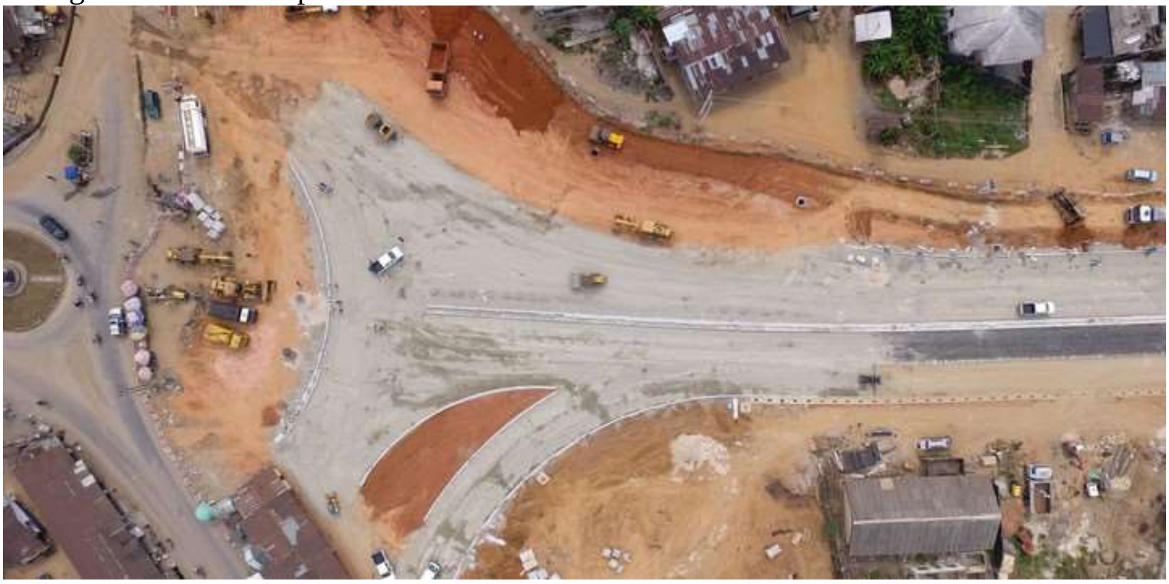

Fig. 4: Eket Uqua road construction damaged by submergence

3.0 Materials and Methods

3.1 Materials

Fields assessments along with laboratory analysis prevail adopted in this research. The field tools used were hand Auger, auger stems, shovel, hand gloves, sample bags, measuring tape and first aid kits. The laboratory tools were: non-corrodible container, drying oven container handling apparatus, standard sieves, sample splitter, mechanical sieve shaker, and pans, cylindrical compaction mold equipped proctor rammer, steel straightedge, metallic tray, and a scoop, liquid limit machine and casagrande grooving tool, plastic limit test apparatus, is sieves, penetration plunger, and loading machine spatula and weighing balance.

3.2 Methods

The British Standard Code for Site Investigation was adopted to acquire the soil samples, with the depth ranging from (1- 3) m was drilled, and samples was collected at 1 m intervals, stamped and stored in sample bags with in-situ interpretation of soil tincture, texture and moisture to the laboratory for further analysis. Sample locations, depths, GPS coordinates and elevations were measured as shown in Table 1.

The samples before the subsoil lay hold of pair contrasting burrows that give the soil to some - extent commonly employed being ridge topsoil during roadway projects. The soil selected breathes graded as saturated and unsaturated matter by Nigeria FMWHS. The characteristics of the soil are laid out in Tables 1 – 4.

3.2.1 Sample Preparation

Primarily, natural moisture content investigation was carried out to differentiate between the wet and dry weights soil. This was accompanied by subsequent tests such as: mechanical analysis to determine the percentage distribution of sand, silt, and clay in immersed and drained samples. Compaction test for soil density and extracting air enhance the stability and rigidity of subsoil. Atterberg limit test to evaluate the plastic, liquid state, and plastic indexes, and CBR test to evaluate the subsoil stability, depth, and overburden capacity of roadway concrete. Ultimately, calculate the resilient modulus (Mr) to determine the elastic modulus for the soil subgrade.

3.2.2 Particle Size Analysis.

Mechanical analysis otherwise called particle size distribution calculates the proportions of extents accompanied with sand, silt, and clay revealed being the hundredth overall dried mass. The apparatus set up were: Drying oven maintained at 110 ± 5°C, Standard sieves, Sample splitter, Mechanical sieve shaker, and Pans. The procedure consists of the following: Drying the soil sample in an oven for 24 hours to get rid of moisture, measuring 500 g of the dry sample, and soaking in water for 24 hours. Proceedings the mass of the stain container, and compute the soil mass preserved on an individual besides deducting the mass of an unfilled griddle following the analysis. However, aggregate mass sampling preserves were added on comparatively with a primary mass of the soil sampling. The portion of the sample preserved on individual stains was split up primarily and calculates the entire portion flowing along with its cumulative percentage reserved and the ones above it from the totality. On the other hand, the grain size allocation reflects how the medium-fine sand was plotted to calculate its deviation measure (Cu) expresses the variety in particle sizes of soil ratio of D60 to D10 as shown in Eqn.1.

$$C_u = \frac{D_{60}}{D_{10}} \qquad 1$$

Conversely C_u is exceeding four, the soil is grouped being competent grading; whereas a C_u values underneath four, the soil is grouped simultaneously imperfectly graded and uniformly graded respectively.

3.2.3 Compaction Test

This is a conventional compression process that uses a set amount of compactive effort to obtain a soil density that can be compared to site density readings. On building sites, this is the most prevalent form of quality control. The initial test consisted of compacting the earth in three about equal layers in a calibre framework with a 2.5kg hammer dropping from 305mm above the high point. Greater densities were now possible on the ground, thanks to the introduction of heavier compaction machinery. A modified version of the analytical breathe was developed to allow for increased compaction effort in five about equal layers utilising a 4.5kg hammer dropping through a 457mm height (modified or heavy compaction test). The soil sample is air-dried, sieved (typically with a 4.75-mm (No. 4) or 19-mm sieve), thoroughly mixed with water, and then compacted in layers. A concretion of compacted test breathes (W) is computed, along with a small sample obtained to determine the moisture content (w). After then, more water is applied to the soil, and the process is continued until the dry density achieved lowers. Finally, as illustrated in Eqn.2, the dry unit weight (d) was computed.

$$\gamma_d = \frac{W - W_m}{(1 + w) \times V} \qquad 2$$

Where: W = the weight of the mold and the soil mass (kg), W_m = the weight of the mold (kg)
w = the water content of the soil (%) and V = the volume of the mold (m^3)

The procedure was repeated four 4 times, for a given selected water content from lower to higher than the optimum. Hence, the calculated dry unit weights were plotted against their corresponding water contents to determine OMC and MDD along the Zero Air Voids at a 100% saturation line. On the other hand, the Zero-Voids curve is calculated as shown in Eqn. 3

$$\gamma_d = \frac{G_S \times \gamma_W}{1 + w \times G_S} \qquad 3$$

Where: G_S = the specific gravity of soil particles, γ_W = the saturated unit weight of the soil (kN/m^3) w = the water content of the soil (%)

3.2.4 Atterberg Limit

The Atterberg limits specify the moisture content of the soil as it transitions from one condition to the next. The liquid limit (LL), the plastic limit (PL), and the shrinkage limit are some of them (SL). They are determined by tests performed at the 75m (No. 200) sieve using fine topsoil fragments. The liquid limit may be defined as the bottom reservoir cheery as regards topsoil determination drift undergoing a standard shearing force. Plastic limits estimate the firmness of wet at ease. The plasticity index (PI) is algebraic contrast linking fluid and plastic limits. Thus, it indicates the range of moisture content over which the soil remains deformable. Liquid index (LI) treats the throwback attributes as regards the natural soil and is calculated as shown in Eqn. 4

$$LI \qquad \frac{W_n - PL}{PI} \qquad 4$$

The procedure involved: 150 g air-dry soil samples passing sieve No.40 were used. The Moisture was adjusted by adding 20% of water to sampling and mixing thoroughly. The samples were allowed to condition for at least 16 hours. For a LL Test, a little proportion sampling was spread in the brass LL apparatus case grinder. A groove was cut to at least a 2 mm base with a grooving tool, turns the device and notes the number of blows (N), and stops when the channel inside the soil closes. Finally, a sample and oven-dry were taken to determine its moisture content. The tests were repeated three times and plotted the moisture content against the number of blows to determine LL, PL, and SL respectively

3.2.5 California Bearing Ratio (CBR)

The California Division of Highways developed the CBR test in the 1930s as part of a study of pavement failures. It was created with the goal of determining the relative stability of fine crushed rock foundation materials. The test is currently extensively used across the world for evaluating the stability, sub-gradient, and other flexible paving materials for road design. Soil, density, and moisture content all play a role in sub-gradient soil stability. As a result, it is clear that the density-moisture content-strength connection unique to the subgrade soils encountered along the project road must be determined. As a result, the CBR design of the subgrade soil should be assessed at the wet at ease density, which is typical of the subgrade state during construction. Procedure: Soil samples were measured at about 6kg, added water to the sample, and mixed thoroughly. Using a 2.5 kg rammer, Weight of empty mold, compact the mixed sample into three (3) layers with 61 blows per layer. After compaction, the collar was removed, and taken a sample to determine moisture content. Record the weight of mold plus compressed sample respectively. Mold was placed on the drenching panzer quadruplet for soaked and ignored for unsoaked. The process was repeated for another set of samples after quadruplet, measuring as regards inflate finding the percentage swell, after, the mold was removed via panzer and allowed fluid drainage. Then the soil sample was placed under the penetration piston and placed a surcharge load of 2.5 kg, applied the load, and noted the penetration load values were. Finally, the graph of piston load against penetration was plotted to determine the California bearing ratio desirability, along with Dry Density to obtain its concretion strength.

3.2.6 Resilient Modulus (M_R.)

The resilient modulus (MR.) is an expandable module derived from a repeated load test that mimics actual pavement loading. The percentage applied to recurrent deviator strain to an unlikely axial strain is determined. The most representative test for soils and aggregates under highway loading conditions has just been recognised as MR. Because repeated moving wheel loads cause stress in pavements, this test replicates the soil under a succession of load applications. Consequently, the sample preparation, conditioning, and testing are conducted to simulate field conditions as prescribed by AASHTO T-274 standard method. Consequently, the stress to strain relationship for the subgrade breathes a vital factor contributing to surface deflection. Also, a subgrade elastic coefficient is considered a crucial factor in flexible pavement performance. There are two major types of load to induce flexible pavement failure: fatigue cracking and rutting. The concrete strain decreases as the elastic coefficient of the subgrade increases. Strains decrease as the load applications are before cracking for the concrete surfacing. The test is creditable to the perfect category unbounded related to road data varying along with coherent compatibility via the sustained medium. However, according to the asphalt institute, the test recommendations are made to correlate the CBR values with the resilient modulus as shown in Eqn. 5.

$$M_R = 10.35 \text{ x CBR Value} \qquad 5$$

Table 1. Sample locations, geographic coordinates and elevations.

Locations	Sample ID	Depth(m)	Latitude (^{0})	Longitude(^{0})	Elevations
1	EKET A	1-3	4.6467	7.9429	24.95
2	EKET B	1- 3	4.6309	8.0706	15.00
3	EKET C	1 -3	4.5377	7.9157	7.00
4	EKET D	1 -3	4.7427	7.9488	34.00
5	EKET E	1-3	4.5650	8.0725	16.00
6	EKET F	1-3	4.5258	7.8140	13.00
7	EKET G	1-3	4.5293	7.6728	27.00
8	EKET H	1-3	4.5339	7.7669	12.00
9	EKET I	1-3	4.7756	8.1907	15.00
10	EKET J	1-3	4.7162	8.0222	18.00

Table 2: The summary of the characteristics of soil test results (Mechanical, Atterbery Limit and Natural Moisture Content)

Soil	Mechanical analysis (% passing sieve 200)	Atterbery limit (%)			NMC (%)
		LL	PL	PI	
Soil 1: Sand +clayey gravel	22.1	30	16	14	7.91
Soil 2: Silty + Clayey gravel	37.1	44	32	12	15.90

Table 3: The summary of the characteristics of soil test results (Compaction, California Bearing Ratio and Resilient Modulus)

Soils	Compaction		(CBR) (%) Original			Repeated			M_R (Mpa)
	OMC (%)	MDD(g/cm^3)	Days	Unsoaked	soaked	Days	Unsoaked	soaked	
Soil 1: Sand +clayey gravel	11.5	0.91	1 2 3	64.5	50.2 47.2 42.0	1 2 3	64.5	57.3 54.4 48.8	519.6 488.5 434.7
Soil 2 Silty +Clayey gravel	6.5	1.83	1 2 3	44.8	24.5 20.2 10.4	1 2 3	44.8	26.3 20.8 12.5	253.6 212.1 107.6

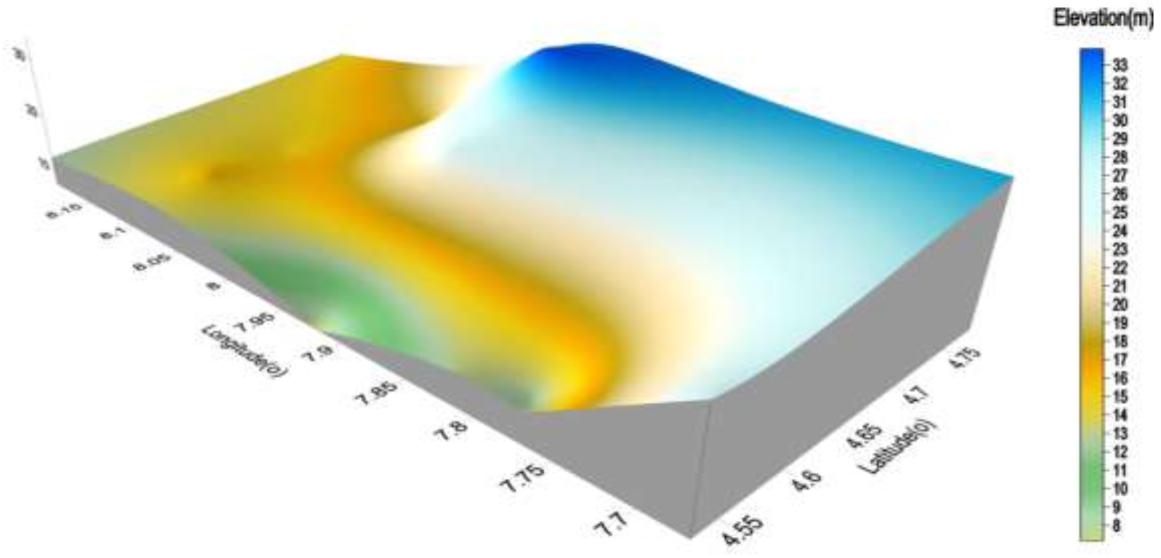

Fig.5. 3D Terrain Sketch showing the study locations

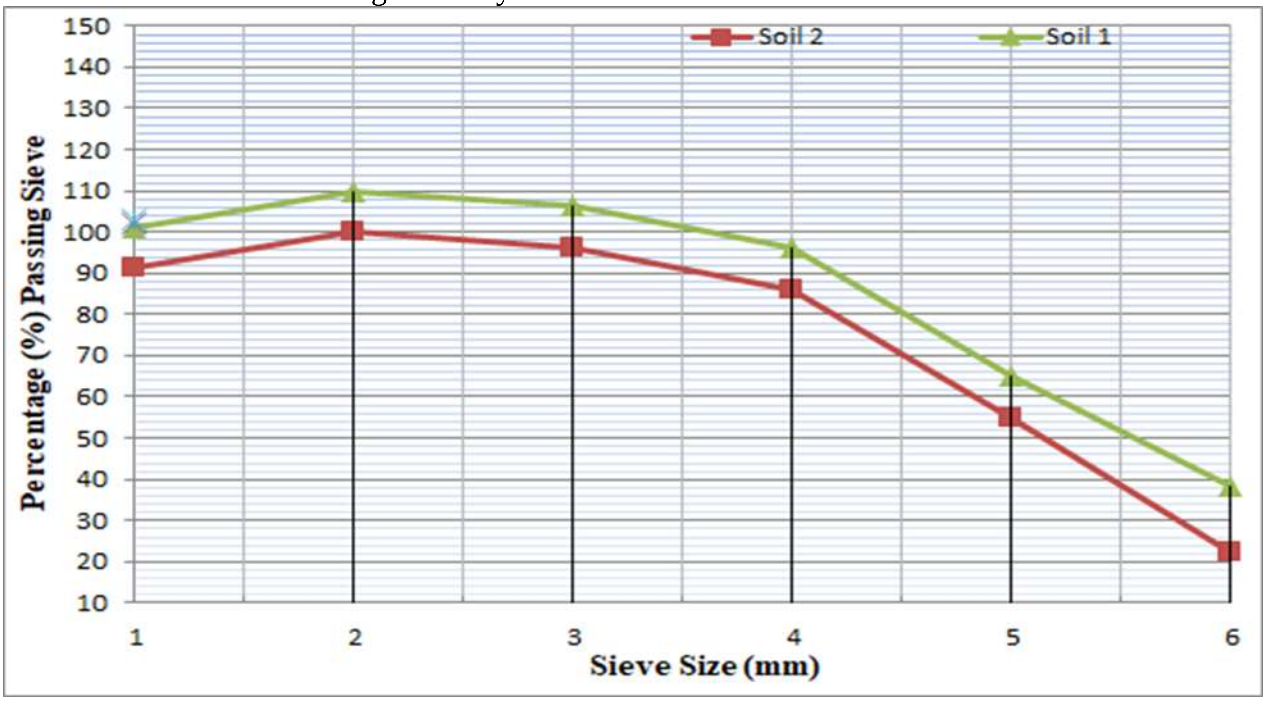

Fig. 6: A graph of Percentage (%) passing sieve against sieve size (mm)

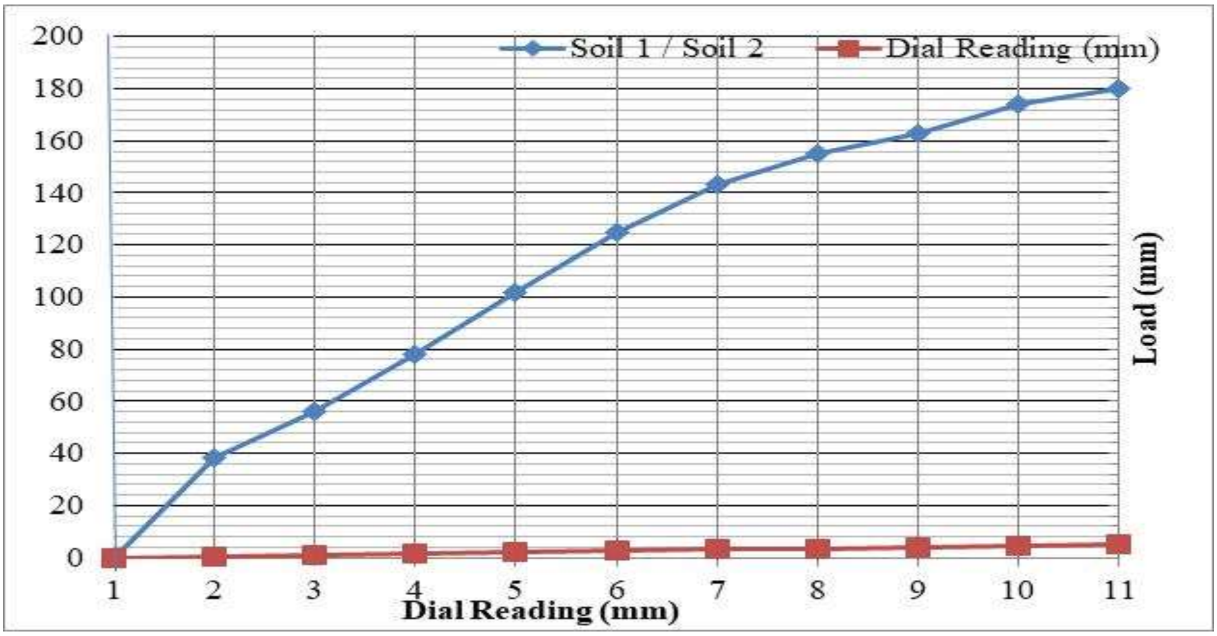

Fig. 7: A graph of load (mm) against penetration (mm)

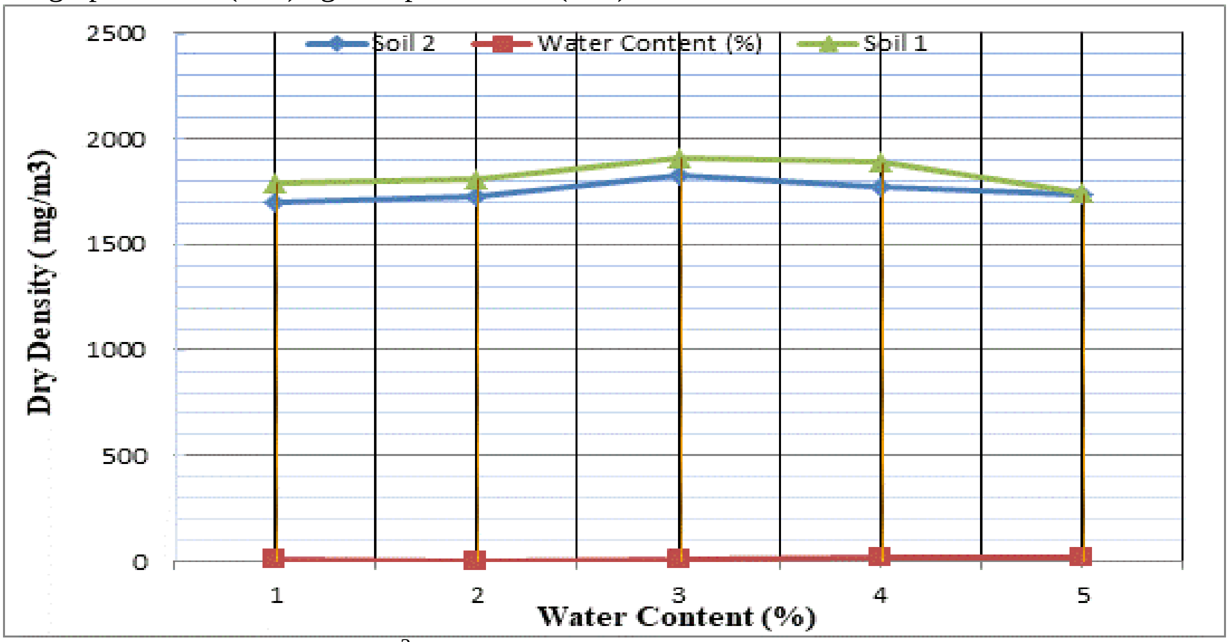

Fig. 8: A graph of dry density (mg/m^3) against water content (%)

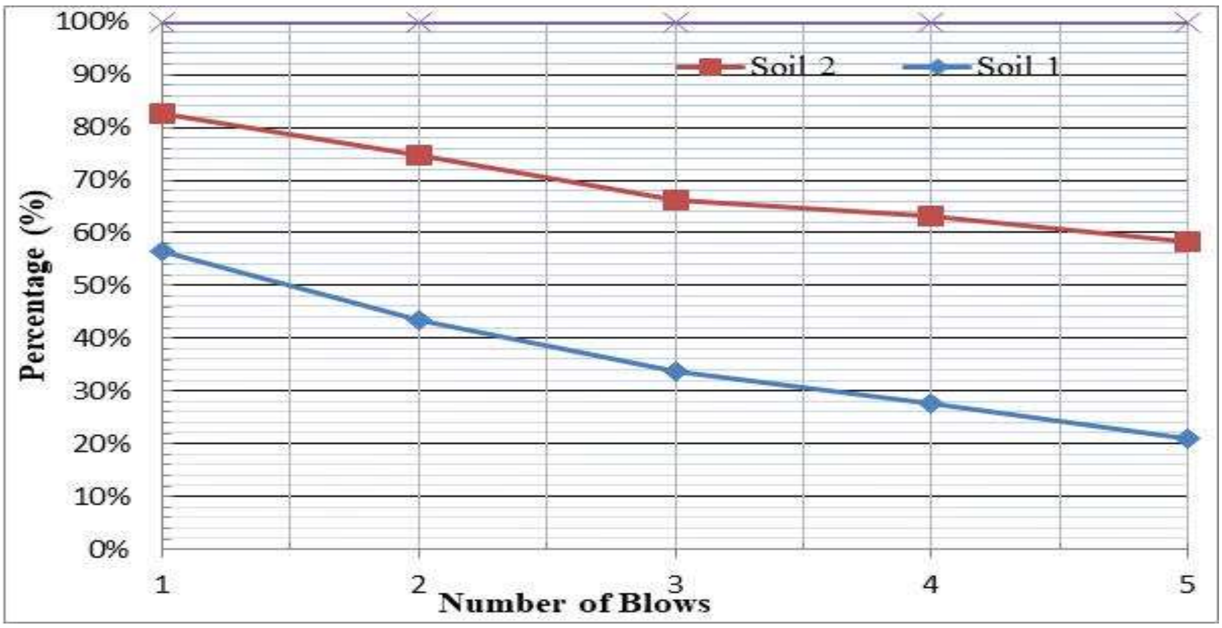

Fig. 9: A graph of percentage (%) moisture content against number of blows

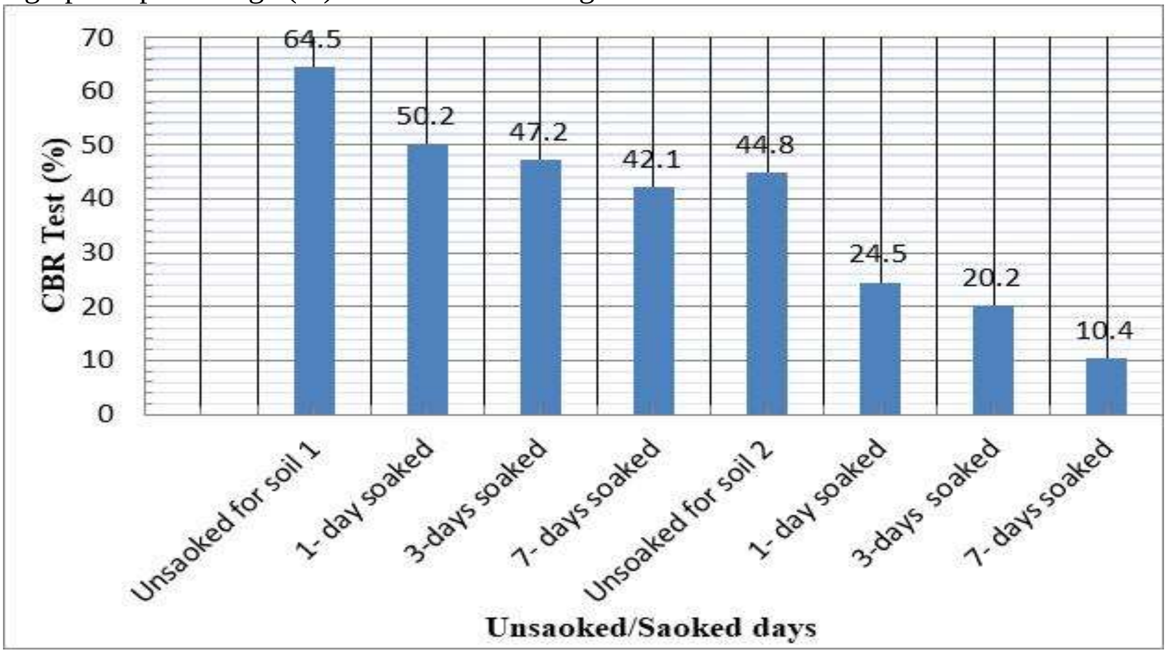

Fig. 10: Comparison of CBR test (%) values of unsoaked and soaked soils (1&2) samples

4.0 Results and Discussion

The soil characteristics results for the saturated and unsaturated soils 1 and 2 for ten sample locations are presented in Tables 1, 2 and 3. Fig. 5 shows the 3D terrain sketch of the area located in basins which act as gathering points for submergence water and waters draining from surrounding upland areas. The latitudes and longitudes are (4.5258 – 4.7756) 0N and (7.6728 – 8.1907) 0N, respectively, with corresponding elevations of (7 – 34) m above sea level. Thus, Eket C, having the lowest elevation among the study locations, has its low lying areas receive submergence waters after rainfall, thereby making it more prone to submergence risk. The natural moisture content value for soils 1 and 2 was 7.91 % and 15.90 %. This indicates that the percentage of moisture content on soil 1 is less as a result of its lower hydraulic conductivity rating that ascertains its frost susceptibility. Soil 2, with a high moisture percentage, drained the road structure quality as a result of moisture fluctuation in sub-grade soils. The results were correlated for various soil characteristics and are presented in Figs. 6 –10. Figure 6 shows the percentage (%) of soils 1 and 2 that pass the 0.075 mm no. 200 sieve, with values of 22.1% and 37.1%, respectively. on AASHTO determinations for a comparable grade of soils employed within sub-grade, sub-base, dam, and foundation. The soils classified as A-1 by a sub-space of A-1-b have 0.075 mm no.200 sift values of 22.1 %. This indicates a fine-classified coarse-grained substantial ground at a common mechanical analysis, LL, PL, and PI values of 30 %, 16%, and 14% for soil 1, while 35.8%, 24.0%, and 12.0% were captured for soil 2 respectively. However, the soil evaluation was done employing the empiric method as regards finding a group index (GI) of the sampling. The group index evaluated shows approximately 26% and 5% for soils 1 and 2. This reveals that the GI of soil arises as the subgrade materials lessen. This reveals that G1 of 26% gives a faulty intimation of sub-grade significance due to a long submerging of sampling, while a GI of 5% gives moderate sub-grade significance. The CBR results presented in Fig. 7 show the correlation between topsoil robustness and submerged and un-submerged soil environments. The topsoil selected was kept immersed for 1, 3, and 7 days as a result of a numerical timeline for submerged ambiance. In Fig. 10, the pictorial histogram shows the comparability of the CBR test results of submerged and un-submerged soils 1 and 2 selected. In distinction to the histogram, CBR values in an un-submerged situation moderately surpass those in a submerged situation as a result of the soaking era of the topsoil sampling test. This indicates that the CBR values of an un-submerged environment breathe 64.5 % as well as a submerged sampling of 1, 3, and 7 days being 50.2 %, 47.2 %, and 42.0 % for soil1. Sequentially, for soil 2, the un-submerged value breathed 44.8 % as regards submerged sampling of 1, 3, and 7 days, being 24.5 %, 20.2 5, and 10.4 % concerning the repeated CBR values. Noticeably, submerging of soil samples for longer periods of time lessens the soil stability. However, topsoil is stale, losing its durability continuously from the first day of submerging, in contrast to an un-submerging environment. The selected un-submerged sampling indicates the strong competence in upholding a greater burden following its unsubstantial loss of solidity. Also, un-submerged soil shows primarily elevation in terms of indurated topsoil analyses. Moreover, CBR values for the submerged environment lessen as regards its stability based on the submerging age for individually submerged sampling. Thus, the farther the scope of submerged sampling for days, the lower their CBR value continuously, which leads to a weighty drop in soil stability. Hence, the CBR test was repeated and correlated with its original values to ascertain soil sub-grade, strength, thickness, and load-bearing capacity.

From Table 3, the compaction test for soils 1 and 2 indicates the OMC and MDD values of 11.5 % with 0.91 g/cm^3 and 6.5 % with 1.83 g/cm^3. Soil 1 with fine sandy soil has relatively enhanced uppermost densities at lower optimal moisture levels, but soil 2 with clayey soils has lower densities and greater OMC, according to the association between OMC and MDD. The barrier between clay particles, on the other hand, resists compaction attempts, inhibiting the formation of a denser structure. The compactive effort is a measurement of the mechanical energy placed on the earth during compaction. As a result, when a better-graded soil 1 is compacted, the gaps between big particles are filled with smaller particles, resulting in a higher density than when a poorly graded soil 2 is compressed. In general, increasing soil density improves stability while decreasing porosity and deformability. When loose topsoil is squeezed by a constant amount of energy, the dry thickness achieved is proportional to the wetness gratification. For soils 1 and 2, the relationship between moisture content and dry density was displayed in Fig.8. The dry density of the soil will vary with its water content for a particular compacting effort, as can be observed from this connection. The soil is dry and stiff with low moisture content, and friction between neighboring particles prevents relative movement between particles from forming a denser arrangement. As more water is injected, a bigger film of water forms over the particles, causing lubricating effects and making relative motions between particles easier, allowing the particles to form a denser structure. As the moisture content rises and reaches the maximum practicable degree of saturation (S=100 percent), the density rises and the air content falls. As a result, any more water will cause the voids to overfill with water, producing particle separation and a fall in density. The dry density, on the other hand, falls when the total voids grow at higher moisture contents than the optimal moisture values. The Atterberg analysis in Table 2 shows the average values of PL, LL, and PI of soils 1 and 2 as 16.0 %, 30.0 %, 14.0%, and 32 %, 43.8 %, as shown in Fig. 8. The LL and PL values of soil1 are lower than soil 2 showing that soils have high moisture restraint as well as flexibility ratio, subgrades, and engineering materials. However, soil 2 silty to clayey formations show fair to poor significant constituent materials, the liquid limit and plastic limit depend on the type and amount of clay in the soils. The stiffness of soil1 fine-grained soils depends on their moisture content which varies with variations in the amount of moisture present. As a result, soils with the same liquid limit but differing plasticity index vary their rate of volume change, dry strength rises, and permeability reduces as the plasticity index increases. In soils with the same plasticity index but differing liquid limits, compressibility and permeability improve, while dry strength falls as the liquid limit increases. In general, according to Nigeria (F.M.W. & H), requirements for liquid limit and plastic index of soils are not more than 35 % and 12 %, as determined by the American Society for Testing Materials Method (ASTM). Hence, the subgrade of soil 1 is suitable to be used in road construction since liquid limit and plastic index values do not exceed the standard limits of 35 % and 12 % whereas soil 2 shows fair to poor suitability. The analogue of existing link M_R and soaked CBR values for soils 1 and 2 with a standard correlation factor attested by asphalt institute recommendations was presented in Table 3. From the analysis, it was noticed that the M_R ranged from (519.6 - 434.7) MPa to (253.6 - 107.6) MPa, with averages of 480.9 MPa and 191.1 MPa for soils 1 and 2 via 1, 3, and 7 days of soaking. This shows that M_R for soil 1, regarding 2.5 stresses, is greater than soil 2. The dry and wet samples show that the M_R values lessen on account of their solidity upshot, water content, and curing period. In general, the M_R value trend increases with an increase in enclosed constraint and lessens concerning deviant strain. However, as regards continual density, sampling compressed dryly shows a higher M_R value while wet sampling shows low values. Consequently, M_R values established an increase with increasing density and a decrease with increasing water content.

5.0 Conclusion

The investigational study has been carried out to regulate soil sampling strength while assessing contrasting submerging states. The natural moisture content shows the percentage of moisture content on soil1 being less as a result of its lower hydraulic conductivity, while soil 2 shows a high moisture percentage that drained the road structure quality as a result of moisture fluctuation in sub-grade soils. Based on AASHTO determinations, the particle size distribution of samples 1 and 2 graded the soil as A-1 by A-1-b sub-group having fine coarse-grained ground and soil 2 having silty-clay ground. The OMC and MDD compaction test correlation revealed that Soil 1 with fine sandy soil possesses moderately elevated topmost densities at lower optimum moisture contents, while soil 2 with clayey soils has lower densities and higher OMC. The Atterberg analysis rating of liquid limit and plastic index for soil1 is lower than soil2, which has a good moisture restraint and flexibility ratio, subgrades, and engineering materials. However, soil 2 silty to clayey formations show fair to poor significant constituent materials in which the liquid limit and plastic limit depend on the type and amount of clay in the soils. Uniformly, the resilient modulus trends increase with increasing density and decrease with increased water content. On the other hand, a dry sample shows higher resilient modulus values, which are linked with the corresponding low values of wet sampling. CBR values for soils 1 and 2 submerged environments are limited as regards their stability based on the submerging age for individually submerged sampling. Thus, the farther slope of submerged sampling for days lessens its CBR values continuously, which leads to a weighty drop in soil stability, which generates a lot of runoff and has led to the crusting of the soil, which is evident in the high bulk density values of the soil and the compaction of lower soil horizons.

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