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Investigation of Stability Index Characteristics on Soil Profile in Sakita

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Abstract: ***This research examines the suitability of soil as infrastructure which can help in the classification and identification of its properties for ideal engineering structures. Sakita, an area in Gesse III as a case study, is a virgin land, allocated for residential buildings. The need to investigate the soil profile in the report area prompted these studies as its physical properties are used for classifying its various engineering applications. These properties indicate qualitative behaviors of soil when subjected to various types of loads. Apart from physical/visual observation made of the soil, trial pits were dug to depths of 0.5m, 1.0m, 1.5m, 2.0m, and 2.5m respectively and disturbed soil samples were taken for tests. The disturbed soil samples obtained were analyzed for grading including mechanical sieve analysis, specific gravity, plastic limit, liquid limit, and bulk density tests. The resistances of the cone against penetration, compaction, consolidation, and permeability properties were also assessed. The detected geotechnical properties varied significantly with depth, except for specific gravity, which did not vary significantly at 0.5 m with depth. Soil samples from all pits consist mainly of poorly sorted gravel and sand with little fineness. They contain a medium- to coarse-grained fraction of sand on average above 85%. The puncture resistance obtained from the cone puncture test ranges from 100 knm^2 to 950 knm^2. The average safe bearing capacity estimated for the footing using a factor of safety of 3 at a depth of 1 m was not less than 473 km^2 anywhere in the study area. The samples from the three locations generally have good compaction parameters, medium to high permeability, and low compressibility. The highest load-bearing capacity is associated with the lateralized basement ceiling. This means that the safety depth for placing infrastructure foundations in the prescribed research area (Sakita) is the depth where it meets the lateralized basement.***

Keywords: Index properties, soil profile, undisturbed soil, laterite soil, residual soil

1. Introduction

On Earth, there are varieties of soil that lay the entire surface and they all exhibit different kinds of behavior. The properties of soils vary in their types, grain arrangement, and moisture content in them. They behave differently in a dense and dry state. These properties are further evaluated according to their grain characteristics, that is, the arrangement of particles and moisture content. Using these evaluated values, the soil can now be classified into different categories. So, the properties of soil that were used in the classification and identification of soil are called index properties [1].

These properties can further be divided into soil grain properties (which depend solely on individual soil such as metrological composition, the specific gravity of the solids, size, and shape of grain) and soil aggregate properties which also depend on the soil mass as a whole, the history on how it was formed, and the soil structure. These represent the collective behavior of the soil. Index properties of soil are of great significance in civil and engineering practices. However, soil properties used for classification and identification purposes are called soil property indicators. Since many scientists define soil as organic or inorganic material with different properties, it is within the domain of civil engineers. To overcome the unsettlement of the foundation, shear failure, and development of cracks in the structure, the Geotechnical engineer needed to select the most suitable type of soil to provide the hard soil strata. Index properties are known as inductive engineering properties. The index properties give some information about engineering properties such as permeability, compressibility, and shear strength [2].

For soil to be suitable for civil engineering, it must meet certain strength standards as well as existing local regulations regarding measured products [3]. The relative abundance of soil varies from place to place, but the combination of these factors generally determines the type of soil formed in a place [4]. In general terms, soil can be classified as residual soil, migration soil, or organic soil according to its formation method. Residual soil is formed "in situ" by chemical weathering and can be found in horizontal rocks where the movement of elements creates soil with little tendency to move. These include topsoil and sandy soils [5]. In most tropical countries, sand is widely used as a material in various construction projects. This soil erodes under heat and moisture conditions with alternating dry and rainy seasons, resulting in poor engineering properties such as high plasticity, poor performance, low strength, compressive permeability, easy storage of moisture, and high natural moisture content [6]. This is the main reason why the results of a test or a small soil test sample at the beginning of the excavation are used to represent soil at credit depth. Therefore, ignoring the changes in the measured properties of the remaining soil with depth will lead to incorrect results and cause serious damage to the geotechnical structure. Neglecting the purpose of determining soil profile measurement points will fail in the process and complete collapse of the geotechnical structure [7].

Conclusively, this study focuses on determining the soil profile that shows the best properties. Therefore, this work aims to investigate the characteristics of residual soil at Sakita in Gesse III, Birnin Kebbi.

2. Materials and Method

The trial pits were dug to depths of 2.5m at the report area and disturbed samples at 0.5m, 1.0m, 1.5m, 2.0m, and 2.5m depths were collected. During the process, the soil profile was visually inspected. Disturbed samples collected from the trial pits were air-dried and tested for moisture content, liquid limit, plastic limit, specific gravity, bulk density, and compaction as per the British Standards (BS: 1377 – 1997).

3. Results and Discussions

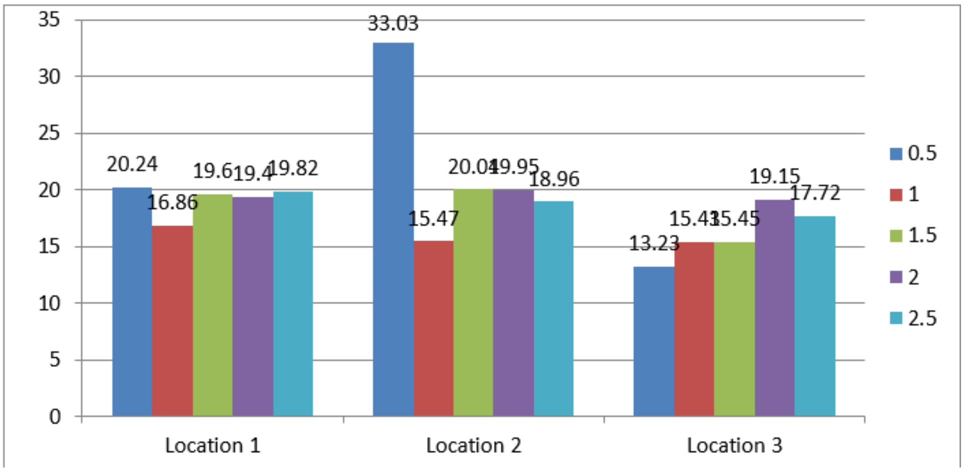
3.1 Tests Results

The profile of the trial pit showed a deposit of light brownish topsoil. Beneath this layer was a light black layer consisting of fairly graded soil. Under this layer was a light reddish and silt formation as observed. At 2.5m depth, the underlying layer was lateritic and dense and looked brown with a mere deposition of clay.

3.1.1 Natural Moisture Content

Table 3.1: Natural Moisture Content

Depths (m)	0.5	1.0	1.5	2.0	2.5
Natural moisture content for location 1 (%)	20.24	16.86	19.60	19.40	19.82
Natural moisture content for location 2 (%)	33.03	15.47	20.04	19.95	18.96
Natural moisture content for location 3 (%)	13.23	15.43	15.45	19.15	17.72



Graph 3.1 Overall results of the natural moisture content

The values of the moisture content for the first location dropped drastically from 20.24% at depth 0.5m to 16.86% at depth 1.0m. The decrease is an indication of the absence of a water table before the hard base. At depth 2.0m, the moisture content rose to 19.40%, and at depth 2.5m, to 19.82%. This is due to the infiltration of surface water through the soil by the force of gravity. This applies to the other two locations as the values of moisture content keep increasing and decreasing.

3.1.2 Atterberg limit

Table 3.2: Atterberg Limits Particle Size Distribution

Locations	Characteristics (%)	Depths (M)				
		0.5	1.0	1.5	2.0	2.5
1	Liquid limit	24.5	29.0	35.0	32.0	30
	Plastic limit	15.9	19.8	15.2	21.3	13.8
	Plasticity index	8.7	9.3	19.8	10.7	16.2
2	Liquid limit	26.5	24.5	32.0	34.0	30.0
	Plastic limit	15.3	12.7	18.2	14.9	15.7
	Plasticity index	11.2	11.8	13.8	19.2	14.3
3	Liquid limit	25.0	31.0	33.0	38.0	37.0
	Plastic limit	14.0	14.1	14.8	14.8	16.5
	Plasticity index	11.1	16.9	18.2	23.3	20.6

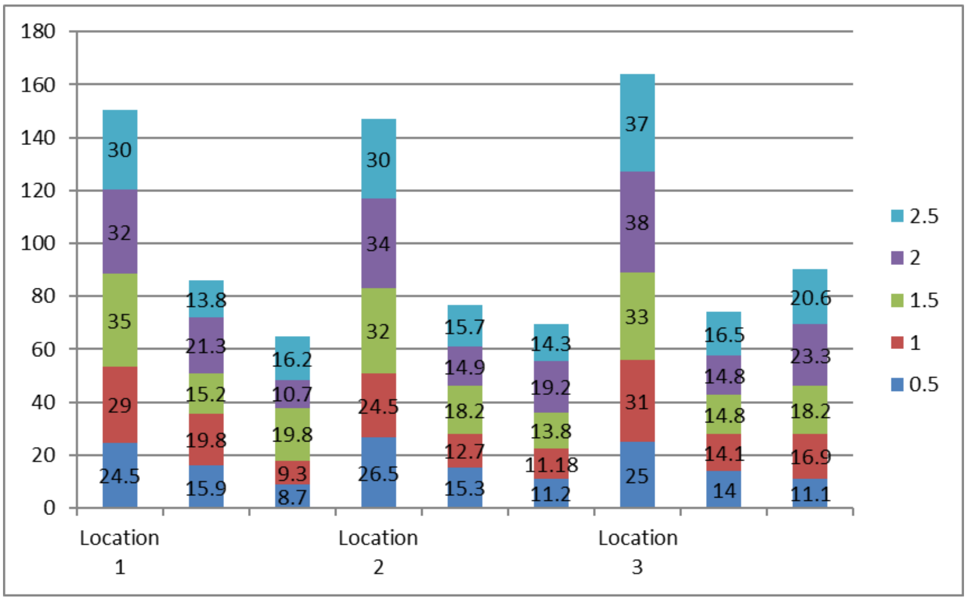


Fig. 3.2 Overall results of Atterberg limits

The values of the Atterberg limits with depths in Table 3.2 are represented. The liquid limit increased to 35% at a depth of 1.5m for the first location and then fell a little or no change. This is due to the accumulation of clay-sized particles that were leached from the lateritic profile. Also for the second location, the liquid limit falls at depth 1.0m and increases to 32% at depth 2.0m, and thereafter, falls to 30% at 2.5m which is insignificant. As for the third location, the liquid limit recorded at 2.5m is due to the accumulation of clay minerals in the soil as well as its nature.

The plastic limit, on the other hand, increased from 15.9% at 0.5m to 19.8% at 1.0m. The value reduced to 15.2% at 1.5m, then increased to 21.3% at 2.0m and further decreased again at 2.5m to 13.8%.

The same fluctuation in values of plastic limit occurred at the second location, which confirms the accumulation of clay-sized particles just below the soil profile. But for the third location, the values of the plasticity index up to depth 2.5m. The trend of the Atterberg limit is also probably due to the leaching of organic matter from the surface of the ground.

3.1.3 Specific Gravity

Table 3.3: Summary of specific gravity

Depths (m)	0.5	1.0	1.5	2.0	2.5
Location 1	2.55	2.59	2.60	2.64	2.64
Location 2	2.48	2.59	2.63	2.61	2.63
Location 3	2.50	2.59	2.55	2.59	2.58

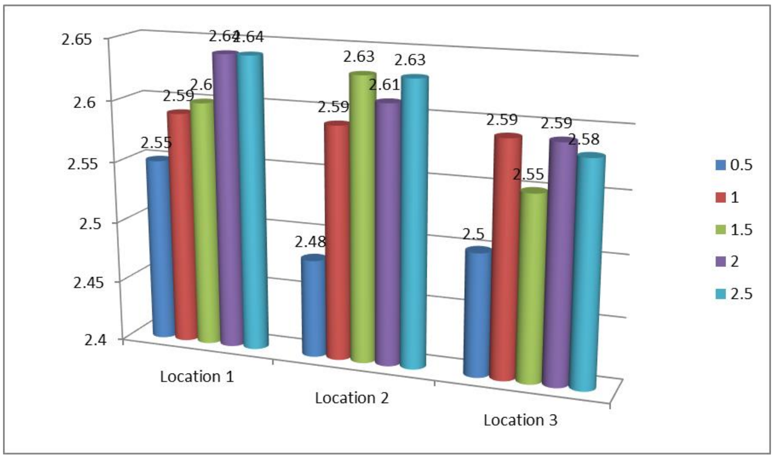


Fig. 3.3 Overall results of the specific gravity

The specific gravity was 2.55 at 0.5m for the first location. The value kept on increasing up to a depth of 2.0m and remained stable at a depth of 2.5m. The higher values recorded were probably due to the presence of free irons in the depths which are heavier than the ordinary soil particles. A similar episode occurred in the second location and also a slight change in value for the third location was obtained. Thus, this shows that, for the three different locations, free irons were present.

3.1.4 Bulk Density

Table 3.4: Summary of bulk density test

Depths (m)	0.5	1.0	1.5	2.0	2.5
Location 1	17.3	17.6	17.7	17.9	18.5
Location 2	18.47	19.87	18.47	18.72	20.76
Location 3	16.56	20.38	19.87	18.60	20.12

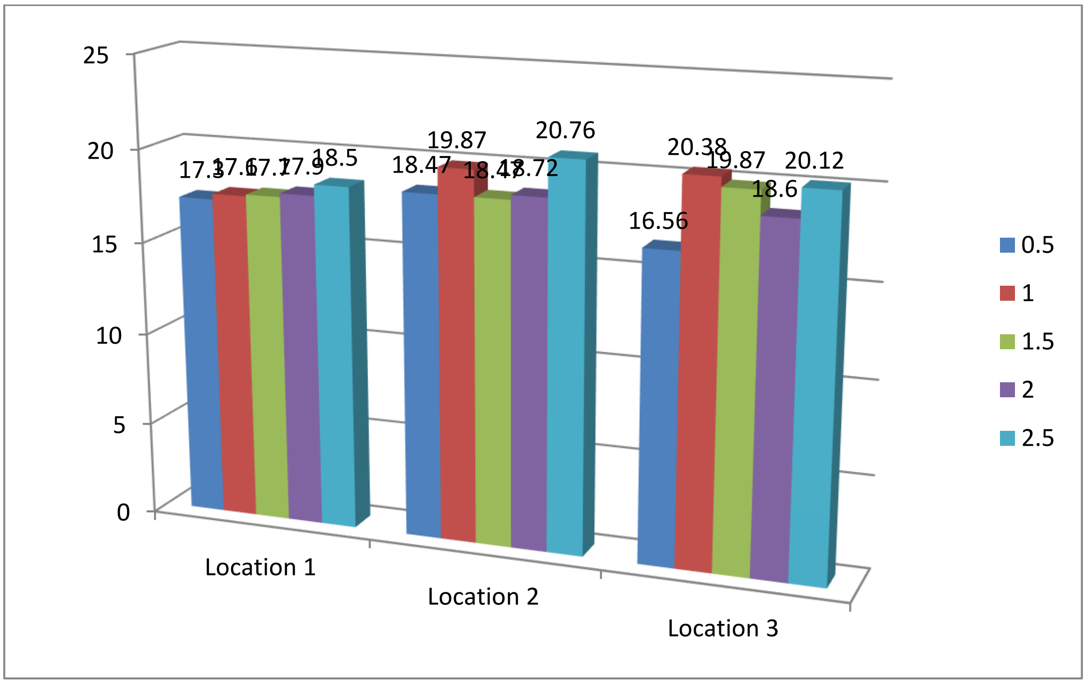


Fig. 3.4 Overall results for bulk density

The value for the unit weight increased from 17.3 mg/m^3 at 0.5m to 18.5 mg/m^3 at 2.5m for the first location. This shows a decrease in the level of porosity in the soil profile. Also in the other locations, a slight change in the unit weight was observed and as such, this shows that the porosity level for the soil profile generally is low.

3.2 Discussion of Results

The general rating for the soil as sub-grade at 0.5m depth for each location was excellent. But for the other depths in all the locations, the sub-grade rating was generally poor. All the soils in the depth of 0.5m studied at the three different locations were composed mainly of clayey –gravel and sand, with the first location having a percentage of fine sand to be 67.9%, the second location having a percentage of 66.2%, and the third location to be 76.5%. So the general rating for the sub-grade material tends to be good for the depth. Also for depth 1.0m, the percentages of fines for different locations were 59.3%, 63.3%, and 57% respectively. Values for fine for the 1.5m depth were recorded to be 56.3%, 56.6% and 51.5%. For the 2.0m depth, the percentages of fines for the different locations were 59.7%, 57.9%, and 54.0%. Finally, for the last depth dug, the percentages of the fine were 57.9%, 56.4%, and 57.8%.

Having all the stated values of fine sand to be very high, the soil profile is said to be poorly graded. This also could be due to the low availability of gravel or partially decomposed rocks.

4. Conclusion

From the result of the investigations, the following conclusion can be drawn:

The profile is composed mainly of fine-grain soils with little silt and clay particles present in the soil profile. The liquid limit of the stratum studied varied for each depth at the different locations. The highest value was obtained at the depth of 2.0m to be 38% which was observed to be the clayey layer. It is clear that all index properties of the soil profile studied varied with depth and the results obtained for soils at one layer should not be used to represent the result of soils at the other layer for avoidance of in-accurate design of soil structures.

In Geotechnical Engineering, more than in any other field of civil engineering success depends on practical experience. The design of ordinary soil-supporting or soil-supported structures is necessary to be based on simple empirical rules but these rules can be used safely only by the engineer who has a background of experience. Large projects involving unusual features may call for extensive application of scientific methods to design, but the program for the required investigation cannot be laid out wisely, the engineer in charge of design possesses a large amount of experience. Since personal experience is somewhat limited, the engineer is compelled to rely at least to some extent on the records of the experience of others. If these records contain adequate descriptions of the soil conditions, misleading. Consequently, one of the foremost aims in attempts to reduce the hazards in dealing with soils has been to find simple methods for discriminating among the different kinds of soil in a given category. The properties on which the distinctions are based are known as index properties and the test required determining the index properties classification test.

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