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Determination of Some Mechanical And Hydraulic Properties Of Biu Clayey Soils, Nigeria

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ABSTRACT: *The analysis of particle size (PS), Atterberg limit (AL), Maximum Water Holding Capacity (MWHC), and Shear Strength (SS) of Clay Loam and Sandy Clay soils of Biu, Biu Local Government Area were conducted in a laboratory. The soils had varying AL 46.9% and 56.5% liquid limit respectively, 23.5% and 22.7% plastic limits respectively, 23.4% and 33.8% plasticity index respectively for the two soils. For maximum water holding capacity, Sandy clay and Clay loam soils indicated 39% and 41% moisture contents respectively. Sandy clay soil had higher shear strength than Clay loam soil, but Clay loam had higher hydraulic properties. Both soils could be put to agricultural and structural uses but sandy clay would be more preferred for structural uses and clay loam for agricultural. Output of the study could be useful in predicting irrigation scheduling and for determining the sustainability of the soils for structural purposes in the study area.*

Keywords: *Mechanical properties, Hydraulic properties, Clayey soils, Biu area, Semi arid region*

I. INTRODUCTION

The soils in Biu area are clayey-dominated, and are cultivated for agricultural crop production on one hand, and are used civil engineering works either as a construction material or structural support. Agriculture is, however, the major economy of the area. The soils therefore misbehave with hydraulic variation. Problems of structural failure, such as road disruption, settling and cracking of buildings, drainage failure, are not uncommon in the area. This has been one of the sources of socio-economic dilemma confronting the inhabitants of the area. Another factor contributing to the economic insecurity of the area is droughts that usually occur in the first quarters of the rainy seasons. The clayey soils crack when dry, crops dry up correspondingly, and irrigation becomes indispensable for sustainable crop production. Farmers normally replant, but mostly with little or no success. Water holding capacity is the amount of water that is held in a soil after gravitational water loss has ceased and substantive implications on soil and water conservation [1]. It is a measure of the amount of water held in the soil at between field capacity and permanent wilting point of a soil. Shear strength of a soil mass is the internal resistance per unit area that a soil mass can offer against failure and/or sliding along any plane [2]. It is a measure of the soil resistance to deformation by continuous displacement of its individual soil particles that gives the strength of a soil to resist shearing. Shearing displacement has been recognized as important in traction mechanics [2], as the role of displacement in shearing strength measurements is largely dependent on the state of compactness of the soil. Shearing strength characteristics are also influenced by moisture content [3]. Shear strength in soils depends primarily on the interactions between soil particles. The shear resistance of a soil seeks to describe the mechanical properties of a soil mass by indicating its abilities to withstand impact on its cross-sectional area, while water holding capacity symbolize the hydraulic properties of the soil at different water conditions as it relates to water retention within the soil mass. Both the properties are indirectly mutually related and are readily affected by the physical properties of the soil [4]

Up to date data on soil the water holding capacity is an indispensable tool in irrigation scheduling [4], which in turn is necessary for successful design and profitable operation and management of irrigation.

All soils are compressible and could undergo deformation when subjected to stress. Foundation settlements also represent the great problems occurring in building constructions, also many buildings have become distressed due to settlement. This problem, which is often caused by weak or improperly consolidated soils, and affect most buildings which are built on soft but compactable leading to high risk for structural failure. Soils, however, differ significantly in response to varying stress and/moisture contents [5]. This study was therefore initiated to examine the variation in water holding capacity and shear strength of the two major Biu soils with different moisture contents and loads.

II. MATERIALS AND METHODS

Study Area

Biu is a town and a Local Government Area (LGA) is located in the southern Brno State of Nigeria located at Longitude 10.6111°N and Latitude 12.195°E, it lies on the Biu Plateaus at an average elevation of 626 meters above mean sea level. The climate is semi-arid region in the Northern Guinea Savannah (NGA) Agroecological zone with a small portion in the North East lying in the dryer Sudan Savannah Zone.

Sample Collection and Preparation

Soil samples were collected from five randomly selected locations within the Biu Local Government Area. Simple auger was employed in soil sample collection at 15 cm incremental depth from the soil surface to 90 cm depth. The sample collected was then poured in a polythene bag to minimize alteration of the soil properties during conveyance to laboratory. For soil test involving the determination of shear strength, cylindrical moulds (10 mm in diameter and 13 mm in height) were used for sample collection to avoid disturbing the soil.

Sample analysis

The particle sizes of the soils were analyzed applying the Stoke's settling velocity principle as detailed by Day [6]. Approximately 50 grams of air-dried soil passing a 2 mm sieve was weighed and quantitatively poured into dispersing cup and was used for the determination of Particle Size Distribution of the soils. The Atterberg Limits (Liquid limit (LL), Plastic Limit (PL), and Plasticity index (PI) were also determined following the methods adopted [2].

The soil sample was air-dried to reduce the moisture content to 3.72% and 5.53 for sandy clay and clay loam respectively. 500 grams of each of the samples was stirred and fully saturated with 194 ml of water and used for the determination of the maximum water holding capacity of the soil. The Triaxial Machine was used to determine the shear strength of the soils adopting the methods of Dayakar *et al*. [7].

III. RESULTS AND DISCUSSION

Particle Size Distribution

The results of the particle size distribution of the soils are presented in Table 1.

Table 1: Computed Values for Particle Size Analysis

Sample number	Hydrometer reading (H_1)	Hydrometer reading (H_2)	Temp. (T_1)^oC	Temp. (T_2)^oC	% Sand	% Clay	% Silt	Soil Class
1	30.9	21.4	24	25	51.6	40.8	7.6	Sandy clay
2	33.2	18.4	24	25	36.0	34.8	29.2	Sandy clay

The Table above demonstrated the significantly large percentage of clay in the samples following the sand fractions. On the other hand, Clay loam results obtained shows that there was almost equal size distribution between the three particles when analyzed.

Atterberg Limits

The values of liquid and plastic limits of Sandy clay and Clay loam were significantly influenced by affected variation in moisture content. Using the data on Figure 1, the plastic index (I_p) for Biu Sandy clay and Clay Loam soils at 25 blows was computed to be 23.4 % and 33.8 % respectively.

Water Holding Capacity.

Table 2 presents the water holding capacities of the tested soils demonstrating water holding capacity of 195.3 and 202.6 g of water for every meter of the soil at field capacity for Sandy clay and Clay loam soil respectively. This implies 195.3 grams and 202.6grams of water will be required to raise the moisture content of Sandy clay and Clay loam soils respectively to field capacity These figures represent 39 % moisture content for sandy clay and 41% moisture content for clay loam.

Table 2: Computed Values for Water Holding Capacities

Sandy clay Soil							
Sample No	Volume of dry soil used (g)	Volume of water added (g)	Volume of water collected (g)	Time taken for water to drain (g)	Volume of water retained (g)	Droplets	Water holding capacity per meter of soil
1	500	340	145.0	09:56-10:23	195	Max:64d Min:Od	(at 0.39 MC) 195.3g of Water/m of soil at field capacity
2	500	390	195.0	07:25-08:50	195	Max:63d Min:ld	
3	500	390	194.0	09:04-09:44	196	Max:65d Min:ld	

Sandy clay Soil							
Sample No	Volume of dry soil used (g)	Volume of water added (g)	Volume of water collected (g)	Time taken for water to drain (g)	Volume of water retained (g)	Droplets	Water holding capacity per meter of soil
1	500	394	190.0	07:45-09:00	204	Max:60d Min:Od	(at 0.41 MC) 202.6g of water/m of soil at field capacity
2	500	353	152.0	09:23-10:15	201	Max:60d Min:ld	
3	500	394	191.0	08:55-09:32	203	Max:60d Min:ld	

Shear Strength

The results obtained from the shear strength test were computed and polynomial graphs used to represent these values to further buttress the varying shear strength values for the soils tested under different stress conditions as shown in Figures 1 and 2. Similar *intermediate failure* modes (a failure in which soil particles tend slide over another diagonally with a very slight rupture were exhibited by both the soils) when subjected to an axial compressive loads. Sandy clay soil exhibited greater shear strength as compared to clay loam within the limit of experimental errors. While the overall conclusion drawn from the soil tests conducted on disturbed soil sample depicts that for the different number of hammer blows (10, 15 and 20) to which the soil samples were subjected, clay loam exhibited greater shear strength as compared to sandy clay soil. The optimum moisture content was a determining factor that greatly affected the cohesion and densities exhibited by the soil samples used in conducting the test.

For both the soils, shear strength relates to moisture content quadratically with R^2 values near or equal to unity as depicted in Figures 1 and 2.

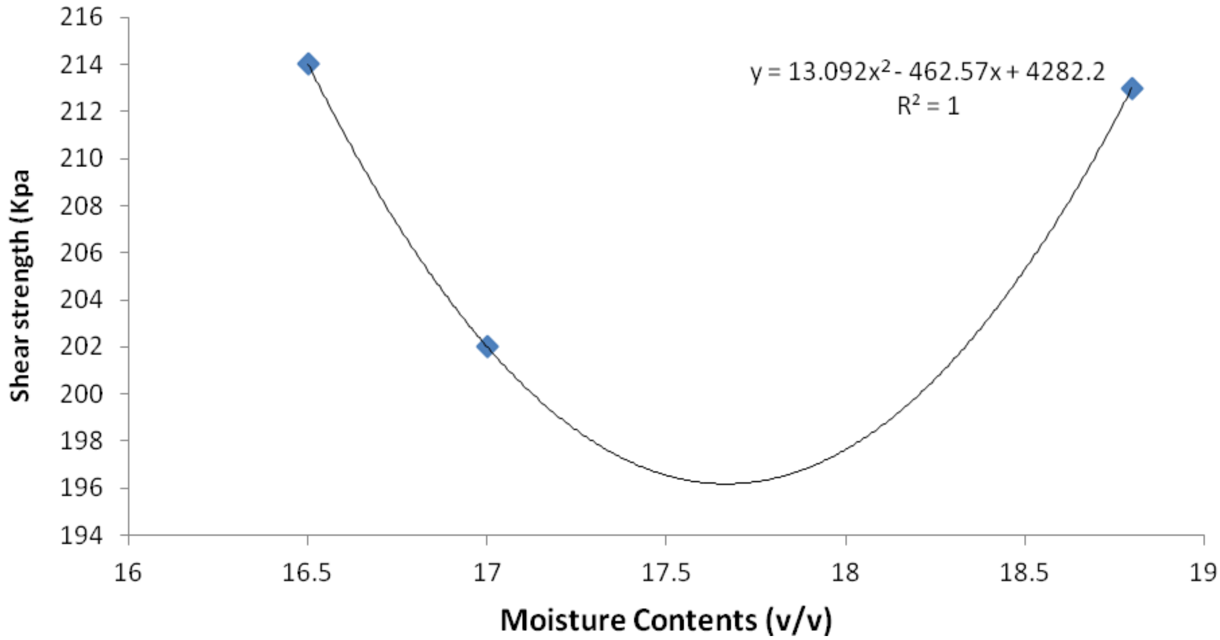

Figure 1: Graph of shear strength for disturbed sandy clay soil at 20 hammer blows

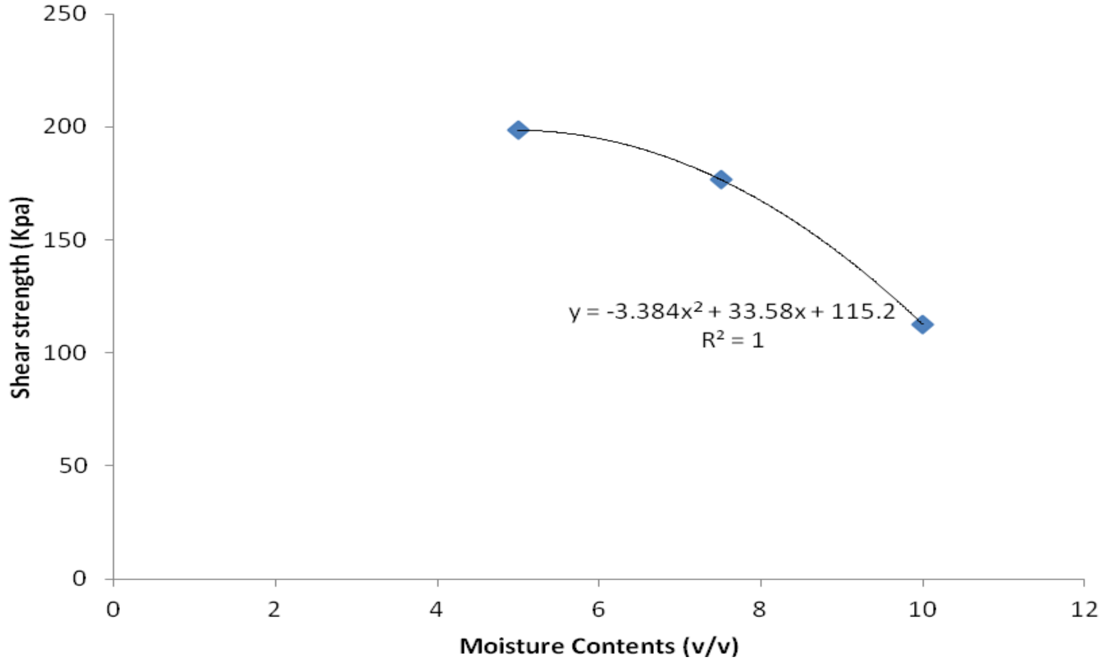

Figure 2: Graph of shear strength for disturbed Clay loam soil at 20 hammer blows

IV. CONCLUSION

From the results, it was observed that clay loam has more proportionate distribution of its particles compared to sandy loam and it had higher moisture characteristics (Atterberg limits and water holding capacities). But Sandy clay proved to have comparatively greater shear strength than the clay loam. Thus in practice, sandy clay would fit in for structural purposes more than clay loam and for agricultural purposes reverse would be the case. The study therefore recommends the consideration adequate modifications of the Clay loam soil when it is to be applied in structural and foundation purposes and suitable the adaptable crop and cropping practice must be employed when the sandy clay must support agriculture.

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