International Conference of Sciences, Engineering & Environmental Technology (ICONSEET), 6(28): 213 – 222, 2021
ISSN 0794-9650
www.repcomseet.com

THE EFFECT OF WATER CONTENT ON THE SHEAR STRENGTH OF CLAY SOIL TREATED WITH CEMENT

[1] Emmanuel O. Ibiwoye, [2]Abdulwasiu Abdulkadir , [3]Abdulmumin Naallah and [4]Sanni Abubakar
[1,2,3,4,] Department of Civil Engineering, Kwara State Polytechnic, Ilorin, Kwara State,Nigeria
Corresponding e – mail: ibiwoyeeo2008@yahoo.com

Abstract: Clay soil treated with cement so as to monitor, determine cohesion and the angle of internal friction of sample collected from trial pit at Akerebiata Ilorin East Kwara state. The soil sample was mixed with cement and subjected to direct shear box test in accordance with BS1377. The moisture content, bulk and dry density, specific gravity, Atterberg limits and direct shear box test were determined. Based on the result obtained from the direct shear box test with the variation of water and cement to obtain maximum strength from 0% to 12%, It shows that maximum angle of internal friction is 18^{O} at 4% and 12% of the specimen and the least of 13^{O} at 6% of the sample. The result showed that the angle began to decrease. It was concluded that the soil is silt Clay soil and the results of tests show that the soil is highly recommended for use as an embankment in the dam construction, as if satisfies the standard recommendations.
Keywords: Water content, Shear strength, Foundation, Geotechnical, Weathering.

1.0 Introduction

Soil is essential to life as it serve several purposes ranging from agricultural application to engineering application and uses. Soil material is a critical component in the mining, construction and landscape development industries. Soil serves as a foundation for most construction projects. The movement of massive volumes of soil can be involved in surface mining, road building and dam construction. Earth sheltering is the architectural practice of using soil for external thermal mass against building walls. Many building materials are soil based Leake et. al (2014). Soil acts as an engineering medium, a habitat for soil organisms, a recycling system for nutrients and organic wastes, a regulator of water quality, a modifier of atmospheric composition, and a medium for plant growth, making it a critically important provider of ecosystem services (Dominati, et. al, 2010).

Consequently, the understanding of the nature, behavior and probable methods of effective usage of soil is very important to the civil and geotechnical engineers in general. The most valued property of soils to engineers is their strength characteristics and behavior of soil under load. The strength of soil is a measure of the maximum stress that can be induced on the soil without failure. Therefore, the strength of the soil depend on the degree of moisture content and normal loads applied (smith, 2005). In certain type of soil (clay), moisture content causes a significant change in the volume of the soil due to shrinkage and swelling phenomena (Roy, 2001).

Finally, for safe and economical construction of structures, the shear strength and other characteristics of soil should be properly investigated on the field and in the laboratory. Moulding is the process of manufacturing by shaping liquids or pliable raw materials using a rigid frame called mould or matrix. A mould or matrix is a hollowed-out black that is filled with liquid or pliable materials such as plastic, glass, metal or ceramic materials, the liquid hardens or sets inside the mould adopting its shape.

Water content is the quantity amount of water contained in materials such as soil, rock, ceramics, crop and wood. It is used widely in a wide range of specific and technical areas. It is measured directly using dry oven and it can be given in volumetric or gravimetric basis. Moulding water content affect the swelling and shrinkage properties of the soil. It also influences the long-term stability of mineral liner clay, swelling may be treated in case of liner clay as an advantageous featured, or improving the sealing properties by increasing water holding capacity of clays. Clays are essentially fine-grained, earthy materials that become plastic and tenacious when moist and permanently hard when dried or fired. They may composed of mixtures of Clay materials and clay sized crystals of other minerals such as quartz, carbonate and metal oxides. They are commonly formed either as product of chemical weathering of pre-existing tropical and subtropical regions of the world or as a result of the hydrothermal alterations.

Clay and clay minerals are economic minerals that have been found used in manufacturing and environmental industries where they served as major raw materials in the making of ceramics, paint, paper, refractory, plaster of Paris, pharmaceutical products. Other application of clay include: cure of ulcers, for cleansing purposes, detoxification, absorption, skin emulsifier and cure against dysentery and cholera (Olushola et al, 2014).

Cement is a binder, a substance used for construction that sets, hardens, and adhere to either materials to bind them together. Cement is seldom used on its own but rather to bind sand and gravel (aggregate) together. It is mixed with fine aggregate produce mortal for masonry or with sand, gravel, cement produce concrete. It is mostly used materials in existence and is only behind water as the planet's most consumed resources.

2.0 Sample collection

The samples were collected from harmony estate Akerebiata area of Ilorin east LGA kwara state by trial pits i.e soakaway. Okelele was well known for its earthen pots production which employed majority of the house wives in the area. The chosen location for the project research is Akerebiata Ilorin where for decades clay soil has been found, deposited and worked by the locals especially for pottery makers. Samples collected were placed in an air-tight polythene bag to prevent excessive loss of its natural water content and then transported to the laboratory form determination of its water content and shear strength.

2.1 Laboratory Test

The laboratory test carried out on this research work includes moisture content determination, specific gravity test, wet and dry density, Atterberg limits (plastic limit, liquid limit, plasticity index, and direct shear box test.

2.2 Moisture content

The moisture content was determined by weighing the soil samples, then drying the samples in an oven at a temperature of 105°C - 110°C and reweighing. A drying period of 24hours was allowed for the samples before reweighing. The moisture content was calculated as follow;

Moisture content (W%) = Ww/Ws X 100%,

Where, Ww = weight of the water

Ws = weight of the soil

2.3 Specific Gravity

The specific gravity is the ratio of the soil particles by density of water. The specific gravity of sample was determined by using the density bottle method. The bottle was weighed empty with cork and the mass was recorded as W_1. Small quantity of the samples was poured to fill ⅓ of its volume, it was then weighed and the mass was recorded as W_2. The bottle contained the soil was filled with water to capacity, corked, weighed, and the mass was recorded as W_3. The bottle content was later emptied, washed, and filled with water to capacity, corked, weighed, and the mass was recorded as W_4.

2.4 Wet and Dry density

The bulk density of a soil sample is the ratio weight of the soil and moisture content per unit volume. It is sometimes refers to as moist unit weight. The dry density also called dried unit weight is the weight of the soil solid per unit volume excluding water. These were determined in the laboratory as follows; The sample of the soil at the natural moisture content was used to fill the standard mould and then spatula was used to cut “off” the excess. The mould and the sample was weighed and the mass was recorded as WsM. The moulded soil sample was carefully removed into a container of known mass and then dried for 24hours in an oven.

After drying, it was cooled, weighed and the weight was recorded as Ws. The bulk density wascalculated using;

ΎY = Ws/V

Where ΎY = bulk density (kg/m³).

WsM = weight of the soil sample + weight of mould

Wm = weight of mould

V = volume of mould

The dry density or dried unit weight was calculated as follows;

ϒd = Ws/V

Where, ϒd = dry density (kg/m³)

Ws = weight of the dry soil

2.5 Atterberg´s limits

Atterberg's (consistent) limits are means of determining the consistency of soil as its moisture content changes. This includes the plastic limit, liquid limit and plasticity index which is done in accordance with BS 1377, Part 2: 1990.

2.6 Direct Shear Box Test

The test equipment consists of a metal shear box in which the soil is placed on the box is split horizontally in two halves. Shear strength of the soil samples at varying moisture content of 0%,2%, 4%, 6%, 8%, 10%, and 12% was subjected to Normal load of 5kg, 10kg, and 15kg was determined by cement-water mix. This test is done in accordance with BS 1377:7:1990

3.0 Result and Analysis

The result of physical characteristics of the soil samples and its shear strength parameters, moisture content relationship is as presented

3.1 Water content

A summary of the laboratory test carried out is as shown in Table 1.

Table 1: Water content Determination

Container no (cup)	A_1	A_2
Wt. of cup + wet soil (g)	125.5	133.2
Wt. of cup + dry soil (g)	123.5	131.5
Wt. of cup (g)	16.5	22.0
Wt. of dry soil (g)	107.0	109.0
Wt. of water(g)	2.0	2.2
Water content %	1.8	2.0

Average =1.9%

Table 2: Specific gravity

Wt. of empty bottle (g) (W_1)	124.0	124.0	124.0	124.0	124.0
Wt. of empty bottle + 1/3 o soil (g) (W_2)	155.5	155.0			
Wt. of empty bottle + 1/3 of soil + water (g) (W_3)	232.1	232.0			
Wt. of empty bottle + water only (g) 1/3 of soil + water (g) (W_4)	215.0	215.0	215.0	215.0	215.0
Specific gravity =$\frac{(w_2 - w_1)}{(w4\text{-}w1) - w3\text{-}w2}$	2.19	2.21			

Average = 2.21

$$Gs = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

$$Gs = \frac{1550 - 1240}{(215.0 - 124.0) - (232.0 - 155.0)} = 2.21$$

Table.3: Bulk Density

Wt. of mould + wet soil (g)	123.5	125.2				
Wt. of mould (g)	14.0	14.0	14.0	14.0	14.0	14.0
Volume of mould (cm^3)	80.7	80.7	80.7	80.7	80.7	80.7
Bulk Density (g/cm^3)	1.36	1.38				
Average =		1.37gcm^3				
Wt.of pan + dr4y soil (g)						
Wt. of pan soil (g)	32.0	32.0	32.0	32.0	32.0	32.0
Wt. of dry soil (g)	107.0	109.0				
Volume of mould (cm^2)	80.7	80.7	80.7	80.7	80.7	80.7
Dry Density (g/cm^2)	1.33	1.35				

Average = 1.34g/cm^3

Table 4: Atterberg limit for liquid limits

Can no	A	B	C	D
Wt of wet soil + can (f)	32.5	31.0	33.1	38.2
Wt. of dry soil + can (g)	27.5	24.0	26.1	29.2
Wt. can (g)	16.5	11.0	13.0	15.7
Wt. of dry sol	11.0	13.0	12.5	13.5
Wt. moisture (g)	5.0	7.0	7.0	9.0
Water content w%	45.5	53.8	56.0	66.7
No of blows N	44	27	29	13

Water content= $\frac{wt\ of\ water}{wt\ \ of\ drysoil}$ x 100

Table 5: Shear box test parameters

Weight of frame	10kg
Weight of effective lever arm	9kg
Proving Ring Constant/Load Ring content	1.733
Acceleration due to gravity	9.81 m/s^2
Added/sloted weight	5,10,15kg
Area of the box	60 x 60mm^2
Ratio of machine	10:1

Table 6: Shear strength sample 0 % of water /cement.

Load (Kg)	Normal stress (KN/M^2)	Shear stress (KN/M^2)
5	188	54
10	324	131
15	461	153

C= 15KN/m^2 Ø=17^o

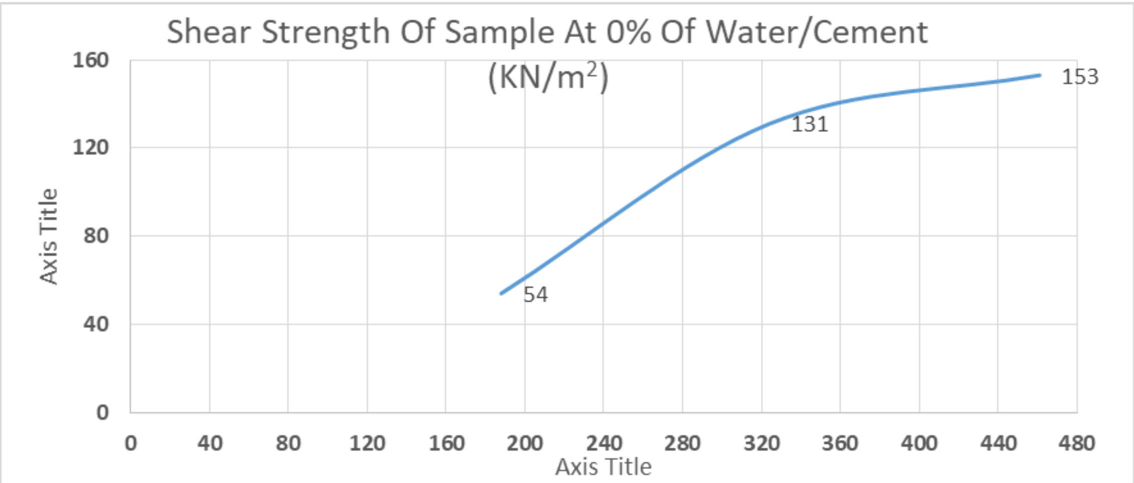

Figure 1: Shear Stress - Normal Stress (KN/m^2) at 0% Water/Cement

Shear Box Test

Sample No: 2% of Water

Table 7: Shear strength sample 2% of water/cement

Load (Kg)	Normal stress (KN/m^2)	Shear stress (KN/m^2)
5	188	78
10	324	133
15	461	154

C= 25KN/m^2 Ø=16^o

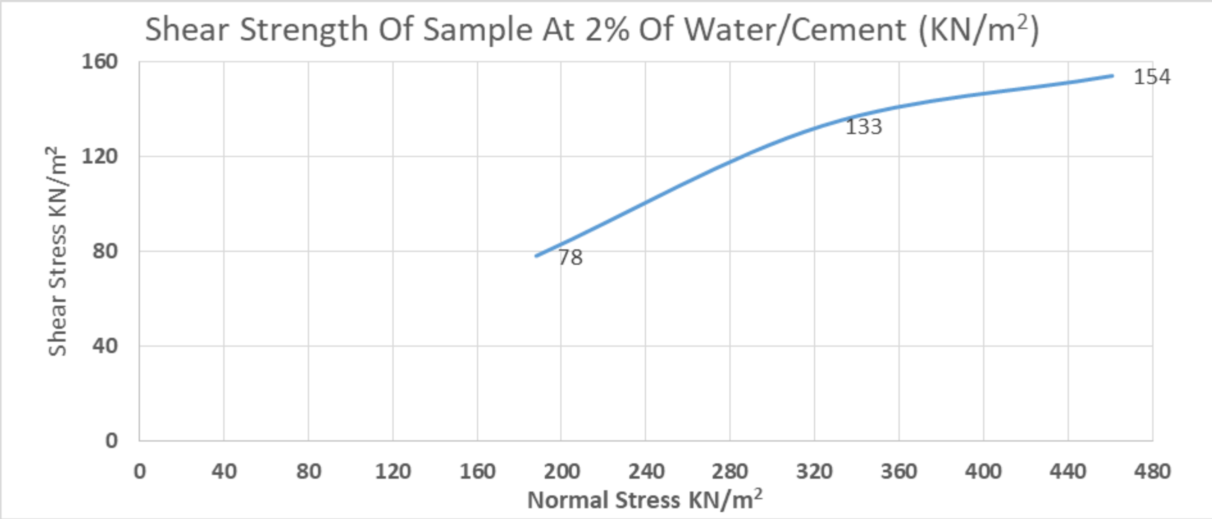

Figure 2: Shear Stress - Normal Stress (KN/m^2) at 2% Water/Cement

Shear Box Test
Sample No: 4% of Water

Table 8: Shear strength for 4% of water /cement

Load (Kg)	Normal stress (KN/m^2)	Shear stress (KN/m^2)
5	188	52
10	324	120
15	461	247

C= 20KN/m^2 Ø=18^o

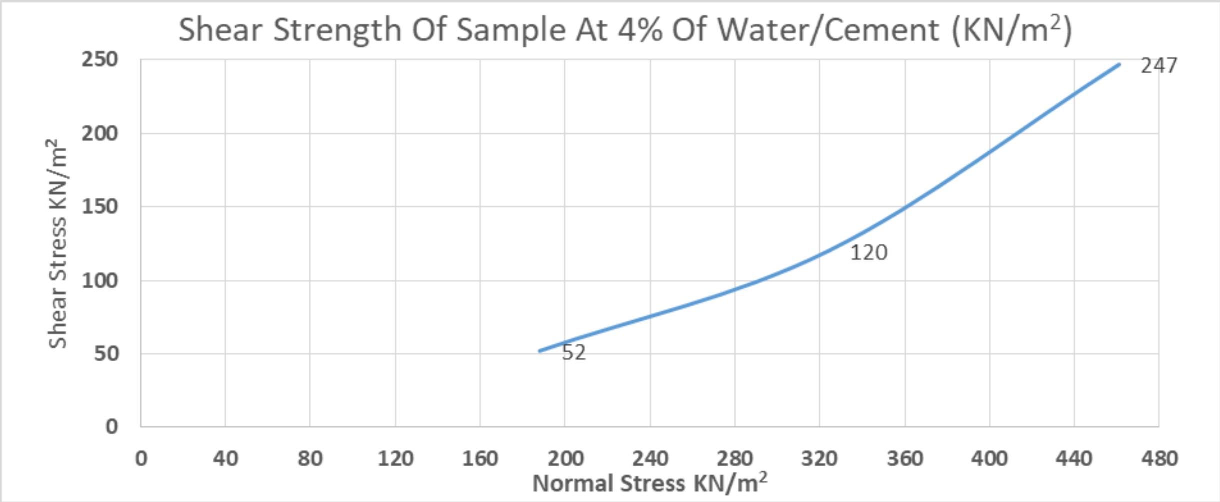

Figure 3: Shear Stress - Normal Stress (KN/m^2) at 4% Water/Cement

Shear Box Test
Sample No: 6% of Water
Table 9: Shear for 6% of water

Load (Kg)	Normal stress (KN/M^2)	Shear stress (KN/m^2)
5	188	64
10	324	107
15	461	134

C= 25KN/M^2 Ø=13^o

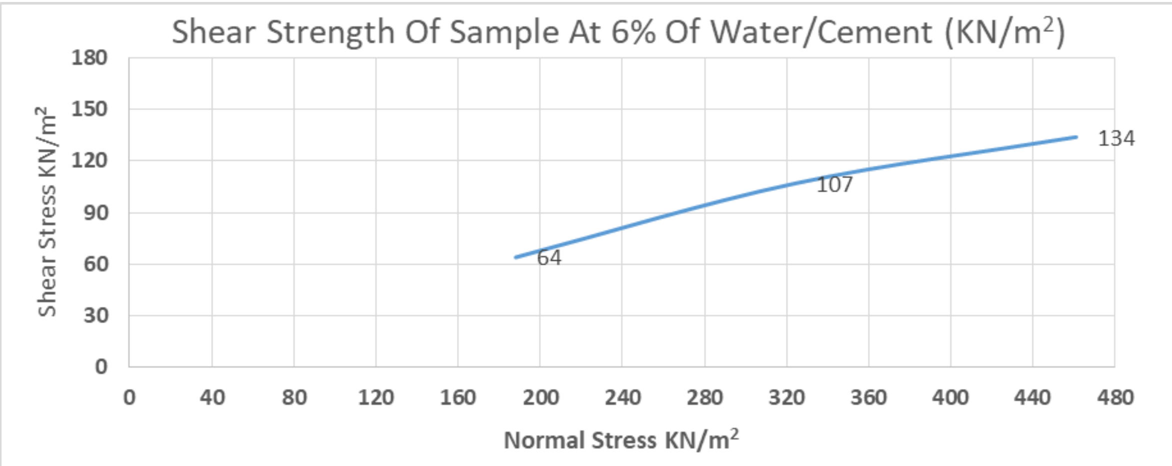

Figure 4: Shear Stress - Normal Stress (KN/m^2) at 6% Water/Cement

Test: Shear Box Test
Sample No: 8% of Water

Table 10: Shear for 8% of water /cement Result

Load (Kg)	Normal stress (KN/m^2)	Shear stress (KN/m^2)
5	188	95
10	324	116
15	461	182

C= 40KN/m^2 Ø=17^o

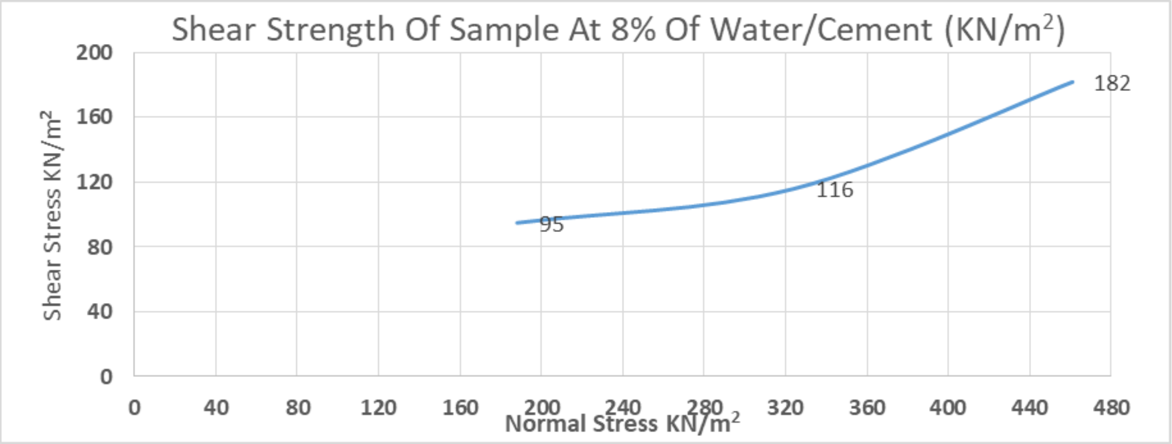

Figure 5: Shear Stress - Normal Stress (KN/m^2) at 8% Water/Cement

Test: Shear Box Test
Sample No: 10% of Water

Table 10: Shear strength for sample 10% of water /cement

Load (Kg)	Normal stress (KN/M^2)	Shear stress (KN/m^2)
5	188	80
10	324	102
15	461	163

C= 25KN/m^2 Ø=16^o

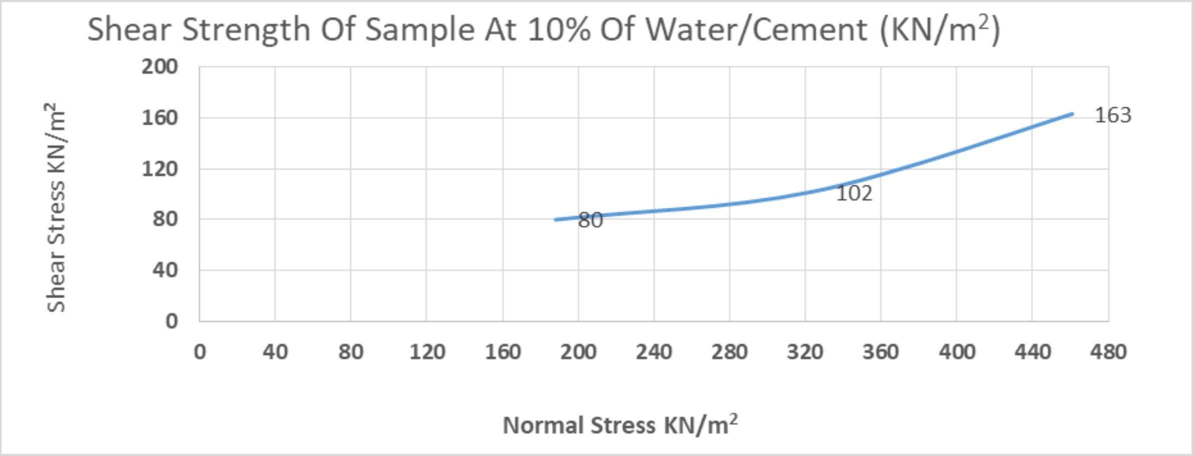

Fig. 6: Plot of Shear Stress against Normal Stress (KN/m^2) at 10% Water/Cement

Test: Shear Box Test
Sample No: 12% of Water

Table 12: Shear strength for sample 12% of water/cement

Load (Kg)	Normal stress (KN/m^2)	Shear stress (KN/m^2)
5	188	88
10	324	123
15	461	163

C= 20KN/m^2 Ø=18^o

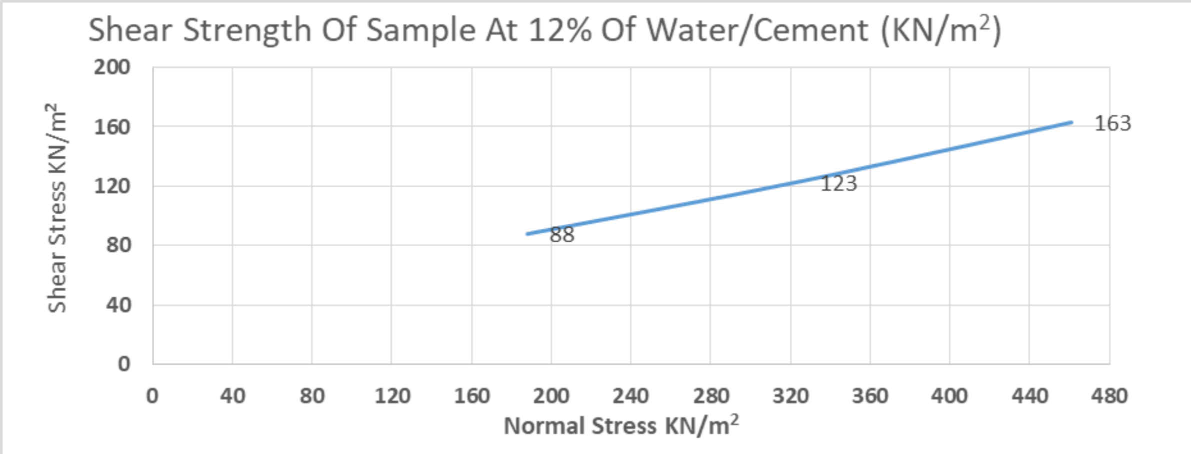

Figure 7: Shear Stress - Normal Stress (KN/m^2) at 12% Water/Cement

Discussion of Result

The result of physical consistency tests of the samples indicated that the average natural moisture content of the soil is 1.9%, the average bulk density is 1.37gkm^3 dry density is 1.34gkm^3. Average specific gravity is 2.21; these are all shown in Tables 1 - 12

Moisture content: the moisture content of any soils has to do with seasonal variation; soil has highest moisture content during rainy season and lowest during dry season. According to Emesiobi, (2000), the natural moisture content in soil varies from 5% to 50% in gravel and sand. The natural moisture content of lateritic soil samples range from 17% to 25%. In respect of this study, the value has to do with the season of testing which indicates soil potential for water retention. Osuji and Akinwamide, 2018).The soil in this study is neither gravel and lateritic, which shows the reduction in the value of moisture content to be 1.9%.

Specific gravity: the average S.G value of this study is 2.21. According to Wright (1986), the standard range of value for Specific gravity of soil lies between 2.6 and 2.8, the value obtained in this study does not fall within this values. Que, et.al. (2008) indicated that the specific gravity is linked with the mineralogy and chemical composition of soil. It is therefore concluded that the sample with highest specific gravity expected to be lateritised sample and the lowest specific gravity is the unlateritised sample. The sample with values lower than the range is classified as clay and silt family.

The Atterberg limit test is to know the liquid & plastic limits this is shown in Figure 4.1. The liquid limit and plastic limit of the soil is 55.5% and 25.2% respectively,. According to Ministry of works and housing (1997) specification, it is recommended that liquid limit value range from 15.8% to 49.6% and a maximum of 50% for housing. When compared with Roy, Whithow (2001), gave a specification of plastic limit to varied from 12.0% to 28.0%, the plasticity index of clay soil in this study is 30.3%. Federal ministry of works and housing (1997) specification give the plastic index value ranging from 3.8% to 19.4%. Hence, the clay soil is then not suitable for construction unless it is stabilized.

The result of physical study of direct shear box based on the effects of moisture content with cement on clay soil from 0% to 12% indicated that the angle of internal friction and cohesion vary from 13^o to 18^o an 15KN/m^2 to 40KNm^2, respectively. This result is in agreement to the research work of Poulos (1989), who stated that the shear strength of soil increases with increase in the cement content added.

4.1 Conclusion

Based on the above results the sample can be classified as silt clay soil which is in conformity with British Specification standard of practice BS.1377.

From the direct shear strength with the variation of water and cement to obtain maximum strength from 0% to 12. It show that the maximum angle of internal friction of 18^o and 4% and 12% of water and cement mix and the least of 13^0 at 6% of the moisture. The result show that the angle of internal friction began to decrease at 6% or 10%, this is due an increase in water content, so the strength of the soil continue to decrease because there is destruction of cohesive force while the soil has high cohesion of 40KN/m^2 and least of 15KN/m^2. The addition of water to the soil makes the cohesive force of the soil to decrease. The cohesive force of soil treated with cement is 15KN/m^2 compared to 10KN/m^2 of water only. The strength of the cement prevent further distribution of cohesive force of the soil behavior under loads.

4.2 Recommendation

i. It was observe that the results of the moisture content, Atterberg limit and direct shear box test show that the soil can be of use as an embankment in the construction of dam as it meets the standard recommended for construction in BS 1377.

ii. Combination of clay and cement mixtures can serve as stabilized material in engineering constructional activities such as engineering materials for potholes filling, road pavement bases or sub-bases and foundation stability where water percolates into wall buildings.

REFERENCES

American Society for Testing and Materials, Designation: D, 3080/D, 3080M-11, Standard Test Method For Direct Shear Test of Soils under Consolidated Drained Conditions, vol. 4.08 of Annual Book of ASTM Standards, 2011.

Boulanger R. W. and Idris I. M.”Evaluation of cyclic so engineering in silts and clays,” Journal of Geotechnical and Geoenvironmental Engineering, vol. 133, no. 6, pp.641-652, 2007.

Bro A. D. Stewart,NJ. P. and Pradel, D. Estimating Undrained strength of clays from Direct Shear Testing at Fast Displacement Rates, Proceedings of ASCE Geocongress, 2013.

BS 1377:1990. Methods of test for soils for civil engineering purposes.

Dafalla M. A. (2013) Effects of clay and moisture content on direct shear strength testsfor clay- sand mixtures. Adv. Mater Sci Eng 2013:562726

Dafalla, M. A. M.Al-Shamrani, A. and Obaid, A. “Reducing erosion along the surface of sloping clay-sand liners,” in proceedings of the ASCE Geo-Congress, San Diego, calif, USA, March 2013.

Dominati, Estelle; Patterson, Murray; Mackay, Alec (2010). "A framework for classifying and quantifying the natural capital and ecosystem services of soils". Ecological Economics. 69 (9):1858–68. doi:10.1016/j.ecolecon.2010.05.002. Archived (P DF) from the original on 8 August 2017. Retrieved 14 February 2021.

Emesiobi, F. C. (2000) Tesing and Quality control of materials in civil and highway engineering., ISBN 078 – 2009 – 36 – 16,Pp. 5 – 7.

Hamidi, A. Yazdanjou, V. and Salami, N. “shear strength characteristics of sand-gravel mixtures, .” International Journal of Geotechnical Engineering, vol. 3, no. 1, pp. 29-38, 2009.

Hassan J. T. 2016, Variation of water content on the soil parameter of clkay soil, Kwara state polytechnic, civil engineering department institute of technology, ilorn , Nigeria

Leake, Simon; Haege, Elke (2014). Soils for landscape development: selection, specification and validation. Clayton, Victoria, Australia: CSIRO Publishing. *ISBN* *978-0643109650*.

Olushola, A. O. ‘Geology and geotechnical setting of the basement complex rocks in southwestern Nigeria; Implications on provenance and evolution”, earth and environmental science, 2014, P. 98.

Osuji, O. S. and Akinwamide, J. T. (2018), Engineering properties of lateritic soils in Ado Ekiti, South Western Nigeria. American Journal of Engineering Research (AJER), 7(1), Pp.353 – 360.

Que, J., Wang, Q., Hen, J., Shi, B., and Meng, Q. (2008), Geotechnical properties of the soft soil in Guangzhou College City. Bull Eng Geol Environ, 67, 479 – 483.

Roy and Whitlow (2001), Basic soil mechanics 2 Edition, Simon and Schuster Publication, New Jersey.

S. J. Poulos, (1989), Liquefaction Related Phenomena, In: Advanced Dam Engineering for Design Construction and Rehabilitation, Van Nostrand Reinhold (ed.) Jansen R. B.,Pp. 292 – 320.

Smith Andrew Mylius, Design and Construction failures caused Singapore Tunnel N.C.E International May, 2005. Polester, England.

Wright, P. H. (1986), Highway Engineering, Sixth Edition. John Willey and Sons: New York.