Ethiopian Journal of Environmental Studies & Management 7(4): 445 – 451, 2014.
ISSN:1998-0507 doi: http://dx.doi.org/10.4314/ejesm.v7i4.11
Submitted: May 05, 2014 Accepted: July 10, 2014

EVALUATION OF THE STRENGTH OF SOME POTENTIAL LOCAL IRRIGATION CANAL LINING MATERIALS FROM MOISTURE - DENSITY RELATIONSHIP

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Abstract

The compaction characteristics of some local materials were determined and a moisture - density relationship was obtained to ascertain their strengths and suitability for canal lining. These materials were: (i) Concrete (GC): which comprised of Cement, Sand and Granite of average sizes of between 9.0 mm and 14 mm, in a ratio of 1:2:4. (ii) Termite Mound (TM) (iii) Clay Cement (CLC) (iv) Cementitious Clay (CCL), and (v) Clay Soil (CLS). The compaction characteristics were determined using the standard compaction mound by subjecting the samples to 5, 15 and 25 blows. Results showed that Concrete sample had the maximum dry densities of 1.55gcm^{-3}, 1.57 gcm^{-3} and 1.58 gcm^{-3} at 5, 10 and 25 blows, at the lowest levels of moistures of 6.7%, 6.5 % and 7.0%, respectively. This was followed by Termite Mound sample with maximum dry densities of 1.45 gcm^{-3}, 1.51 gcm^{-3}, and 1.63 gcm^{-3} at moisture levels of 10.4%, 10.1 % and 9.0%, respectively. Clay soil sample has Maximum dry densities of 1.5 gcm^{-3}, 1.57 gcm^{-3} and 1.56 gcm^{-3} at moistures of 11.6 %, 11.1 % and 10.1 %, respectively. Though concrete, which is conventionally used for canal lining, performed better in terms compaction, the compaction characteristics of the local materials were close to concrete. It was therefore concluded that these materials if well compacted could perform excellently well by reducing seepage along the channel bed.

Key Words: *Channel, Compactive Effort, Dry Density, Moisture Content, Seepage*

Introduction

Major losses in irrigation conveyance are majorly due to seepage and evaporation losses. Evaporation loss is a function of temperature, humidity and wind velocity. This type of loss is practically impossible to prevent while, seepage losses can be prevented by the laying of impervious material along the channel. Most conventional methods used in preventing seepage losses are the use of compacted clay, tiles, soil- cement, concrete, etc. These methods are either too expensive or not very effective and are mostly too expensive for small holder farmers, which according to Tefesse (2003) is one of the main constraints of irrigation development in Sub Sahara Africa.

Soil, which comprised of all earth materials, according to Khair *et al*., (1991) is the cheapest and probably the most used of construction materials. The use of this material is limited by its lack of strength and its susceptibility to moisture content changes and the erosive effects of water on it. To combat these inadequacies, these earth

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materials; clay and Anthill soils are subjected to different compactive forces in order to reinforce their strengths and thus allow them to resist all external forces by improving the intermolecular forces between the particles. Clay, when compacted at the optimum moisture content, has been confirmed to reduce seepage losses considerably (Burt *et al*., 2008).

Reduction of seepage in unlined channels could only be achieved through compaction. Experience has shown that seepage and water-logging in channels could be checkmated through compaction. Compaction is defined as the densification of soil through the removal of air voids using mechanical equipment (Olajubu *et al*., 2004). It can also be defined as an act of artificially increasing the unit weight of the soil through the application of external forces, reducing the voids or pore spaces to a minimum and thus increasing the solid particle content to a maximum (Shahid *et al*., 2011. Compaction in loosed channel soils is done to improve their strength by measuring their unit weight. It is a process in which soil particles are brought closer by mechanical means to reduce settlement and permeability and increase the shear strength of soils (Shahid *et al.,* 2011). The process is achieved by the rearrangement of soil particles. The degree of compaction is measured in terms of its dry unit weight.

The objectives of soil compaction are to: increase the bearing capacity of the soil of the channel; reduce the expected settlement of channel; reduce the soil hydraulic conductivity, and increase the stability of the slopes. The extent to which soil compaction is achieved is controlled by the following factors: Compaction effort, Soil type, Moisture content, and Dry unit weight (dry density). The medium in which optimum compaction can be achieved is through water, which acts as a softening agent and as a lubricant.

In compaction, the moisture content is vital to proper compaction. Inadequate moisture, will not bring about the desired compaction because the soil grains cannot adequately come together to achieve the required density. On the other hand, too much moisture allows agglomeration of water-filled voids, which impedes the realization of a load- bearing ability of the soil mass. The maximum achievable density depends on the type of materials as well as the input energy.

According to Khair *et al*. (1984) as much as 47% of total amount of water diverted in an irrigation scheme in India were lost in conveyance due to seepage in unlined channels. This enormous loss justifies the need for compaction of these low cost materials. Hong *et al*. (2007) reported that an increase in the level of earth compaction decreases the seepage rate values. These attributes, if well exploited is a good index for assessing the suitability of these local materials to reduce canal seepage losses.

Kasali *et al*. (2002), in studying an alternative canal lining materials, suggested the need to investigate into the potentials of some local lining materials. To achieve this, there is the need to investigate into their compaction characteristics in order to ascertain their suitability for canal lining.

The objective of this study was to determine the compaction characteristics of the lining materials to ascertain the optimum compaction needed to improve the materials' bearing capacities for irrigation water conveyance.

Materials and Methods

Experimental Site

The experiment was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin. Ilorin is geographically located in the middle belt of Nigeria with a vegetation of derived savannah, and is situated on a longitude of 4^{θ} 30′ E and latitude of 8^{θ} 26′ N. Ilorin receives an average of 1200 mm annual rainfall. The soil of the experimental site is sandy loam and contains 12.48% clay, 18% silt and 69.52% sand. It is classified as Hyplustalf of Eruwa and Odo-owa series, developed from the parent materials consisting of micaceous schist and gneiss of basement complex which are rich in Ferro-magnesium materials (Ahaneku and Sangodoyin, 2003).

Determination of Particle Size Distribution and Chemical Composition of Samples

Particle size distribution analysis and texture were determined by collecting disturbed samples of clay from the top 15 cm of the sample's profile using soil auger, while the Termite mound was taken using destructive samples. The samples were taken during the dry season when soil moisture content was low. Cement, a component of clay - cement sample was ordinary Portland cement procured from a local store and was in conformity with BS 12, 1978.

The samples were pulverized, air dried and passed through a 2-mm sieve to remove stones and crumbs. The particle size distribution was obtained through sieve analysis of the grains of the samples to determine the sand fraction. The known weight of each of the samples was allowed to pass through standard set of sieves and the weight of the fractions retained on each sieve is recorded. These weights were expressed as the percentages of the total weight of the samples.

The exchangeable Magnesium was extracted and titrated with sulphuric acid, while available phosphorous and potassium were extracted using double acid solution of 0.05N hydrochloric acid and 0.025N sulphuric acid. Sodium was also extracted and titrated with sulphuric acid. Calcium and Magnesium were determined using absorption spectrophotometer. The organic matter contents of the samples were estimated from the carbon content of the sample using the method of Walkley and Black (1934). The textural classes and the chemical compositions of the samples are in Tables 1 and 2, respectively.

Determination of Samples Compaction Characteristics

The compaction characteristics were determined using the standard compaction mound. The samples were subjected to 5, 15 and 25 blows of a standard proctor hammer of 2.5 kg in cylindrical mould of 105mm diameter and 115 mm height, at different moisture contents following the proctor compaction procedure (Lambe, 1951).

The dry densities were determined at four repeated times for each sample at every moisture content and compaction effort.

The bulk density, ρ, in kg/m^3 of each compacted sample was determined as:

$$\rho = \frac{(M_2 - M_1}{V} \qquad (1)$$

where:

M_1 - mass of the mould and base, kg.
M_2 - mass of the mould, base and soil, kg.

The dry density of the soil sample is given as:

$$\rho_d = \frac{\rho}{(1+w)} \qquad Q \qquad (2)$$

The moisture content is calculated as:

$$w = \left(\frac{w_4 - w_3}{w_4 - w_2}\right) \qquad (3)$$

where:

w_4 – weight of can +wet soil, g.
w_3 – weight of can, g.
w_2 – weight of empty can, g.

Compactive Energy, E, is expressed as reported by Ohu and Raghavan (1985) as follows:

$$E = \frac{M.g.h.L.N_B}{V} \quad (4)$$

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M = Mass of hammer, kg.

g = Acceleration due to gravity, 9.81m/s^2

h =Height of fall

L = Number of Layers

N_B = Number of blow

V = volume of mould

Results and Discussion

From the grain size analysis, it was found that the grain seizes of the five samples were distributed within the following ranges; 6-38% silt, 8.48-38.43 clay and 43.57-82.52 % sand. The textural classifications and the chemical composition of the samples are in Tables 1 and 2, respectively.

Table 1: Textural and Organic Properties of the Samples

Components (%)	Samples$^+$				
	GC	TM	CLS	CCL	CLC
Organic Carbon	0.02	0.51	0.24	4.76	2.15
Organic Matter	0.05	0.87	0.67	8.22	3.71
Sand	82.52	59.52	47.52	53.52	43.57
Silt	6.0	30.0	20.0	38.0	18.0
Clay	11.48	10.48	32.48	8.48	38.43

$^+$GC = Concrete TM = Termite Mound

CLC = Clay- Cement CCL = Cementitious Clay CLS = Clay Soil

Table 2: Chemical Properties of Samples

Components	Samples				
	GC	TM	CLC	CCL	CLS
N(%)	0.003	0.07	0.028	0.6	0.09
$Ca^{2+\ (mg/Kg)}$	32.52	67.52	16.43	77.9	36.36
$Mg^{2+\ (mg/Kg)}$	2.58	31.17	1.60	41.56	20.78
$Na^{+\ (mg/Kg)}$	0.049	125.11	129	142.0	136.42
$P^{\ (mg/Kg)}$	0.124	120.54	203.25	154.78	133.36
$Ph^{(mg/Kg)}$	34.0	33.97	27.55	58.05	34.97
$Cl^{2-\ (mg/Kg)}$	0.027	20.38	12.65	29.26	32.07
$Co_3^{(mg/Kg)}$	2.81	8.81	12.93	46.90	21.45
Si	4.38	-	6.62	-	-

GC = Concrete TM = Termite Mound

CLC = Clay- Cement CCL = Cementitious Clay CLS = Clay Soil

The compaction tests reveal that the dry densities of the samples increase with compaction efforts, which shows that dry density is a function of moisture content and compaction effort. The results of the compaction efforts were as shown in Figures 1–5. The peak of each curve shows the maximum dry density for a given compaction effort.

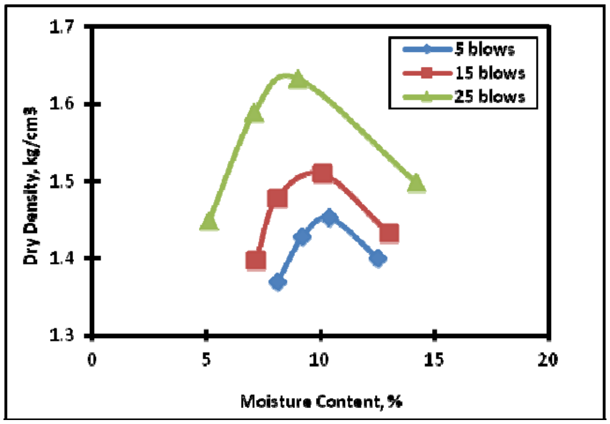

Figure 1: Effect of Moisture content on Dry Density of Termite Mound

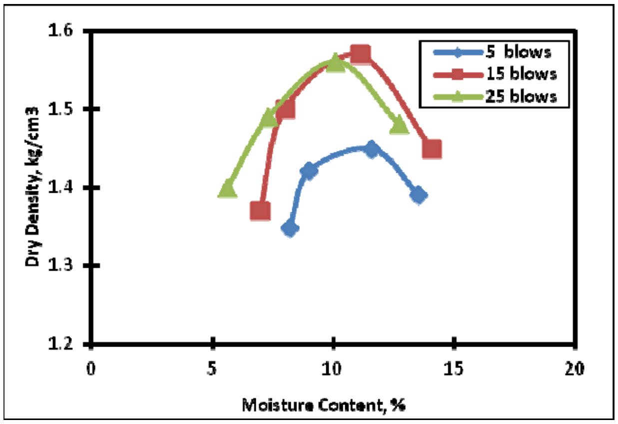

Figure 2: Effect of Moisture Content on Dry Density of Clay Soil

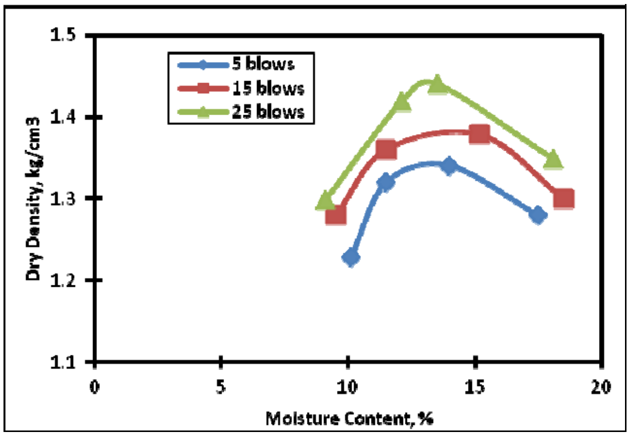

Figure 3: Effect of Moisture Content on Dry Density of Cementitous Clay

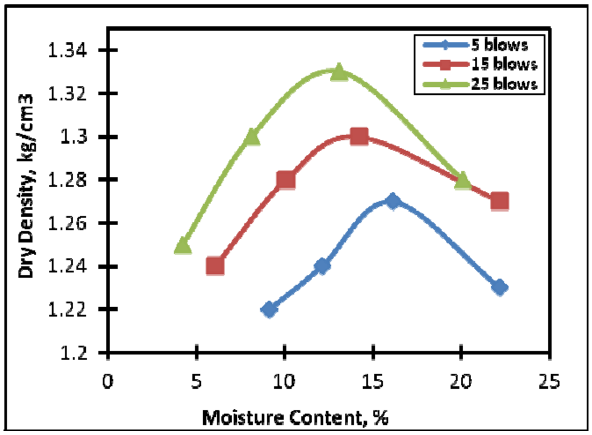

Figure 4: Effect of Moisture Content on Dry Density of Clay Cement

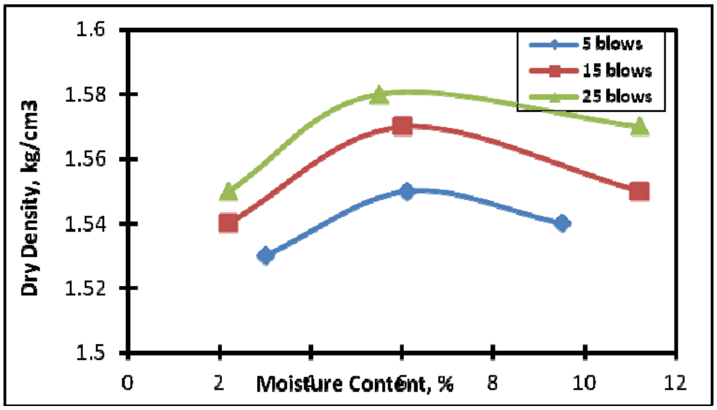

Figure 5: Effect of Moisture Content on Dry Density of Cement

Table 3 shows the Standard Proctor Compaction Test Characteristics of the compaction. The table reveals that the compaction energy increases with the number of blows. The results of the compaction test as revealed in Figures 1-5, could be explained by the fact that at the side of the optimum water content, the dry density increases with the increasing water content.

Table 3: Standard Proctor Compaction Test Characteristics

Description	Mass of Hammer (Kg)	Hammer Drop (mm)	Blows per Layer	Number of Layer	Compaction Energy (kJ/ m^3)
Standard Proctor Compaction Test	2.5	305	5	3	118.54
	2.5	305	15	3	355.62
	2.5	305	25	3	592.70

This is probably due to the development of large water film around the particles, which tends to lubricate the particles and makes them easier to be moved about and re-orientate into a denser configuration. At the wet side of the Optimum Moisture Content (OMC), water starts to replace samples particles in the compaction mould and since the units weight of water is much less than the unit weight of samples, dry density decreases with the increasing water content.

The maximum dry densities of 1.55gcm^{-3}, 1.57 gcm^{-3}, and 1.58 gcm^{-3} were exhibited by granite cement sample at 5, 10 and 25 blows, respectively, at the lowest level of moistures of 6.7%, 6.5 % and 7.0%, respectively. This was followed by Termite Mound sample with maximum dry densities of 1.45 gcm^{-3}, 1.51 gcm^{-3}, and 1.63 gcm^{-3} at moisture levels of 10.4%, 10.1 % and 9.0%, respectively. Clay soil sample has Maximum dry densities of 1.5 gcm^{-3}, 1.57 gcm^{-3} and 1.56 gcm^{-3} at moistures of 11.6 %, 11.1 % and 10.1 %, respectively.

This is followed by Cementitious clay samples with densities of 1.34 gcm^{-3}, 1.38 gcm^{-3} and 1.44 gcm^{-3} at moisture of 14.0 %, 15.2 % and 13.5 %, respectively, while the Clay - Cement sample has the least densities of 1.27 gcm^{-3}, 1.30 gcm^{-3} and 1.33 gcm^{-3}, respectively. Concrete attained the maximum densities at the lowest moisture levels, which was followed by Termite Mound sample. The highest moisture level was exhibited by the Clay- Cement sample.

Results further reveal that an increase in compaction effort increases the maximum dry density but decreases the optimum water content. This was manifested in all the samples and it shows that at a higher compaction effort, the grain particles of the sample become closer together and the unit weights of the samples increase.

It is therefore sensible to say that an increase in compaction effort increases the maximum dry density but decreases the OMC. This is because higher compactive effort yields more parallel orientation of the clay particles, which allow for closer particle orientation and hence a higher unit weight of soil (Holz and Kowacs, 1981; Ige and Ogunsanwo, 2009). These results conform with the results obtained by Ige and Ogunsanwo (2009). This implies that channels with adequate compaction will reduce hydraulic conductivity and hence drastic reduction in seepage.

Conclusion

Though concrete, which is conventionally used for canal lining, performed better in terms compaction, the compaction characteristics of the local materials were close to concrete. It is therefore concluded that these materials if well compacted could perform excellently well by reducing seepage along the channel bed. They are therefore recommended to be exploited for use in canal lining since they could be found in the vicinities of the local farmers.

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