PHYSICO-CHEMICAL AND STRENGTH PROPERTIES OF SOME LOCAL MATERIALS FOR IRRIGATION CANAL LINING

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ABSTRACT

The physico - chemical and strength properties of some local materials for canal lining were investigated. These materials were: (i) Concrete (GC): which comprised of Cement, Sand and Granite of average size of 12 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). Laboratory analysis of the chemical and physical properties of these materials was determined. The shear strengths and the cone indices were determined using the compaction characteristics of the materials. The moisture characteristics of the samples show that Concrete attained the maximum densities of 1.55 gcm^{-3}, 1.57 gcm^{-3}, 1.58 gcm^{-3} at the lowest moisture contents of 6.7%, 6.5 % and 7.0% at 5, 10, 25 blows, respectively, while the Clay - Cement attained maximum densities of 1.27 gcm^{-3}, 1.30 gcm^{-3} and 1.33 gcm^{-3} at the highest moisture contents of 16.0%, 14% and 14.0% at the same levels of blows. The study showed that the plasticity of the materials increased as the clay content increased, while the shear strength and cone index increased with depth and decreased with increase in moisture content.

KEYWORDS: Compactive effort, moisture content, dry density, shear strength, cone index, irrigation canal.

1. INTRODUCTION

To provide irrigation water to crops, water has to be conveyed from the source to the field. Irrigation water conveyance had been an age long practice to get water conveyed from the source to the end users (Irrigation farmers). During this conveyance, considerable quantity of water is lost on transit. This loss has been a daunting problem facing local farmers because there is an irretrievable loss of valuable water resources. These losses in 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.

Seepage losses from irrigation channels have widely been identified as environmentally critical for the resulting groundwater accessions and associated drainage problems (Riaz and Sen, 2005). Seepage, therefore, has a very adverse effect on the surrounding of the canal. It often creates a localized high water table that damages crops in adjacent fields due to waterlogging and soil salinization.

The need for the improvement of the engineering properties of soil has been an age long practice. When soil is to be constructed upon, sometimes the soil at the site may manifest weak properties and the soil is removed and replaced with stronger soil but this method is cumbersome and is being replaced by modern technique that involves the improvement of the engineering properties of the site soil.

Local materials, if carefully prepared, will help to control excessive water losses in irrigation water conveyance as the conventional lining materials. Since concrete, which has been the conventionally used lining material is becoming expensive; there is the need to search for alternative local materials that are in sufficient quantity in farmers' vicinities. These materials must be able to replace concrete in terms of seepage reduction and durability.

The objective of this study was therefore to investigate the strength of these local lining materials to ascertain their potentials and suitability for irrigation canal lining.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

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 4^0 30' E and latitude of 8^0 26' N. It 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).

2.2 Materials

Five sample materials were considered for study. These materials were: (i) Concrete (GC): which comprised of Cement, Sand and Granite of average size of 12 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).

2.3 Determination of Particle Size Distribution and Chemical Composition

Samples of each of the treatments were collected for particle size distribution analysis and texture. The soil samples were 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).

2.4 Consistency Limits and Hydraulic Conductivity

The Atterberg limits (plastic and liquid limits) were determined using Cassagrande method as described by Arku and Ohu (1991).

The Plasticity Index (PI) was determined as in Equation 1:

$$PI = W_L - W_P \qquad 1$$

where: W_L = liquid limit; W_P = plasticity limit; PI = Plasticity Index
The permeability (saturated hydraulic conductivity) of each sample was determined using the falling head permeameter.

The hydraulic conductivity was determined as in Equation 2:

$$K = \frac{QL}{Ah} \qquad 2$$

where: K = Hydraulic conductivity, cm/s; L = Sample length, cm; A = Area of sample, cm^2

2.5 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 105 mm 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 compactive effort.

2.6 Cone Index and Shear Strength of Compacted Samples

The shear strength determination of compacted samples was conducted by sieving the samples through 2 mm sieve size and then compacted. The cone indices of each sample were measured using the Farnell hand held soil penetrometer, fitted with a 30^0 cone. The resulted graphs of the cone indices against the corresponding depths are as shown in Figures 6 – 20.

The shear strengths were also determined for each sample using the Pilcon hand held vane tester with 33 mm vanes. The vane was pushed vertically into the compacted soil to different depths of 5, 15 and 25 levels of blows, respectively. At the end of the shearing, the vane returns almost instantaneously in the anticlockwise direction and the shear strengths were read from the dial of the Vane tester.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution, Chemical Composition, Consistency Limits and Hydraulic Conductivity

The textural classes and chemical compositions of the samples are show in Tables 1 and 2. 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. The liquid limit, plastic limit and the plasticity index values representing the soil types were found to be in the range of 34-49%, 17-24.3% and 17-24.7%, respectively (Table 3).

Table 3 shows that the samples have average values of liquid limits and plasticity index. Clay Cement mixture has the highest plasticity index of 24.7%, while, Concrete has the lowest of 17%. Termite mound, Cementitious Clay and Clay Soil samples have 19.2%, 19.5% and 19.6%, respectively.

The soils were classified into inorganic clays of medium plasticity according to the Cassagrande plasticity chart in the Unified Soil Classification System (USCS) in compliance with ASTM standards (ASTM D 2487-00 standard) as employed by Ince and Ozdemir (2003). This shows that all the materials are workable and are capable of carrying considerable loads.

Generally, conductivity is affected by the size and distribution of soil particles which generally influence the size of voids conducting flow. The factors that affect hydraulic conductivity are mineral composition, texture, particle size distribution, characteristics of wetting fluid, exchangeable- cation, void ratio and degree of saturation of the medium. Results from Table 3 shows that all the samples have medium permeability and could be good materials for canal lining, if properly compacted.

The plasticity indices of the clay - cement and clay soil were the highest of the samples which might be due to the fact that they contain higher silt and lower sand percentage than other samples. It could be observed in Table 1 that the clay and silt contents of the samples decreased as the sand content increased. Similarly, increase in plasticity index with an increase in clay content was observed. This trend in results was in conformity with the results obtained by Ekwue *et. al*. (2002) and Adekalu *et. al.* (2007).

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**

Table 3. Physical and Index Properties of the Samples

Properties	Samples+				
	GC	TM	CLC	CCL	CLS
Bulk Density (kg/m^3)	1.50	1.49	1.50	1.47	1.57
Dry Density (kg/m^3)	1.45	1.47	1.45	1.43	1.49
Specific Gravity	2.68	2.65	2.60	2.67	2.63
Liquid Limit (%)	34.0	39.0	49.0	41.0	37.0
Plastic Limit (%)	17.0	19.8	24.3	21.5	17.4
Plasticity Index (%)	17.0	19.2	24.7	19.5	19.6
Permeability (cm/sec)	8.57 x	2.55 x	5.63 x	1.07 x	8.65 x

	10^{-5}	10^{-4}	10^{-5}	10^{-5}	10^{-5}

+ GC= **Concrete** TM= **Termite Mound**
CLC= **Clay- Cement** CCL= **Cementitious Clay** CLS= **Clay Soil**

From the results of the dry density- moisture relationships (Table 4), it was observed that Concrete reached the maximum dry density at the lowest moisture contents. This corroborates and supported the fact that the sample has higher percentage of sand than the other samples and the plasticity of the sample was the lowest among the samples as revealed in Table 1. The reverse was the case for Clay- Cement, which had the highest plasticity index of 24.7 % and the lowest percentage of sand. This shows that the value of plasticity index of a soil reflects the clay contents in the soil and a high value will reflects the workability of the sample due to cohesion between the soil's grain particles.

The compaction tests revealed that the dry densities of the samples increased with compactive efforts, which shows that dry density is a function of moisture content and compactive effort. The peak of each curve shows the maximum dry density for a given compactive effort.

The results of the compaction test as revealed in Table 4 and 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. 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 (Holtz and Kovacs, 1981).

At the wet side of the Optimum Moisture Content (OMC), water starts to replace soil particles in the compaction mould and since the units weight of water is much less than the unit weight of soil, dry density decreases with the increasing water content. The table shows that the maximum dry densities of 1.55gcm^{-3}, 1.57 gcm^{-3}, 1.58 gcm^{-3} were attained by concrete sample at 5, 10 and 25 blows, 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}, 1.51gcm^{-3}, and 1.63 gcm^{-3} at moisture levels of 10.4%, 10.1 % and 9.0%, respectively. Clay soil sample had 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 was 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 had the least densities of 1.27 gcm^{-3}, 1.30 gcm^{-3} and 1.33 gcm^{-3}, respectively. Results further revealed that an increase in compactive effort increases the maximum dry density but decreases the optimum water content. 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). This was manifested in all the samples and it shows that at a higher compactive effort, the grain particles of the soil become close together and the unit weights of the samples increase.

These results conform with the results obtained by Ige and Ogunsanwo (2009). The implication of this is that channels with adequate compaction will reduce hydraulic conductivity and hence drastic reduction in seepage.

Table 4. Summary of Optimum Moisture Contents and Dry Densities of Samples

Treatments	Optimum Moisture Content (%)			Dry Density(kg/m^3)		
	Number of Blows					
	5	15	25	5	15	25
TM	10.4	10.1	9	1.45	1.51	1.63
CLS	11.6	11.1	10.1	1.45	1.57	1.56
CCL	14.0	15.2	13.5	1.34	1.38	1.35
CLC	16.0	14.0	14.0	1.27	1.30	1.33
GC	6.7	6.5	7.0	1.55	1.57	1.58

GC= **Concrete** TM= **Termite Mound**
CLC= **Clay- Cement** CCL= **Cementitious Clay** CLS= **Clay Soil**

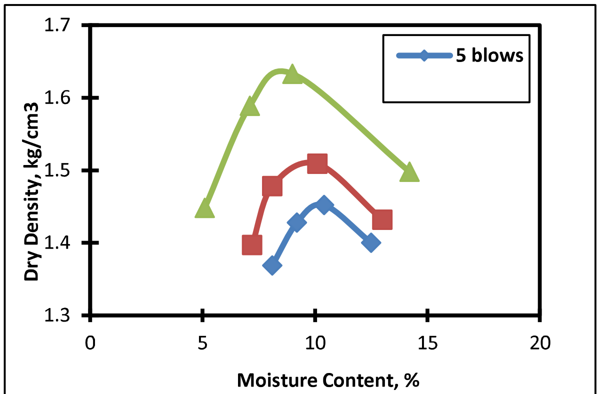

Fig.1.Effect of Moisture Content on Dry Density of Termite Mound

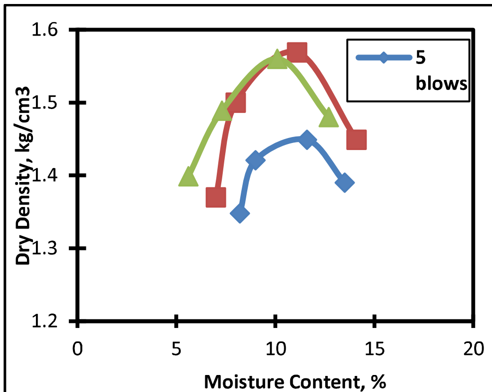

Fig. 2.ffect of Moisture Content on Dry

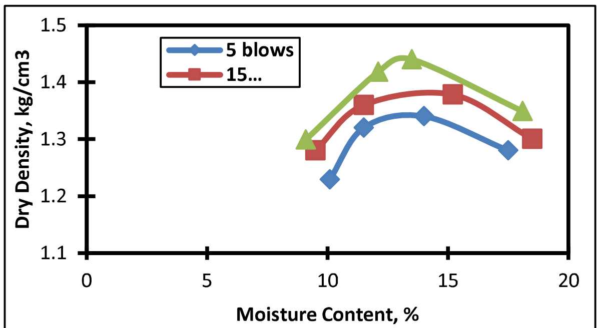

Fig. 3. Effect of Moisture Content on Dry Density of

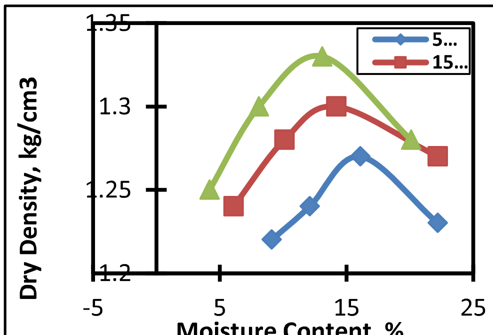

Fig. 4. Effect of Moisture Content on Dry

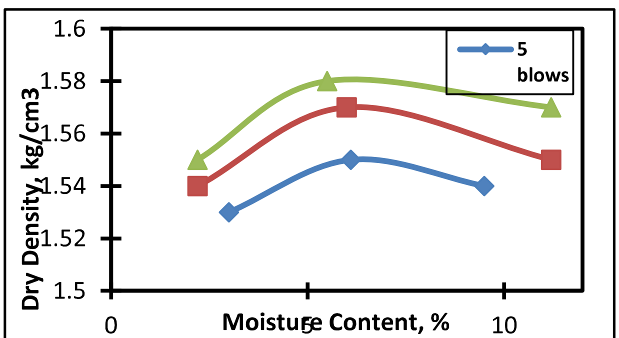

Fig. 5. Effect of Moisture Content on Dry Density of

3.3 Cone Index and Shear Strength

The effects of moisture content on cone index and shear strength at 5, 15 and 25 blows are as in Figures 6 - 20 and 21-35, respectively. The cone indices and the shear strengths of the soils increase with depth and compaction level and as the moisture contents decrease. This trend conforms with the works of Al Rawas (2006); Adeniran and Babatunde (2010) and Manuwa, (2009). This is expected because as the moisture increases, the soil strength decreases and hence the resistance to penetration decreases. The highest cone index of 285.0 kPa was obtained in Clay - Cement sample, while the lowest of 55 kPa was from Concrete sample.

This might be due to large voids between the granite particles and the cement, which allows for easy penetration of the Concrete mix and also the higher percentage of clay in the clay – cement, but as the moisture reduces in the Concrete composite, the penetration resistance is expected to increase because the voids between the granite and the sand grains would be closed up through the reaction between water, sand particles and cement (hydration) to form a very hard aggregate. Clay had the highest shear strength of 126 kPa, while Concrete had the lowest of 28 kPa. The same reasons for the cone index could also be deduced for this trend.

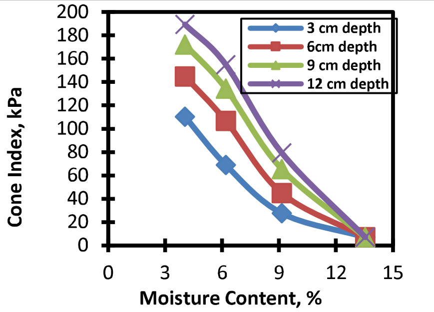

Fig. 6. Effect of Moisture Content on Cone Index of Termite Mound at 5 Level of Blows

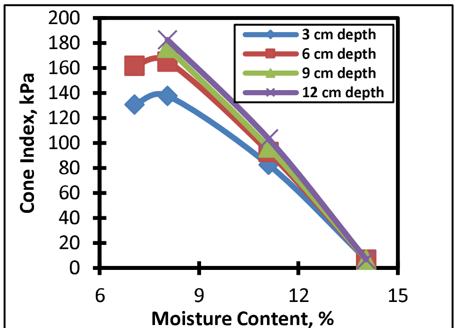

Fig. 7. Effect of Moisture Content on Cone Index of Termite Mound at 15 Level of Blows

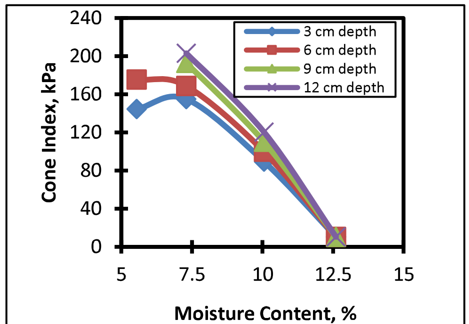

Fig. 8. Effect of Moisture Content on Cone Index of Termite Mound at 25 Level of Blows

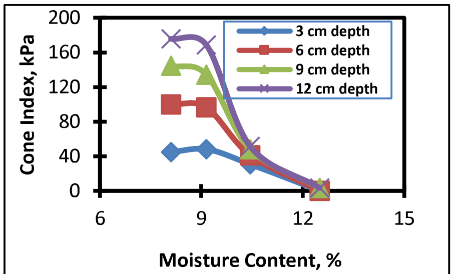

Fig. 9. Effect of Moisture Content on Cone Index of Clay at 5 Level of Blows

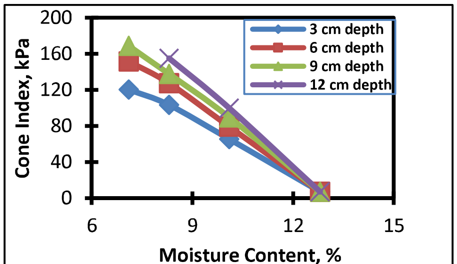

Fig. 10. Effect of Moisture Content on Cone Index of Clay at 15 Level of Blows

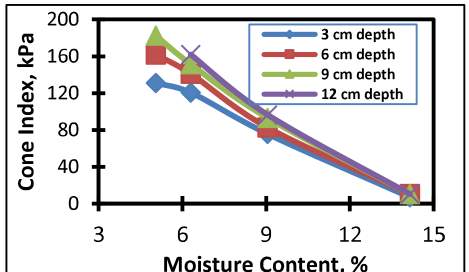

Fig. 11. Effect of Moisture Content on Cone Index of Clay at 25 Level of Blows

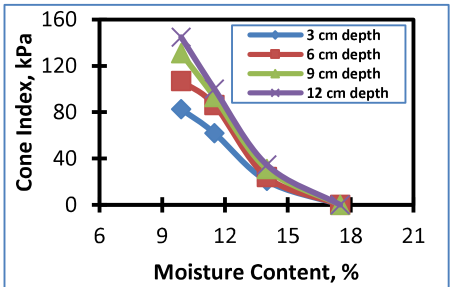

Fig. 12. Effect of Moisture Content on Cone Index of Cementious Clay at 5 Level of Blows

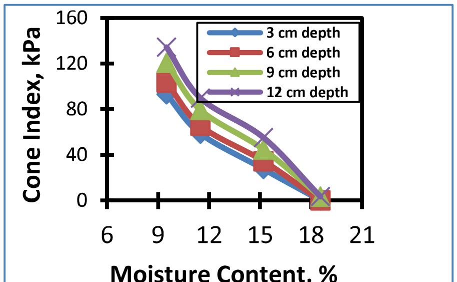

Fig. 13. Effect of Moisture Content on Cone Index of Cementitious at 15 Level of Blows

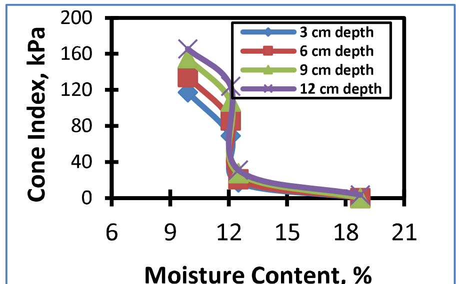

Fig. 14. Effect of Moisture Content on Cone Index of Cementitious Clay at 25 Level of Blows

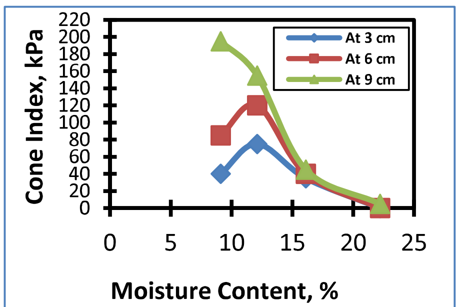

Fig.15. Effect of Moisture Content on Cone Index of Clay Cement Composite at 5 Level of Blows

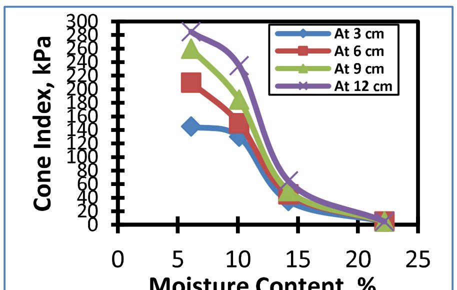

Fig. 16. Effect of Moisture Content on Cone Index of Clay Cement Composite at 15 Level of Blows

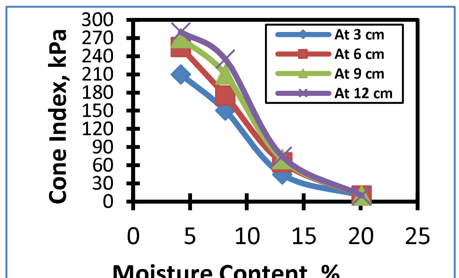

Fig. 17. Effec of Moisture Content on Cone Index of Clay Cement Composite at 25 Level of Blows

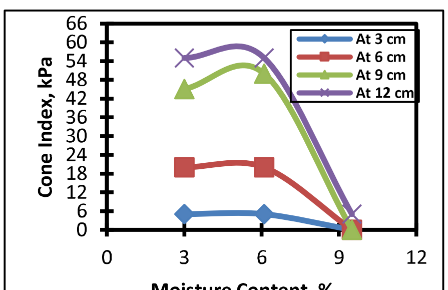

Fig. 18. Effect of Moisture Content on Cone Index of Granite Cement Mxture at 5 Level of Blows

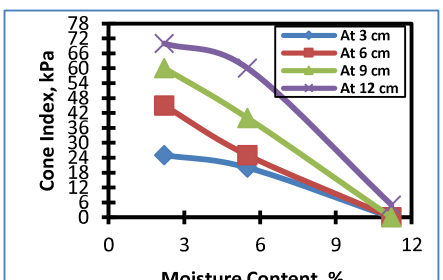

Fig. 19. Effect of Moisture Content on Cone Index of Granite Cement Mixture at 15 Level of blows

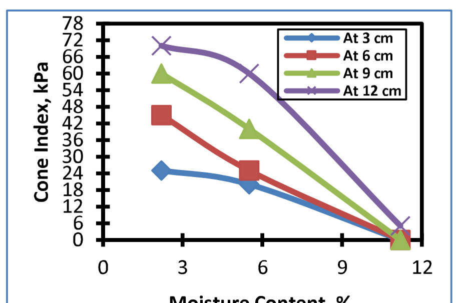

Fig. 20. Effect of Moisture Content on Cone Index of Granite Cemente Mixture at 25 Level of blows

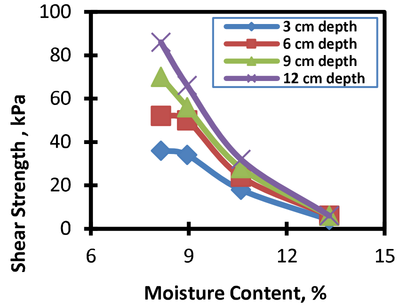

Fig. 21. Effect of Moisture Content on Shear Strength of Termite Mound at 5 Level of Blows

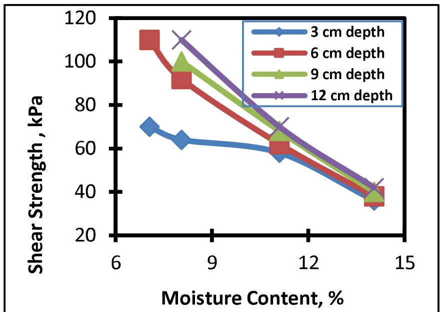

Fig. 22. Effect of Moisture Content on Shear Strength of Termite Mound at 15 Level of Blows

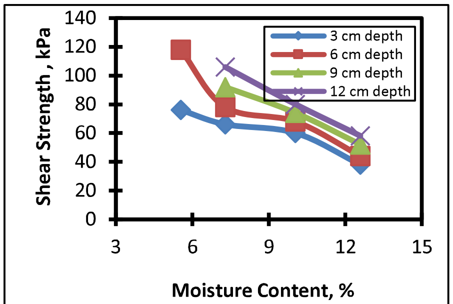

Fig. 23. Effect of Moisture Content on Shear Strength of Termite Mound at 25 Level of Blows

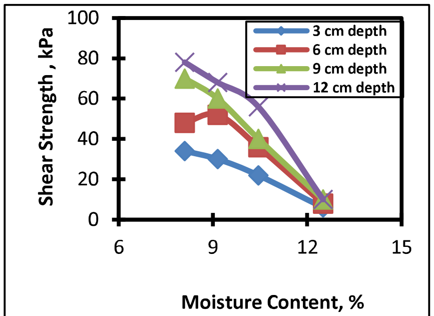

Fig. 24. Effect of Moisture Content on Shear Strength of Clay at 5 Level of Blows

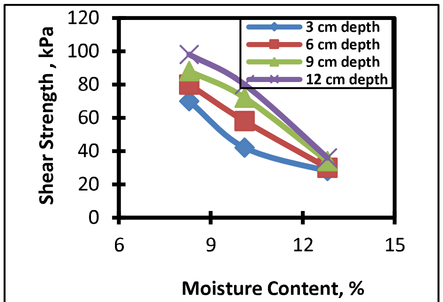

Fig. 25. Effect of Moisture Content on Shear Strength of Clay on 15 Level of Blows

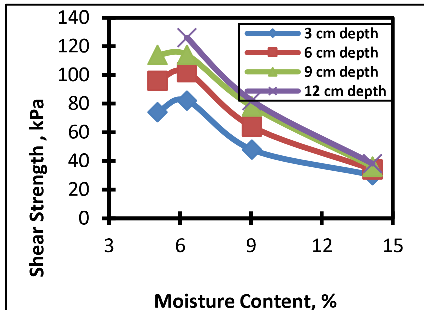

Fig. 26. Effect of Moisture Content on Shear Strength of Clay on 25 Level of Blows

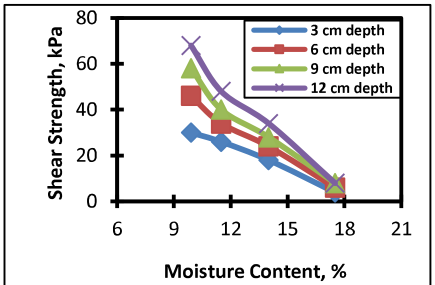

Fig. 27. Effect of moisture content on shear strength of cementitious clay at 5 level of blows

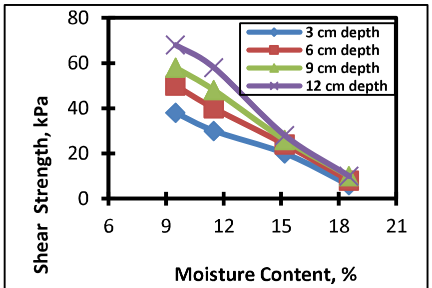

Fig. 28. Effect of Moisture Content on Shear Strength of Cementitious Clay at 15 Level of Blows

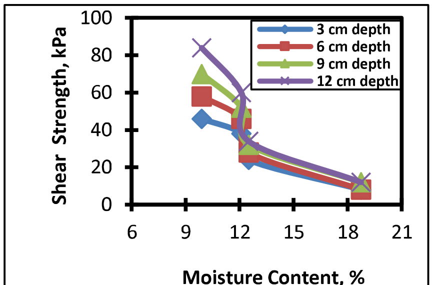

Fig. 29. Effect of Moisture Content on Shear Strength of Cementitious Clay at 25 Level of Blows

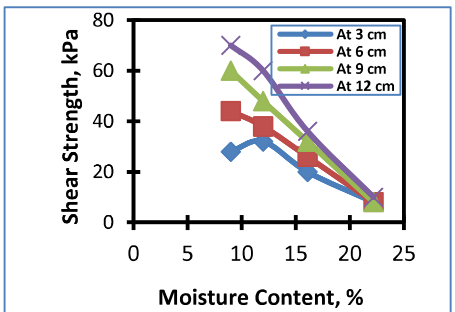

Fig.30. Effect of Moisture Content on Shear Strength of Clay Cement Composite at 5 Level of Blows

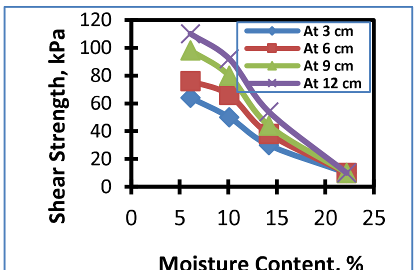

Fig.31. Effect of Moisture Content on Shear Strength of Clay Cement Composite at 15 Level of Blows

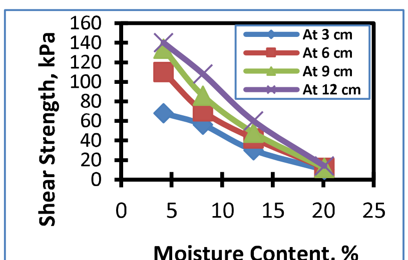

Fig.32. Effect of Moisture Content on Shear Strength of Clay Cement Composite at 25 Level of Blows

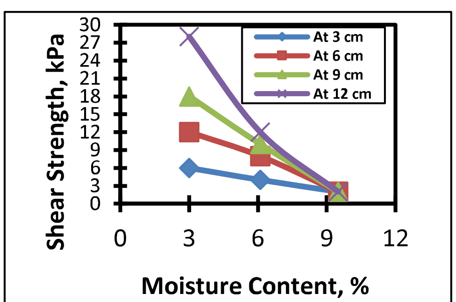

Fig. 33. Effect of moisture content on Shear Strength of Granite Cement mixture at 5 Level of blows

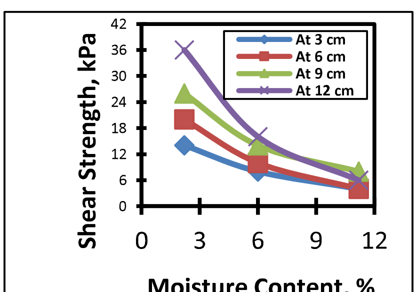

Fig. 34. Effect of moisture content on Shear Strength of Granite Cement mixture at 15 Level of blows

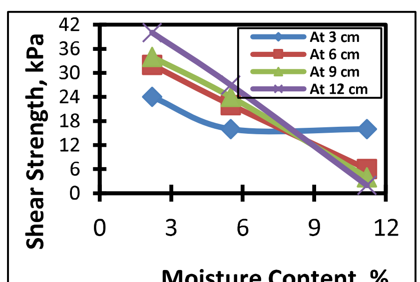

Fig. 35. Effect of moisture content on Shear Strength of Granite Cement mixture at 25 Level of blows

4. CONCLUSIONS

These local materials are very promising for utilization in irrigation canal lining in terms of strength and seepage reduction as revealed by their strengths and hydraulic conductivities. Their performances vis-a-vis concrete is very encouraging, and could perform well if employed in small irrigation canal linings but may not compete in terms of durability. It can therefore be concluded that linings made of local materials have the potential of reducing seepage on a permanent basis, though not as satisfactory as that of concrete but the need for economy and homeward exploitation of these materials that are indigenous and available in the farmers' environs has supported their utilization.

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