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STRENGTH ANALYSIS OF COCONUT FIBER STABILIZED EARTH FOR FARM STRUCTURES

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ABTRACT *Investigation of the strength characteristic of soil from alluvial deposit of River Benue in makurdi stabilized with coconut fiber as a stabilizer was carried as local building material for farm structure. Processed coconut fibers were mixed with the soil at four different mix ratios of 1% fiber, 2% fiber, 3% fiber and 4% fiber by percentage weight with 0% fiber as control. Compaction test and compressive strength were carried out on the various stabilizing ratio. From the compaction test, the correlation between the maximum dry density and optimum moisture content is a second order polynomial with a coefficient of 63% obtained at 1.91kg/m^3 and 20.0% respectively while the compressive strength test shows an optimum failure load of 8.62N/mm^2 at 2%fibre:100% soil mix ratio at 2.16 maximum dry density.*

Key words; coconut fiber, stabilized soil, strength, farm structure

1.0 INTRODUCTION; Soil and earth are synonomous when used in relation to building construction. It refers to subsoil and should not be confused with the geological or agricultural definition of soil, which includes the weathered organic material in topsoil. Topsoil is generally removed before any engineering works are carried out, or before soil is excavated for use as a building material. Mud is the mixture of one or several types of soil with water.

Earth is one of the oldest materials used for building construction in rural areas. Advantages of earth as a building material are it is resistant to fire, it is cheaper than most alternative wall materials and is readily available at most building sites, it has very high thermal capacity that enables it to keep the inside of a building cool when the outside is hot and vice versa, it is a good noise absorbent and it is easy to work using simple tools and skills. These qualities encourage and facilitate self-help and community participation in house building. Despite its good qualities, the material has the following weaknesses as a building material: It has low resistance to water penetration resulting in crumbling and structural failure, it has a very high shrinkage/ swelling ratio resulting in major structural cracks when exposed to changing weather conditions and it has low resistance to abrasion and requires frequent repairs and maintenance when used in building construction. However, there are several ways to overcome most of these weaknesses and make earth a suitable building material for many purposes.(FOA,2012).

The clay fraction is of major importance in earth construction since it binds the larger particles together. However, soils with more than 30% clay tend to have very high shrinkage/swelling ratios which, together with their tendency to absorb moisture, may result in major cracks in the end product. High clay soils require very high proportions of stabilizer or a combination of stabilizers.

Some soils produce unpredictable results due to undesirable chemical reactions with the stabilizer. Generally soils which are good for building construction purposes, are characterized by good grading, i.e. they contain a mix of different sized particles similar to the ratios in Table 1, so that all voids between larger particles are filled by smaller ones. Depending on use, the maximum size of course particles should be 4 to 20mm.

Table 1 ***Soil Grading Suitable for Construction***

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Use	Clay %	Silt %	Clay& Silt%	Sand %	Gravel %	Sand & Gravel%	Cobble %	Organic matter%	Soluble Salts%
Rammed earth walls	5-20	10-30	15-35	35-80	0-30	50-80	0-10	0-03	0-1.0
Pressed soil blocks	5-25	15-35	20-40	40-80	0-20	60-80	-	0-03	0-1.0
Mud bricks (adobe)	10-30	10-40	20-50	50-80	-	50-80	-	0-0.3	0-1.0
Ideal, general purpose mix	15	20	35	60	5	65	-	0	0

Source; FOA,2012

If the soil at hand is not suitable it may be improved by adding clay or sand. The best soils for construction are sandy loam and sandy clay loam. Sandy clay gives fair results if stabilized.

Soil Stabilization:
The aim of soil stabilization is to increase the soil's resistance to destructive weather conditions in one or more of the following ways; By cementing the particles of the soil together, leading to increased strength and cohesion, By reducing the movements (shrinkage and swelling) of the soil when its moisture content varies due to weather conditions and By making the soil waterproof or at least less permeable to moisture. A great number of substances may be used for soil stabilization. Because of the many different kinds of soils and the many types of stabilizers, there is not one answer for all cases.

It is up to the builder to make trial blocks with various amounts and kinds of stabilizers. Stabilizers in common use are: Sand or clay, portland cement ,Lime ,Bitumen, pozzolanas (e.g., fly ash, rice husk ash, volcanic ash) ,Natural fibres (e.g., grass, straw, sisal, sawdust),Sodium silicate(water-glass),Commercial soil stabilizers (for roads),Resins, whey, molasses, gypsum, cow dung .

The use of coconut fiber, which are now most often considered as waste, as a resource to produce farm building material to substitute wood product offers many advantages. The Philipines for example have to import a large part of their wood based building materials, and an alternative supply from local sources is of interest . In the Philipines 325 million coconut trees are growing, yielding 12 billion nuts from which about 4 million tons of ecoboard can be produced . commercial use of the fiber would substantially increase the profitability of the of coconut farming and contribution to the economy and export of the Philipines (Luisito et-al).

Coconut fiber is obtained from the fibrous husk (mesocarp) of the coconut (Cocos nucifera) from the coconut palm, which belongs to the palm family (Palmae). Coconut fiber has high lignin content and thus low cellulose content, as a result of which it is resilient, strong and highly durable. The remarkable lightness of the fibers is due to the cavities arising from the dried out sieve cells.

According to Maljid (2011),there are many general advantages of coconut fibres e.g. they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean.

Li et al. (2006) studied untreated and alkalized coconut fibres with two lengths of 20 and 40 mm in cementitious composites as reinforcement materials. Mortar was mixed in a laboratory mixer at a constant speed of 30 rpm, with cement: sand: water: super plasticizer ratio of 1: 3: 0.43: 0.01 by weight and fibres were slowly put into the running mixer. Australian standards AS 1012.8.1- 2000 and 1012.8.2-2000 were used. The resulting mortar had better flexural strength, higher energy absorbing ability and ductility, and lighter than the conventional mortar. Good results were achieved with the addition of a low percentage of coconut fibres and chemical agents in cementitious matrix.

Coir erosion fabrics provide firm support on slopes and unlike other natural fibre alternatives like cotton or jute, do not degrade until 5 years. They have the necessary strength and come in a number of forms such as matting, rolls and logs and are used for soil stabilization.

Coconut fiber finds applications in slope stabilization in railway cutting and embankments, protection of water courses, reinforcement of temporary walls and rural unpaved roads, providing a sub base layer in road pavements, land reclamation and filtration in road drains,

Containment of soil and concrete as temporary seeding etc, highway cut and fill slopes, control of gully erosion and shallow mass waste.

Most local farm structures are specially built structure made from a mixture of dry grass and clay. One of such structure is the Rhombus which consists of a bin resting on large stones and covered with a thatched roof (plate 1).

A mud rhombus consists basically the following; Foundation – floor assembly, Shell or wall and Roof.The shape and sizes of the mud rhombus depend on the tradition of the area and the availability of the materials. The shape could be cylindrical, spherical, or circular shaped. The height ranges from 7 – 10 meters while the diameter ranges between 3 and 7 meters. The capacity of mud rhombus ranges from 1000kg – 8,000kg of unthreshed cereals and legumes. They are generally not moisture proof, rodent proof or airtight. According to Adejumo ans Raji (2007), the physical defects of mud structures are usually on the roof and wall of the structure. The physical defect includes leakages of roof, cracks on the wall. The defects are usually as a result of poor strength of materials, change in climate condition and structural failure. The maintenance methods include the repair and replacement of structural parts.

Plate 2; A mud rhombus (Adejumo and Raji, 2007)

The abundance of alluvial deposit along river benue has proved the compitence of brick industry in this part of Nigeria. To abate the defect of our local farm structure, there is need to source reinforcement of this soil using local materials such as coconut fibre wich are lying wasting in most villages within the study area. They could be used for making building blocks, traditional ceramic pots and insulation bricks. The clay may be beneficiated to enhance its porosity for application as an adsorbent. Thus, the objective of this study is to the porosity and failure strength of the alluvial deposit at different fibre ration in attempt to determine the optimal strength and moisture for building of farm structures

2.0 MATERIALS AND METHODS

Material Sourcing and Extraction Process

The coconut fiber was obtained from the pod or husk of the coconut that were dumped at the vendor market at the railway station. The husk was retted by immersion (soaking) in slightly saline water (obtained from Chemistry laboratory) of the University of Agriculture Makurdi. The fiber aggregates disintegrated in the water and the fibers were extracted (plate 1).

The soil used was gotten from the bank of River Benue by SIWES farm of the University of Agriculture, Makurdi.

Plate 2: Coconut husk, Grated fiber and finished fiber

Stabilization of the soil

The soil was sun dried for a week then crushed into fine particle using the hand rammer. It was then allowed to pass through the 63µm BS sieve and 90% particle retained (Craig, 2004). The coconut fiber was grated to smaller form then mixed with equal amount of the soil at four (4) different mix ratio by percentage weight of 100%:1%, 100%:2%, 100%:3% and 100%:4% respectively of soil and grated coconut fiber. Water was sprinkled on the stabilized soil while it is being mixed by hand until it form a firm lump when squeezed in the hand and just enough moisture appeared on the surface to give a shiny appearance.

Moisture content determination

Clean containers were weighed together with their lid and wet stabilized soil were added to each and then weighed with the values noted. The samples were labeled and then oven dried to a temperature of about 110^{0}C for 24hours and transferred into desicator for another 6hours. The moisture content for each ratio of the stabilized soil was evaluated using the equation.

$$M = \frac{M_w}{M_s} X100\% ------1$$

Where; *M=moisture content%*

M_w=mass of moisture (M_1-M_c)

M_d=mass of dry soil (M_2-M_c)

M_c=mass of container

M_1= Mass of container + wet soil

M_2= mass of container + dry soil

Compaction test

Three (3) kg of each sample were weighed and sieve through the BS sieve and then 3% by weight of water of the original water content were added and mixed thoroughly. Using a scoop, a trowel and a mixing bowl, water was added to mix and turned over and over to form a homogeneous mixture. For each of the replacement levels, the quantities of the materials were measured using a weighing balance. With a rammer falling freely through, the soil was compacted into three layers with 27 blows on each of the layer, making sure that the blows are evenly distributed. The collar of the mould was then removed and the soil trimmed off evenly with a straight edge. The cylinder were then cleaned and the weight of the mould with the soil in it taken. Some quantity of the soil sample was then removed and top for moisture content determination. The procedure was repeated for 5 times until the weight of the soil and the mould begins to fall.

Determination of compressive strength of the stabilized Sample.

After determination of moisture content, each sample was placed in the formwork immediately in layers of about 10cm and thoroughly compressed with a ram weighing 8 to 10 kg before the next layer is placed. At the completion of this, the moulds were made ready and oiled. The purpose of oiled is to enhance demoulding. The mix is then transferred into the mould and with the aid of the motorized electric vibrator; they were vibrated for about 2 minutes. At the end of vibration, they were then gently and carefully demoulded, and left in a clean dry environment to cure at a temperature of 29^{0}C for three weeks. For each of the replacement levels (including the control), a total of (10) cubes of dimension (125 X 102 X 65) mm^3 were caste. The compressive strength test was carried out at the completion of 3 weeks of curing with the aid of an ELE-branded hydraulic powered compressive machine. The samples were placed in-between the plates of the machine and an axial force was applied at a constant rate to the specimen until it failed. The average of the two samples for each replacement level was taken and the strength for each replacement level calculated (table 3) and reported according to BS standard (1999).

3.0 RESULTS AND DISCUSSION

Moisture Content;

The result of experiment conducted to evaluate the moisture content of the stabilized soil material as described in 2.2 is presented in table 2. From the moisture content experiment, the moisture content of the soil sample was found to increases with

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increasing percentage of fibre which attest to moisture retention of the materials.

Table 2: Moisture Content (dry base) for stabilized Soil sample

Soil/fiber	M_1	M_2	M_w	M_c	M_s	m(%)
0%	74.0	64.7	9.3	15.8	48.9	18.40
1%	77.5	67.6	9.7	16.0	51.8	18.73
2%	72.5	62.3	10.2	16.6	45.7	22.32
3%	98.9	64.3	26.6	16.4	47.9	43.53
4%	74.8	58.3	23.17	16.6	41.7	55.57

This phenomenon is not same for the case of dry density as it could be observed that it rises to 2% fibre ratio to drop afterwards. Physical appreciation of plot of moisture content and the dry density was used to establish the optimum moisture content at the maximum dry density (fig 1). From the plot of (table 3), the maximum dry density (MPD) increases at constant rate up to the optimum point with sharp return after peak at optimum moisture content (OMC) with values obtained to be 1.91kg/m^3 and 20.0% respectively. The relationship appears to be polynomial of second order with correlation coefficient (R^2) value of 63% as a third order polynomial will be an extinct or hyperbolic.

Table 3; Compaction test on soil/ fibre samples

Soil/fiber	Weight of mould (kg/m^3)	Particle density	Bulk density	Moisture content (%)	(kg)	(kg/m^3)
0%	1.82	1.81	1.62	18.40		
1%	1.87	1.88	1.63	18.73		
2%	1.77	1.95	1.65	22.32		
3%	1.67	1.85	1.53	42.53		
4%	1.72	1.81	1.50	55.57		

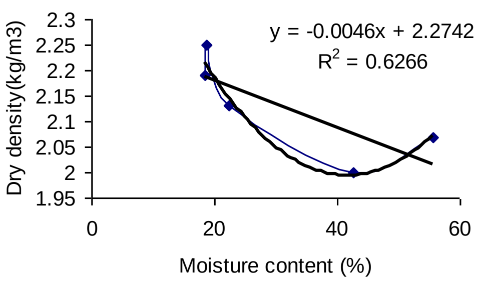

Fig 1; A polynomial function of MDD and OMC

3.4 Compressive strength

The results of the compressive strength test and the performance of the different mix ratio for the experiment are presented in table 4.

Table 4 Compressive Strength of the Sample

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Replacement level (%) Clay: Fiber	Weight (kg) 1	2	Average weight (Kg)	Density (kg/m^3) X 10^3	Failure loads (KN/m^3)		Average (KN/m^3)	Compressive strength (KN/m^2)
100 : 0	1.78	1.85	1.82	2.19	120	126	123	5.58
100 : 1	1.87	1.86	1.87	2.25	170	180	175	7.94
100 : 2	1.77	1.76	1.77	2.13	180	200	190	8.62
100 : 3	1.61	1.71	1.66	2.00	160	140	150	6.81
100 : 4	1.72	1.72	1.72	2.07	140	120	130	5.90

The compressive strengths of the samples increased steadily to a peak of 8.62KN/m^2 after which it began to drop. Also the densities reduced slightly with

increase in the fiber-content of the mix. The increase in the compressive strength is due to the increases cohesive strength between the soil particles and the fibers. Hence, when compressive axial load is imposed on the sample, an internal tensile stress is reduced which tries to prevent the sample from splitting/failing. However at higher replacement levels of the fiber, the density reduces and the cohesion between soil particles is impaired and hence the compressive strength drops. Fig 2 gives the visual appreciation of the possible relationship between the compressive strength, failure load and the optimum ration of reinforcement of the soil and fibre.

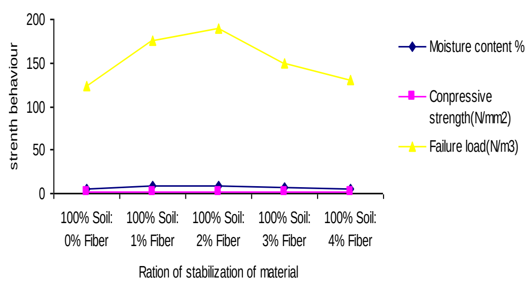

Fig. 2; Compressive strength behaviour of stabilized material

4. CONCLUSSION

From this study conclusion can be drawn that alluvial clay stabilized with coconut fibre can be use for farm structures as it has the potential of absorbing moisture that could course damage to stored produce, reduce surface wearing of structure when in contact with rain storm however, the material perform best at stabilization ratio of 2% fibre:100% replacement level with OMC of 20% , failure load of 8.62KN/m^2 at dry MPD of 2.13kg/m^3.

It is therefore recommended for use by farmer in dynamic climatic condition such as that of tropical countries.

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