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IMPROVING THE PROPERTIES OF LATERITIC CLAY SOIL STABILIZED WITH RICE HUSK ASH FOR BRICK PRODUCTION

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ABSTRACT: Improving Properties Lateritic Clay Soil Stabilized Rice Husk Ash Brick Production.

INTRODUCTION

The scarcity and high cost of resources have become an issue in some parts of the world, prompting the development of novel building masonry materials. Roads and structures were built for the use of the citizens by the citizens in the early days of the Roman empire, and many methods to improve the soil and building materials were used. In Nigeria and other nations, the development of innovative unfired clay brick technology is critical for construction. This study examines the use of rice husk to improve the quality of unfired clay bricks, which will reduce waste rice husk and reduce the amount of gases released into the atmosphere during the production of fired clay bricks. The final cost of unfired clay brickwork is expected to be lower, while the environmental impact of fired clay bricks is expected to be lower. The use of industrial byproducts and natural clay to stabilize and function as a binder for the manufacturing of unfired clay bricks. Clay bricks are widely used in construction projects all around the world.

The use of stabilizing agents (binder material) in poor soils to increase geotechnical attributes such as compressibility, strength, permeability, and durability is known as soil stabilization. (Makusa, 2012).

Different materials can be used as binders for the production of improved clay bricks, some of them are as follows:

1. Rice husk (ash or powdered)

2. Magnesium oxide
3. Glass waste
4. Fly ash
5. Soft sludge from fiber
6. Waste sugar cane bagasse
7. Blast furnace slag

It's also worth noting that most soil stabilization for roads is done with cementitious binders, which improve the soil's engineering qualities and boost its carrying capacity.

MATERIALS AND METHOD

MATERIALS

For this project, locally sourced laterite from Landmark University (the commercial farm) was used, as well as rice husk from the Landmark University Teaching and Research Farms that will be burned via controlled burning for the ash to be used as the binder. After passing through a 300mm sieve, the RHA was homogeneously mixed with a shovel and masonry trowel, then fed into a 100x200mm interlocking stone mold that was greased to enable removal and allowed to dry. A total of 90 bricks were made, with 18 bricks produced for each mix fraction.

Plate 3.1 Rice husk obtained from the Landmark University Commercial Farm.

Plate 3.2Rice husk burnt to ash by controlled burning.

Tests Carried Out on Materials

Tests Carried Out on Lateritic Soil Alone

Specific gravity

The specific gravity of an object is the ratio of its density to that of a reference substance. The specific gravity can inform us whether an object will sink or float in our reference substance dependent on its value. The density of items and liquids is affected by changes in pressure and temperature, which affects the specific gravity of objects and liquids. This complies with ASTM D 854-00.

Materials and Equipment include; Density bottle of 50 ml with stopper having capillary hole, Balance to weigh the materials (accuracy 10gm), Wash bottle with distilled water, Alcohol and ether.

Procedure;

1. Make sure the density bottle is clean and dry.
   a. Fill the bottle halfway with water and drain it.
   b. Wash it in alcohol and drain it to get rid of the water.
   c. Wash it in ether to get rid of the alcohol and drain the ether.
2. Using the stopper, weigh the empty bottle (W1)
3. Cool the oven dirt sample in a desiccator for about 10 to 20 grams. Fill the bottle with it. Calculate the bottle and soil weights (W2).
4. Fill the bottle with 10ml of distilled water to completely soak the soil. Allow it to sit for about 2 hours.

5. Fill the bottle entirely with distilled water, close it, and maintain it in a water bath at a steady temperature (Tx0).
6. Take the bottle outdoors and wipe it down with a clean, dry paper towel. Determine the bottle's weight now.
7. Now drain the bottle and clean it completely. Weigh the bottle after filling it with solely distilled water. Let's say it's W4 at room temperature (Tx0 C).
8. Repeat the process two or three times more to get an average reading.

Natural Moisture Content;

The amount of water contained in a material, such as soil, is referred to as its water content or moisture content. Water content is a ratio that can range from 0 (totally dry) to the value of the materials' porosity at saturation and is utilized in a wide range of scientific and technical fields. Water is generally present in a finite amount in soils, which can be stated as a percentage.

Materials and Equipment include; Metal container with lid (air tight, non-corrodible), Balance (0.01g sensitivity for fine grained soils and 0.1g sensitivity for medium grained soils), Oven (interior for non-corrodible material, controlled at 105o – 110oC temperature), Desiccator, Tong (one pair).

Procedure;

1. Clean and dry the metal container before weighing it with the lid.
2. Take a 30 g fine-grained soil sample (in its natural condition) or a 250 g medium-grained soil sample (in its natural state). Place the soil sample in the container loosely and weigh it with the lid.
3. Take off the cover of the container and place it in the oven. Maintain a temperature of 105o–110oC in the oven for normal soils and 60o–80oC in the oven for organic soils. Dry the soil specimen in the oven till its mass is constant. Drying is deemed complete when the difference in the successive mass of the cooled specimen is about 0.1 percent of the original mass of the sample. The drying period of the soil specimen is usually 16-24 hours in normal conditions.

4. Remove the container from the oven once it has dried, retain the cover on it, and set it in a desiccator to cool.
5. Weigh the container with the lid and dry dirt inside.
6. Make a note of your findings in the moisture content table (oven-drying method) below.

Sieve Analysis;

In Civil Engineering, particle size determination is particularly significant since particle size impacts the effectiveness of the final product. The size of a particle determines its bulk density, physical stability, permeability, and other characteristics. The sieve analysis test procedure is an effective approach for determining particle size distribution that has been used in the past. The particle size distribution is characterized by mass or volume in sieve analysis. Sieve analysis is a laboratory test process in which particles pass through a sieve mesh vertically or horizontally. The smallest sieve is at the bottom of the stack, followed by each layered sieve in sequence of increasing sieve size. When a granular material sample is placed on the top sieve and sifted, the individual particles of the material are separated onto the last layer through which the particle could not pass. This experiment follows the ASTM D422 standard.

Materials and Equipment include; balance, set of sieves, cleaning brush, sieve shaker, mixer (blender), 152H, hydrometer, sedimentation cylinder, control cylinder, thermometer, beaker, timing device.

Procedure;

1. Make a list of the weights of each sieve and the bottom pan that will be used in the analysis.
2. Write down the weight of the dry soil sample you've been given.
3. Clean all of the sieves and arrange them in increasing order of sieve numbers (#4 sieves at the top, #200 sieve at the bottom). Place the pan on top of the #200 sieve. Fill the top sieve with the soil sample and cover it with the cap.
4. Shake the sieve stack for 10 minutes in the mechanical shaker.
5. Carefully weigh and record the weight of each sieve with its retained dirt after removing the stack from the shaker. Remember to weigh and record the weight of the bottom pan

with the fine soil that has been retained.

Atterberg Limits;
The Atterberg limits are three basic measurements of a fine-grained soil's critical water content: shrinkage, plasticity, and liquidity. Geotechnical engineers must examine soils intended to support structures, pavements, or other loads in order to forecast their behavior under applied stresses and changeable moisture conditions. A soil might be solid, semi-solid, plastic, or liquid depending on the amount of water it contains. The consistency and behavior of a soil varies with state, and as a result, so do its engineering properties. As a result, a change in the behavior of the soil can be used to identify the boundary between each condition. The Atterberg limits can be used to differentiate between silt and clay, as well as distinct varieties of silt and clay.

Materials and Equipment includes; liquid limit device and grooving tools IS: 2720Pt.V, shrinkage limit set, glass plate, distilled water, oven, balance with 0.01 gm sensitivity, evaporating dishes, measuring cylinder, spatula, desiccator, glass cup.

Plastic limit;
This is the amount of water in a plastic as it transitions to a semi-solid state. This test is rolling a soil sample into a thread repeatedly until it crumbles. This thread will hold its shape down to a very small diameter if the soil is at a moisture level where it behaves plastically. After then, the sample can be remolded and the test can be repeated. The thread will begin to break apart at greater diameters as the moisture content decreases due to evaporation. The process is described in ASTM Standard D 4318.

Procedure; About 15g of oven-dried soil specimen passes through an IS 425-micron filter and is thoroughly combined with distilled water until the soil mass becomes pliable enough to be readily formed into a ball with fingers. Take a piece of the ball and roll it on a glass plate to make a thread out of the soil mass. Keep in mind that the diameter should be between 3 and 4 mm. The soil is remolded into a ball after the diameter reaches 3mm. The rolling and remolding operation is repeated until the dirt has a diameter of 8mm and is crumbling. Water content is determined by keeping the disintegrated threads. 9 more samples are added to the test. The plastic limit is then taken as the average of the three water content values.

Liquid limit;
When a soil specimen is just fluid enough for a groove to close when jolted in a specific manner, this is the water content at which it transforms from a plastic to a liquid condition. Over a wide range of water volumes, the change from plastic to liquid behavior is slow.

Procedure; In the evaporating dish, around 100g of soil samples passing through a 425-micron filter is thoroughly combined with distilled water to make a homogenous paste. In the cup of liquid limit device, a portion of the paste is placed. The mix should be leveled to a maximum depth of 1cm. Holding the tool perpendicular to the cup, draw the grooving tool through the sample along the symmetry axis of the cup. Count the number of blows by rotating the handle at a rate of around 2 revolutions per second until the two sections come into contact at the bottom of the groove. Some soils slide around the cup's surface rather than flowing.If this happens, the test should be redone and the findings disregarded. Using the oven drying method, determine the water content of roughly 10gm of soil near the closed groove. Obtain 5 readings in the range of 20-35 blows by changing the water content of the soil and repeating the procedure.

Shrinkage limit;
The shrinkage limit (SL) is the water content at which further moisture loss does not result in further volume loss. A soil pat of moist test material was molded into a specific shrinkage dish to determine the shrinkage limit. The specimen's volume is measured by water displacement after the dish and soil have been oven-dried and weighed.
Procedure;

1. Take a sample of at least 300 g of the material that passes the No. 36 B.S. sieve (0.425 mm) and is processed according to the technique for disturbed soil sample preparation for testing. Place this sample in the mixing basin and, using the spatula, thoroughly mix with distilled water until the mass forms a thick uniform paste. Add enough water to make it as wet as the liquid limit, if not slightly wetter.
2. Grease a clean shrinkage mold on the interior. By lightly tapping the mold's base, remove any air bubbles from each layer of wet soil. Fill the mold

to the brim, then use the spatula to smooth off any excess material. Remove any soil that is stuck to the mold's rim.

3. Dry the specimen at room temperature for about 24 hours, or until a clear color change can be seen. Place in an oven and dry between 105 and 110 degrees Celsius.
4. Allow the specimen to cool before measuring the longitudinal shrinkage Ls to the millimeter. If the specimen breaks into fragments, keep the pieces together firmly and calculate the shrinkage Ls. Remove the specimen from the mold if it curls, and measure the length of the top and bottom surfaces. To calculate the shrinkage, subtract the mean of these two lengths from the mold's internal length.

Plasticity Index;

The plasticity index (PI) is determined by subtracting the liquid limit (LL) from the plastic limit (PL): PI = LLPL. The Atterberg limits are these three parameters taken together (ASTM 2010). As a result, the PI is a metric for a soil's plasticity. As a result, the PI is used to determine the amount and kind of clay in a soil.

Procedure; The plasticity index may be calculated as the difference of liquid limit and plastic limit. Thus, plasticity index.

$$IP = WI - WP$$

Tests Carried Out on RHA

XRF (X-ray florescence) test;

An X-ray fluorescence (XRF) spectrometer is a non-destructive x-ray equipment used for routine chemical investigations of rocks, minerals, sediments, and fluids. It operates on the same wavelength-dispersive spectroscopic principles as an electron microprobe (EPMA). The behavior of atoms when they interact with radiation allows x-ray fluorescence to be used to analyze major and trace elements in geological rocks.

Tests Carried Out On The Bricks

Compressive tests;

Compressive testing demonstrates how a material will react when compressed. Compression testing can be used to identify a material's behavior or response under crushing loads, as well as to determine its plastic flow behavior and ductile fracture limits. Compression tests are essential for determining the elastic and compressive fracture properties of brittle and lowductility materials. The modulus of elasticity, proportional limit, compressive yield point, compressive yield strength, and compressive strength are all determined via compression testing. These characteristics are crucial in determining whether a material is suitable for a certain application or whether it will fail under certain loads. Some materials break at their compressive strength limit, while others deform permanently, therefore a certain degree of deformation can be regarded the compressive load limit. Compressive strength is an important factor to consider while designing structures.

Plate 3.3 Compressive test

Flexural Test;

Flexural testing establishes a material's resistance to flexing or stiffness by measuring the force necessary to bend a beam of plastic material. The flex modulus of a material indicates how much it can flex before permanent distortion. When using a plastic lock arm or snap fit assembly, the arm must bend to allow adequate connection seating, then return to its original position to secure the connection in place. When the locking mechanism is composed of brittle material, it has a higher chance of breaking when flexed. On the compression or tension side of the specimen, flexural strength is defined as the greatest stress at the outermost fiber. The material is laid horizontally over two points of contact (lower support span), and then a force is applied to the top of the material (upper loading span) through either one or two points of contact until the sample fails. The flexural strength of that particular sample is the maximum recorded force.

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Plate 3.4 Flexural test

Mix Design

In this project, the RHA is combined with lateritic clay in proportions of 0, 4, 8, 12, and 16 percent (%) by weight, and the studies on the bricks are carried out after 7, 21, and 35 days of curing. The bricks are 200x50mm in size and weigh 1.225kg each.

There was a total of 90 samples made. The mix was designed to produce 18 bricks per mix, with the total weight of clay required and RHA required properly calculated in percentages (%) of 0, 4, 8, 12 and 16 respectively. There are 18 samples produced for each degree of RHA addition.

Weight of total clay per mix;

- 100% = 1.225*18 = 22.05kg
- 96% = 1.176*18 = 21.168kg
- 92% = 1.127*18 = 20.286kg
- 88% = 1.078*18 = 19.404kg
- 84% = 1.029*18 = 18.522kg

Total weight of clay = 101.43kg.

Weight of total RHA per mix;

- 100% = 0kg
- 96% = 0.049*18 = 0.882kg
- 92% = 0.098*18 = 1.764kg
- 88% = 0.147*18 = 2.646kg
- 84% = 0.196*18 = 3.528kg

Total weight of RHA = 8.82kg.

Table 3. 1Mix design

LATERTIC CONTENT (%)	RHA CONTENT (%)	WEIGHT OF CLAY (KG)	WEIGHT OF RHA (KG)
100	0	1.225	-
96	4	1.176	0.049
92	8	1.127	0.098
88	12	1.078	0.147
84	16	1.029	0.196

RESULTS AND DISCUSSION

Tests Carried Out on Lateritic Soil Alone

Specific gravity

Table 4.1 shows the summary of the specific gravity of the clay sample. It was observed that the specific gravity of the clay for sample 1 was 2.9 and that of sample 2 was 2.3 and the average of both is 2.6 which is a typical of sedimentary clay and this signifies that this soil has large amounts of organic matter or porous particle.

Table 4.1Specific gravity

	SPECIFIC GRAVITY	
Samples	1	2
Weight of bottle W1 (g)	20.0	20.0
Weight of bottle + sample W2 (g)	44.5	39.5
Weight of bottle + sample +bottle W3 (g)	85.5	83.5
Weight of water + bottle W4 (g)	72.5	72.5
Specific Gravity (g)	2.9	2.3
Average	2.6	

Natural moisture content

The natural moisture content of a clay signifies the ratio of the weight of water to the weight of the solids in a given mass of soil, this ratio is usually expressed in percentage. Table 4.2 shows the natural moister content of the clay. The average moisture content for the clay is 10.3%.

Table 4.2 Natural moisture content

NATURAL MOISTURE CONTENT			
Container no	1	2	3
Weight of container with lid W1 (g)	0.49	0.66	0.14
Weight of container + wet soil W2 (g)	30.7	38.5	20.2
Weight of container + dry soil W3 (g)	29.0	36.5	18.5
Weight of moisture Ww (g)	1.7	1.9	1.7
Weight of dry soil Ws (g)	28.51	35.94	18.36
Moisture content (g)	5.96	5.29	9.26
Average		10.3	

Sieve analysis
Sieve analysis is used to access the particle size distribution also called gradation of a granular material by allowing the material to pass through a series of sieves of progressively smaller size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.

Table 4.3 shows the gradation results for the clay and it signifies that the Cu is 5.1 and the Cc is 2.4, therefore the soil is a well graded soil according to the USCS classification system.

Fig 4.1 shows the curve chat of the particle size distribution.

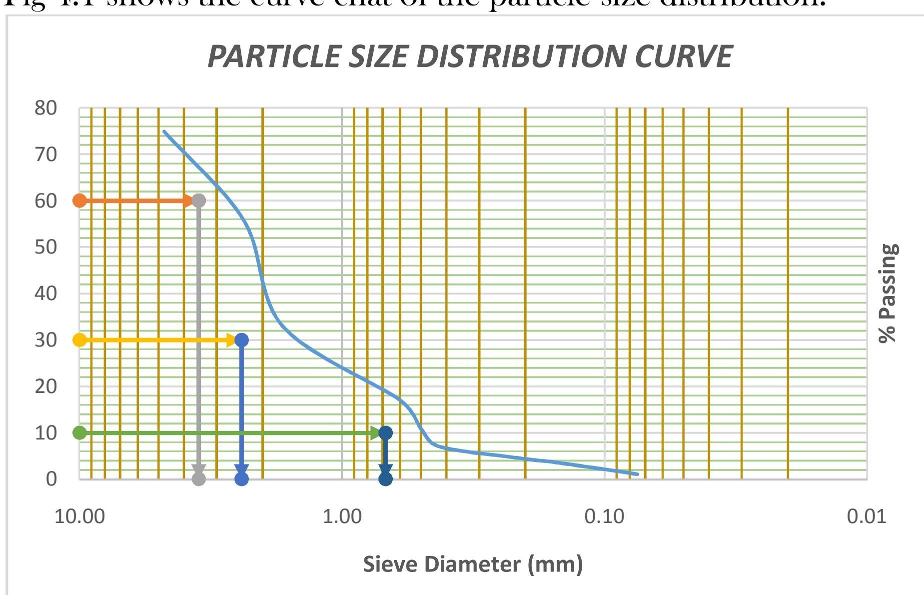

Fig 4.1 Particle size distribution curve

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Atterberg limits

Atterberg limits are the description of relationship between clay particles in the presence of water. Plastic and liquid limits are governed by the mineralogical composition and clay content of soil. It was observed that the plastic limit for the clay ranges from 29.4 to 34.7 with an average of 30.1 which indicates that the clay is a kaolinite. The liquid limit ranges from 37.0 to 73.5 which also indicates that this clay is a kaolinite with the plasticity index of 22.9 which indicated that the clay is a silty clay. The shrinkage limit was also observed and is ranging from 6.9 to 12 with an average of 9.47.

Table 4.3 Plastic limit

PLASTIC LIMIT				
no of trials	W1	W2	W3	MC
1	20.3	37	32.7	34.7
2	19.9	36.7	33.2	26.3
3	19.9	38.4	34.2	29.4
			Average	30.1

Table 4.4 Liquid limit

LIQUID LIMIT					
no of trials	Penetration	W1	W2	W3	MC
1	16	20.5	26.8	25.1	37.0
2	20	20.4	26.1	24.3	46.2
3	27	15.2	22.1	19.7	53.3
4	32	20.5	27.5	24.7	66.7
5	39	4.8	10.7	8.2	73.5

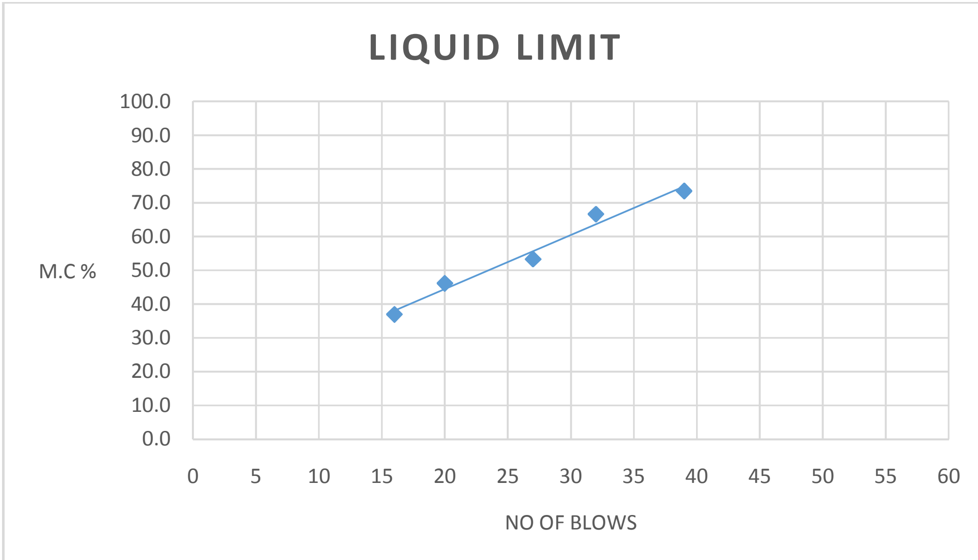

Fig 4. 2 Liquid limit

Table 4.5 Plasticity index

PLASTICITY INDEX	
LIQUID LIMIT(LL):	53
PLASTIC LIMIT(PL):	30.1
PLASTICITY INDEX(PI):	22.9

Table 4.6 Shrinkage limit

LINERA SHRINKAGE LIMIT			
no of trials	W1	W2	SL
1	14	12.5	12
2	14	13.1	6.9
		Average	9.45

Tests Carried Out on RHA

XRF (X-ray florescence) test

Table 4.8 below shows the XRF test results obtained from the RHA.

Table 4.7 XRF test

According to the ASTM C-618 (2005), the summation of SiO_2, Fe_2O_3, and Al_2O_3 should greater than 70, The summation of SiO_2, Fe_2O_3, and Al_2O_3 of the RHA used is 74.069 therefore the RHA satisfies the ASTM C-618 (2005).

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	K_2O	CaO	SO_2	P_2O_5	Ag_2O	MgO	Ta_2O_5	Nb_2O_5	Cl	TiO_2	Na_2O	V_2O_5
CPA	71.9	1.069	1.1	6.104	3.243	1.362	13.125	0.008	0	0.007	0.001	1.163	0.1	0.30	0.006

Tests Carried Out on the Bricks

Compressive tests

The compressive strength test was carried out on the produced clay bricks to determine the flexural test. The results obtained at 7, 21 and 35 days are shown below.

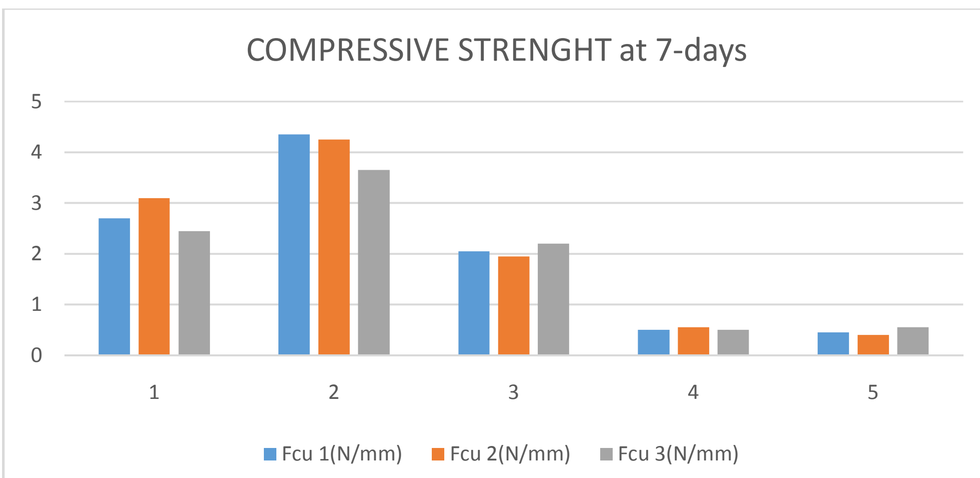

Fig 4.3 Compressive strength at 7-days

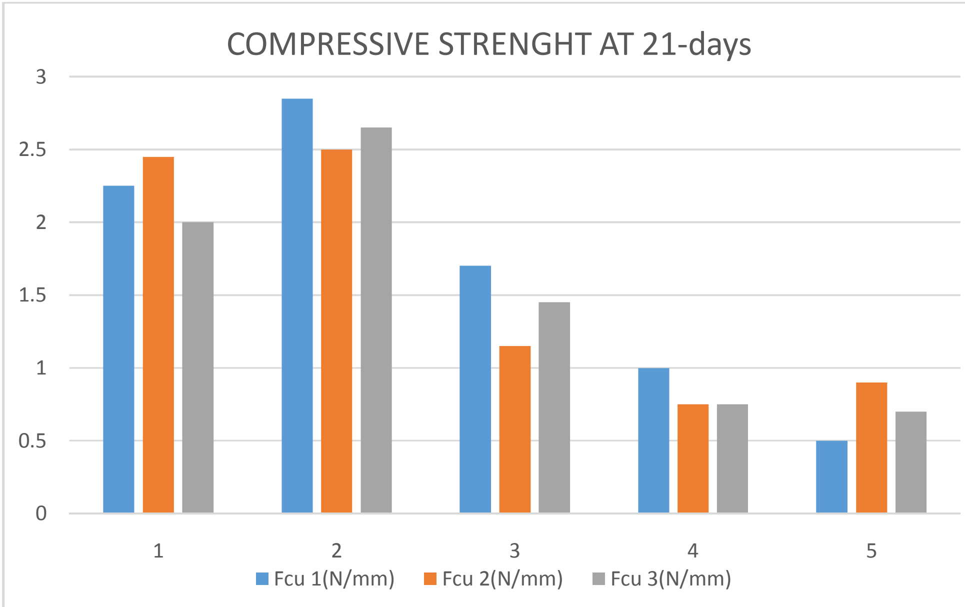

Fig 4.4 Compressive strength at 21-days

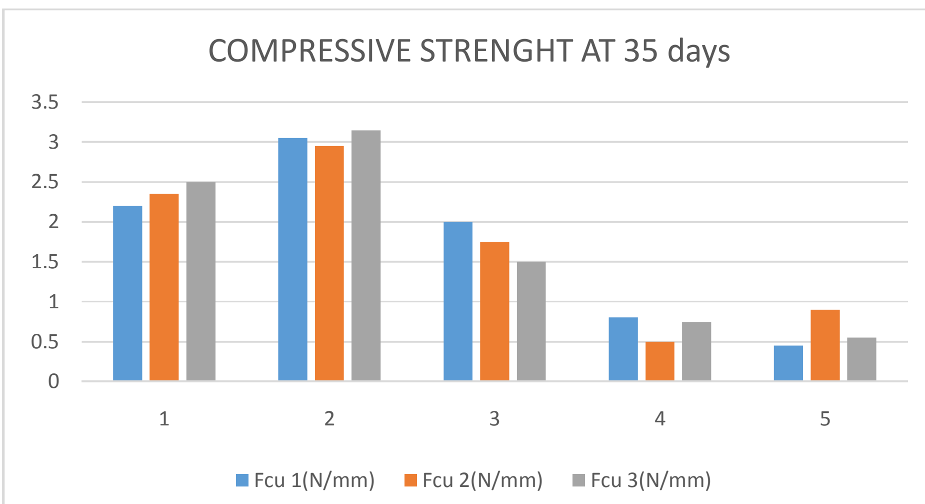

Fig 4.5 Compressive strength at 35-days

The result shows that the control specimen which is without RHA is higher than some of the specimens with RHA. The specimen with the highest compressive test value is at 4% RHA addition (2 on the charts above) and decreases drastically as it gets to the 12% RHA addition, (5 on the chart above). A brick's compressive strength should not be less than 5 N/mm2 according to BS 3921. In practice, however, the compressive strengths of stabilized soil bricks are typically less than 4 N/mm2. Local bricks now in use have compressive strengths ranging from 0.5 N/mm2 to 1.75 N/mm2, well below industry norms (Bogahawatta V.T.L). When the building loads are low, a compressive strength of 1- 4 N/mm2 is sufficient for single-story structures. Values in this range are recommended by several building authorities across the world. These stabilized bricks can also be utilized for non-load bearing partition walls where compressive strength isn't as important. As the bricks produced for this experiment were locally made, it is important to note that RHA can be used to stabilize lateritic clay at 4% of the weight of a brick for structures with low load capacity and single-story buildings.

Flexural test

Flexural strength of brick specimen is normally associated with the microstructure of the specimens. Flexural strength test was carried out on the produced clay bricks to determine the flexural test. The results obtained at 7, 21 and 35 days are shown below.

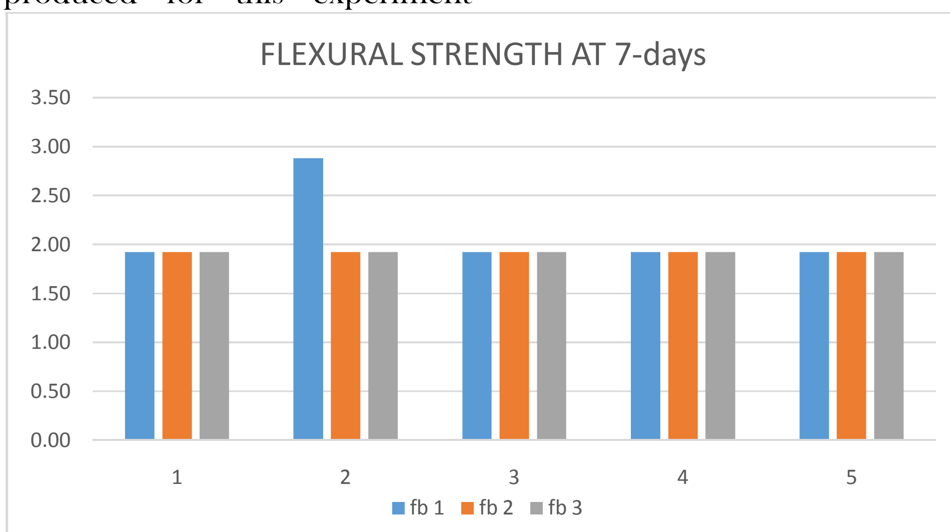

Fig 4. 6 Flexural strength at 7-days

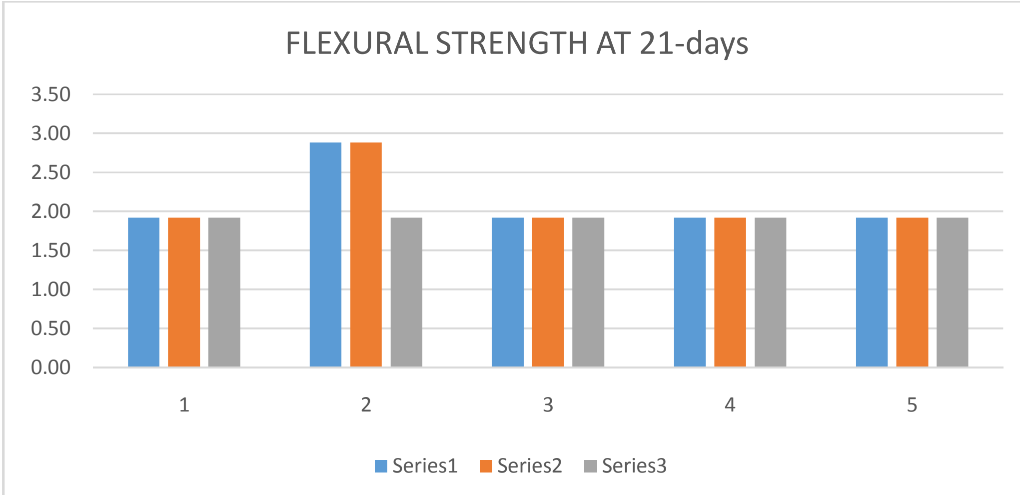

Fig 4.7 Flexural strength at 21-days

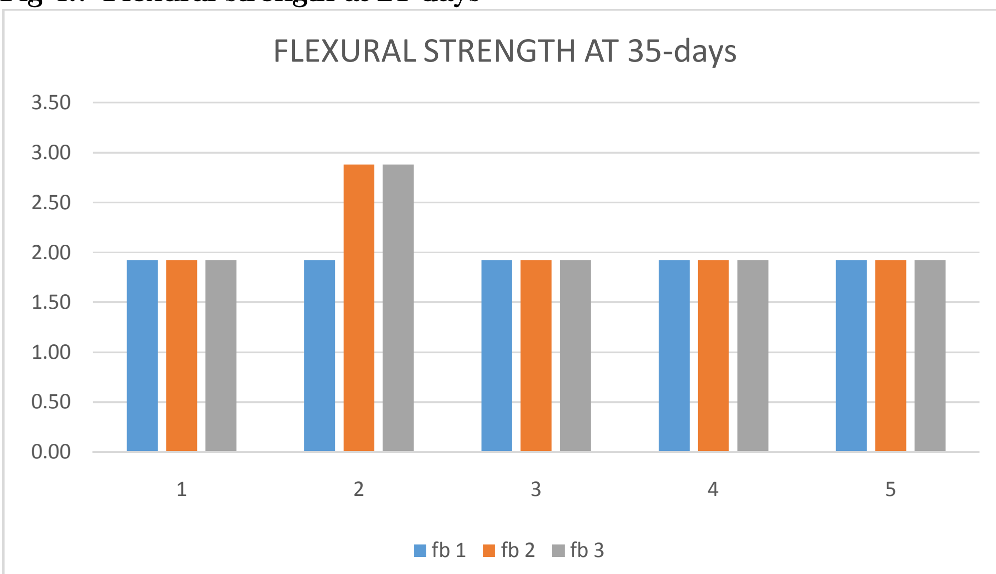

Fig 4.8 Flexural strength at 35-day

The flexural test results show that for RHA addition of 0%, 8%, 12% and 16% (1,3,4 and 5on the chart above), no significant change of the flexural strength was observed and it is at 1.92. at 4% the flexural strength had a change, at 7 days it is at 2.24 and at 21 and 35 days, it is at 2.56. According to ASTM C 67 guidelines, the minimum permissible limit for modulus of rupture is 0.65 MPa. All the tested brick specimens exhibited modulus of rupture values in the range of 1.92 to 2.56 MPa. Therefore, it can be concluded that bricks incorporating RHA can be efficiently produced on massive scale leading to economical and sustainable construction.

CONCLUSION AND RECOMMENDATION

Conclusion

In this study, the properties of clay bricks incorporating rice husk ash (RHA) were investigated. Utilization of RHA wastes as a raw material in manufacturing of clay bricks can be an important way of recycling for final disposal of these abundant wastes, leading to conservation of fertile soil. The environmental profile of the unfired clay bricks was excellent when compared to fired brick production process which is very energy intensive. Most of the emissions to the environment are attributed to the energy used for firing the kiln. The ability to handle the freshly extruded unfired clay brick is an extremely positive outcome. Although the compressive strength of the bricks decreased on addition of RHA at 4% addition, there was maximum strength with this or at 4% addition mix, bricks for low load single-story building and be produced at massive scale and would help save the environment from emissions from fired clay which is from the kiln and also from the production of cement.

According to ASTM C 67 guidelines, the minimum permissible limit for modulus of rupture is 0.65 MPa. All the tested brick specimens exhibited modulus of rupture values in the range of 1.92 to 2.56 MPa. Therefore, it can be concluded that bricks incorporating RHA can be efficiently produced on massive scale leading to economical and sustainable construction. As the bricks produced for this experiment were locally made, it is important to note that RHA can be used to stabilize lateritic clay at 4% of the weight of a brick for structures with low load capacity and single-story buildings.

RECOMMENDATION

During the course of this experiment, a few challenges were faced and some of them were beyond my control. The main challenge was the weather condition, as unfired clay bricks require a very good weather condition in order for the bricks to attain maximum strength, the weather condition during the time frame of this experiment was rainy and there was not sufficient sun to help get the bricks to attain maximum strength. I recommend that this research be carried out in a location with sufficient sun in order to attain maximum strength

and also in the post graduate level in order to expose more properties in the RHA and also determine the best type of RHA and also the lateritic clay soil to use to attain maximum strength.
I also recommend that this research should be carried out but with lower level of RHA addition to help recognize if there is maximum strength at a lower mix. My research was done in mix levels of 4%, 8%, 12% and 16%, it can be done in a different mix level to ascertain maximum strength.

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