CEDTECH International Journal of Agriculture Research & Life Science
Volume 2, Number 4, December 2021
http://www.cedtechjournals.org
ISSN: 2756-455X

COMPARATIVE STUDY ON THE USE OF RICE HUSK ASH, CASSAVA PEEL ASH, PERINKLE SHELL ASH, AND GYPSUM AS STABILIZING AGENT FOR CLAY BRICK PRODUCTION.

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ABSTRACT

Clay soil was stabilized using cassava peel ash (CPA), rice husk ash (RHA), gypsum, and littorina littorea (periwinkle) shell ash (PSA). The soil is classified as a medium coarse sandy clay. Periwinkle shell ash (PSA), followed by gypsum was shown to be the best stabilizing element in the tests. The compressive strength of the soil was increased by the periwinkle shell, and it was diminished by CPA. Because of their improved compressive strength and flexural strength, periwinkle shell ash, gypsum, and RHA are ideal materials for clay soil stabilization. The stabilized clay's specific gravity and moisture content are both acceptable. These compounds are recommended for stabilizing sandy clay soils since they improve the engineering qualities of such soils in general.

Keywords: *Comparative study, Rice Husk Ash, Cassava Peel Ash, Peerinkle shell Ash, Gympsum, Stabilizing agent, pride bride production.*

INTRODUCTION

The first artificial materials produced by men for building purposes which proved easy to make, being resistant and durable as attested by several examples which is being seen around the world, having endured and still endures centuries of rough climatic and climacteric conditions were clay bricks. Brick is made of clay (Kaolin) which is formed, dried and fired into a durable ceramic product. Formed using three ways in determining the shape and size it can either be extruded (stiff), molded (soft) or dry pressed of which the majority is made using the extrusion method. As said, earlier that it varies in size but this is due to the manufacturing process being used and as such these variations are addressed via the

ASTM standards. It is said that the texture of a brick is dependent on the method used.

These were simply produced by mixing water with clay of which hardening methods evolved from drying in the sun to industrial ovens which had notable effects on strength and durability in the increase. Though the durability of clay bricks was firstly affected by inadequate raw materials as well as its usage's contamination, presently, urban pollution and incorrect use of materials fosters a more rapid deterioration of existing bricks, adding to this is the general absence of maintenance observed in buildings(Fernandes, 2018). Some of these defects on already made include; efflorescence, lime run-off, stains from external sources (pollution, corrosion etc.) and several others(Brick Industry Association, 2006). These defects affect both the physical and chemical properties thereof and as such this proposal aims to make use of the materials given; towards understanding how stability and less effect of defect can be achieved via a comparative study thereof. Thus, rice husk ash (RHA), fly ash, periwinkle shell powder and gypsum are to be used as stabilizing agents for the soil clay which is to be used in brick production. It is believed that these materials having their specific properties are to affect the physical as well as the chemical properties of the clay in terms of strength (shear) as well as compressive stress, shear resistance and cohesion.

MATERIALS AND METHODS:

Materials

The materials used for this project are clay soil (kaolin), roughly 20 brick mould, water, lubricating oil, cellophane bag. All these to be put forward for the purpose of producing stabilized clay bricks.

Clay soil

Clay is a fine-grained natural soil medium with clay minerals in it. When wet, clays become plastic due to a molecular layer of water coating the clay particles, but when dry or shot, they become stiff, fragile, and non-plastic. The majority of pure clay minerals are white or light-colored, but impurities may give natural clays a number of colors, such as a reddish or brownish color from small quantities of iron oxide. Clay's plasticity occurs when damp and tendency to harden when dry or fired are the distinguishing mechanical properties(Akinyele et al., 2015). Clays are particularly plastic over a wide variety of water content, with a minimal water content (referred to as the plasticity limit) where the clay is only moist enough to deform to a maximum water content (referred to as the liquid limit) where the moulded clay is just dry enough to maintain its form(Brick, 2019).

Brick mould

The brick mould (225mm x 112.5mm x 75mm) is going to be used to facilitate the production of the clay brick. A variation between the top and bottom of the mould in thickness aids easy removal of the brick.

Water

Water is an inorganic, translucent, tasteless, odorless, and almost colorless chemical element that is the primary component of the Earth's hydrosphere and other recognized living organisms' fluids(Sultana et al., 2014). Even if it contains no calories or organic nutrients, it is essential for all recognized ways of life. It has a density of 997 kg/m3, a boiling point of 100 degrees Celsius, and a melting point of 0 degrees Celsius. As a result, the formula is H_2O (which is Two moles of Hydrogen and One mole of Oxygen, with a molar mass of 18.01528 g/mol and an IUPAC ID of Oxidane, Water. The water for the project would come straight from a reservoir that is slightly raised. A significant element in the manufacture of clay bricks is the reaction between clay and water. It can also be used to lubricate the brick mould and to speed up the curing process.

Lubricating oil

The lubricating oil will be mixed with water to lubricate the brick mould before the clay soil and water mix is transferred therein, this aids ease of removal upon brick setting as well as reduce friction, heat and wear between the mechanical components of the mixed clay and the brick mould.

Methodology

The experiment process of this project will include different concurrent phases for the purpose of evaluation. These are the control sample phases, in which industrial quality clay bricks are made. The modification stage would include the processing of clay bricks that have been modified with equivalent amounts of rice husk ash, cassava peel ash, periwinkle shell ash, and gypsum. It will also require the data collection and analysis step, in which different analyses will be performed on the manufactured samples and the results analyzed. Curing will also be done in the same way as it is done in the brick industry.

Production of the control samples

This entails the development of clay bricks of industrial quality. The ordinary bricks were produced using clay with water-clay ratio of 0.9 being used with the brick mould in use, mixing was done manually. During production, compaction was performed in two layers with the use of a trowel and via gravity i.e. (dropping the mould from a minimum height a number of times); the moulded bricks was then cured using open air curing for a period of three to five days before being moved to the oven; oven curing taking place for a period of forty-eight hours.

Casting of the control samples

The brick mould was stripped of all previous mortar and stains. The materials for the production of the bricks were batched in groups of ten for efficient curing practices. The mass of clay required was weighed using a top-head weighing balance and poured on the mixing platform. Using the clay-water ratio, the required mass of water was added to the clay until a homogeneous mixture of water and clay was formed. The brick mould was then assembled and its interior surface lubricated for ease of demolding. The mixture was then added into the mould being compacted by both trowel and gravity (i.e., lifting the mould to a height of 300mm and dropping the mould three times). The upper surface of the formed wet brick was levelled using the trowel and the brick-in-mould was cured using open air curing for a period of three to five days, before being demolded and placed on a cellophane platform of which it was then moved to the oven for drying.

Modification with RHA, CPA, PSA and Gypsum

This stage involved the modification of the standard mix of clay and water with RHA, CPA, PSA and Gypsum in order to check the stabilization properties of the produced bricks. The following four variations were carried out with ten bricks being produced per variation.

- Bricks produced using clay and water with RHA (which was ten percent the amount of clay weighed). The RHA was mixed homogeneously with the clay before water was added to form wet clay and transferred to the mould.

- Bricks produced using clay and water with CPA (which was ten percent the amount of clay weighed). The CPA was mixed homogeneously with the clay before water was added to form wet clay and transferred to the mould.
- Bricks produced using clay and water with PSA (which was ten percent the amount of clay weighed). The PSA was mixed homogeneously with the clay before water was added to form wet clay and transferred to the mould.
- Bricks produced using clay and water with Gypsum (which was ten percent the amount of clay weighed). The Gypsum was mixed homogeneously with the clay before water was added to form wet clay and transferred to the mould.

Casting of the Modified Samples

The bricks which were modified with the samples was cast in the manner such that for each ten bricks casted, fifty kilograms [50kg] of clay soil with the stabilizing materials which was weighed as (ten percent the amount of clay soil being five kilograms [5kg] of RHA, CPA, PSA and Gypsum) were weighed on the top-head weighing balance, then transferred to the mixing platform and mixed homogeneously with water added therein.

Mixing with the shovel and the brick moulds all lubricated, the homogeneous mixture of clay, water and the stabilizing agents was transferred to the assembled moulds compacting thus with a trowel and by the action of gravity (i.e., lifting the mould to a height of 300mm and dropping the mould three times). The upper surface of the formed wet brick was levelled and the brick-in-mould was cured using open air curing for a period of three to five days before demolding takes place and then placed on a cellophane platform of which it was then moved to the oven along with the control samples for drying.

Production Process

Batching

After considering variables such as bulking and shrinkage of the clay soil, batching was done by mass of the succeeding components, utilizing the specified density of the materials and a weighing balance to calculate the number of materials that would be needed for the construction of each set (ten bricks).

Production of the Ash from the Materials Rice Husk, Cassava Peel and Periwinkle Shell.

The rice husk, cassava peel and periwinkle shell were all obtained from Omu-Aran, Kwara state, Nigeria. In obtaining the ash from each constituent material, they were dried in an open space for a period of eight to ten hours. Then making use of open air burning; the rice husk and cassava peel were reduced to ash of which was later milled then properly sieved using the 150mm sieve, the periwinkle shell however was combusted hence minimizing the hardness of the shell to the barest minimum, before it underwent milling to achieve the powdery state of which was later sieved using the 150mm sieve.
(**P.S**: The Gypsum was obtained from Ilorin as there wasn't any need to convert to ash.).

Mixing

All mixing activities took place on the casting platform of the concrete shed. The clay was weighed then opened up before water was added and further mixing occurred. This was done with the control samples. However, for the modified samples, the clay being weighed then opened up, the ashes of each material as well as gypsum was mixed with each batch of clay soil provided; this was done homogeneously before water was added and further mixed.

Demolding

The brick mould used is the interlock size. After the mix was added into the mould (clay only, clay and RHA, clay and CPA, clay and PSA, clay and Gypsum) and sufficient compaction had taken place, the mould filled with the wet samples were cured in an open space for three to five days before the mould was flipped over. This was done with every sense of precision thus ensuring that the casted bricks do not crumble, revealing the formed bricks.

Curing

The curing process used were in two forms which are the open-air curing and the oven curing. Open-air curing occurred upon filling the samples into the mould and left to solidify for a period of three to five days of which when demolding occurred, retaining the shape of the casted bricks.
Oven curing followed, with all fifty bricks (ten bricks each for the samples clay, clay and RHA, clay and CPA, clay and PSA, clay and Gypsum)

moved to the oven in the concrete lab, this was done for a period of forty-eight hours with the oven being set to a temperature of 250^0C to 300^0C.

Testing

The following tests were carried out on the samples.

Compressive strength: This is the maximum compressive load a sample can bear; hence it is the capacity of a material or structure to withstand loads tending to reduce size. That is, it resists compression. Each clay brick was crushed using a 2000KN capacity compression machine. The brick was crushed on it as cast face. Flat metal surfaces wide enough to encompass the gross area of the brick were placed on the top and the bottom of the blocks thus facilitating uniform distribution of stress around the brick. Based on the gross area, compressive strength was calculated using the formula.

$$Compressive\ strength = \frac{P}{A}$$

$$where\ P\ is\ the\ as\ cast\ crushing\ load$$

$$and\ A\ is\ the\ area = L * B\ (L\ is\ length\ and\ B\ is\ breadth)$$

Sieve analysis: This is a procedure used to assess the particle size distribution of a granular material hence aiding in determining compliance with design, production, control requirement and verification specifications of engineering works. This test was carried out on the clay used for the production of the clay bricks as well as the substitute materials added to the clay. The test involved arranging a set of sieves with the *2mm* sieve being on top and the *0.075mm* sieve being at the bottom. The assembly then placed in a sieve shaker accurately clamped and turned on for ten minutes; after which the weight of clay retained on each sieve being measured and the particle size distribution graph drawn.

Plate 3.1: Sieve shaker and sieves (Source: indiamart.com)

Moisture content: The determination of soil moisture content is a common laboratory operation. ASTM has issued a standard for it, ASTM D-2216-90, which can be found in "ASTM Standards vol. 4.08," as well as AASHTO T-265, which can be found in "AASHTO Materials: Part II: Tests." This is a lab process for calculating the amount of water (Ww) in a quantity of soil in terms of its dry weight (Ws). It is calculated using the formula:

$$\frac{Weight\ of\ wet\ soil - Weight\ of\ dry\ soil}{Weight\ of\ wet\ soil} x100$$

Specific Gravity: The mass of a given volume of solids proportional to the mass of an equivalent volume of water at 4°C is the specific gravity of solid particles. The symbol "G" represents for this. There are a variety of techniques for identifying the specific gravity of solids, but we'll center here on density bottle method here. The formular is given by:

$$\frac{W_2 - W_1}{\left(W_{2-W_1}\right) - (W_3 - W_4)}$$

with,

- W_1 is the weight of empty bottle, W_2 is the weight of bottle and soil
- W_3 is the weight of bottle, soil and water, W_4 is the weight of bottle and water.

Plate 3.2: Density bottle (Source: indiamart.com)

Flexural strength: Also known as modulus of rupture or bend strength or transverse rupture strength is a material property defined as the stress in a material just before it yields in a flexure test. Each clay brick was crushed using a 2000KN capacity compression machine with its settings changed for flexural strength. The brick was crushed on its as cast face. Flat metal surfaces wide enough to encompass the gross area of the brick were placed on the top and the bottom of the blocks not excluding two 2mm diameter rods placed therein with the midpoint of the clay bricks resting on the 2mm rods. Based on the gross area, flexural strength was calculated using the formula.

- $Flexural\ strength\ or\ modulus\ of\ rupture\ f_b = \frac{PL}{BD^2}$
  $where\ P\ is\ the\ failure\ load,$
  $L\ is\ the\ effective\ length\ of\ clay\ brick,$
  $B\ is\ the\ breadth\ and\ D\ is\ the\ depth\ of\ brick.$

Plate 3.3: Flexural testing machine (Source: indiamart.com)

Mix Design

The material properties were:

- Clay brick dimension: 200*100*50mm.
- Density of clay: 1600kg/m^3
- Water-clay ratio: 0.75
- Clay-constituents ratio: 10:1

Table 3.1: Description of brick sets and their groupings

Brick code	Mass of Clay (kg)	Mass of CPA (kg)	Mass of PSA (kg)	Mass of RHA (kg)	Mass of GYPSUM (kg)	Mass of Water (kg)
A	50.00	0.00	0.00	0.00	0.00	37.50
B	50.00	5.00	0.00	0.00	0.00	37.50
C	50.00	0.00	5.00	0.00	0.00	37.50
D	50.00	0.00	0.00	5.00	0.00	37.50
E	50.00	0.00	0.00	0.00	5.00	37.50

RESULTS AND DISCUSSION

Sieve Analysis

A sieve analysis test was carried out on the clay provided for production purposed. This was done to reveal the particle size distribution of the clay and to ascertain its suitability for its intended use.

Mass of initial sample = 200.0g

Table 4.1: Results of sieve analysis for clay soil

S/N	Sieve No.	Sieve Size (mm)	Mass Retained (g)	% Retained	Cumulative % Retained	% Passing
1	10	2.000	23.500	11.750	11.750	88.250
2	18	1.180	30.500	15.250	27.000	73.000
3	30	0.600	39.500	19.750	46.750	53.250
4	40	0.425	24.000	12.000	58.750	41.250

5	50	0.300	10.000	5.000	63.750	36.250
6	70	0.212	16.000	8.000	71.750	28.250
7	100	0.150	15.000	7.500	79.250	20.750
8	200	0.075	10.000	5.000	82.250	17.750
		Pan	29.500	13.250	92.750	7.250
		Total	198.000			

i) Mass lost during sieve analysis = $\frac{Mass\ before\ sieving - Mass\ after\ sieving}{Mass\ before\ sieving} x\ 100$

$$= \frac{200 - 198}{200} x\ 100 = 1.00\%$$

ii) Soil Classification:

<u>USCS</u>

F_{200}= 17.750%

R_{200} = 82.250%

D_{10}=0.04mm

D_{30}= 0.23mm

D_{60} = 0.79mm

C_U (Coefficient of Uniformity) = D_{60}/D_{10}= 19.75

C_C (Coefficient of Curvature) = D_{30}^2/D_{10} x D_{60} =1.67

<u>AASHTO</u>

% Passing

Sieve No. 10 = 88.250%

Sieve No. 40 = 41.250%

Sieve No. 200 = 17.750%

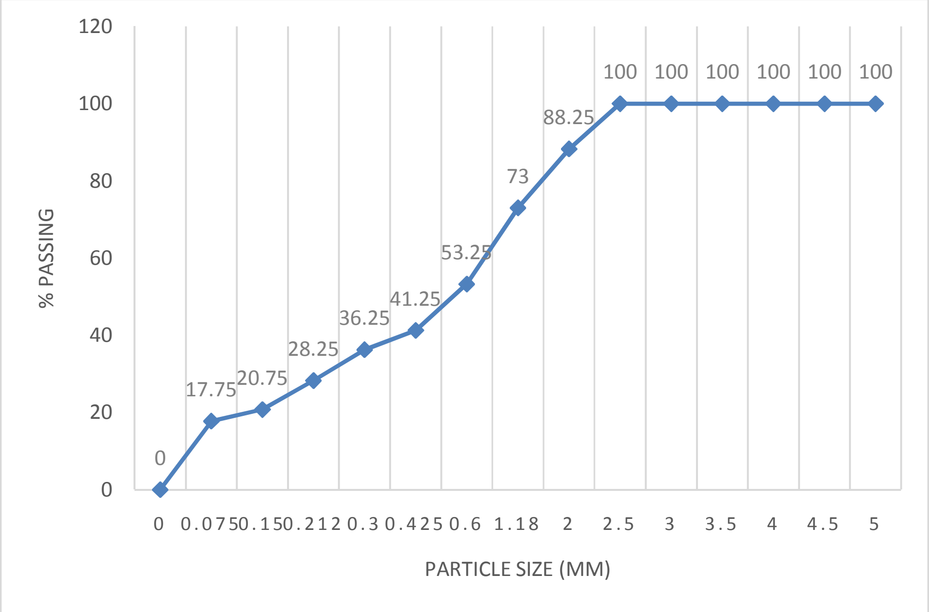

Figure 4.1: Particle size distribution for fine aggregate

The figure 4.1 shows the particle size distribution of the clay used for the production of the clay bricks. 88.25% of the sample passed through sieve no. 10, 41.25% of the sample passed sieve no. 40 and 17.75% passed through sieve no. 200. According to AASHTO (American association of state highway and transport officials) soil classification, the sample can be classified loosely as clay. 1% of the sample was lost during sieve analysis, which is acceptable due to the value being less than 2%. For the USCS (Unified soil classification system) based on the parameters acquired during the sieve analysis, the soil is better classified as "SC" which is "Clayey Sand".

Compressive Strength

The compressive strength of the brick samples was determined by dividing the loading at the failure by the net area of the as-cast face of the brick. Crushing occurred at a rate of 10N/mm using a "Controls" crushing machine. This was done after curing the bricks using the oven for seven days.

Table 4.2: Failure Load for each brick set under compressive loading (4 days)

Failure Load	Clay (KN)	Clay with CPA (KN)	Clay with PSA (KN)	Clay with RHA (KN)	Clay with Gypsum (KN)
F_1	23.00	16.00	27.00	30.00	28.00
F_2	35.00	24.00	34.00	29.00	23.00
F_3	17.00	26.00	17.00	22.00	36.00

Table 4.3: Compressive strength by reason of the failure loads for each sample.

Brick code	Days	Failure Load (KN)	Area (mm^2)	Compressive Strength (KN/mm^2)	Compressive Strength (N/mm^2)
A	7	23.00	20000.00	0.00115	1.15
	7	35.00	20000.00	0.00175	1.75
	7	17.00	20000.00	0.00085	0.85
B	7	16.00	20000.00	0.00080	0.80
	7	24.00	20000.00	0.00120	1.20
	7	26.00	20000.00	0.00130	1.30
C	7	27.00	20000.00	0.00135	1.35
	7	34.00	20000.00	0.00170	1.70
	7	17.00	20000.00	0.00085	0.85
D	7	30.00	20000.00	0.00150	1.50
	7	29.00	20000.00	0.00145	1.45
	7	22.00	20000.00	0.00110	1.10
E	7	28.00	20000.00	0.00140	1.40
	7	23.00	20000.00	0.00115	1.15
	7	36.00	20000.00	0.00180	1.80

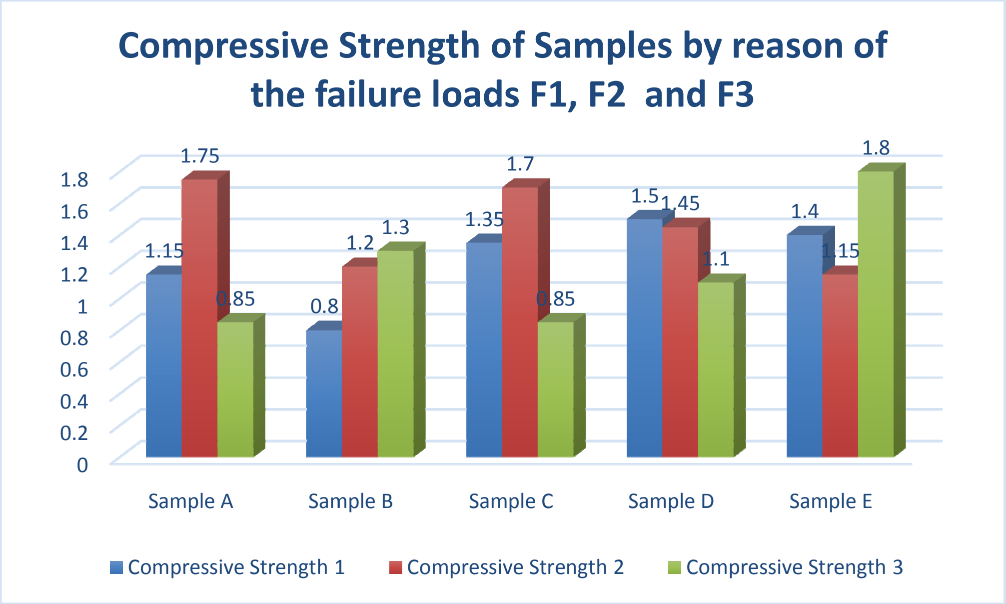

Figure 4.2: Compressive strength of samples by reason of failure loads.

From the graph of compressive strength by reason of failure load, it is observed that upon the first loading the sample D (clay with RHA) seemed to have the highest compressive strength, followed by sample E (clay with Gypsum) and sample C (clay with PSA) with sample B (clay with CPA) being the least compared to sample A (clay) itself. Upon the application of the second loading, it is observed that the sample C (clay with PSA) seemed to have the highest compressive strength, followed by sample D (clay with RHA) and sample B (clay with CPA) with sample E (clay with Gypsum) being the least compared to sample A (clay) itself. Upon the application of the final loading, it is observed that the sample E (clay with Gypsum) seemed to have the highest compressive strength, followed by sample B (clay with CPA) and sample D (clay with RHA) with sample C (clay with PSA) being the least compared to sample A (clay) itself. Thus, however due to its varied strength, we get an average value of the compressive strength for the above samples drawing out our conclusion thus.

Average of the failure loads, F_1, F_2 and F_3. Gives

i) $Clay = \frac{23+35+17}{3} = 25KN$

ii) $Clay\ with\ CPA = \frac{16+24+26}{3} = 22KN$

iii) $Clay\ with\ PSA = \frac{27+34+23}{3} = 28KN$

iv) $Clay\ with\ RHA = \frac{30+29+22}{3} = 27KN$

v) $Clay$ with Gypsum = $\frac{28+23+36}{3} = 29KN.$

Table 4.3: Average compressive strength by reason of the average failure loads for each sample.

Brick code	Days	Avg. Failure Load (KN)	Area (mm^2)	Avg. Compressive Strength (KN/mm^2)	Avg. Compressive Strength (N/mm^2)
A	7	25.00	20000.00	0.00125	1.25
B	7	22.00	20000.00	0.0011	1.11
C	7	28.00	20000.00	0.0014	1.40
D	7	27.00	20000.00	0.00135	1.35
E	7	29.00	20000.00	0.00145	1.45

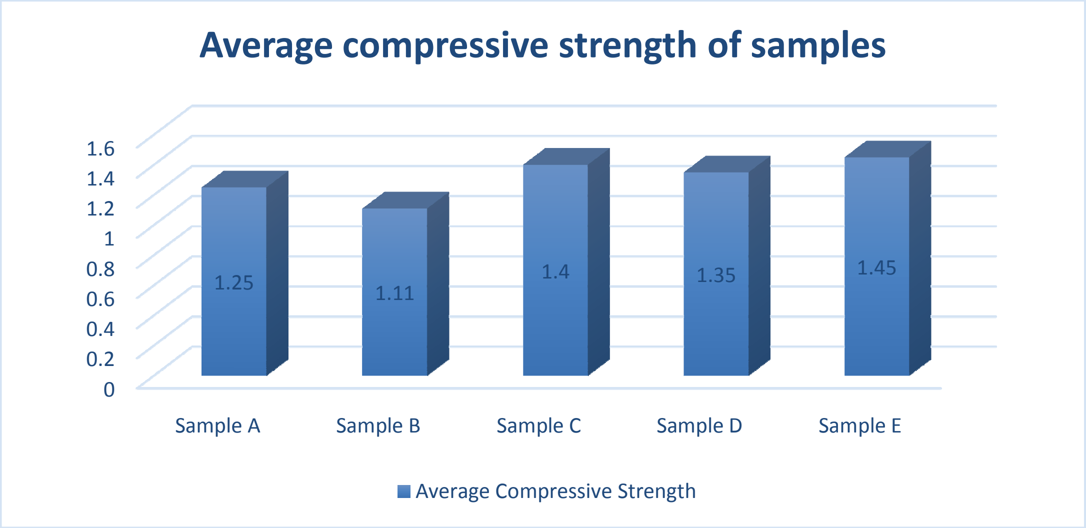

Figure 4.3: Average compressive strength of samples

From the graph above, upon getting the average of the samples, from the Table 4.3, it is observed that the compressive strength from ascending to descending order has sample E (Clay with Gypsum) as the highest, followed by the sample C (Clay with PSA), then sample D (Clay with RHA) with sample B (Clay with CPA) being the least compared to sample A (Clay).

Flexural Strength

The flexural strength of the brick samples was determined by dividing (the loading at failure multiplied by the length of the brick) by (the breadth and square of the depth of the as-cast face of the brick). Crushing occurred at a rate of 10N/mm using a "Controls" crushing machine. This was done after curing the bricks using the oven for seven days.

Table 4.4: Failure Load for each brick set under flexural loading (4 days)

Failure Load	Clay (KN)	Clay with CPA (KN)	Clay with PSA (KN)	Clay with RHA (KN)	Clay with Gypsum (KN)
F_1	2.00	2.00	2.00	2.00	2.00
F_2	1.00	1.00	2.00	1.00	1.00
F_3	1.00	2.00	2.00	2.00	1.00

Table 4.5: Flexural strength by reason of the failure loads for each sample.

Brick code	Days	Failure Load (KN)	Length (mm)	Breadth (mm)	Depth (mm)	Flexural Strength (KN/mm^2)	Flexural Strength (N/mm^2)
A	7	2.00	200.00	100.00	50.00	0.0016	1.60
	7	1.00	200.00	100.00	50.00	0.0008	0.8
	7	1.00	200.00	100.00	50.00	0.0008	0.8
B	7	2.00	200.00	100.00	50.00	0.0016	1.60
	7	1.00	200.00	100.00	50.00	0.0008	0.8
	7	2.00	200.00	100.00	50.00	0.0016	1.60
C	7	2.00	200.00	100.00	50.00	0.0016	1.60
	7	2.00	200.00	100.00	50.00	0.0016	1.60

	7	2.00	200.00	100.00	50.00	0.0016	1.60
D	7	2.00	200.00	100.00	50.00	0.0016	1.60
	7	1.00	200.00	100.00	50.00	0.0008	0.8
	7	2.00	200.00	100.00	50.00	0.0016	1.60
E	7	2.00	200.00	100.00	50.00	0.0016	1.60
	7	1.00	200.00	100.00	50.00	0.0008	0.8
	7	1.00	200.00	100.00	50.00	0.0008	0.8

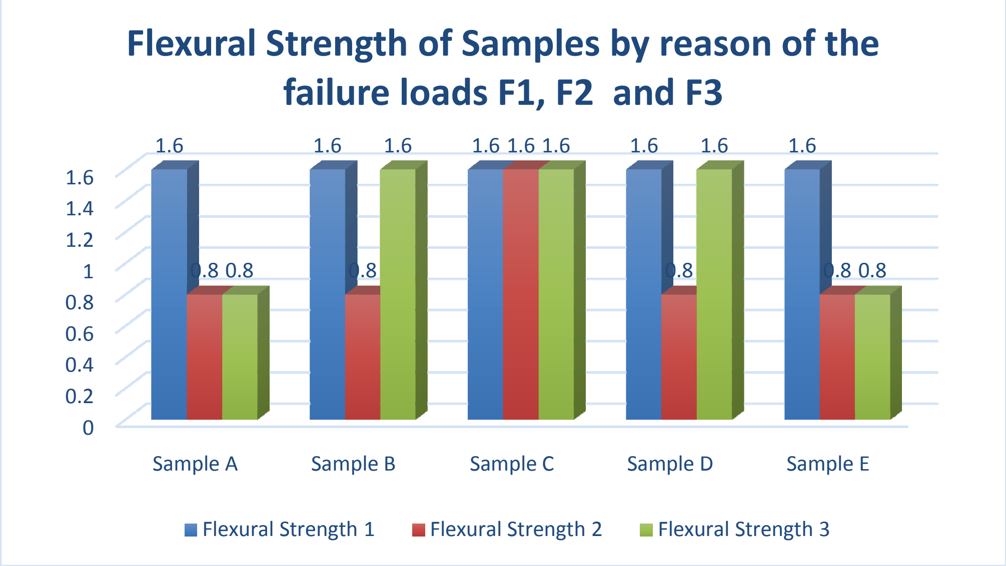

Figure 4.4: Flexural strength of samples by reason of failure loads.

From the graph of flexural strength by reason of failure load, it is observed that upon the first loading the sample D (clay with RHA),sample E (clay with Gypsum), sample C (clay with PSA) and sample B (clay with CPA) possess the same flexural strength compared to sample A (clay) itself. Upon the application of the second loading, it is observed that the sample C (clay with PSA) seemed to have the highest flexural strength, followed by sample D (clay with RHA), sample B (clay with CPA), sample E (clay with Gypsum) being the same compared to sample A (clay) itself. Upon the application of the final loading, it is observed that the sample B (clay with CPA), sample D (clay with RHA) and sample C (clay with PSA) possess the same flexural strength-highest with the sample E (clay with Gypsum)to be of low flexural strength compared to sample A (clay) itself. Thus, however due to its varied strength, we get an average value of the flexural strength for the above samples drawing out our conclusion thus.

Average of the failure loads, F_1, $F_2$and F_3. Gives

i) $Clay = \frac{2+1+1}{3} = 1.33KN$

ii) $Clay\ with\ CPA = \frac{2+1+2}{3} = 1.67KN$

iii) $Clay\ with\ PSA = \frac{2+2+2}{3} = 2.00KN$

iv) $Clay\ with\ RHA = \frac{2+1+2}{3} = 1.67KN$

v) $Clay$ with Gypsum = $\frac{2+1+1}{3} = 1.33KN.$

Table 4.6: Average flexural strength by reason of the failure loads for each sample.

Brick code	Days	Failure Load (KN)	Length (mm)	Breadth (mm)	Depth (mm)	Flexural Strength (KN/mm^2)	Flexural Strength (N/mm^2)
A	7	1.33	200.00	100.00	50.00	0.001064	1.064
B	7	1.67	200.00	100.00	50.00	0.001336	1.336
C	7	2.00	200.00	100.00	50.00	0.0016	1.6
D	7	1.67	200.00	100.00	50.00	0.001336	1.336
E	7	1.33	200.00	100.00	50.00	0.001064	1.064

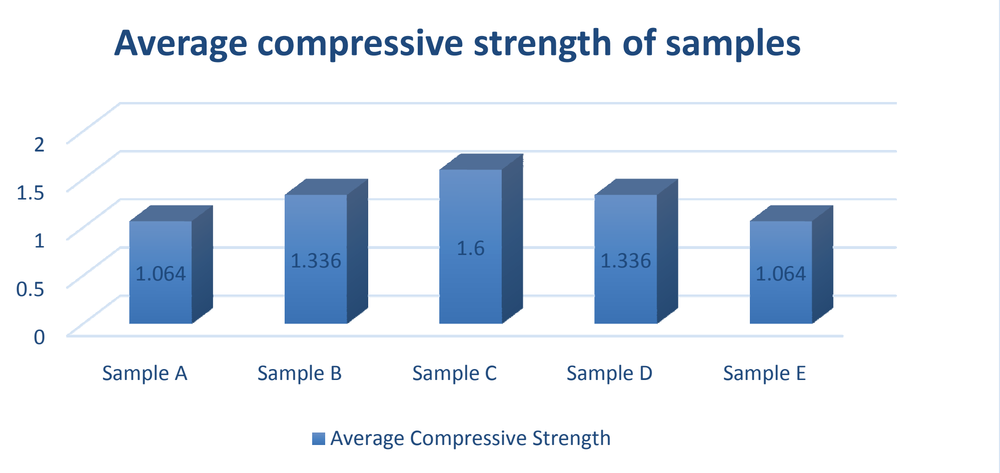

Figure 4.5: Average flexural strength of samples

From the graph above, upon getting the average of the samples, from the Table 4.3, it is observed that the flexural strength from ascending to descending order has sample C (Clay with PSA) followed by the sample D (Clay with RHA) and sample B (Clay with CPA) possessing the same value for flexural strength with sample E (Clay with Gypsum)being the least compared to sample A (Clay).

Moisture Content

The moisture content of the soil samples A, B, C, D and E was determined by obtaining the samples and weighing them (this was termed the weight of wet soil), thus enclosing them in the oven at a temperature of 1250 C and leaving for a period of twenty-four to forty-eight hours. Upon the completion of the twenty-four to forty-eight period, the oven obtained sample was weighed and using the moisture content formula, the moisture content was obtained.

Table 4.7: Moisture content of the samples A, B, C, D and E.

Samples	Weight of Can	Weight of Can and Soil (Wet)	Weight of Can and Soil (Dry)	Weight of Wet Soil (g)	Weight of Dry Soil (g)	Moisture Content (w, %)
A	21.00	51.00	46.40	30.00	25.40	15.33
B	21.00	51.00	46.80	30.00	25.80	14.00
C	22.00	52.00	47.90	30.00	25.90	13.67
D	21.00	51.00	46.50	30.00	25.50	15.00
E	21.00	51.00	47.10	30.00	26.10	13.00

Moisture content calculation gives using the formular $\frac{Weight\ of\ wet\ soil - Weight\ of\ dry\ soil}{Weight\ of\ wet\ soil} x100$

i) $Clay = \frac{30-25.4}{30} x100 = 15.33\%$

ii) $Clay\ with\ CPA = \frac{30-25.80}{30} x100 = 14.00\%$

iii) $Clay\ with\ PSA = \frac{30-25.90}{30} x100 = 13.67\%$

iv) $Clay\ with\ RHA = \frac{30-25.50}{30} x100 = 15.00\%$

v) $Clay$ with Gypsum = $\frac{30-26.10}{30} = 13.00\%.$

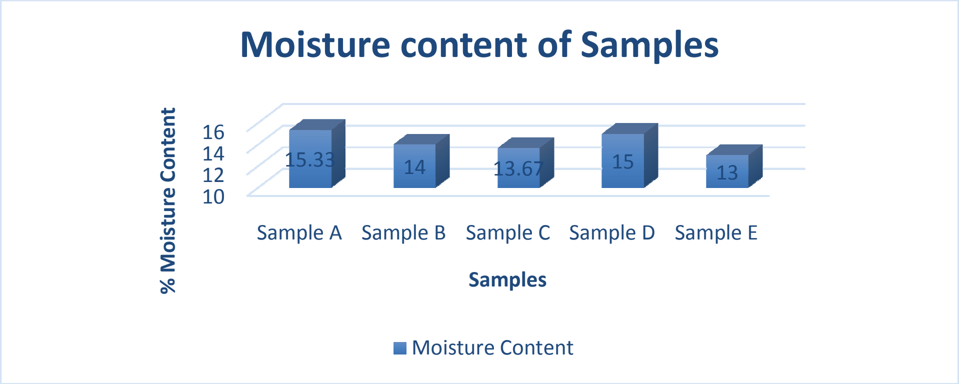

Figure 4.6: Moisture content of samples

From the graph above, compared to the moisture content of sample A (Clay), the sample D (Clay with RHA) is said to possess the highest moisture content, with sample B (Clay with CPA), sample C (Clay with

PSA) and sample E (Clay with Gypsum) following thereafter. This implies that the moisture content of clay mixed with RHA possess a lesser moisture content than Clay itself, of which clay mixed with CPA appears to be lesser, clay mixed with PSA following and clay mixed with Gypsum possess the lowest moisture content.

Specific Gravity

The specific gravity of the soil samples A, B, C, D and E was determined firstly by getting a density bottle, fully rinsed and weighing to get its weight, called W1. Of which the samples were put into the density bottle then weighed, called W2. Adding distilled water and shaking evenly, the mixture was weighed, called W3. Lastly, the mixture of each sample were poured out, with the density bottle rinsed properly and filling with distilled water and weighed, called W4. Using the formula for obtaining specific gravity by density bottle, the specific gravity for all samples were gotten.

Table 4.8: Specific content of the samples A, B, C, D and E.

Samples	Weight of Bottle, (W1,g)	Weight of Bottle and Soil (W_2,g)	Weight of Bottle and Soil and Water (W_3 ,g)	Weight of Bottle and Water (W_4,g)	Specific Gravity
A	20.00	40.00	84.00	73.00	2.22
B	20.00	50.00	88.00	73.00	2.00
C	20.00	50.00	81.00	73.00	1.36
D	20.00	40.00	76.00	73.00	1.18
E	20.00	51.00	84.00	73.00	1.55

Specific Gravity calculation gives using the formular, $\frac{W_2-W_1}{(W_2-w_1)-(W_3-W_4)}$

with,

- W_1 is the weight of empty bottle
- W_2 is the weight of bottle and soil
- W_3 is the weight of bottle, soil and water
- W_4 is the weight of bottle and water.

i) $Clay = \frac{40-20}{(40-20)-(84-73)} = 2.22$

ii) $$Clay\ with\ CPA = \frac{50-20}{(50-20)-(88-73)} = 2.00$$

iii) $$Clay\ with\ PSA = \frac{50-20}{(50-20)-(81-73)} = 1.36$$

iv) $$Clay\ with\ RHA = \frac{40-20}{(40-20)-(76-73)} = 1.18$$

v) $$Clay\ \text{with Gypsum} = \frac{51-20}{(51-20)-(84-73)} = 1.60.$$

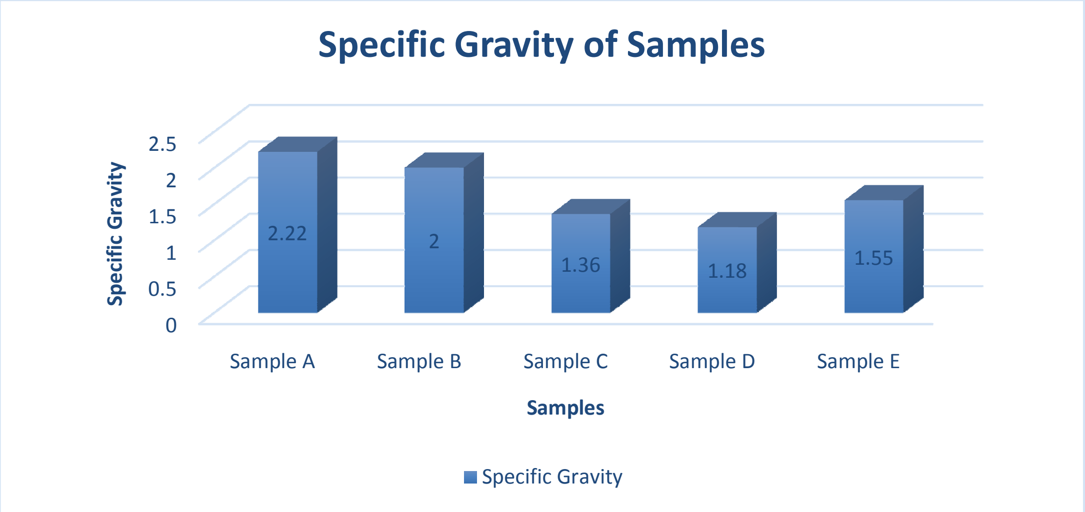

Figure 4.7: Specific gravity of samples

Relationship between compressive strength and flexural strength

Table 4.9: Average compressive strength to the average flexural strength of the samples A, B, C, D and E.

Samples	Avg. Compressive Strength (KN/mm^2)	Avg. Compressive Strength (N/mm^2)	Avg. Flexural Strength (KN/mm^2)	Avg. Flexural Strength (N/mm^2)
A	0.00125	1.25	0.001064	1.064
B	0.0011	1.11	0.001336	1.336
C	0.0014	1.40	0.0016	1.6
D	0.00135	1.35	0.001336	1.336
E	0.00145	1.45	0.001064	1.064

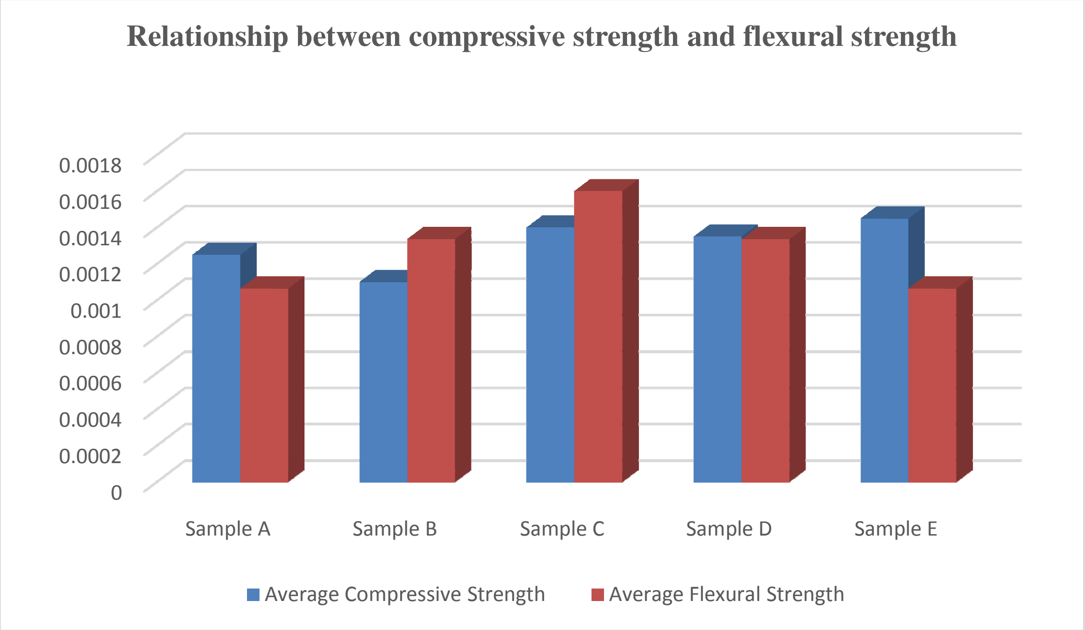

Figure 4.8: Compressive strength to flexural strength of samples

Relationship between compressive strength and moisture content

Table 4.10: Average compressive strength to moisture content of the samples A, B, C, D and E.

Samples	Avg. Compressive Strength (KN/mm^2)	Avg. Compressive Strength (N/mm^2)	Moisture Content (w, %)
A	0.00125	1.25	15.33
B	0.0011	1.11	14.00
C	0.0014	1.40	13.67
D	0.00135	1.35	15.00
E	0.00145	1.45	13.00

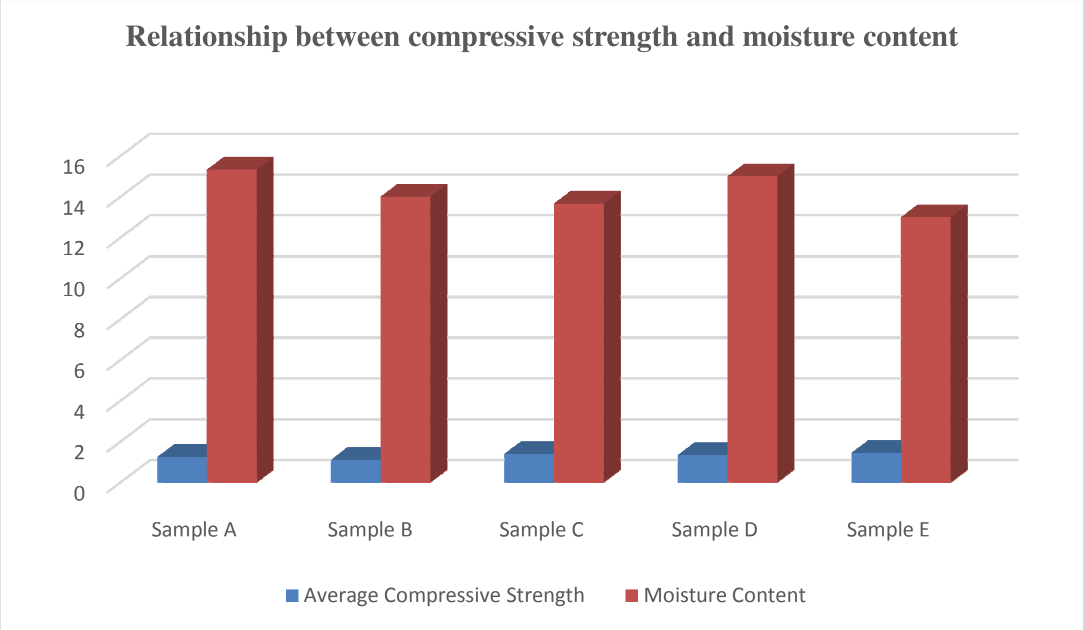

Figure 4.9: Compressive strength to moisture content of samples

Relationship between compressive strength and specific gravity

Table 4.11: Average compressive strength to specific gravity of the samples
A, B, C, D and E.

Samples	Avg. Compressive Strength (KN/mm²)	Avg. Compressive Strength (N/mm²)	Specific Gravity
A	0.00125	1.25	2.22
B	0.0011	1.11	2.00
C	0.0014	1.40	1.36
D	0.00135	1.35	1.18
E	0.00145	1.45	1.55

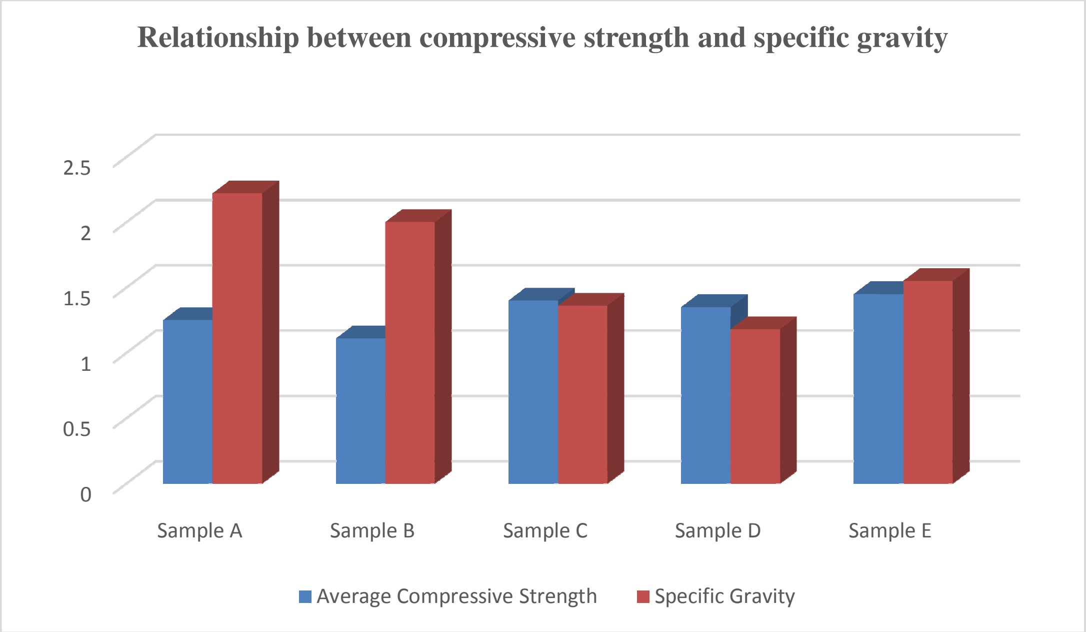

Figure 4.10: Compressive strength to specific gravity of samples

Relationship between flexural strength and moisture content

Table 4.12: Average flexural strength to moisture content of the samples A, B, C, D and E.

Samples	Avg. Flexural Strength (KN/mm²)	Avg. Flexural Strength (N/mm²)	Moisture Content (w, %)
A	0.001064	1.064	15.33
B	0.001336	1.336	14.00
C	0.0016	1.6	13.67
D	0.001336	1.336	15.00
E	0.001064	1.064	13.00

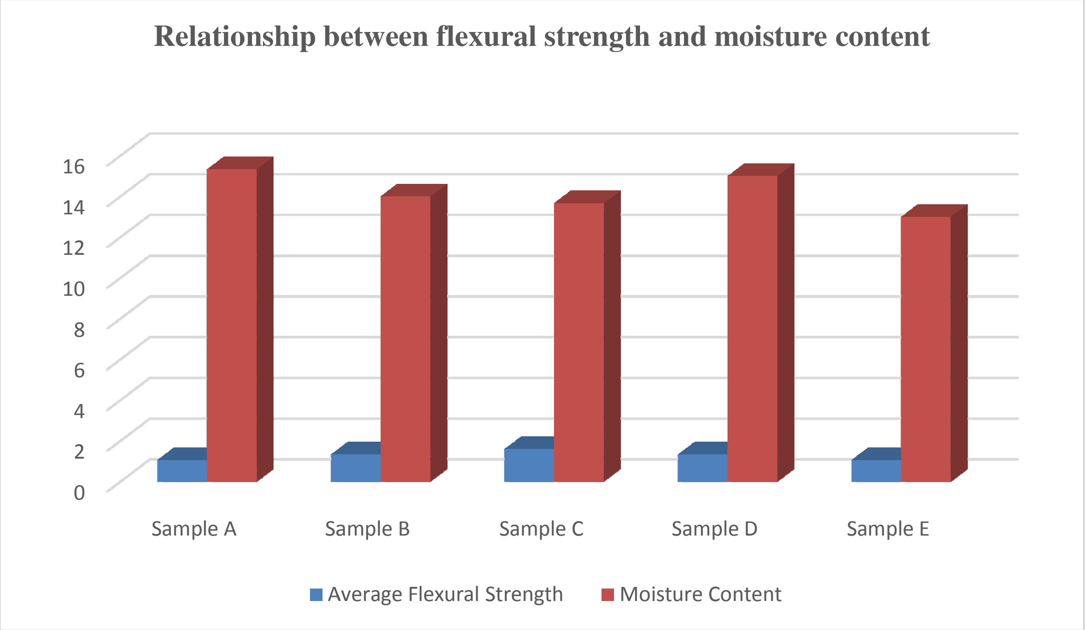

Figure 4.11: flexural strength to moisture content of samples

Relationship between flexural strength and specific gravity

Table 4.13: Average flexural strength to specific gravity of the samples A, B, C, D and E.

Samples	Avg. Flexural Strength (KN/mm^2)	Avg. Flexural Strength (N/mm^2)	Specific Gravity
A	0.001064	1.064	2.22
B	0.001336	1.336	2.00
C	0.0016	1.6	1.36
D	0.001336	1.336	1.18
E	0.001064	1.064	1.55

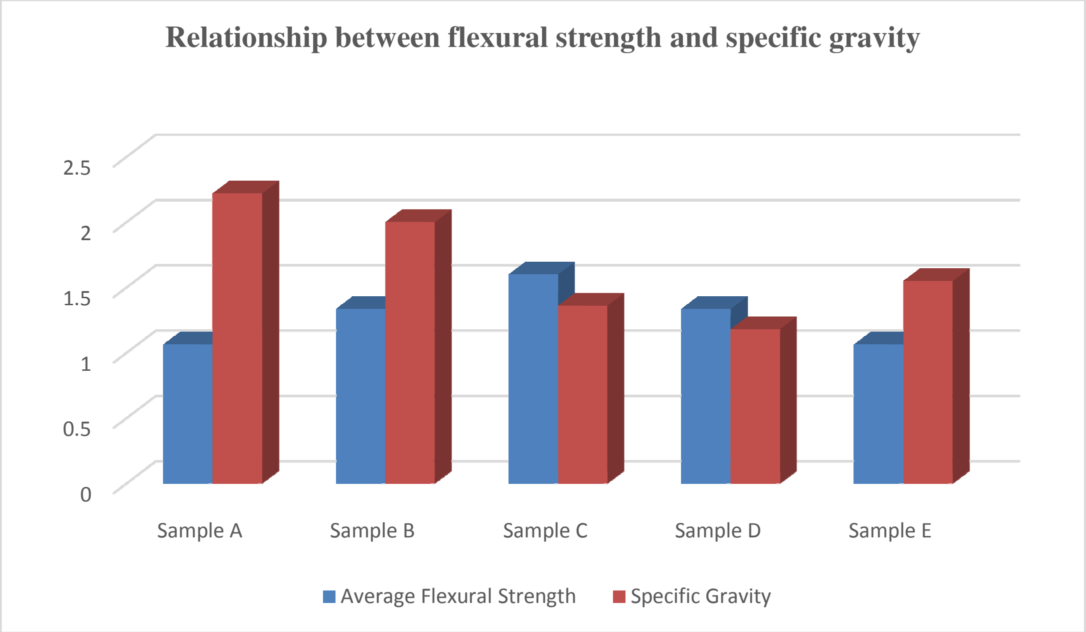

Figure 4.12: flexural strength to specific gravity of samples

Relationship between moisture content and specific gravity

Table 4.14: Moisture content to specific gravity of the samples A, B, C, D and E.

Samples	Moisture Content (w, %)	Specific Gravity
A	15.33	2.22
B	14.00	2.00
C	13.67	1.36
D	15.00	1.18
E	13.00	1.55

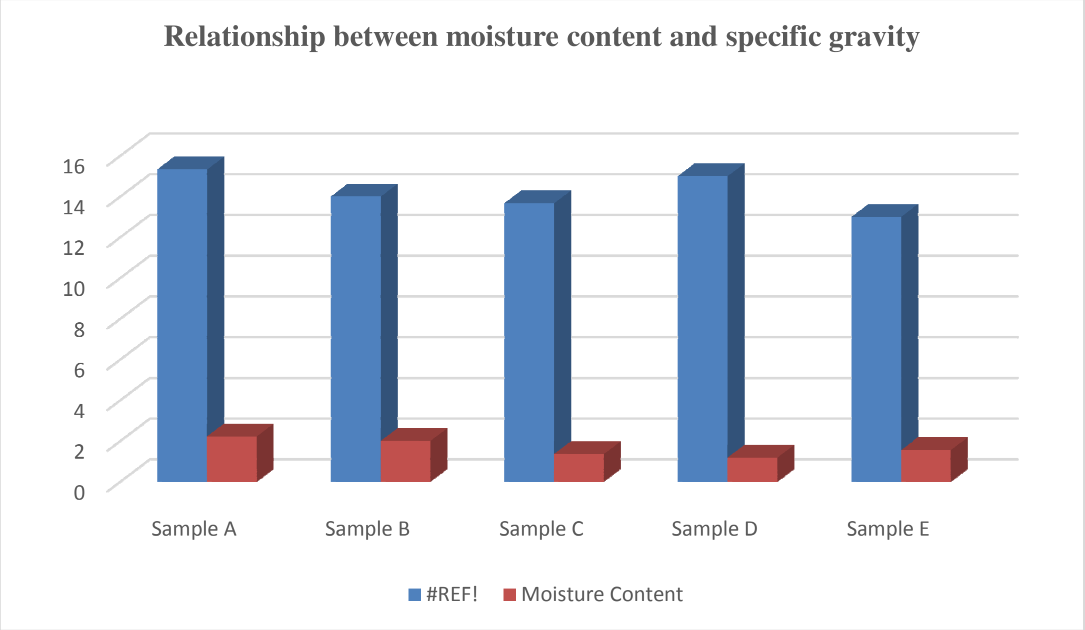

Figure 4.13: moisture content to specific gravity of samples

.Conclusion

This project was carried out to determine the compressive strength, flexural strength and other properties of an ordinary clay brick (unstablized) as well as determine the compressive strength, flexural strength and other properties of a clay brick when the clay is mixed with each of the materials above (stabilized). Comparing its properties to the ordinary clay brick. From the acquired results, it can be concluded that in terms of compressive strength, compared to the unstablized clay's compressive strength with a value of (1.25N/mm^2).

- Clay stabilized with Gypsum possessed the highest compressive strength with a value of (1.45N/mm^2).
- Clay stabilized with PSA (Periwinkle shell ash) possessed closer compressive strength to Gypsum with a value of (1.40N/mm^2).
- Clay stabilized with RHA (Rice husk ash) possessed relative compressive strength with a value of (1.35N/mm^2).
- Clay stabilized with CPA (Cassava peel ash) possessed the lowest compressive strength with a value of (1.11N/mm^2) lower than the compressive strength of the unstablized clay.

From the acquired results, it can be concluded that in terms of flexural strength, compared to the unstablized clay's flexural strength with a value of (1.064N/mm^2).

- Clay stabilized with PSA (Periwinkle shell ash) possessed the highest flexural strength with a value of (1.60N/mm^2).
- Clay stabilized with RHA (Rice husk ash) and clay stabilized with CPA (Cassava peel ash) possessed the same flexural strength to PSA with a value of (1.336N/mm^2).
- Clay stabilized with Gypsum possessed the same flexural strength as that of clay with a value of (1.064N/mm^2).

From the acquired results, it can be concluded that in terms of moisture content, compared to the unstablized clay's moisture content with a value of (15.33%).

- Clay stabilized with RHA (Rice husk ash) possessed a moisture content closest to the moisture content of unstablized clay with a value of (15.00%).
- Clay stabilized with CPA (Cassava peel ash) possessed a moisture content closest to that of the clay stabilized with RHA with a value of (14.00%).
- Clay stabilized with PSA (Periwinkle shell ash) possessed relatively low moisture content with a value of (13.67%).
- Clay stabilized with Gypsum possessed the lowest moisture content with a value of (13.00%).

From the acquired results, it can be concluded that in terms of specific gravity, compared to the unstablized clay's specific gravity with a value of (2.22).

- Clay stabilized with CPA (Cassava peel ash) possessed specific gravity closest to that of the unstablized clay with a value of (2.00).
- Clay stabilized with Gypsum possessed specific gravity closest to that of the clay stabilized with CPA with a value of (1.55).
- Clay stabilized with PSA (Periwinkle shell ash) possessed specific gravity with a value of (1.36).
- Clay stabilized with RHA (Rice hush ash) possessed the lowest specific gravity with a value of (1.18).

It is therefore deduced in terms of serviceability and durability with reference to the compressive strength, flexural strength, moisture content and specific gravity. Clay stabilized with Gypsum is considered the best option for building based on the highest compressive strength, low moisture content and specific gravity, excluding the properties of flexural strength. Of which in its unavailability, clay stabilized with PSA can be recommended based on the above properties, compressive strength closer to gypsum and a relatively higher moisture content to gypsum. Clay stabilized with RHA and CPA are considered as not viable options due to their relatively low compressive strength values and high moisture content though they possess the same flexural strength closer to the highest flexural strength of PSA and clay stabilized with CPA having specific gravity closer to that of clay.

Clay stabilized with PSA is therefore the recommended option being viable in terms of a balance in the compressive strength properties, flexural strength properties, moisture content properties and specific gravity properties.

RECOMMENDATION

The following recommendations are presented for further research.

i) To investigate the effect of stabilization of clay with other stabilization methods listed below.

- Clay soil-cement stabilization,
- calcium chloride stabilization,
- lime stabilization (mixture of lime-portland and lime-bituminous stabilization),
- bituminous clay soil stabilization.

ii) Investigation to discover whether the improvement in soil properties brought about by the addition of the above stabilization method is permanent when the material is subjected to weathering.

iii) Economic study of feasibility of the above stabilization method.

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