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Effect of Local Additives on Engineering Properties of Okelele-Ilorin (Nigeria) Clay

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Abstract: *Most additives usually used in clay are imported to the country, Nigeria. Meanwhile there are several agricultural bi-products and other materials which are regarded as wastes in the country that are underutilized which could be used as additives to alter/improve clay properties. Previous works had revealed that some properties of many Nigerian clays need to be improved on to be found suitable for many engineering applications. This paper aims at investigating the effects of the locally available additives on properties of a selected clay sample. The clay sample obtained from a popular Okelele clay deposit at Ilorin, Kwara state, Nigeria was purified through the process of picking/sorting, crushing/grinding and sizing (sieving). The sieved clay sample was thoroughly mixed with five (5) different locally available additives (Palm kernel nutshell, Anthill, rice-husk ash, Groug) and Portland cement separately at the ratio of 1:14 by weight. The mixtures were moulded into rectangular shaped brick of 50mm x 50mm x 50mm diameter. The moulded bricks were fired at the temperature of 1200^{0}C, which were subjected to series of laboratory tests using British Standard (BS) American Standard of Testing of Materials (ASTM). However, the result revealed that the additive has significant effect on the properties of the clay. The result of this study also revealed that the additives possess the ability to enhance the strengths of the clay, its mouldness and prevent its cracking and rupture during firing. As such, these additives are suitable as replacement for Portland cement (as additive) in clay material for engineering applications. The effects of the additives on the strength of the clay at yield and at failure are geometrically in order arrangement of groug, anthill, palm kernel nutshell and rice husk better than Portland cement as additive to clay.*
Key words: *Clay, Additives, Engineering Properties, Bricks, Okelele*

I. Introduction

Clay is an important material for engineering works. Ii is a traditional material commonly used in construction industries, such as in the manufacturing of clay bricks, pipes, ceramic tiles, and constructional devices. Nigeria is highly blessed with this resource and has a reasonable supply naturally [1]. Some of Nigerian clays need to be improved on to be found suitable for many engineering applications [2,3,4].

Clay is the finest and most active portion of the soil material, which is generally characterized by high to very dry strength [4]. The clays in different varieties are laid down at different geological periods, ranging from soft to much relatively harder shales, which are used in brick industries. Brick is one of the oldest building materials. Clay must have plasticity when mixed with water so that it can be moulded or shaped. It must have sufficient tensile strength to keep after forming. Clay properties must fuse together when subjected to sufficiently high temperatures.

The plasticity of clay, most especially when wet is a characteristic that makes possible the use of clay for numerous industrial, domestic and commercial activities, such as in pottery earthen ware, cooking ware, insulators, oil industries for bleaching, filtration, manufacturing refractories, pharmaceutical, paint, rubber, plastic, fertilizers, textiles, plumbing fixtures, tiles, bricks, stoves, insecticides, etc. Though, appropriate use of clay depends on its properties, composition, shrinkage, plasticity, feasibility, among others.

Okelele in Ilorin East Local Government Area of Kwara State, Nigeria is the most populous area in the state that is well known for good pottery making of international standard, little of local ceramics production and experts in local clay house construction. Pottery making through the use of available clay has made Ilorin to be a tourist attractive centre [5]. The clay products**,** most especially from Kankatu area in Okelele are used as special gifts to tourists. This trade (pottery making) contributes immensely to the economic development of the town.

This clay is found to crack or fail when subjected to high stress/load [1]. It is very essential to investigate the suitability and possible means of enhancing the clay properties for other reasonable applications, which is the major aim of this paper. It is believed that if the quality of the clay is improved on, it could be found more useful for essential engineering activities which would be a good channel towards provision of more jobs and enhances the economic self-reliance of the people in the area, and boost the income of Kwara State in particular and Nigeria in general.

The capacity of a material to withstand a static load can be determined through torsional or compressional test. The load capacity of constructional materials in either tension or compression and ability to withstand limited deformation without fracture is almost related the importance of such materials [6]. This ability or capacity is usually assessed through the test for some properties like modulus of elasticity, yield or proof stress, tensile strength and percentage elongation, among others. In addition to size, compressive strength is the basic requirement of concrete blocks, except non load-bearing blocks, which are required to comply with the transverse breaking strength test of handling.

Engineers are primarily concerned with mechanical behaviour of materials [6,7], in the case of clay, as the compressional strength is the most especially the only mechanical property used in brick specification.
Additives are non-mettallic materials that possess chemical and physical properties applicable for structure, which are readily available, and relatively cheap [1]. The use of additives to enhance some physical and mechanical properties of clay, such as durability, workability, collapsibility, surface finish or strength is a common practice. Admixture (additive), such as Portland cement or aggregate is used in clay to modify its properties in order to speed or retard setting hardening, workability, segregation, hardness, ductility, strength and other mechanical properties. It facilitates the block manufacturing processes or to import certain special properties to the finished blocks. It is also sometimes to extend the product range. Literatures have reported that the introduction of additives into clay has effects on the clay properties [2,3,8]. For most construction purposes a standard type of Portland cement is used. This material is rarely cost and at times scarce in the market, since raw materials used in the production are imported into the country, Nigeria. It is essential to look inward for alternative materials, which are readily available, affordable and more effectives in terms of strength, durability, workability, collapsibility, and surface finish.

Shuaib-Babata and Abdulqadir expressed the need to improve the engineering properties of clay to meet many engineering properties [1]. The significant of the application of additives to improve the qualities of clay for several engineering applications were also made known by earlier Researchers [3,8]. Adequate consideration of economic cost of additive to be used for improvement of the properties of clay is equally importance as the need to improve the clay engineering properties [9]. Most of the selected local additives for this study are in excess, which turn to be waste and may serve as nuisance to the environment if not well controlled.

This work aims at investigating the suitability of some available local additives, which are cheap and readily available, on clay for constructional and structural applications.

II. Experimental Methods

2.1 Materials

The basic raw material for this research work is clay. The clay samples were obtained from Okelele clay deposit within Ilorin (Nigeria) metropolis. The locally available agricultural wastes, such as Rice-husk, palm kernel shell and sawdust were collected as wastes within the town from the process of local rice, oil or butter production and sawmill. The Anti-hill and Groug were obtained on a farm site while they were also regarded as wastes. Portland cement was obtained from a commercial market in the town. All these materials were used as additives in the study work.

2.1.1 Processing of Materials

The clay sample was dug from the deposit, crushed and grinded. Sorting and pickling of unwanted materials was also carried out. Subsequently, the sieving of the clay was done with sieve opening 600µm (ASTM standard sieve number 30) in line with the Mital and Shukla guidelines [4]. The oversized clay particles were re-crushed and later re-sieved. The powdered clay was thoroughly mixed with water to the right plastic condition. The particle sizes of the selected additives were also obtained by crushing or grinding the materials into powder form and made to pass through a sieve opening of 250µm in line with the practice of Samuel and Adeyemi [3].

2.2 Determination of chemical composition of the materials

The clay sample was prepared as pure clay from sieved clay. The chemical constituents of the clay were determined using Atomic Absorption Spectrometer (ASS) at the Federal Institute of Industrial Research Organisation (FIIRO), Oshodi, Lagos, Nigeria.

2.3 Brick preparation

The mixing of individual additive with the dried-sieved clay sample was made in ratio of 1:14 by weight separately. The choice of the mixing ratio was in line with the earlier work of Adeyemi and Samuel [3]. The mixture was thoroughly mixed and water was added until homogenous mixture and adequate plasticity were achieved. It is believed that incorrect mixing, shaping, firing and undesirable chemical compositions are the major cause of defects in clay products [14]. The homogenous mixture of the materials was moulded into rectangular shape brick, size 50mm x 50mm x 50mm with the use of wooden block mould. The bricks were left on the laboratory to air-dry slowly for two weeks at room temperature for proper drying to avoid cracking during firing. The bricks were then pre-heated in an oven for an hour at initial temperature of 37^{o}C to final temperature of 350^{o}C to prevent sudden breakage. The brick samples were then fired in an electric resistance furnace up to firing temperature of 1200^{o}C. The mechanical testing of the compositions (additive/clay mixes) was carried out to investigate the effect of individual selected additives on some properties of the clay to elicit its suitability for foundry and ceramic industries use.

III. Determination Of The Clay Properties

3.1 Grain size distribution test

The sieve analysis of the samples was carried out using BS 1377 (1975) guideline [10]. 5.0 kg and 500kg weight of naturally dried sample of the additives (each) and the clay sample respectively were individually taking unto a set of electrical sieve shaker of sieves with different sizes. The shaker was allowed to vibrate for 15 minutes. The residues on each sieve were removed and weighed. The sieve sizes were recorded and classified according to the mesh numbers as presented in tables 2 and 3.

3.2 Mechanical Testing

Six (6) samples of moulded additive clays (bricks) each were selected for mechanical testing using ASTMguidelines [11]. The specimens (bricks) were subjected to compressional load using computerized universal testing machine to determine the stress and strain of the brick at various stages, ductility, and toughness.

IV. Discussion Of Results

4.1 Chemical constituents of the clay sample

In table 1, the elemental chemical compositions of the clay sample are shown. The major constituents of specimens are silica and alumina. The silica content in the clay is greater than 50%, while the alumina content is lesser than 30% and iron oxide is 1%. Other substances such as oxides of sodium, titanium, and calcium are in small proportions. The result shows that the clay sample belongs to the family of aluminosilicate and semi-acid refractory since the alumina value falls within the classification [12]. The value of the clay sample's loss of ignition is also within the recommended range of 12-15% for kaolinitic clay [13].

Table 1: Elemental chemical composition of Okelele clay sample (Weight Percentage

Composition [Weight Percent (%)]								
SiO_2	**Al_2O_3**	**TiO_2**	**Fe_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**L.O.I**
53.0	**29.8**	**1.19**	**1.0**	**0.3**	**0.2**	**0.25**	**2.1**	**12.1**

Tables 2 and 3 show the sieve analysis (particle distributions) of the clay sample and the various additives used. According to the American Association of State Highway and Transportation Officials (AASHTO), Soil classification through sieve analysis plays the particle size distribution curve and determines the uniformity coefficient of the soil [15].The result shows the clay content of Okelele clay sample to be 64% and belongs to group of silt-clay materials since the value is more than 35% (passing no. 200 sieve)

Table 2: Sieve Analysis of the clay

S/N	Sieve	Particle Size (mm)	Mass Retained (g)	Percentage Retained (%)	% Finer (Passing)
1	9.5mm	9.5	0	0	100
2	4.75mm	4.75	0	0	100
3	2.36mm	2.36	0.7	0.1	99.9
4	1.18mm	1.18	6.4	1.3	98.6
5	600µ	0.600	10.3	2.1	96.5
6	300µ	0.300	32.8	6.6	89.9
7	150µ	0.150	57.2	11.4	78.5
8	75µ	0.075	72.5	14.5	64.0

Table 3: Sieve Analysis of local Additives

S/N	SIEVE SIZE	MASS RETAINED				
		ANTHILL (g)	PALM KERNEL SHELL (g)	RISK HUSK (g)	SHEAR BUTTER SHELL (g)	GROUG (g)
1	2.00 mm	-	3.2	-	1.0	-
2	1.70 mm	-	5.5	-	1.1	-
3	1.00 mm	-	60.4	0.8	3.3	6.0
4	710 µm	-	45.5	6.1	6.0	30.0
5	355 µm	36.7	53.8	91.5	60.0	50.0
6	250 µm	50.5	20.1	51.8	43.6	51.0
7	150 µm	37.6	8.7	35.8	20.0	38.6
8	106µm	38.5	3.6	12.8	12.0	10.4
9	75 µm	16.1	0.8	1.2	10.0	3.2
10	53 µm	20.6	-	-	20.8	11.8
	Last pan	-	-	-	22.2	-

4.2 Water Absorption

Observation during the processing and firing of the materials showed that palm kernel nutshell, groug and Anthill (unlike Portland cement) did not easily absorb water from clay which enhanced its mouldness. The refractory products from the mixture of anthill with clay and groug with clay were soft and the water absorption rate was lower in the two cases. This also reflected in the result presented in table 4 with brick from anthill with clay and groug with clay having water absorption value of 9% and 8% respectively.

It was hard to achieve homogeneous mixture with Portland cement and clay at the same mixing ratio like other additives. The portland/clay mixture dried rapidly and not easy to mould. High pressure was required to withdraw the product from the die.

During the process of firing, all the bricks irrespective of their constituents exhibited homogeneous characteristics during the first one-hour of firing (pre-firing period). The bricks turned blackish at the pre-firing period. Subsequently, the change in the colours of the brick samples differed as stated in table 4

Table 4: Resulted colours of brick samples after pre-firing period

S/N	SAMPLES	Brick Colour at cold stage	Brick Colour after after firing process	Status of brick after firing
1	Palm kernel nutshell /clay brick	Change colour to whittish during drying	Reddish-black	No cracking
2	Anthill /clay brick	No colour change	Brownish colour	No cracking
3	Groug /clay brick	Brownish	Brownish-red	No cracking
4	Portland cement/clay brick	Whittish	Whittish	Cracked bricks

4.3 Shrinkage

Table 5 also shows some of the properties of the clay sample. The essential brick properties like water absorption, apparent porosity and shrinkage are indicated in the result. It is revealed through the result that the clay with Portland cement has the highest shrinkage percentage after firing, while Anthill-clay brick has the minimum shrinkage effect. This implies that the tendency of Portland cement to remove moisture from the specimen is more pronounced.

Table 5: Some of the Properties of the bricks

Samples	Water Absorption (%)	Apparent Porosity (%)	Dried Shrinkage (%)	Fired Shrinkage (%)	Total Shrinkage (%)
Palm kernel nutshell /clay brick	15.0	29.6	2.2	1.6	3.7
Anthill /clay brick	9.0	23.3	3.3	0.4	2.7
Groug/clay brick	8.0	26.1	4.0	0.6	4.5
Rice husk /clay brick	17.0	18.0	5.2	25.9	31.6
Portland cement/clay brick	15.0	24.4	2.4	7.7	10.2

4.3 Mechanical properties of the samples

Mechanical properties of materials, such as strength, toughness and young modulus are important in determining the performance of material while in service [6].

4.3.1. Compressive strength

The results of the compressional test are presented in table 6. The samples compressive strengths at yield and at point of failure are indicated. The strengths of the clay sample increased appreciably as result of addition of additives. The result shows groug, anthill, palm kernel nutshell and rice husk in the order of arrangement to be better than Portland cement as additive to clay. These additives also prevent clay cracking and rupture during firing as it occurred in the case of Portland cement in clay.

Table 6: Some Mechanical Properties of the clay products (Bricks)

S/N	SAMPLES	Yield stress (N/mm^2)	Breaking stress (N/mm^2)	Toughness (Nm)	Young Modulus (N/mm^2)
1	Pure clay	0.5	1.83	0.56	65.75
2	Palm kernel nutshell /clay brick	4.8	4.61	4.72	49.15
3	Anthill /clay brick	5.2	4.13	4.62	59.10
4	Groug /clay brick	6.5	5.35	4.39	43.74
5	Rice-husk /clay brick	3.7	4.12	4.83	60.03
6`	Portland cement/clay brick	3.5	3.82	1.93	34.97

4.3.2 Toughness and young modulus

The presence of all the local additives in the clay sample appreciably improved the toughness of the clay. The effectiveness of the local additives on the toughness of the clay falls within the same range (4.39 - 4.83Nm), which are more pronounced than the effect of Portland cement on the clay sample with the value of 1.93Nm. Apparently, the value of the clay young modulus is also negatively affected by all the additives, including Portland cement. Though, with lesser effect from the Portland cement.

Clay products (such as tiles, bricks) from clay particles with appreciable strength and toughness are likely to perform better in service. The studied local additives could be used for manufacturing in the production of structural materials like tiles, ceramics, cooking pots, bricks and other engineering materials. This study revealed that the locally available additives studied are found suitable as replacement for Portland cement (as additive) in clay for better performance.

V. Conclusion and Recommendation

5.1 Conclusion

From the study, the studied locally available additives (groug, anthill, rice husk and palm kernel shell) are found suitable as replacement for Portland cement (as additive) in clay for better performance. Unlike Portland cement in clay, these additives enhance the clay mouldness and prevent its cracking and rupture during firing. The strengths of the clay sample can also be appreciably improved on as result of addition of any of the studied locally additives. The effects of the additives on the strength of the clay at yield and at failure are geometrically in order arrangement of groug, anthill, palm kernel nutshell and rice husk better than Portland cement as additive to clay. The clay with Portland cement has the highest shrinkage percentage after firing, which responsible for cracking and rupture during clay firing, while Anthill-clay brick has the minimum shrinkage effect.

5.2 Recommendation

The mixture of the clay with any of the local additives, most especially anthill and groug is recommended for any engineering application where appreciable compressive strength (not more than $6.6N/mm^2$) and toughness (4.62Nm) are required, such as in the production of tiles, ceramics, and other constructional/structural applications.

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