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Physical Properties of Kaolin Used In Soap Production In Nigeria

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ABSTRACT

Kaolin has been identified as a very important group of clay mineral, which is copiously utilized as an industrial mineral commodity. The various physical attributes of kaolin mineral have made it useful in various ways industrially and these include paints, ceramics, rubber, paper, petroleum and glass industries. Kaolin is often used in soap production as a filler, which facilitates the structure and riser attribute of the soap. In this research, nine samples were collected from three different companies in Aba (South-Eastern Nigeria). The samples were analyzed to determine their suitability for soap production. Their physical properties such as particle size, moisture content, shrinkage, grit and viscosity were evaluated. The results show that all samples were fine and ranges from well-graded to uniformly-graded kaolin samples, with low moisture content (0.5% to 1.9%), low shrinkage (4.3% to 11.4%), low grit (0.4% to 3%) and high efflux time (37 secs to 58 secs).

KEYWORD: kaolin; particle size; moisture content; shrinkage; grit; efflux time

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I. INTRODUCTION

Kaolin is the most common mineral of a group of hydrous aluminium silicate, which result from the breaking of aluminium rich silicate rock, such as feldspar and nephalin syenite, either through weathering or hydrothermal activity. Kaolin when pure corresponds to the formula, $Al_2Si_2O_5(OH)_4$, and occurs in white clay-like masses. Impurities may cause various colours or tints. X-ray powder photograph by Gruner (1932) revealed a two layered mono-clinic cell symmetry. Later two investigators, Brindley and Nakahira (1958) found only single layer triclinic cell symmetry. Its physical properties include: a rarely hexagonal scale; perfect basal cleavage; flexible but not elastic; hardness of 2 to 2.5; specific gravity in a range of 2.60 to 2.63; luster in nature; white when pure but may be yellow, red, blue or brown; and translucent to opaque. Types of kaolin may include any group of clay mineral which contains kaolinite, nacrite, dickite, anauxite and halloysite. The chemical structure of a typical kaolin layer is illustrated in Figure 1. Table 1 presents a summary of the types of kaolin and their corresponding characteristics.Kaolin is a mineral of widespread occurrence, well distributed throughout the world. The finest kaolin locality in Europe is said to be in France, from where the clay is obtained for porcelain ware. Cornwall and Devonshire in England supply large quantities of this mineral. In the United States, Pennsylvania, Virginia, Colorado, Georgia and South Carolina contain deposits of kaolin. Adegoke et al (1989) reported large deposits in Nigeria in areas such as Ozubulu and Umuahia (Eastern Nigeria); Itu, Odukpani, Calabar and Obudu (South-South Nigeria). The word kaolin or kaolinite are said to be a corruption of a Chinese word “kauling”, the name of a locality where this mineral is found. Kauling means high ridge—named after a hill near Jauchau Fu in China where kaolin clay was mined for many centuries (Holdridge and Moore, 1953).

1.1 Origin and Mode of Occurrence

Kaolin like clay can be classified as primary or secondary deposits. Primary deposits are formed in-situ directly from hydrothermal alteration of volcanic and granitic rocks with examples as hydrothermal and volcanic clay types. Secondary clay deposits are products of weathering of pre-existing rocks, and subsequent alteration of the aluminosilicate into clays such as residual and sedimentary clays. However, clay can easily be classified on the basis of genetic and industrial characteristics. Table 2 presents a summary of the genetic classification of clay rocks. Table 3 shows the group, composition and origin of clay minerals.

1.2 Application and Uses of Kaolin

Kaolin is an important industrial mineral because of its excellent firing properties and relatively high melting point. Its major application or use is often extended to paint, ceramic, rubber and paper industries.

In the paint industry, kaolin is used very extensively in water based paint system as a functional extended pigment with moisture content exceeding 1%. Resistivity test using the conductivity bridge gives an indication of residual soluble salts in paints due to the presence of kaolin.In the rubber industry, kaolin is used because of its reinforcing and stiffening properties. It is cheaper than other substance that may compete. Fine kaolin gives good resistance to abrasion. There are some tests based on properties of kaolin that are to be conducted before using it for the manufacturing of rubber. They include water setting characteristics, oil absorption, stress/strain, tear resistance, abrasion resistance, heat generation, energy rebound, extrusion and plasticity, hardness, aging characteristics, water absorption and free moisture.

The ceramic industry is a large consumer of kaolin clay in white ware, insulators and refractory. Several tests are used to evaluate kaolin for use in ceramics. These include plasticity, shrinkage modules or rupture, absorption, fired colour, coating rate and chemical analysis.The paper industry is the largest consumer of kaolin. Kaolin is used both as filler and as a coating. The most important size fraction of kaolin used in coating clays is less than 2 microns. Coating clay for publication paper contains 80% of very fine particle. In petroleum and related cracking industries, kaolin is used as a catalyst to break down long chain hydrocarbon to gasoline. Kaolin is also used in the manufacturing of pencils. The amount of kaolin present ranges from 20% to 50%. Kaolin is usually added to cement as a whitener during the manufacturing process.

1.3 Kaolin in Soap Production

Kaolin is mainly used as a filler in soap production. It also gives the structure and acts as a riser, but the most important function of kaolin is to reduce cost of production. Kaolin is often processed by kaolin suppliers and companies before finished products are supplied to the soap industry. It is usually gotten in a pulverized form and it is added to the soap directly with no further process needed before addition. The stage of addition of kaolin varies from company to company and with respect to the kind of soap (laundry and toilet soaps) produced. In PZ Cussons Plc, kaolin is only added to laundry soap, and is usually added in the mixer stage (i.e. when the soap has been dried and is ready for all other ingredient such as: colour, perfume etc.). In International Equitable Association, kaolin is mostly added in low grade laundry and toilet soaps. But in laundry soaps it is added before the soap is dried while in toilet soaps, it is added at the mixer together with the soap nodules and finally milled before the final ingredient. In Lever Bothers Nigeria Aba, soap is not produced but kaolin is added to detergent. It is usually added in the slurry stage.The quantity of kaolin added during soap production is usually about 5% for PZ and it is only in laundry soap. The amount added in International Equitable ranges from 5% to 10% of the soap. The quantity of kaolin added in Lever Brothers Nigeria is usually a trade secret.

II. EXPERIMENTAL

Experiments were conducted to determine the suitability of kaolin in soap production by evaluating the moisture, particle size, solubility, pH and colour. Kaolin samples were collected from the aforementioned three companies and labelled appropriately as presented in Table 4. The samples of clay were already milled into fine grains. The tests involved the use of a mechanical sieve shaker, mortar and pestle, Teflon beaker, moulds of accurate dimensions, stop clock and a glass viscometer. About 100g to 200g mostly of each sample was weighed poured into sieves arranged in order of magnitude 600µm, 425µm, 300µm, 212µm, 150µm, 63µm and pan. The stacked of sieves were placed on a mechanical shaker and allowed to sieve for five minutes. After which they were removed and the weight of material retained on each sieve was obtained using a chemical balance. The particle size was then calculated using Eq. 1:

$$\mathrm{P.S.} = \frac{\mathrm{W.R.}}{\mathrm{A.D.W.}} \times 100 \qquad (1)$$

where,
P.S. = Particle Size
W.R. = Weight retained, g
A.D.W. = Absolute dry weight, g

The shrinkage test was evaluated by measuring 30g of each sample and converting it into paste with distilled water. This was poured into a mould and oven dried for 24 hours. The length of the brick before and after oven drying at about 110°C was obtained. The dry shrinkage was calculated using Eq. 2

$$\mathrm{D.S.} = \frac{1 - \mathrm{O.D.L.}}{\mathrm{I.L.}} \times 100 \qquad (2)$$

where,
D.S. = Dry shrinkage, %
O.D.L. = Oven dry length,
I.L. = Initial length,

The efflux time was determined for the prepared paste by sieving it through a mesh of 452µm, a glass viscometer and stop clock. The moisture content of the prepared samples was then analyzed from the amount of water removed after oven drying for 24 hours. The prepared paste was placed in a moisture content tin and weighed appropriately. The moisture content is calculated in using Eq. 3.

$$\mathrm{M.C.} = \frac{m_2 - m_3}{m_3 - m_1} \times 100 \qquad (3)$$

where,
M.C. = moisture content, %
m_1 = mass of tin only, g
m_2 = mass of wet clay + tin, g
m_3 = mass of dry clay + tin, g

The screen grit size was analyzed using 50g and 100g of the collected samples. They are dispersed in about 150Cl to 200Cl of water. The clay are bunged on a high speed mixer for about 5 minutes, screened, weighed using the moisture content tin, dried and the percentage retained on 425µm mesh determine. Thus, the grit is calculated using Eq. 4

$$\mathrm{Grit}\ (\%) = \frac{M_2 - m_1}{M_3} \times 100 \qquad (4)$$

where,
M_2 = Dry mass remaining + tin, g
M_3 = Initial mass, g

III. RESULTS AND DISCUSSION

The results of grain size distribution as shown in Fig. 2 depicts that samples obtained from PZ were well-graded. Other behavioural patterns were classed as "uniformly-graded" with sample label IEA/II/LX3 as the least graded. In general, the performance of the each particle size distribution shows that kaolin was deposited under similar conditions. It also attests to the sedimentary origin of the kaolin. The fine-grain texture of the kaolin makes it useful as fillers in soap production and also coating materials in paints, rubber, cosmetics, pharmaceutical and paper industries.The results from the dry-shrinkage test, moisture content test, grit test and efflux time measurement are presented in Table 5. The low shrinkage values obtained for all samples suggest that the kaolin are suitable materials in soap production and the manufacture of pottery wares because of the negligible distortion expected in the shape of the final products. A moisture content value ranging from 0.5% to 1.9% was incurred for all samples. This low moisture content indicates that the samples are very dry thereby confirming their suitability for soap production. If the moisture content exceeds 2% it is not accepted in any soap manufacturing company. Screen residues (grit) of 0.4% to 3% were retained on a 425µm mesh screen. Quartz, mica, feldspar along with agglomerates of tightly bonded clay is the most common mineral retained on the screen. The percentage of the residue is important in determining the fraction in either wet or dry processing plants. Finally, the efflux time for viscosity measurement indicates that kaolin could be easily moulded and moulds to retain the shape when dried, which makes it suitable in soap production for binding the soap together and giving its shape.

IV. CONCLUSION

From the physical properties determined along with colour characteristics observed from the various kaolin samples, it can be concluded that kaolin are suitable for soap production and manufacture of other materials. In general, the physical tests used in this work have been found to be very useful to determine kaolin suitability for soap production.

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FIGURES

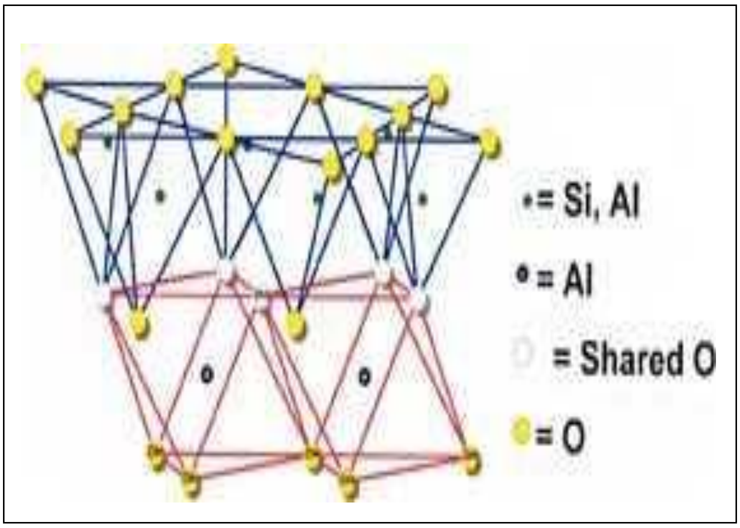


Figure 1: Structure of Kaolin Layer

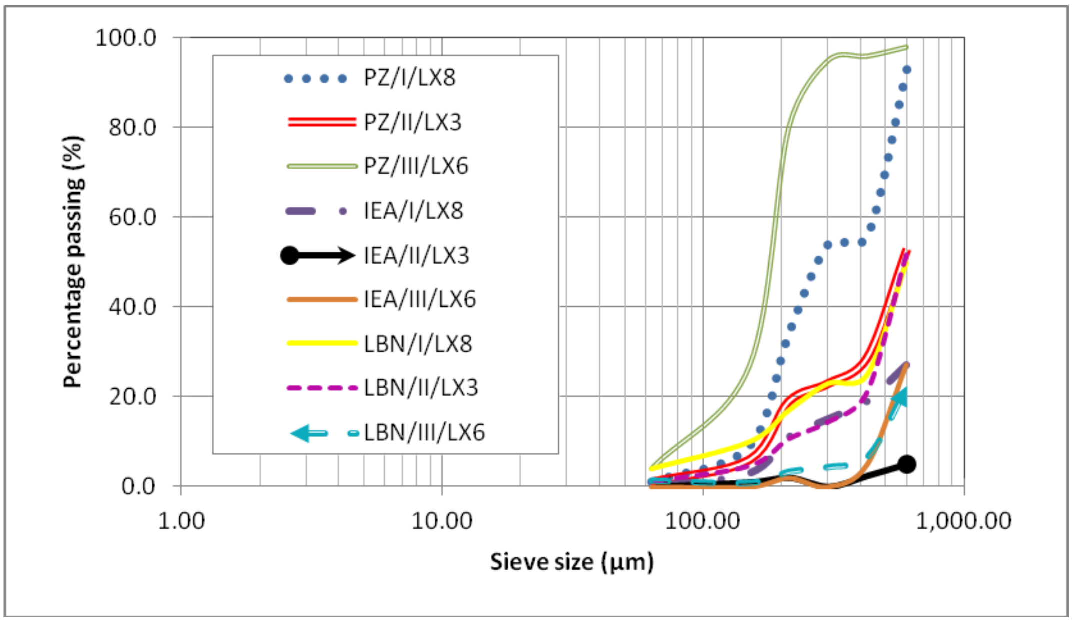
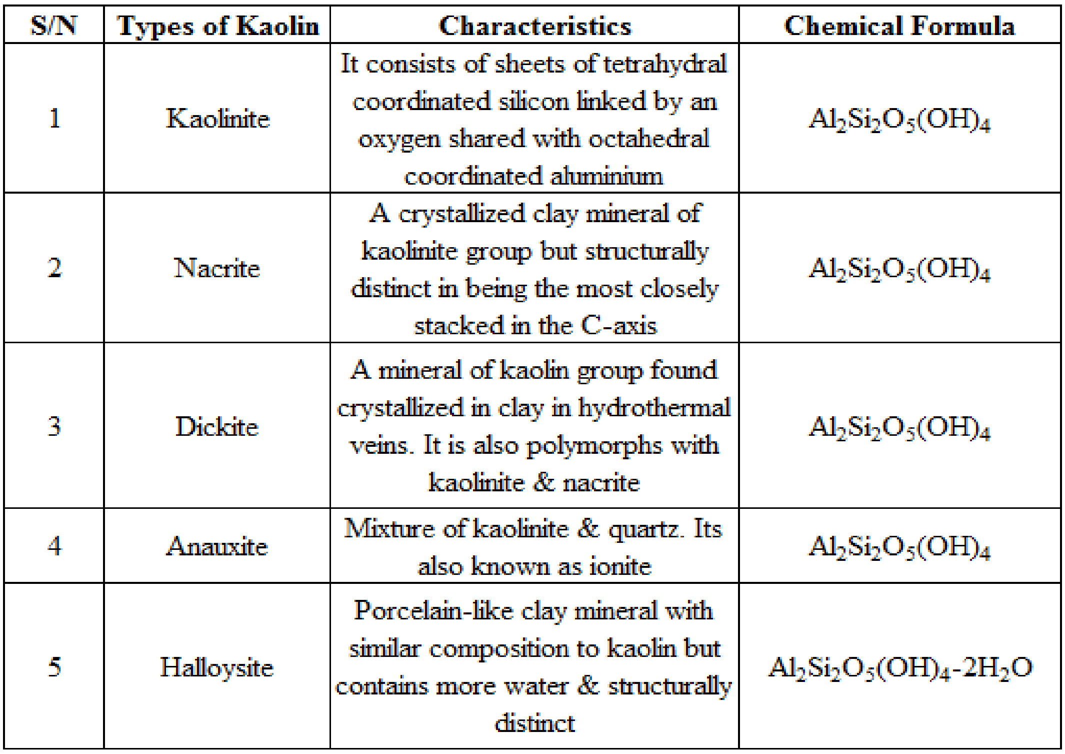


Fig. 2: Particle Size Distribution

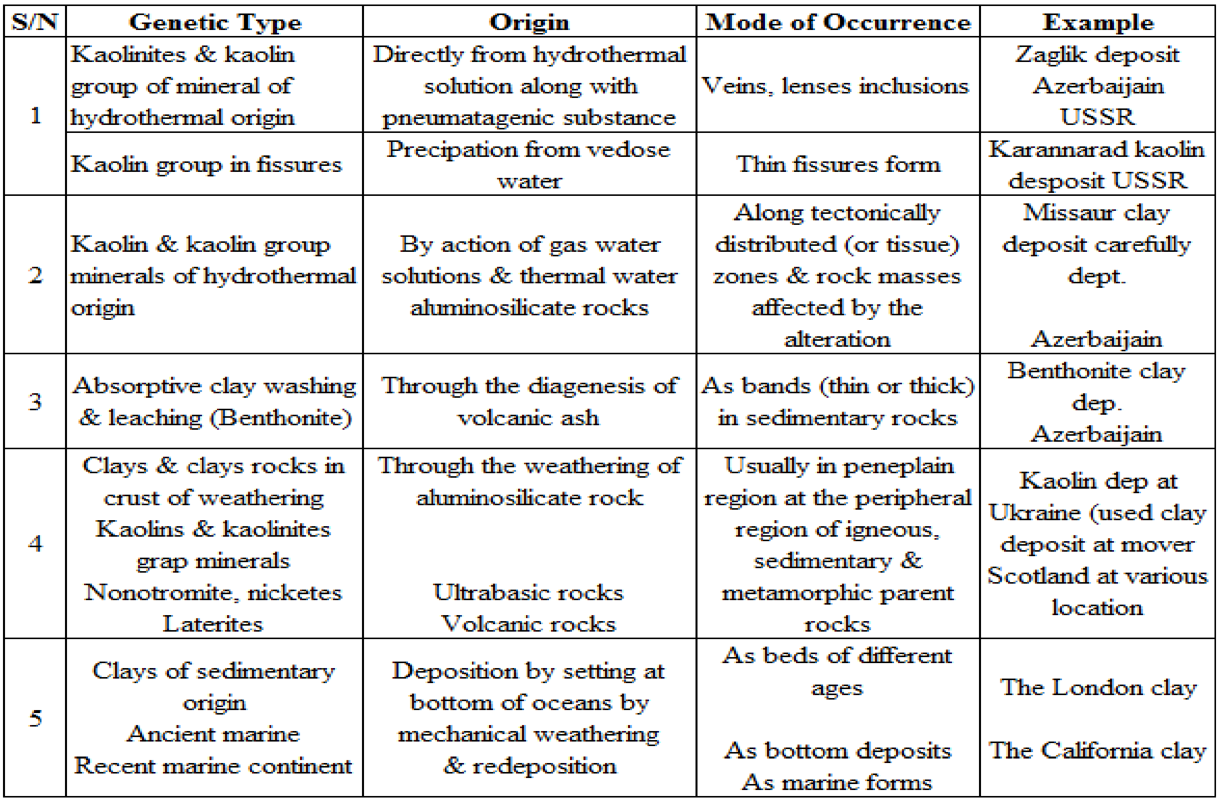
TABLES

Table 1: Types of Kaolin and their Corresponding Characteristics



S/N	Types of Kaolin	Characteristics	Chemical Formula
1	Kaolinite	It consists of sheets of tetrahydral coordinated silicon linked by an oxygen shared with octahedral coordinated aluminium	$Al_2Si_2O_5(OH)_4$
2	Nacrite	A crystallized clay mineral of kaolinite group but structurally distinct in being the most closely stacked in the C-axis	$Al_2Si_2O_5(OH)_4$
3	Dickite	A mineral of kaolin group found crystallized in clay in hydrothermal veins. It is also polymorphs with kaolinite & nacrite	$Al_2Si_2O_5(OH)_4$
4	Anauxite	Mixture of kaolinite & quartz. Its also known as ionite	$Al_2Si_2O_5(OH)_4$
5	Halloysite	Porcelain-like clay mineral with similar composition to kaolin but contains more water & structurally distinct	$Al_2Si_2O_5(OH)_4\text{-}2H_2O$

Table 2: Genetic Classification of Clay Rocks (Kashkai, 1959)



S/N	Genetic Type	Origin	Mode of Occurrence	Example
1	Kaolinites & kaolin group of mineral of hydrothermal origin	Directly from hydrothermal solution along with pneumatagenic substance	Veins, lenses inclusions	Zaglik deposit Azerbaijain USSR
	Kaolin group in fissures	Precipation from vedose water	Thin fissures form	Karannarad kaolin desposit USSR
2	Kaolin & kaolin group minerals of hydrothermal origin	By action of gas water solutions & thermal water aluminosilicate rocks	Along tectonically distributed (or tissue) zones & rock masses affected by the alteration	Missaur clay deposit carefully dept. Azerbaijain
3	Absorptive clay washing & leaching (Benthonite)	Through the diagenesis of volcanic ash	As bands (thin or thick) in sedimentary rocks	Benthonite clay dep. Azerbaijain
4	Clays & clays rocks in crust of weathering Kaolins & kaolinites grap minerals Nonotromite, nicketes Laterites	Through the weathering of aluminosilicate rock Ultrabasic rocks Volcanic rocks	Usually in peneplain region at the peripheral region of igneous, sedimentary & metamorphic parent rocks	Kaolin dep at Ukraine (used clay deposit at mover Scotland at various location
5	Clays of sedimentary origin Ancient marine Recent marine continent	Deposition by setting at bottom of oceans by mechanical weathering & redeposition	As beds of different ages As bottom deposits As marine forms	The London clay The California clay

Table 3: Group, Composition and Origin of Clay Minerals (Jensen and Bateman, 1979)

Group	Composition	Origin
(a) Kaolinites:		
i. Kaolinites	$Al_2Si_2O_5(OH)_4$	H. W. China clay H. underclays, soil, wall rock.
ii. Dickite	$Al_2Si_2O_5(OH)_4$	H. wall rocks, U
iii. Nacrite	$Al_2Si_2O_5(OH)_4$	H. wall rocks, U
iv. Anauxite	$Al_2Si_2O_5(OH)_4$	H. soils, U
v. Halloysite	$Al_2Si_2O_5(OH)_4$	W. soils, U H. W. soils
vi. Ladellite	$Al_2Si_2O_5(OH)_4$	W. soils
(b) Montmorillonite		
i. Montmorillonite	$Mg_2Al_{10}Si_{22}O_{60}(OH)_{12}(Na_2Ca)$	H. W. soils, butunite, fulles earth H. wall rocks
ii. Nontronite	$FeSi_{22}Al_2O_6(OH)_{12}(Na_2Ca)$	H. veins
iii. Saponite	$Mg_{18}Si_{22}N_2O_{60}(OH)_{12}(Na_2)$	H. veins
iv. Bedellite	$Al_{18}Si_{12}N_2O_{60}(OH)_{12}(Na_2)$	H. vein gauge
v. Hectorite	$Li_2Mg_{10}Si_{22}O_{60}(OH)_{12}(Na_2)$	W. clays
(c) Hyfoasmicas (illites)	$(OH)_4K_2S_{12}O_{20}$	W. soils, marine clay, underclays
(d) Miscallaneous		
i. Palongonite	$Mg_5Al_8O_{20}(OH_2)_4.4H_2O$	W. fuller earth
ii. Saprollite like	$Mg_6Si_8O_{20}(OH)_4.4H_20$	W. clay soils
iii. Allophane	$Al + SiO_2 + H_2O$	

W = weathering, H = hydrothermal, U = uncommon

Table 4: Characteristics of Collected Kaolin Samples

S/N	Sample Label	Colour	Characteristics
1	PZ/I/LX8	Brownish	Less silca content
2	PZ/II/LX3	Yellowish	Less silca content
3	PZ/III/LX6	Off-white	High silca content
4	IEA/I/LX8	Brownish	Less silca content & high plascity
5	IEA/II/LX3	Yellowish	Less silca content
6	IEA/III/LX6	Off-white	High silca content & plascity
7	LBN/I/LX8	Brownish	Less silca content
8	LBN/II/LX3	Yellowish	Less silca content
9	LBN/III/LX6	Off-white	Less silca content

PZ : Patterson Zochonis
IEA : International Equitable Association
LBN : Lever Brothers Nigeria

Table 5: Moisture, Shrinkage, Grit and Efflux Time Results

S/N	Sample Label	Moisture Content (%)	Dry Shrinkage (%)	Grit (%)	Efflux Time (secs)
1	PZ/II/LX3	1.12	4.3	2.0	40
2	PZ/I/LX8	0.57	5.0	1.0	52
3	PZ/III/LX6	1.32	4.3	3.0	53
4	IEA/I/LX8	0.50	5.0	1.0	48
5	IEA/II/LX3	1.12	11.0	2.0	58
6	IEA/III/LX6	1.60	4.3	1.0	54
7	LBN/I/LX8	0.50	5.0	2.4	52
8	LBN/II/LX3	0.90	11.4	0.5	37
9	LBN/III/LX6	1.90	4.3	0.4	58