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COMPARISON BETWEEN KAOLIN AND QUARTZITIC CLAY PERFORMANCE IN THE EFFECT OF WOOD ASH ADDITION ON THE MECHANICAL AND OTHER PROPERTIES OF PORCELAINISED STONEWARE TILES

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ABSTRACT

Porcelain represents the foundation of the ceramic discipline and one of the most complex ceramic materials. Composed primarily of clay, feldspar and quartz, porcelains are heat treated to form a mixture of glass and crystalline phases. This focuses on raw materials with the addition of wood ash processing and mechanical behaviors. The use of wood ash as in manufacturing ceramic tiles can increase the utilization, as well as reduce the cost of raw materials in the tile industry and provide a competitive edge to Nigerian tile Manufactures against foreign competitions. Ring was taken ensured completion of the pozzolainic reactions instituted by the wood ash and the production of dense compounds acting as filler within the pores of the porcelain mass. It was also found that the higher the wood ash content in the porcelain the lower their strength and density, the permeability 5-10 % cow dung un clays is the best ratio that gives the desired combination of opposing qualities and density, thus the ratio that gives the optimum mechanical and other properties. It was noticed from this research work, clay with kaolinitic content is better used than clay with quartzitic content in formulating porcelainised stoneware tile specimen consisting of the mixture of both quartizitic and kaolinitic clay has better performance than ordinary quartzitic clay sample.

(Key words : kaolinitic , quartzitic wood ash, permeability , firing, scanning electron micros copy and procelainised stoneware tile

INTRODUCTION

Most of the wood ash generated in Nigeria is deposited in landfills and inefficiently utilized, although a sizeable number of ceramic industries apply it. The use of wood ask as a major ingredient in manufacturing ceramic tiles can increase the ash utilization, as well as reduce the cost of raw materials in edge to Nigerian tile manufacturers against foreign competition (Mahendra and Misra, (1993). Wood Ash Composition as a Function of Furnace Temperature). The porcelainised stoneware tiles are low porosity, dense products with high technical performance, particularly with respect to abrasion and frost resistance, modulus of rupture and resistance to chemical attach. As in the work of Olgun, Erdogan, Ayhan and Zeybek (2005), Development of ceramic tiles from coal fly as an tin cal ore waste, Ceramics International, 31: 153 – 158.), they have worked on "Ceramic Tiles from High-Carbon Fly Ash". Only about 20% of Illinois fly ask is utilized, mostly by the concrete industry. The results produced in this study confirm that fly-ash based tiles can be successfully made from mixes containing up to 40% fly ash. The temperature profile of thermal treatment was developed providing optimum conditions for carbon removal by oxidation. The results obtained in the small batch commercial production were further confirmed by the experimental run on the mass production commercial equipment. The selection of raw materials for stoneware tiles is of utmost importance as it plays a vital role in ultimate product quality. A typical stoneware oxides consists of SiO_2 and Al_2O_3 as major oxides and CaO, MgO, Na_2O, K_2O and ZrO_2 as minor compounds. Fe_2O_3 and TiO_2 are kept to a minimum as they lead to a colored tile body. For supplementing these compounds, the raw material is selected from a group of plastic and non-plastic minerals. Clayey minerals such as kaolinite, illite, montmorillonite, etc. belong to the first group and contribute to strength development of green tiles. The second group consists of feldspar, felspathoid, quartz, pegmatite and quartzite, and is used as flux (5 and 6.)

(Dondi *et al., (*1995) studied the influence of chemical composition on micro structural and mechanical properties of stoneware tiles. The result found that increasing the alumina content of the composition improved the mechanical strength of the tiles. Similarly, Harada *et al.* (1996) also reported that additions of alumina to the feldspathic porcelain body could raise the flexural strength from 80 to 150MPa. Wood ash is a solid residue of the combustion of sawdust or wood in air and is composed of carbonates and oxides of metals.

MATERIALS AND METHODS

Collection of raw materials

100kg of each representative sample of two clay samples were collected from two clay deposits located in Abeokuta metropolis, Ogun State as well as other raw materials.

The chemical properties of the two different selected clay samples and three additives were examined at IITA, Ibadan. The mineralogical properties of the three clay samples with carrying proportion of wood ash were also examined at Center for Energy Research and Development OAU-Ife, and the mechanical properties of the three clay samples specimen with varying proportion of wood ash were examined at Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, all in the South West Nigeria.

Preparation of porcelain specimens

Two clay samples and three non-clay materials (wood ash and feldspar as flux, and quartz as filler) were used in formulating three porcelain specimens after sun-dried. The samples were manually crushed and sieved in order to reproduce particles without damaging the crystal lattices. Moisture was added until the samples became plastic enough to be `pressed. The tile specimen was pressed manually. The slurries was dried and disintegrated. The dried powders were thoroughly mixed with water and cylindrical rods (30mm diameter x 40mm height) were prepared using compaction by manual ramming. The compacted rod was dried at 110°C to reduce the moisture content, and then fired at a temperature of 1200°C for a soaking period of 2hours in an electric furnace. The percentage composition of the mixtures of each samples were shown in Table 1.

Chemical analysis: Atomic Absorption Spectroscopy.

Chemical analyses of the materials were determined using Atomic Absorption Spectrophotometer (AAS).

Analysis of X-Ray Diffraction (XRD)

The mineralogical composition of the unfired individual two clay samples, feldspar, wood ash and quartz was determined at Centre for Energy Research and Development OAU-Ife. The mineralogical data were obtained on powdered samples using XRD instrument; diffractometer MD 10, Radicon.MD 10.00 UM, Version 2.00.1 using CuKα radiation at 40Kv/40mA from $16^o<2\theta<72^o$, with exposure time of 1200/1200 sec.

Mechanical Properties of the Porcelain Specimens

Cylinder rod of dimension 30 mm diameters x 40mm height were prepared for each of the three clay sample mixtures. This was achieved by compacting the clay in a mold of 30mm diameter x 40mm height applying a manual pressure until the rod was well formed. Necessary measurements were obtained before the rods air dried for 5 days, and then oven dried at 110^{o}C for 2 days before the final firing at a temperature of 1200^{o}C in an oxidizing electric furnace, for 2 hours. The rate of heating was kept at 10^{o}C/minute.

Flexural Strength of the Porcelain Specimen

Flexural strength was determined for all the three clay specimen samples with varying proportion of wood ash content. The flexural strength was determined on the samples in the form of cylindrical rods (30mm diameter x 40mm height in N/mm^2).

Young's Modulus of the Porcelain Specimen.

Young's modulus, E, can be calculated by dividing the **tensile stress** by the **tensile strain** in the elastic (initial, linear) portion of the **stress-strain curve:**

$$E = \frac{\text{tensile stress}}{} = \frac{\sigma}{\varepsilon} \quad \frac{F/A_0}{}$$

$$= FA_0 \div L/L_o = FL_0 \div A_0 \Delta L$$

Where,

E is the Young's modulus (modulus of elasticity)

F- is the force applied to the object;

Ao is the original cross-sectional area through which the force is applied; ΔL is the amount by which the length of the object changes.

L_o- is the original length of the object.

Compressive Strength of the Porcelain Specimen

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushes. The compressive strength of the samples was obtained by placing the fired sample on the base of the machine Universal testing machine. (Tenstometric for compressive strength. The compressive stress would therefore correspond to the point on the engineering stress strain curve.

(e^*_e, O^*_e) defined by: O*e $\quad \square_e = \frac{F^*}{A_0}$

$$e^*_e = \frac{l^* - l_o}{l_o}$$

where F^* = load applied just before crushing and 1^* = specimen length just before crushing.

Scanning Electron Microscopy (SEM)

The Scanning electron microscope (SEM) JSM 840 with attachment using a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens.

RESULTS AND DISCUSSIONS

Percentage of Chemical Composition.

Table 2 showed the mineralogical analysis (wt %) of the two clays and three non-clay minerals used in this research work. The chemical composition of kaolinitic clay showed a high percentage of quartz (88.39wt %) and high percentage of kaolin of kaolin (35.57) percentage of alumina compared with other constituents. From the chemical formula, a pure kaolinite clay sample would lose 13.9 wt% of its mass on ignition due to dehydroxylation with water release. The kaolinitic clay sample has 8.95wt% loss on ignition.

Analysis of x-ray diffraction (XRD)

The crystalline phases in unfired kaolinitic clay sample were identified using XRD instrument diffractometer MD10. Radicon MD10.00UM, Version 2.00.1 using CuKα radiation at 40Kv/40mA from 160<20<72^0, exposure time of 1200/1200sec. The XRD analysis showed aluminum silicate and silicon oxide as the main clay minerals having the strongest peak at 34.62^0 20 and other lower peaks, while silicon oxide was detected at 27.26^0 20, and aluminum silicate hydroxide was also detected.

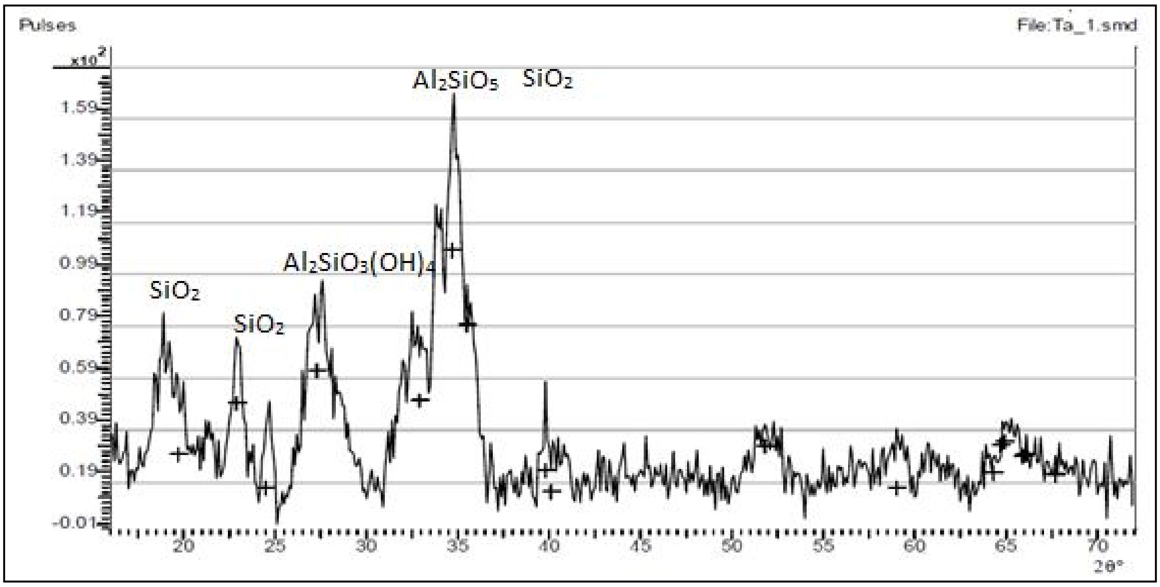


Plate 1: XRD spectrum for Kaolinitic clay.

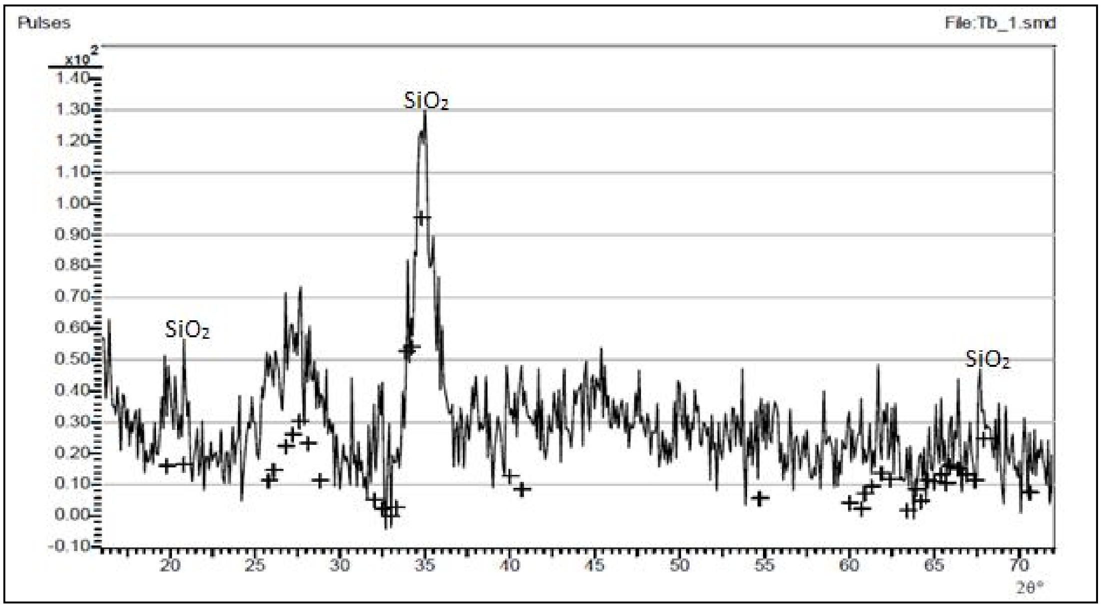


Plate 2: XRD spectrum of Quartzitic clay

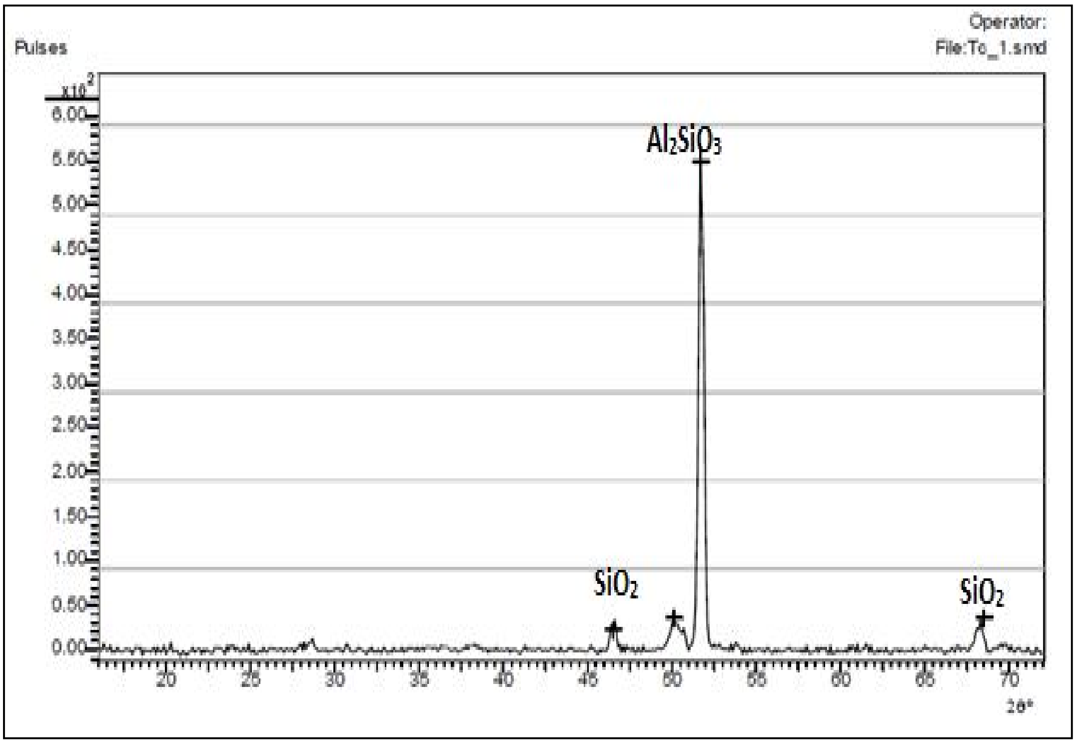


Plate 3 : XRD spectrum for Feldspar

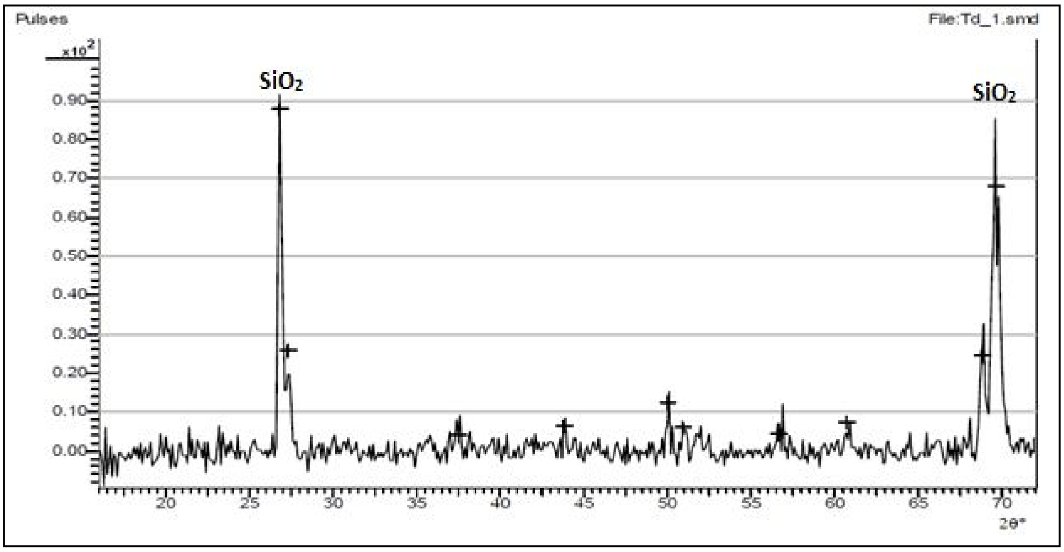


Plate 4: XRD spectrum for Quartz

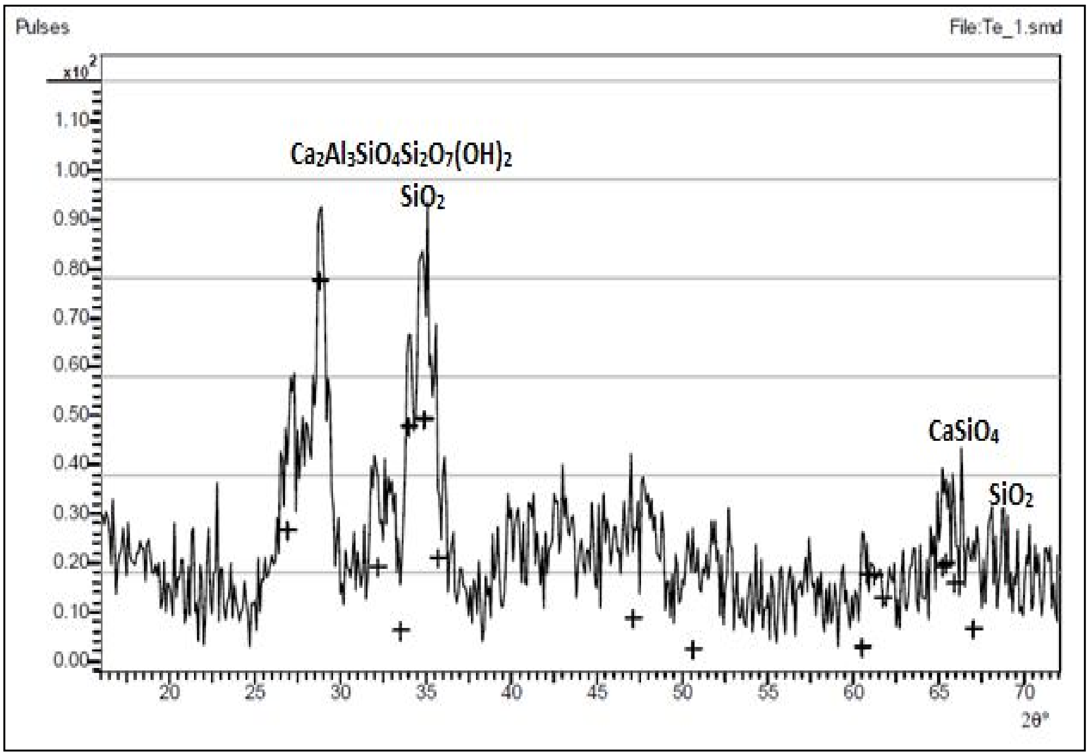


Plate 5: XRD spectrum for Wood ash

Mechanical Properties of the Porcelain Specimens

Cylindrical rod of dimension 30mm diameter x 40mm height were prepared for each of the three clay sample mixtures. This was achieved by compacting the clay in a mold of 30mm diameter x 40mm height applying a manual pressure until the rod as well formed. Necessary measurements were obtained before the rods air dried for 5 days, and then over dried at 110^{0}C for 2days before the final firing at a temperature of 1200^{0}C in an oxidizing electric furnace, for 2hours. The rate of heating was kept at 10^{0}C/minutes.

Flexural Strength of the Porcelain Specimen

Flexural strength was determined for all the three clay specimen samples with varying proportion of wood ash content. The flexural strength was determined on the samples in the form of cylindrical rods (30mm diameter x 40mm height in N/mm^{2}).

Mechanical Properties of the Porcelainised Stoneware tile specimens.

Cylindrical rod of dimension 30 mm diameters x 40mm height were prepared for the two tile specimens. Measurements were obtained before and after the rods were fired at temperature of 12000C in an oxidizing electric furnace.

Flexural Strength of Porcelainised Stoneware Tiles

The relationship between the flexural strength and wood ash content in the three samples is shown in Figure 1.

Young's Modulus of Porcelainised Stoneware Tiles

The relationship between the young's modules and wood ash content in the three samples is shown in Figure 2

Scanning Electron Microscopy of Porcelainised Stoneware Tiles

The SEM of the porcelainised stoneware tile from kaolinitic clay without the with wood ash were shown below and the dense microstructure is responsible for good mechanical properties of tiles.

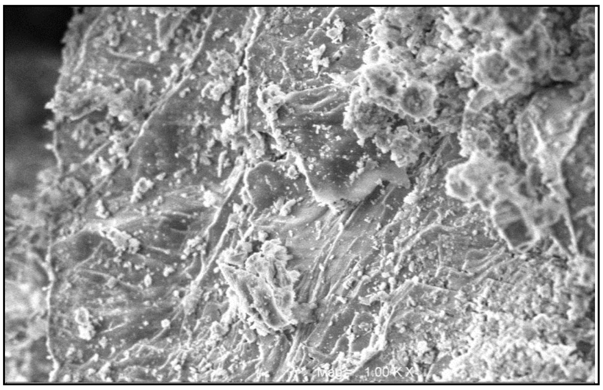


Plate 6: SEM of procelainised stoneware tile without wood ash M x 5000

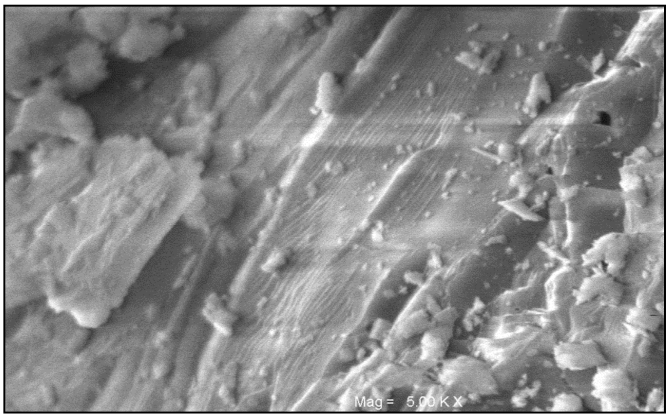


Plate 9: SEM of porcelainised stoneware tile with (kaolinitic clay) 5% wood ash M X 5000

Scanning Electron Microscopy of porcelainised stone tile with wood ash; since a low addition of wood ash gives best properties compared to all other compositions, the scanning electron microscopy of the surface of porcelainised stoneware tile with (kaolinitic clay) 5% wood ash fired at 12000C.

It was generally observed that variations in the chemical composition of the selected clay deposits in Abeokuta can be attributed to the compositional differences in the source areas and variations in the residual supply unit.

The X-Ray Diffraction (XRD) analysis of kaolinitic clay in Abeokuta showed aluminum silicate and silicon oxide as the main clay minerals having the strongest peak at 34.620 and other lower peaks, while silicon oxide was detected at 27.260 20, and aluminum silicate hydroxide was also detected at 35.550 20, at its strongest peak.

It can be observed from the table that the young's modulus value initially decreases gradually in the kaolinitic clay sample up to 25% wood ash content after which it exhibited successive increase and decreases then increase at 40% wood ash – with it maximum value at 5%. The quartzitic clay samples exhibits an abnormal trend of initial increase values in young's modulus which decreases and increases with maximum value at 10% wood ash content. The mixture of quartzitic and kaolinitic clay on the other hand also exhibited an initial decrease in young's modulus value up to 30% wood ash, it then experience successive increase and decrease, with its maximum value at 5% wood ash content. The effect of wood ash on comprehensive strength of procelainised stoneware tiles from kaolinitic clay quartzitic clay and mixture of quartzitic and kaolinitic clay samples. It can be observed from the tables that the compressive strength value initially decreases up to 35 % of wood ash content after which it increased at 40% wood ash content. The quartzitic clay samples exhibits an abnormal trend of initial increase in compressive strength then further decreases and increases with maximum value at 10% wood ash content. The mixture of quartzitic and kaolinitic clay on the other hand exhibited an initial increase in compressive strength value up to 10% wood ash, it then experience a decrease up to 40% wood ash content with its maximum value at 10% wood ash content.

Table 1: Composition of nine batches of porcelain specimen

CONSTITU-ENTS	**Clay (wt %)**	**Wood ash (wt %)**	**Feldspar (wt %)**	**Quartz (wt %)**
T1 / Q1	50	0	20	30
T2 / Q2	45	5	20	30
T3 / Q3	40	10	20	30
T4/ Q4	35	15	20	30
T5 / Q5	30	20	20	30
T6 / Q6	25	25	20	30
T7 / Q7	20	30	20	30
T8 / Q8	15	35	20	30
T9 / Q9	10	40	20	30

where,
T1/Q1-T1/Q9. Composition of nine batches of porcelain specimen.

Table 2: Chemical Constituents (wt%) of Feldspar

Constituents (Wt %)	CaO	MgO	K_2O	Na_2O	ZnO	MnO_2	CuO	Fe_2O3	SiO_2	Al_2O_3	$CaSiO_3$	L.O.I.
Kaolin	0.05	0.02	0.03	0.02	0.12	0.09	0.01	0.54	53.60	36.57	ND	8.95
Quartz-clay	0.98	0.09	0.17	0.01	1.06	1.85	0.02	0.96	82.37	5.20	ND	7.29
Feldspar	0.06	0.03	0.04	0.02	0.12	0.09	0.01	0.54	77.22	9.21	ND	4.24
Quartz	0.97	0.08	0.16	0.01	1.06	1.88	0.02	0.95	88.39	0.83	ND	5.65
Wood ash	12.93	0.65	4.54	0.67	0.44	2.94	0.12	6.13	27.82	ND	30.03	13.73

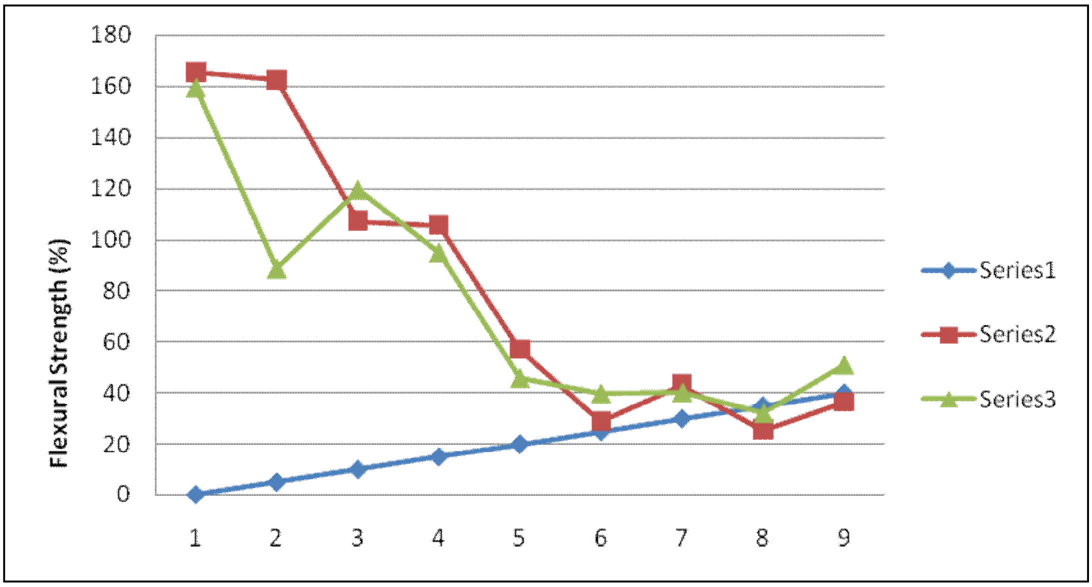
L.O.I: Loss on ignition,
ND: Not Detected

Table 3: Flexural strength of kaolinitic clay

Clay Samples	0	5	10	15	20	25	30	35	40
Kaolin	1.41	1.24	0.61	0.50	0.26	0.17	0.16	0.11	0.16
Quartzitic	1.05	0.90	0.91	0.81	0.47	0.19	0.26	0.17	0.29
Qc + Kaolin	0.69	0.75	1.02	0.87	0.74	0.60	0.21	0.17	0.21

Table 4: The young's Modulus of the specimen

Clay Samples	0	5	10	15	20	25	30	35	40
Kaolin	165.52	162.55	107.18	105.53	56.86	28.86	43.10	25.46	36.33
Quartzitic	159.51	88.50	119.37	94.87	45.58	39.57	40.13	31.99	50.79
Qc + Kaolin	116.86	141.38	138.15	132.69	115.67	71.28	43.28	47.07	23.25



CONCLUSION

5 – 10% wood ash in clays is the best ratio that gives the desired combination of opposing qualities of strength and density, thus the ratio that gives the optimum mechanical and other properties. Thus, from this research work, clay with high kaolinitic content is better used than clay with high quartzitic content in formulating porcelainised stoneware tile bodies, due to better performance posed by the porcelainised stoneware tile specimen with higher kaolinitic clay content. It is also observed that the clay sample consisting of the mixture of both quartzitic and kaolinitic clay has better performance that the ordinary quartzitic clay sample.

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