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Characterization of Ceramic Tile Bodies Prepared From Clays Collected from Four Clay Deposites in Sierra Leone

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Abstract:- Sierra Leone has high potentials for the setting-up of ceramic industry because of its huge virgin deposits of raw materials, chiefly clay, but lacks the technological know-how to utilize these materials to an economically sound level.

Tile body offers a foundation for the performance of a glaze. The chemical and mineralogical composition of these clay bodies coupled with some physical properties, such a plasticity, bulk density, porosity, and water absorption, play significant role in determining the quality of the glazed surface.This is attested by certain glaze defects like pinholes, crazing and crawling on the glaze surface resulting mainly from bubble development within the body matrix during firing.

The study aims at contributing to the promotion and use of appropriate ceramic building materials technology in Sierra Leone, by providing relevant research data to guide the production of quality ceramic products. The three key objectives, were to determine (1) the physical properties (2) chemical properties (3) mechanical properties of the clay samples investigated for their suitability in clay tile bodies production.

Clay samples were collected from four sites in Sierra Leone namely Matankay (C-M) in the Western Rural District, Bo (C-B) in Bo District, Koribondo (C-K) in Pujehun District and Yele (C-Y) in Tonkolili District.

Based on their plasticity index values, grain size distribution, bulk density, porosity and dry-fired shrinkage results obtained from this study, the four clay samples investigated are suitable for clay tile body production provided grog, frits, fluxes and other components are added proportionately and fired at temperatures above 1100°C to improve vitrification of the clay tile body during biscuit firing before application of the glaze.

Keywords:- *Ceramic Tile Body, Glaze Defect, Clay, Plasticity, Firing Shrinkage, Bulk Density, Vitrification, Grog, Frit, Fluxes, Crushing Strength, Kiln.*

I. INTRODUCTION

The body of a ceramic tile is a combination of many minerals; chiefly clay, feldspar, limestone, sand, talc, wollastonite, and pyrophyllite. These materials are subjected to standard processing technologies followed by heat treatment at higher temperatures. The composition of these minerals varies among the tile types, that is, for wall, floor, porcelain and roofing tiles.

Tile body offers a foundation for the performance of a glaze. The chemical and mineralogical composition of these bodies coupled with some physical properties, such a plasticity, bulk density, porosity, and water absorption, play significant role in determining the quality of the glazed surface. This is attested by certain glaze defects like pinholes, crazing and crawling on the glaze surface resulting mainly from bubble development within the body matrix during firing.

During the process of vitrification, the gases retained inside the tile body bubbled out which leads to pinhole formation. Iron Oxide minerals in these clay bodies are indices of gas formation by dissociation at high temperatures in the firing kilns. The crazing defect is mainly caused by a mismatch between the thermal expansion coefficients of the glaze and the body. Such a mismatch induces stresses in both the glaze and the body when the glazed body is cooled to room temperature after firing. If these stresses are not properly allowed for, fractures in the glaze will occur. Crawling is a glaze defect associated with uncovered regions where the glaze cannot flow thereby showing the body. Crawling is caused by several factors mainly, extensive shrinkage, viscosity and surface tension of the molten glaze and body, bad adherence of glaze to the body due to the surface tension of the body, temperature, and action of colors, bonding between glaze and body.

To this regard, knowledge of the ceramic characteristics of the clay tile bodies used in this investigation is a compliment to the study of the surface properties of glaze systems.

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A. Problem Analysis

Sierra Leone has high potentials for the setting-up of ceramic industry because of its huge virgin deposits of raw materials, chiefly clay, but lacks the technological know-how to utilize these materials to an economically sound level. However, very few deposits have been systematically and exhaustively investigated [Fofanah et al 2000] in relation to the ceramic and refractory potential for improved properties in currently produced pottery wares and bricks. Consequently, very little scientific data is available, on which to base plans and predictions for large scale, long term commercial development, even though many of the large deposits are considered to be viable in terms of supply tonnage.

The traditional ceramic industry in Sierra Leone has been extremely slow in adopting the automation techniques developed in industrialized countries and did not make appreciable efforts in developing techniques of its own, mainly due to lack of technological expertise.

Presently, the country can only boast of one ceramic industry (Ceratec Engineering) at Mabettor/Lunsar in Port Loko District, which is still at it embryonic stage, crippling to survive. Despite the technical support rendered by the Departments of Industrial Technology of Njala University, the experimental results cannot be practically applied by the industry. This is due to rudimentary machinery and kilns used, lack of technical staff to monitor production, especially processing of the raw materials and firing and national acceptance.

Using the above yardstick, it is easy to see why the ceramic industry in Sierra Leone has either stagnated or failed. Another case in point is the first ever clay factory in Freetown which failed four years after its establishment in 1976 for want of relevant research data to guide its production.

For the traditional ceramic industry to survive and to contribute positively to nation building, high quality and affordable products must be introduced into the market to compete with imported building materials. To achieve this goal, the traditional ceramic industry in Sierra Leone has to learn how to better relate the characteristics and the performance of the raw materials it uses, especially for imported glazes which is posing significant problem of mismatch with the tile bodies prepared from the variable colored clays. By doing so it will eventually be able to produce ceramic products using non-conventional raw materials such as zircon, rutile, bauxite and sand for which the country has abundant raw materials. The use of these non-traditional raw materials becomes important because Sierra Leone should utilize her raw materials rather than depending on export of these materials, and importing the processed ceramic products, especially tiles, at exorbitant cost.

B. Aim and Objectives of the Study

The study aims at contributing to the promotion and use of appropriate ceramic building materials technology in Sierra Leone, by providing relevant research data to guide the production of quality ceramic products.

The study targets three key objectives, namely to determine (1) the physical properties (2) chemical properties (3) mechanical properties of the tile body samples investigated.

II. LITERATURE REVIEW

The production of ceramic tiles is growing worldwide at a rate of 300 million m^2 per year and has already passes 10 billion m^2 in 2012. Such impressive growth means an increase demand for raw materials that can be consumed globally estimated approximately 230 million tons / year (Stock 2012).The ceramic tile industry is a dynamic sector whose technological innovation and market trends have drawn a complex picture of products and processes (Michele et al 2014). Clay minerals are the primary raw materials for the production of most conventional tiles as they show characteristics transformation effects during thermal decomposition which are useful in the attainment of the required properties of the ceramic bodies after firing (Perera et al 2020).

Many research works have been achieved on ceramics studies in many countries and some of the results obtained utilized in promoting ceramic technology worldwide either by upgrading one or combination of the clay properties. Papargyris et al (1996) studied the microstructure of clay-based ceramics (clay for ceramic production) and concluded that the final microstucture of clay-based ceramics is influenced by their chemical, and minerological compositions, particles size distribution and by the fabrication conditions of the sintering temperature and time. Sintering temperature is the temperature at which structural changes of meta kaolinite occurs usually 1100ºC. As the temperature in the kiln increases during firing of ceramic bodies, densification of particles occurs at certain temperature, usually above 1000ºC, due to the liquid phase formation where some of the particles will begin to melt and form a glass leading to further shrinkage(Abubakar et al 2021).

Clay compositions containing a higher amount of quartzitic clays possess lower shrinkage (<1.0%) in the temperature range of 1050–1150 °C (Swapan et al 2005). The properties of the tile can be improved by varying the composition of the main ingredients in the formulation of tiles (Abadir et al 2002, Peter et al 2006, David et al 2015).

Clay materials exhibit a dependence of strength on temperature. Jaroslav (1992) studied the dependence of strength on temperature for sintered Al_2O_3 using the behaviour of strength of casting steel and grey cast iron for comparison. He observed that even though ceramics mostly show a lower strength than many metallic materials at normal temperature, they increase their strength progressively to considerable high temperatures, where that of metals has decreased sharply.

Furthermore, Hamano et al (1994) evaluated the effect of quartzes addition on mechanical strength of porcelain bodies prepared from clay, they observed that excess addition of quartz on clay bodies is capable of raising the firing temperature above optimum (that is a temperature at which a clay body attained its required ceramic quality) and thereby weakening the strength of the clay product,

Plasticity is another important phenomena that occurs in clay bodies as it provides the bases for moulding into prescribed forms, the plastic behavior of clays has been found by Allen (1986) to be derived almost entirely from the clay fraction. The plasticity of clay is related to the texture and morphology of the plate-like clay mineral particles that slide over the others when water is added, which acts as a lubricant. A relative small percentage of fines can form stable contacts between coarse grains, providing strength and stiffness to the soil (Santamarina et al, 2002). Water affects the interaction between mineral grains, and this may affect their plasticity and their cohesiveness (Holtz et al, 2011). As the water content of clay is increased, plasticity increases up to a maximum, depending on the nature of the clay (Andrade et al 2011).

III. EXPERIMENTAL PROCEDURES

A. *Preparation of Tile Bodies Samples*

Clay samples were collected from four sites in Sierra Leone namely Matankay (C-M) in the Western Rural District, Bo (C-B) in the Bo District, Koribondo (C-K) in Pujehun District and Yele (C-Y) in Tonkolili District.

Each of the four as-mined clay samples collected from the four sites were crushed and ball milled for 12 h followed by drying of the slurries in an oven at 110 °C for 4 h. The dry powders were homogenised and passed through a standard US-sieve No. 12 (<1.68 mm). Appropriate compositions were made for the tile bodies and again ball milled for 4h. The slurries were dried and the dry powder passed through US-sieve No.12. 5 mass-% of water was added to the sieved powder, homogeneously mixed to consistence plasticity and aged for 36h. Test bars of dimensions 2 x 10 x 10 cm^3 were pressed using a hydraulic press at a pressure of 36 MPa as presented in Figure 1.

Fig 1: Clay Tile Bodies Investigated

B. *Firing Technique*

The test bars were dried at room temperature for 48 h followed by moisture oven at 110ºC for 12h. The dried bars were then fired in an electric furnace at 1100ºC at a heating rate of 200ºC/h with a soaking period of 1h. The samples were subjected to natural cooling inside the furnace.

C. *Physical, Chemical and Mechanical Properties of the Tiles Body Samples*

➢ *Physical Properties*

- *Determination of Plasticity by Deformation Technique*

2 kg each of the seven clay samples, in as mined condition, were mixed into workable plasticity. The plastic clay mixtures were rolled into spherical balls of 5cm diameter; five balls for each clay sample. The balls were weighed to fix

weight of 113g and each ball was subjected to a deformation test by a freefalling plate with a mass of 1.192 kg as described by the Pfefferkorn Method.

The force of deformation F and the height H of the clay ball before deformation and height (h) after deformation were measured to determine the plasticity Index (PI).

Plasticity Index (P) was calculated with the following equation shown in Equation 1.

$$P = F \times (H - h) \qquad \text{..............Equation 1}$$

- *Determination of Shrinkage*

- *Wet-Dry Shrinkage*

3kg of each of the clay samples were mixed with water to optimum plasticity. Five test pieces of dimension 10mm×500mm×800mm were made from each clay sample by de-airing of the plastic bodies and subsequently cutting the flat de-aired mass with a rectangular copper tile cutter. Two parallel lines exactly 503mm (wet length, L_w) apart joined by a diagonal line were marked across all the test pieces and the pieces were oven dried at 110°C for 18hours. Measurements were taken for the dry length (L_d) as shown in Equation 2.

$$S_w = \frac{L_w - L_d}{L_w} \times 100 \qquad \text{..............Equation 2}$$

Where S_w is the wet-dry shrinkage expressed as vol.-%, L_w is the wet length, and L_d is the dry length.

- *Firing Shrinkage*

Following the wet-dry shrinkage test, the oven dried tile pieces for each clay sample were fired at 1000°C, 1150°C, and 1250°C and dry- firing shrinkage (S_f) calculated from the measured values obtained as shown in equation 3.

$$S_f = \frac{L_d - L_f}{L_d} \times 100 \ (\%) \qquad \text{......Equation 3}$$

Where L_f is the fired length.

- *Determination of Water Absorption, Bulk density and Porosity of the Tile Body Samples*

The ISO/TC 187, Part 3 standard test for determination of water absorption, bulk density and porosity was used. In these determinations, the Archimedes Immersion Technique was used. Ten tile pieces of dimension (8mm×50mm×70mm) were prepared from each clay sample and were allowed to dry at room temperatures for 48 hours and then dried in a moisture oven at 110°C for 18 hours. The weight of the dried tile pieces G_0 were measured by an electric balance and then fired in an electric kiln at 500°C, 1000°C, 1150°C, and 1250°C with a socking time of 30mins. The fired tile samples were boiled in water for two hours and allowed to cool for three hours at room temperature. The wet weight, G_1 in grams of all the tile samples were measured by electric balance followed by the determination of the weight of water displaced G_2 by the tile samples when immersed in a beaker of water.

Water Absorption (WA) Vol.-% was obtained using Equation 4.

$$WA\ (\%) = \frac{G_1 - G_0}{G_0} \times 100 \qquad \text{.........Equation 4}$$

Bulk density (Bd) g/cm^3 as shown in Equation 5

$$Bd\,(g/cm^3) = \frac{G_0}{G_1 - G_2} \qquad \text{..........Equation 5}$$

Apparent Porosity (AP) vol.-% as shown in Equation 6

$$AP\,(vol.-\%) = \frac{G_1 - G_0}{G_1 - G_2} \times 100 \qquad \text{............Equation 6}$$

- *Determination of Crushing Strength of Fired Tile Body Samples*

The determination of the crushing strength of the fired tile bodies conformed to the ISO/TC 187 (Ceramic Tile), Part 4.

Ten fired tiles of dimension (2mm×50mm×70mm), from each clay sample were rubbed free from imperfections with sand paper and fully saturated with water. Three plywood sheets, 3mm thick, were used as seating between the upper and the lower platens of the testing machine and the specimen. The specimens were then tested on flat at loading rate of 200lb/in^3/min as shown in Equation 7.

$$Sco = Sco\ (0.8 + \frac{0.2}{L/\sqrt{A}}) \qquad \text{............... Equation 7}$$

Where Sc is the recorded strength, Sco is the compressive strength read from the testing machine, L is the length between the bearer plates, and A is the square end of the tile area.

- *Determination of Particle Size Distribution of the Clay Samples*

The particle size distribution of the clay samples was determined using standard test methods for particle size distribution (Gradation) of soils using sieve analysis as described by ASTM D6913-04 (2009)e1.

➢ *Chemical Analysis of Clay Samples*

- *X-Ray Fluorescence (XRF)*

The clay materials used in the fabrication of the tile bodies were chemically analyzed for Al_2O_3, SiO_2, TiO_2, Fe_2O_3, and CaO, MgO, Na_2O, and K_2O by XRF using a lithium tetra-borate fusion technique. The American National Bureau of Standards (NBS) 98 was used. Table 7 presents the order of chemical analysis by XRF.

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Table 1: Order of Chemical Analysis by XRF

Standard	**Fe_2O_3**	**TiO_3**	**Al_2O_3**	**CaO**	**SiO_2**	**MgO**	**Na_2O**	**K_2O**
	NBS98							
Operation	Vacuum							
Tube volts (kV)	20	20	40	20	40	20	20	20
Current (mA)	6	6	20	6	20	6	6	6
Crystals	LiF	LiF	EDDT	LiF	EDDT	LiF	LiF	LiF
Counter	Scintillation 980V		Gas flow proportional 1630V. 100cm^3 P1gas/min.					
2q (Ka_1a_2)	57.52^o	86.15^o	142.46^o	113.08^o	108^o	54.36^o	96.14^o	96.32^o
Actual setting	57.55^o	86.18^o	112.62^o	113.40^o	78.02^o	54.52^o	88.06^o	88.00^o
Discrimination:								
Attenuation	2	1	2	2	2	2	2	2
Amplitude (V)	23.5	17	25.5	64	32	64	18	17.8
Channel (V)	24	24	32	32	32	32	24	24
	Integrated time constant (I.T.C.) 0.2; differential time constant (D.T.C.),¥							
Fixed count	256,000	32,000	64,000	256,000	64,000	256,000	256,000	256,000

➢ *Mechanical Properties Measurement*

- *Crushing Strength*

The determination of the crushing strength of the fired tile bodies conformed to the ISO/TC 189 (Ceramic Tile). Results are presented in Table 6.

IV. DISCUSSION OF RESULTS

A. Physical Characterization of the Tile Body

The physical properties of the raw clay samples were determined for plasticity, grain size distribution, water absorption, porosity and bulk density and shrinkage.

B. Plasticity of the Clay Samples

The results of the analysis revealed that Matankay, Bo and Yele clay samples have comparative high plasticity as shown by their plasticity index values of 30.30% and 27.87 respectively presented in Table 1. These results have very close relationship with results of the grain size distribution of the clay samples of Table 2, which shows Matankay and Bo to have the highest percentage of fine fractions of 61% and 57.45% for Matankay and Bo respectively.

Table1: Results of Plasticity of the Four Clay Samples Investigated

Clay source	**Clay sample**	**Plasticity Index (Wt% water content)**	**Interpretation**
Matankay	C-M	30.30	Very High
Bo	C-B	27.87	High
Koribondo	C-K	19.08	Medium
Yele	C-Y	24.54	High

Shrinkage of the tile bodies at different firing temperatures.

Figure 2 presents results of the wet-dry shrinkage and dry-fired shrinkage of the tile bodies samples at different firing temperature.

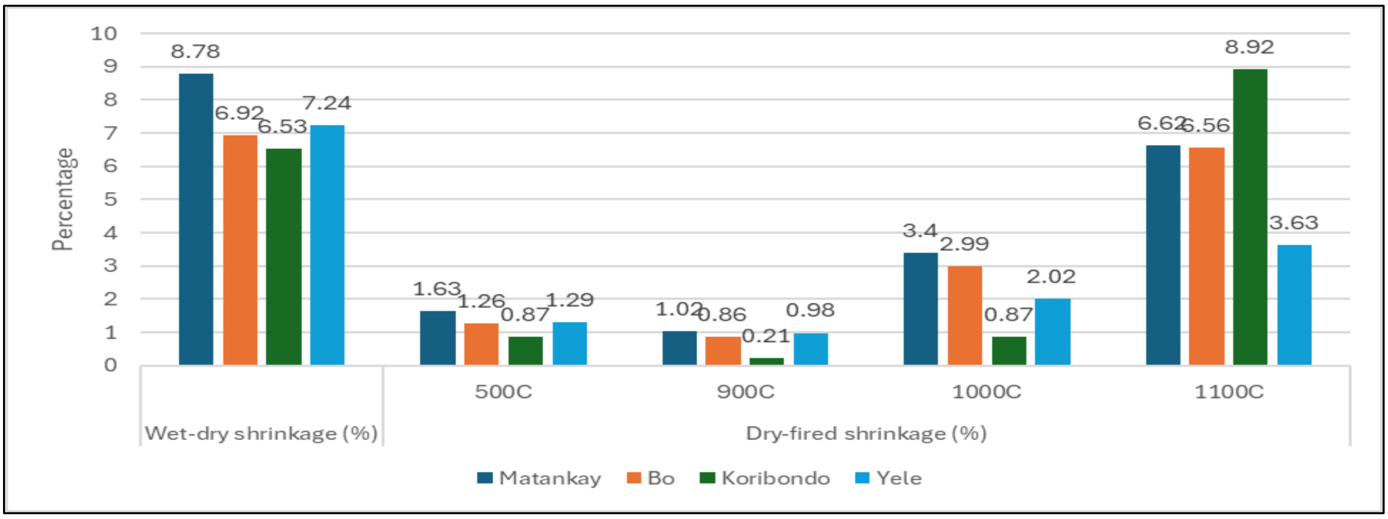

Fig 2: Wet-Dry Shrinkage and Dry-Fired Shrinkage of Tile Bodies

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Koribondo clay showed comparatively lower wet-dry shrinkage (6.53%) and the highest dry-fired shrinkage (8.92%) at 1100°C. This could be attributed to several factors and key among them are the chemical compositions and loss on ignition (LoI) of these clays as presented in Table 3. The Yele clay sample has the highest percentage of silica (SiO_2) content corresponding to the lowest dry-fired shrinkage (3.63%) at 1100°C. This result is in accordance with research studies which showed that compositions containing a higher amount of quartzitic clays possess lower shrinkage (<1.0%) in the temperature range of 1050–1150 °C (Swapan et al 2005).

The results of the chemical analysis revealed the presence of silica (SiO_2) and alumina (Al_2O_3)in significant level than other oxides in the clay samples.The presence of iron oxide (Fe_2O_3) in appreciable amount in Koribondo (6.24%), Bo (5.06%) and Matankay (4.83%) accounts for the brownish color of these clays as presented in Table 3.

Shrinkage of ceramic clay tile bodies occurs during drying and firing processes as a result of evaporation of water from the bodies and the chemical, physical and mineralogical changes that occur during the processes. The finer the particle size of the clay, the more water layers; hence the more shrinkage. This shrinkage is usually expressed as a percentage of the wet size and is typically between 5% and 20%.

As the temperature in the kiln increases during firing of ceramic bodies, densification of particles occurs at certain temperature, usually above 1000°C, due to the liquid phase formation where some of the particles will begin to melt and form a glass leading to further shrinkage(Abubakar et al 2021).

Hence, dry-fired shrinkage is an index of the degree of vitrification of the clay bodies. A knowledge of firing shrinkage and vitirfication of ceramic tile body is very important in identifying the body-glaze compatibility, especially where engobe is involved.

Table 2: Grain Size Distribution of Clay Samples

Fraction (mm)	**Grain yield(wt.%)**			
	Matankay	**Bo**	**Koribondo**	**Yele**
>2.0	0.00	0.00	0.00	0.00
0.10 - 2.0	2.63	10.68	17.10	19.40
0.05 – 0.10	0.97	4.42	6.05	4.37
0.20 - 0.05	5.41	2.39	2.99	2.46
0.005 – 0.20	20.44	10.26	34.63	29.51
0.002 – 0.005	9.55	14.80	17.70	18.33
< 0.002	61.00	57.45	21.53	44.26

Table 3: Results of Chemical Analyses of the Clay Samples

Oxides (%)	**Clay samples**			
	Matankay	**Bo**	**Koribondo**	**Yele**
SiO_2	56.03	60.12	53.45	61.25
Al_2O_3	21.46	25.45	24.14	26.45
Fe_2O_3	4.83	5.06	6.24	1.54
TiO_2	0.57	0.89	0.53	0.66
CaO	0.13	0.17	0.35	0.93
MgO	0.59	1.22	1.55	0.37
Na_2O	1.22	0.09	0.16	0.11
K_2O	0.28	0.37	0.49	0.64
LoI	14.89	6.63	13.09	8.05

Based on their plasticity index values, grain size distribution and dry-fired shrinkage results obtained from this study, the four clay samples investigated are suitable for glazed tile body production provided grog, frits, fluxes and other components are added proportionately to improve shrinkage during biscuit firing before application of the glaze.

C. Water Absorption

The water absorption results (13.45% to 18.86%) reported for the clays investigated as presented in Figure 2 are comparative high for the production of clay tile body, which value should not exceed 5%. Water absorption is normally reduce with the addition of certain components like frits and fluxes in the clay tile body fired at high temperatures depending on the temperature requirement of the components (normally above 1100°C). At this high temperature, virtification of some particles within the tile body will occur leading to mass reduction of the pore spaces and hence water absorption reduced to am acceptable level. Figure 2 further revealed an inverse relationship between dry-fired shrinkage and water absorption. The Yele clay tile body which had the highest water absorption had the lowest dry-fired shrinkage at the firing temperature of 1100°C. The study found no relationship between plasticity of the raw clay and water absorption of the clay tile bodies fired at 1100°C. This could be attributed to the chemical and mineralogical composition of the clays as shown in Figure 3.

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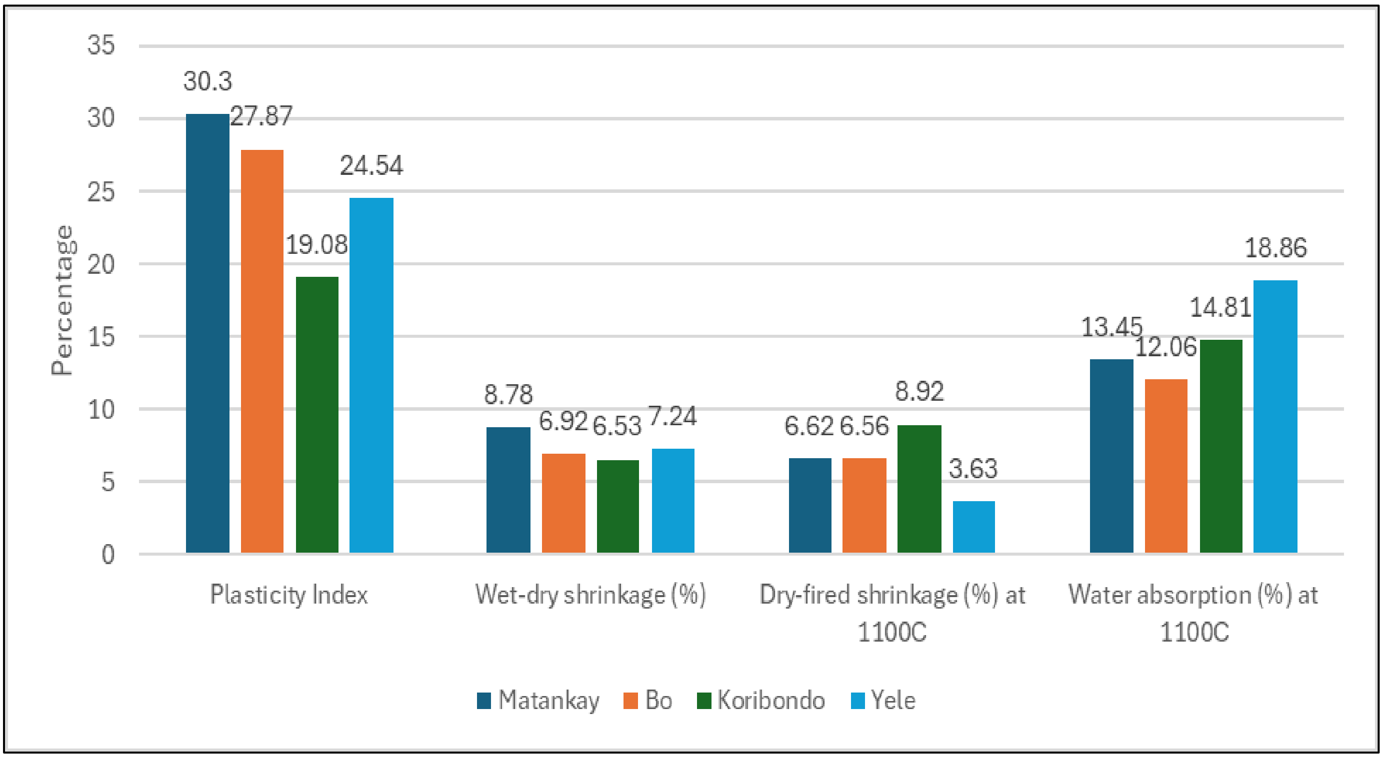

Fig 3: Plasticity Index, Shrinkage and Water Absorption of Tile Bodies Investigated

D. Bulk Density and Porosity of the Clay Tile Bodies

Results of bulk density and porosity of the clay tile bodies at different firing temperatures are presented in Figures 4 and 5. The study revealed that increase in firing temperature will lead to increase in bulk density and decrease in porosity. An inverse linear relationship between bulk density and porosity was observed in the clay tile bodies investigated. Yele sample, which had the lowest bulk density exhibited the highest porosity at 1100°C. The bonding characteristic of ceramic bodies at elevated temperatures has a direct influence on the bulk density. Increase in firing temperature above 1100°C leads to increase in bulk density. The thermal conductivity of traditional ceramics is known to be a function of their porosity or bulk density.(García Ten et al 2010).

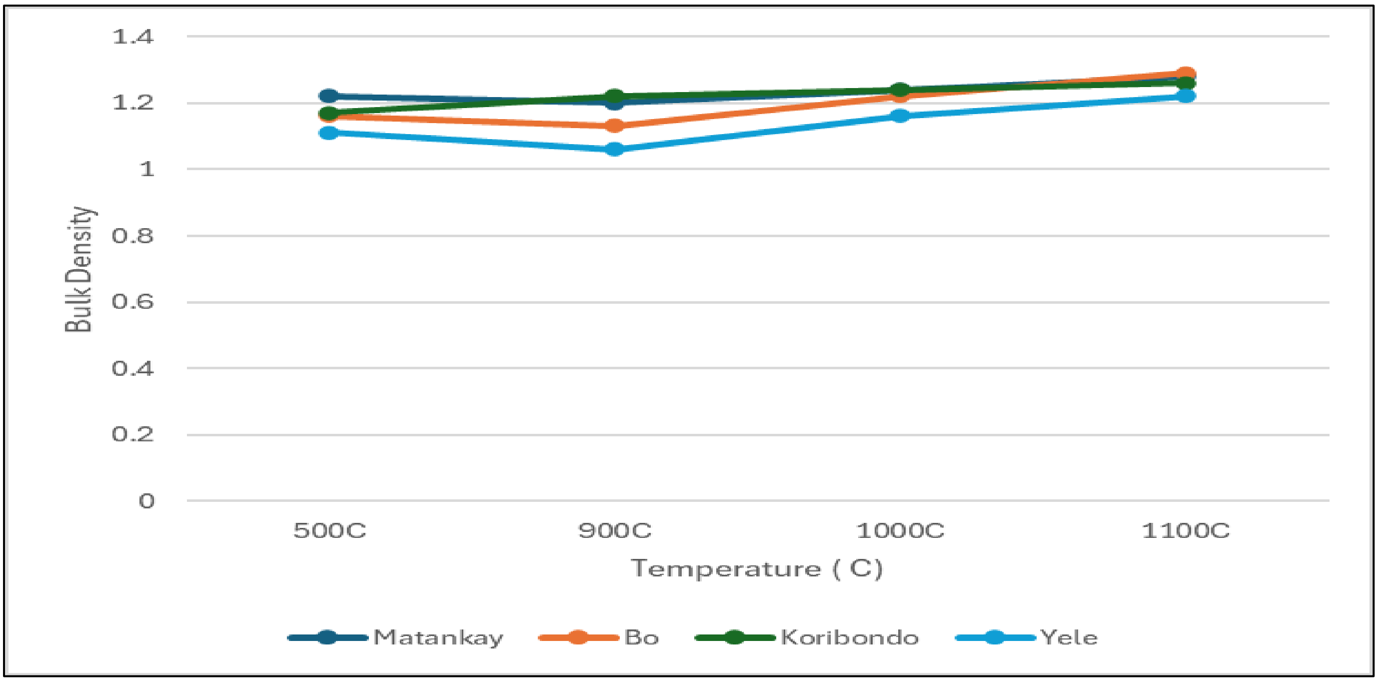

Fig 4: Bulk Density of Clay Tile Bodies at Different Firing Temperatures

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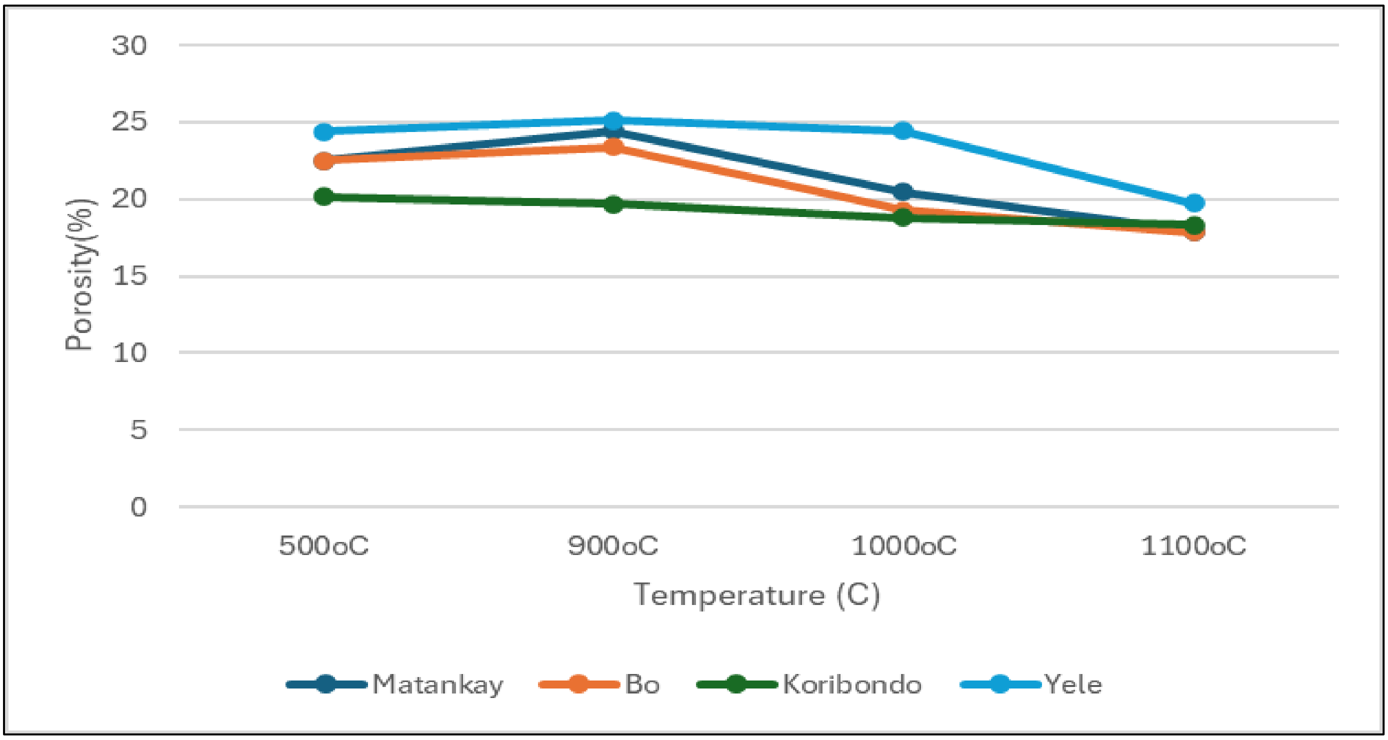

Fig 5: Porosity of Clay Tile Bodies at Different Firing Temperatures

E. Crushing Strength of Clay Tile Bodies Investigated

The results of crushing strength of the clay tile bodies at different firing temperatures presented in Figure 6 revealed a direct linear relationship between crushing strength and firing temperature. The strength property of these clays could be improved with the addition of grog, frits and fluxes in appropriate compositions and fired at temperatures above 1100ºC. Clay materials exhibit a dependence of strength on temperature (Jaroslav (1992).

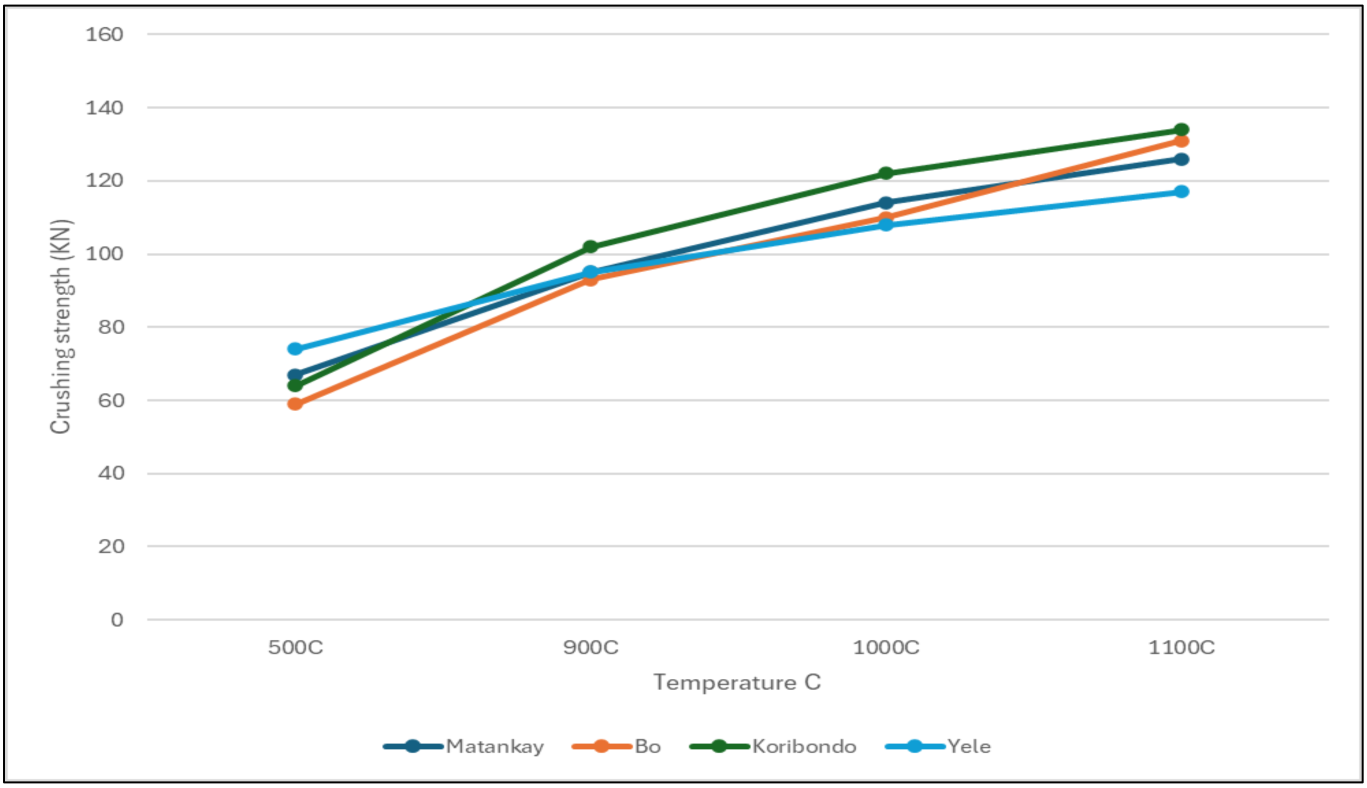

Fig 6: Crushing Strength of Clay Tile Bodies at Different Firing Temperatures

V. CONCLUSIONS

Tile body offers a foundation for the performance of a glaze. The chemical and mineralogical composition of these bodies coupled with some physical properties, such a plasticity, bulk density, porosity, and water absorption, play significant role in determining the quality of the glazed surface.This is attested by certain glaze defects like pinholes, crazing and crawling on the glaze surface resulting mainly from bubble development within the body matrix during firing.

Sierra Leone has high potentials for the setting-up of ceramic industry because of its huge virgin deposits of raw materials but lacks the technological know-how to utilize these materials to an economically sound level. For the traditional ceramic industry to survive and to contribute positively to nation building, high quality and affordable products must be introduced into the market to compete with imported building materials. To achieve this goal, the traditional ceramic industry in Sierra Leone has to learn how to better relate the characteristics and the performance of the raw materials it uses, especially for imported glazes which is posing significant problem of mismatch with the tile bodies prepared from the variable colored clays.

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Based on their plasticity index values, grain size distribution, bulk density, porosity and dry-fired shrinkage results obtained from this study, the four clay samples investigated are suitable for clay tile body production provided grog, frits, fluxes and other components are added proportionately and fired at temperatures above 1100ºC to improve vitrification of the clay tile body during biscuit firing before application of the glaze.

RECOMMENDATIONS

➢ *Base on this Study, the Following Recommendations could be Made, Specifically for Sierra Leone:*

- Sierra Leone has abundant raw materials for the establishment of a ceramic industry but lack both expertise and interest in promoting the technology. The Sierra Leone Government, through the Ministry of Technical and Higher Education should come up with strategies that could attract youths in the field of ceramics science and engineering.
- Traditional potters, who are presently producing improved ceramic cook stoves, earthened wares, and fired bricks, should be assisted technically and financially in order to adopt modern production techniques.
- Reasonable loan schemes should be introduce to traditional potters to increase production and purchase of equipment such as bricks and tiles machines, glazes and other oxides and to construct modern kilns.
- Local and International Non Governmental Organizations are encouraged to partner with the Department of Industrial Technology of Njala University to save this dying ceramic technology in Sierra Leone, which could be a major source of livelihood for rural communities and the country as a whole.

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