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Characterization of Locally Source Raw Materials for the Development of Ceramic White Earthenware Body

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ABSTRACT
Characterization of locally source raw materialsis necessary to understand the properties of the materials and minerals content in other to predict the behavior and the outcome of the finished product. In this work, whiteearthenware body was produced using Ehime Mbano Kaolin [pink coloured], silica, feldspar and cullet prepared from waste flat window glass as substitute for feldspar. All the materials were processed separately. The kaolin was crushed and milled into powder, waste glasses collected from collapsed old building were washed, crushed and ball milled; so was silica and feldspar. All the materials ball milled, were poured into a container separately to settle down after which the water was removed and the slurry was dried in the sun before passing it through a sieve to obtain uniformity in particle size. So all the raw materials used were processed into powder and were characterized using X-ray Diffraction (XRD). Samples containing compositions of six (6) different batches were made. All the materials were weighed according to the required percentages (%), mixed with water and moulded using iron mould of 40×40mm.The samples so produced were fired at the temperature of 1200^{O}C and analysis were carried out on the fired samples to test for the shrinkage, porosity, bulk density, compressive, impact and hardness. One of the physical observation was that the body which was pink in colourin raw state came out white and was dense after firing at 1200^{O}C. All the composition were found to be ideal for the production of ceramic white earthenware bodies.

Keywords: Ehime Mbano Kaolin, feldspar, waste glasses, whitebody.

1. INTRODUCTION

The development of low-cost, pure and high performing ceramic materials for various applications has continued to draw the attention of researchers in ceramics owing to the fact that clay alone cannot in any way give all the required performance in most of ceramic applications. The plasticity and workability of clay varies widely so that clay which serve well for the production of other wares may not be suitable in the production of whiteware.Whiteware are characterized by white or off-white colourwhich are often used in applications where a high level of strenght, durability and aesthetic appeal is required; however the clay abundantly available to local potters in Nigeria are contaminated with iron oxide [1][2]. This in-turn could have influence on the mechanical strenght ofwhitewares. Iron oxide are chemical complexes that occur naturally[3]and are abundance in Nigeria.These therefore brought the idea of material selection, characterization and combination in the production of local whiteware for compatibility, high performance colourof product type[4].The objective is to take advantage of the superior properties of the materials without compromising on the weakness of the other material [5].Ehime Mbano Kaolin is pink in colour and has fired white at the temperature of about

1000^{o}C. In this work, the Ehime Mbano Kaolin is used alongside other local raw materials and is fired at 1200^{o}Cwhile substituting feldspar for cullet in order to convert waste to wealth [6-10] and to reduce production cost. Ceramic – based materials are considered ideal body for the incorporation of GC (Glass- ceramic) as a substitute of natural resources [11].The study is aimed at characterizing local ceramic raw materials for the development of ceramic white earthenware body using Kaolin, Silica, Feldspar and cullet sourced from Imo, Ondo ,Ekiti and Kogi States. Nigeria to reduce the rate of importation of whitewares and to reduce the cost of producing whitewares locally.

Objectives

The objective of the study are:

i. Source for the raw materials suitable to produce whiteware body;

ii. Characterize the raw materials;

iii. Process the raw materials into a homogenous body using predetermine particle sizes;and

iv. Determine the properties of the sample produced.

Scope of the Study

The scope of the research covers the use of selected ceramic local raw materials which include kaolin, soda-lime waste glass, borosilicate waste glass, silica and feldspar. The raw materials will be sourced from Kogi State, Imo State, Edo State, Ondo State and Ekiti State respectively.

II. MATERIALS AND METHOD

The starting materials used for this work are silica, kaolin, feldspar and waste glasses. The raw materials and locations include Ehime Mbano kaolin (EMK) from Imo State, Afowa kaolin (AFK) from Edo State, Ajaokuta feldspar (AJF) from Kogi State, Ilaje silica (IJS) from Igbokoda in Ondo State. Sodalime waste glass (SLWG) sourced from condemned flat window glasses of old houses in Ado Ekiti metropolis; all in Nigeria. The materials were prepared into powder; weighed separately and recorded. Eleven sieves' numbers (1100 – 63 mesh) were selected ranging from coarse to fine sieve; each of the materials was gradually and progressively made to pass through the sieves from coarse to finer sieve mesh. The residue were collected and weighed;the percentage of particles residue were calculated by dividing weight of residue by initial weight; and percentage residue was plotted against the sieve size.All the materials were processed separately into powder. The waste glasses were washed in water, cleaned, dried and packed into a sack, crushed into smaller pieces using wooden pestle and the coarse particle was further reduced using ball mill before grinding to powder with a pulverizer.

Physical properties carried out were shrinkage, water absorption apparent porosity, bulk density using specified method by ASTM C373. Compressive strenght Impact and hardness tests were also carried out to investigate the propertiesof the samples produced using standard procedure. The compressive test was carried out using ELE Compressive Machine. Each of the dried samples was placed in between two plates on a compressive testing Machine and a compressive force wasapplied at a control load rate of 5mm. Charpyimpact test, was done by first introducing stress on the samples by way of notching before a striker of predetermined height and weight was released to strike the samples.

Raw Material Characterization

The structure was examined usingX-ray Diffraction (XRD)technique to determine the chemical and elemental composition of the glass type.The raw kaolin was dried in the sun to enable it absorb water easily beforeit was crushed using a sledgehammer and then soaked in a trough of water for 24 hours to allow every particle to dissolve completely in water; washed and sieved to remove all objectionable matters. The sieved kaolin was left for 72 hours to allow all the particles to settle at the bottom of the trough after which the water was siphoned and the excess moisture removed by squeezing the kaolin in between fine cloth and dried in the sun, for 3 days under hot weather condition; after which it was milled to powder. The potash feldspar was crushed with the sledgehammer before pouringit into a ball mill containing water and grinding media. After the material has been milled intermittently for 60 hours, it was allowed to settle. The water was siphoned, the slurry dried and sieved into powder. The silica was also mill with water,sundried, and sieved before use. The processing of these materials with water is necessary to minimize the accumulation of dust that can be harmful to the human body and for easy grinding due to friction. All the materials were made into powder to allow for accurate measurement.

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Material Characterization.

Table 1:Chemical Composition (Wt. %) of Materials Used

Materials	SiO_2	Na_2O	MgO	CaO	Al_2O_3	Fe_2O_3	K_2O	MnO	TiO	Cl	ZrO_2
EMK	0.98	1.85	1.72	1.82	1.01	1.81	1.48	-	-	-	-
IJS	95.18	-	-	0.88	1.56	0.30	-	0.03	-	-	0.09
AJF	0.87	1.33	-	3.13	1.99	-	2.94	-	-	-	-
SLWG	74.69	-	-	18.74	3.59	0.41	1.05	-	0.18	0.74	0.50

Source: Author’s fieldwork, 2023

Table 2: Sieve Analysis

Sieve Sizes		AFK	EMK	AFJ	SLWG	BSWG
2360	**2.36**	**0**	**0**	**0**	**0**	**0**
1400	1.4	19.61	16.3	16.71	1.45	0
1000	1	15.53	12.43	6.72	9.08	0.19
710	0.71	0.65	0.4	0.29	0.53	0.04
500	0.5	13.53	14.18	9.99	19.67	0.41
350	0.35	14.99	15.4	18.29	32	25.81
250	0.25	5.7	6.86	9.02	9.63	47.01
180	0.18	4.18	5.53	7.02	5.87	20.17
125	0.125	4.01	5.95	7.83	5.22	5.04
90	0.09	4.07	8.01	6.67	3.93	1.63
63	0.063	3.86	2.46	6.5	3.55	0.92
-63	-0.063	10.13	9.47	9.54	4.01	0.64
		96.26	96.99	98.58	94.94	101.86

Source: Author’s Fieldwork, 2024

Experimental ProceduresFlow Chart

Below is the procedure followed to produced whiteware body from raw materials sourcing to characterization of the sample produced

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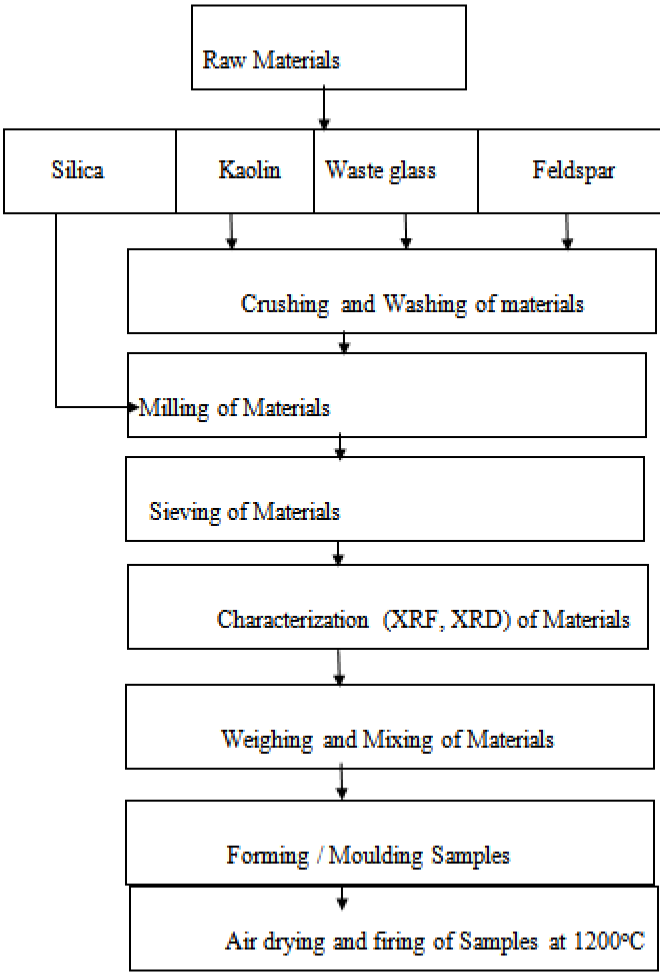

Figure 1: Production Flow Chart

Source: Author's Fieldwork, 2024.

Materials Used

Ehime Mbano -EMK Feldspar- AFJ Silica- IJS SLWG- Waste glass

Plate 1. Processed Raw Materials

Source: Author's Fieldwork, 2024.

Sample Preparation

The white earthenware body samples were prepared using the following batch compositions, see Table 1. Each of the six batches were weighed and moulded with 200ml of water using an iron mould of height 40×40mm and a wooden pallet was used to ram the semi plastic body into the iron mould. The samples were allowed to dry, weighed and fired to the temperature of 1200^{o}C before carrying out all the tests.

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Plate 2: Making of Samples with 40×40mm Iron Mould

Table 3: Batch Composition(wt.%)

Materials	S_1	S_2	S_3	S_4	S_5	S_6
EMK(Ehime Mbano Kaolin)	50	50	50	50	50	50
IJS (Ilaje Silica)	25	25	25	25	25	25
AFJ (Ajaokuta Feldspar)	25	20	15	10	5	0
SLWG (SodalimeWaste Glass)	0	5	10	15	20	25

Source: Author's Fieldwork, 2024

III.RESULTS AND FINDINGS

Physical Properties of the Samples produced.

Sample S1-S6 has variations in the shrinkage levels. Lower shrinkage levels may be desirable for precise dimensional control, while higher shrinkage levels may be necessary to achieve specific shapes or sizes after processing. There is moderation in the percentage of void spaces. Lower porosity levels are desirable for applications where strength and density are important, while higher porosity levels may be necessary for applications where thermal insulation or permeability may be desired. Sample S3 has the highest density which is required where strenght and durability are needed. Sample S1 with lower density level may be required where weight reduction is a priority.

Sample S3 has the highest density, while S1 has the lowest. Higher density levels may be desirable for applications where strength and durability are important, while lower density levels may be preferred for applications where weight reduction is a priority. Sample S5 has the lowest water absorption which is needed to resist moisture in application while S2 can be used for water retention.

Table 4:Average Value of The Physical Properties of the Samples Produced.

Material Sample	Shrinkage (%)	App. Porosity (%)	Bulk Density (g/cm3)	Water Absorption (%)
S_1	5.60	26.11	1.61	15.80
S_1	5.70	26.92	1.65	16.25
S_1	6.30	25.51	1.76	14.36
S_1	5.88	23.31	1.67	13.65
S_1	6.39	18.91	1.70	11.07
S_1	7.01	22.43	1.67	13..03

Source: Author's Fieldwork, 2024

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Mechanical Properties of the Samples Produced

The result of mechanical test of sample S_1 - S_6indicate moderate ability to withstand compressive forces. Higher compression strength is desirable for applications where the material will be subjected to high compressive forces. Sample S_6 has the highest compressive strength which is desirable for materials what will be subjected to high compressive forces. The impact values for these samples are quite consistent, ranging from 88.90 to 91.30 as all samples (S_1-S_6) exhibit high and consistent toughness, indicating a reliable manufacturing process.

Table 5: Average Value of the Mechanical Properties of Samples Produced

Sample Number	Compressive Test (MPa)	Impact Test (Jm^3)	Hardness Test (KN)
S_1	3.92	91.00	0.303
S_2	4.08	90.30	0.331
S_3	14.46	91.30	0.270
S_4	13.36	91.0	0.377
S_5	14.13	88.9	0.991
S_6	22.86	90.70	2.169

Source: Author's Fieldwork, 2024

Phase Composition of the Materials Used

The result of the analysis of the WG shows a multiple profile with quantitative and phase patternrevealing 52(5)% calcite, 35 (5)% titanite, 0.5(14)% osumilite and 12.7(11)% cristobalite. The absence of iron oxide presents the WG as ideal for the composition of ceramic whiteware body.

The Ehime Mbano raw kaolin analysis shows 52(2)% quartz, 25.0(17)% kaolinite, 8.7(4)% muscovite, 4.32(19)% chlorite, 4(2)% albite, 2.72(12)% garnet, and 2.3(8)% illite. The amount of quartz and kaolin present in the raw kaolin show that the raw kaolin is pure enough for production of local white earthernware. . Both the EMK fired white at the temperature of 1000^{o}C; this shows that the raw colours of the kaolin was actually due to impurities which were carbonaceous substances

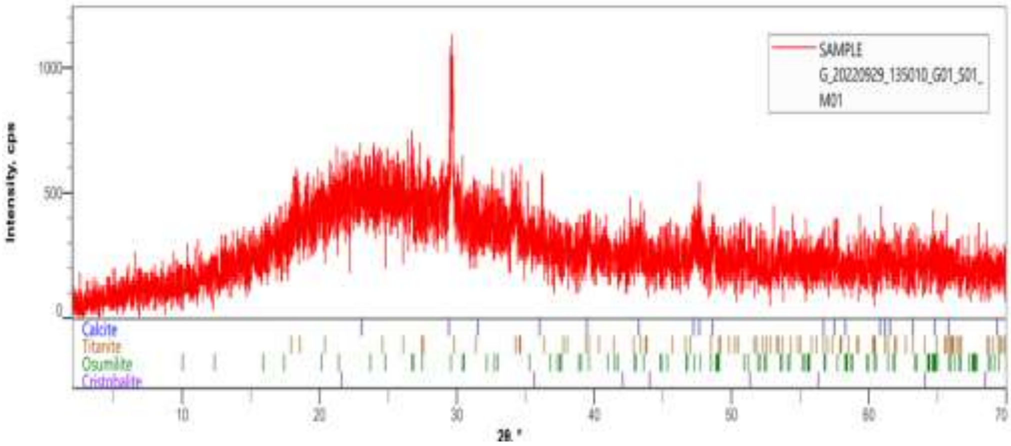

Figure 2: XRD Phase composition of SLWG (Waste Glass) Multiple phase
Source: Author's Fieldwork, 2024

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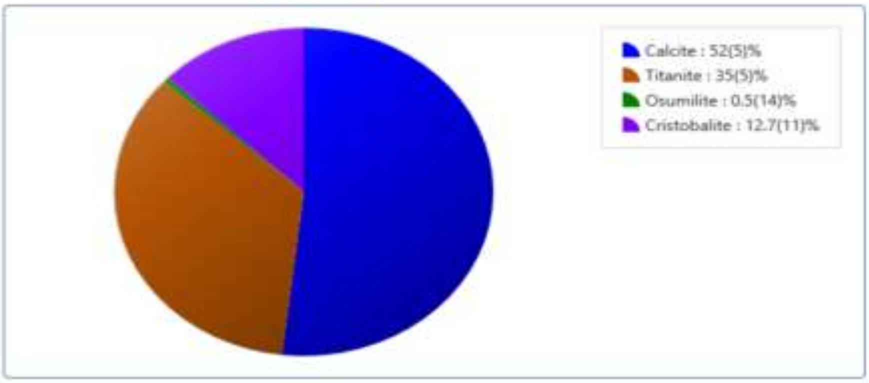

Figure 3: XRD- Quantitative Analysis of Sample (G) SLWG
Source: Author's Fieldwork, 2024

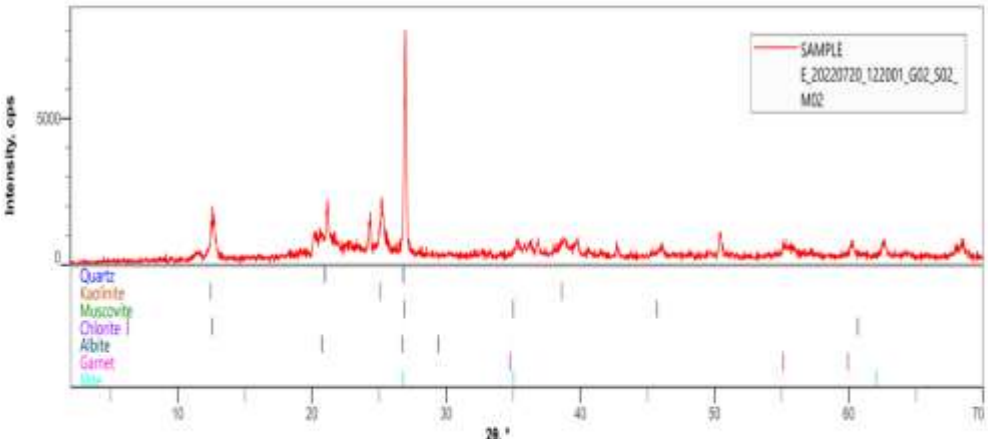

Figure 4: X-Ray Diffraction Analysis of Sample (E) Ehime Mbano Kaolin
Source: Author's Fieldwork, 2024

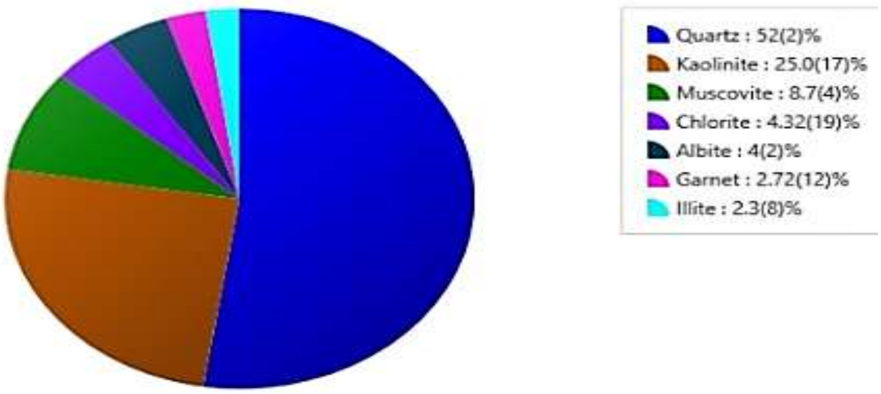

Figure 5: Quantitative Analysis of Sample (E) Ehime Mbano Kaolin
Source: Author's Fieldwork, 2024

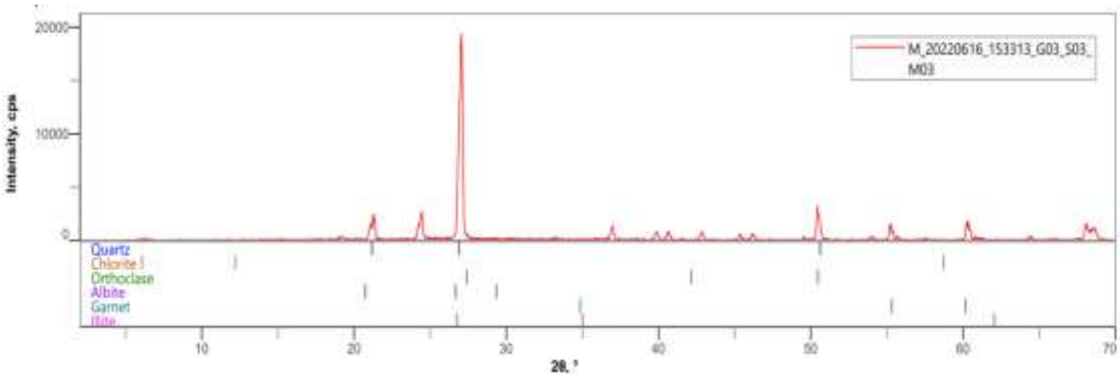

Figure 6: X-Ray Diffraction Qualitative Analysis of Sample (M) Silica
Source: Author's Fieldwork, 2024

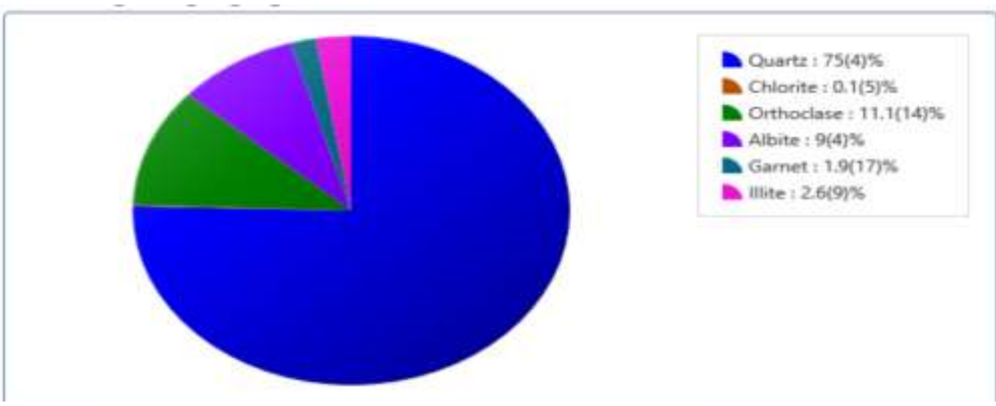

Figure 7: X-Ray Diffraction Quantitative Analysis of Sample (M) Silica
Source: Author's Fieldwork, 2024

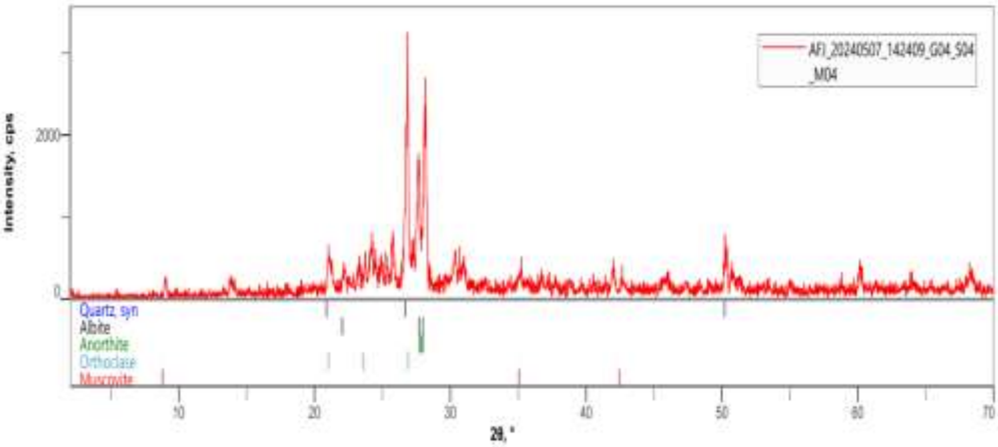

Figure 8: X-Ray Diffraction (Qualitative)Analysis of sample (AFJ) Feldspar
Source: Author's Fieldwork, 2024

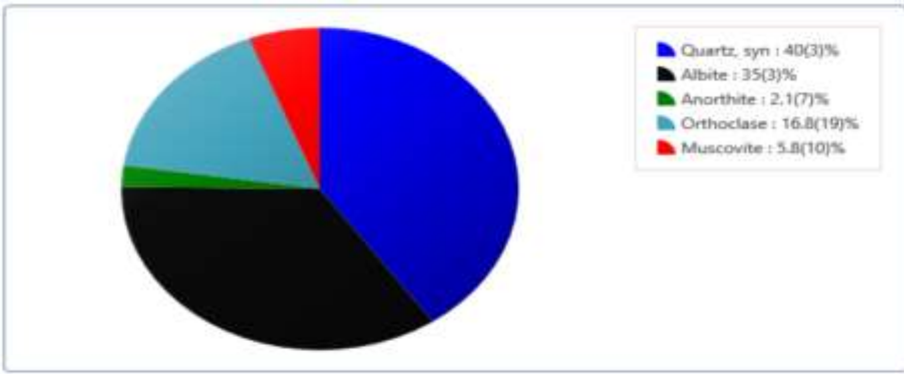

Figure 9: Quantitative Analysis of Sample (AFJ) Feldspar
Source: Author's Fieldwork, 2024

Graphs of the Sieve Analysis

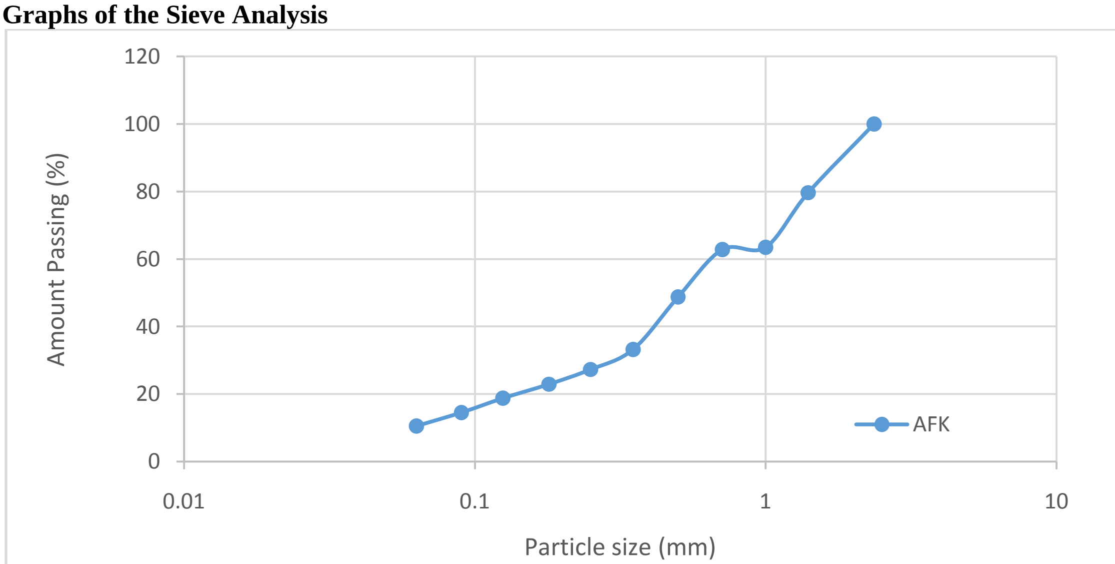

Figure 10 : Sieve Analysis of Afowa Kaolin (AFK)
Source: Author's Fieldwork, 2024

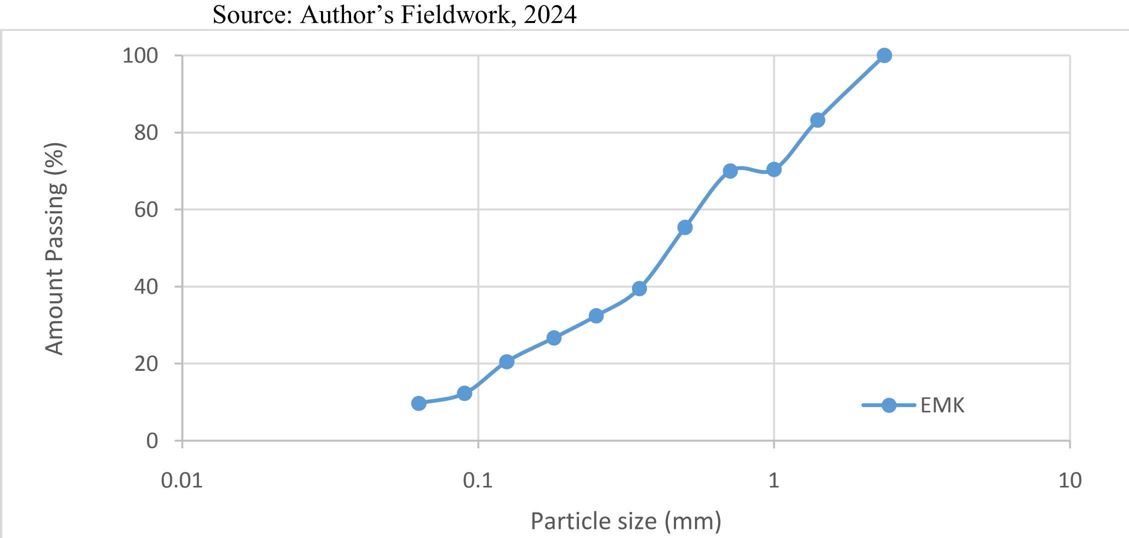

Figure 11: Sieve Analysis of Ehime Mbano Kaolin (EMK)
Source: Author's Fieldwork, 2024

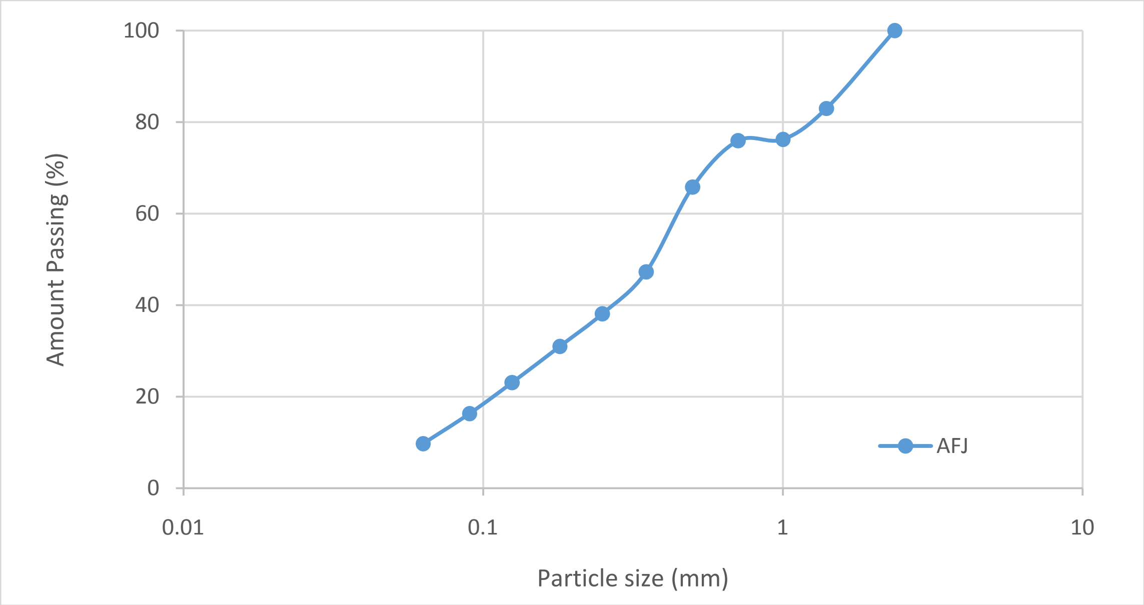

Figure 12: Sieve Analysis of Ajaokuta Feldspar (AFJ)
Source: Author's Fieldwork, 2024

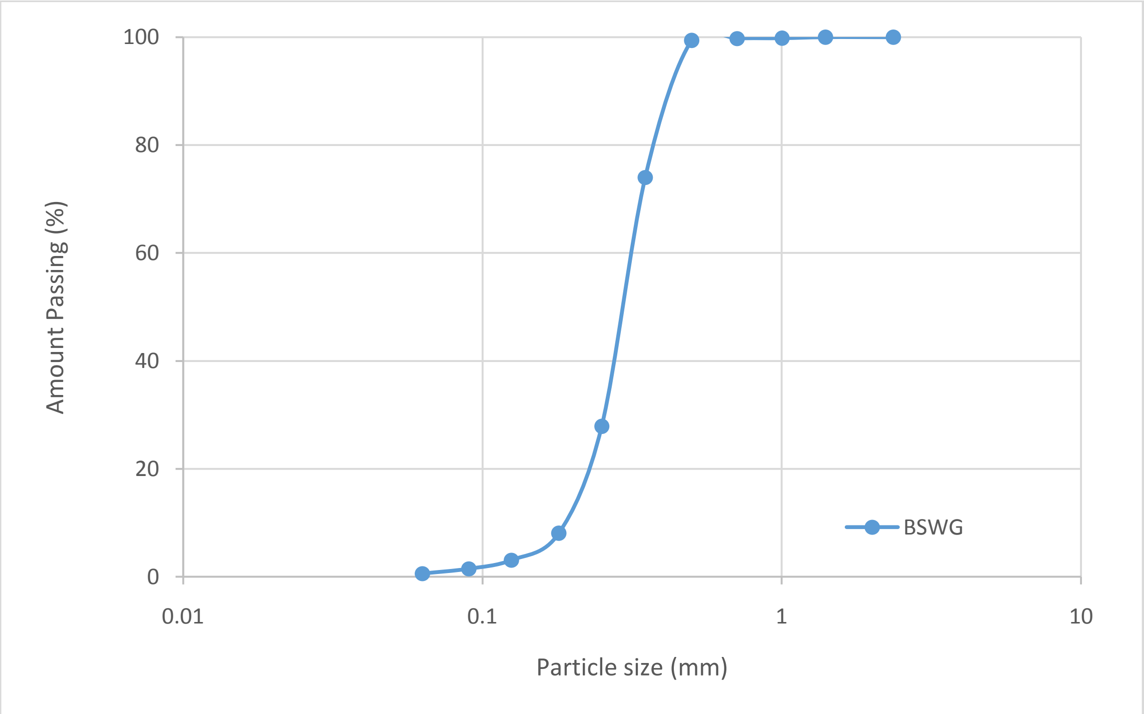

Figure 13: Sieve Analysis of Borosilicate waste Glass (BSWG)
Source: Author's Fieldwork, 2024

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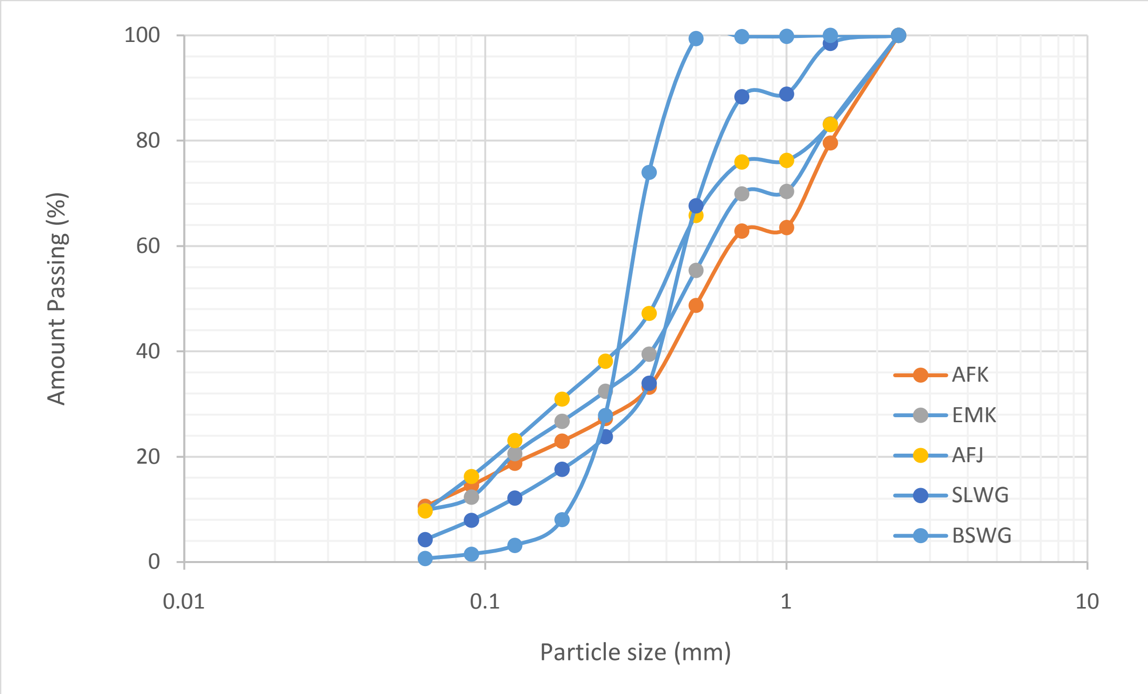

Figure 14: Sieve Analysis of Raw Materials Used
Source: Author's Fieldwork, 2024

IV. SUMMARY

The procedure for characterization of locally source raw materials for the development of ceramic white earthenware body starts from raw materials sourcing, processing,Crushing and Washing of materials, Milling of Materials, Sieving of Materials, Characterization (XRF, XRD) of Materials,Weighing and Mixing of Materials, Forming / Moulding Samples firing and carrying out test analysis- Shrinkage, Porosity, Water absorption, Density, Apparent porosity, Impact and Compressive strength Test Analysis

V. CONCLUSION

This work has to do with the characterization of locally source raw materials for the development of ceramic whitebody. The following conclusion are arrived at based on the experiment.

- EMK (Ehime Mbano Kaolin)though pink in colour, fired white at the temperature of 1200^oC; this shows that the raw colours of the kaolin was actually due to impurities which were carbonaceous in natureand can be used in the production of ceramic whiteware**.**
- There is moderation in the percentage of void spaces as revealed in the physical Properties
- Sample S_3 has the highest density which is required where strenght and durability are needed.
- Sample S_2 has the highest compressive strength which is desirable for materials that will be subjected to high compressive forces.
- The impact values for these samples are quite consistent, ranging from 88.90 to 91.30 as all samples (S_1-S_2) exhibit high and consistent toughness, indicating a reliable manufacturing process.

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