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Evaluation of thermo-Mechanical Behaviour of Clay- Silica Sand Blends For Fireclay Bricks Production

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ABSTRACT: In this study, the thermo-mechanical behavior of clay-silica sand blends was evaluated with a view to establishing its suitability for fire-clay bricks production.The study involved Standard bricks using proportional clay mixtures (0-100%) with 10% increment of silica sand. Results obtained indicate that addition of silica sand to Makurdi clay improved foundry properties of cold crushing strength, bulk density, shrinkage, apparent porosity, thermal shock resistance, permeability and refractoriness Based on these results it is concluded that Makurdi clay is suitable for fire clay bricks production if blend with silica sand (SiO_2).
Keywords: Thermo-mechanical, evaluation, clay, silica sand, fireclay bricks.

I. INTRODUCTION

Clay is a complex mixture, with widely varying composition depending on the geographical location. It is a natural substance occurring in great abundance and being constantly formed on the earth's surface as a result of rock weathering.The term clay applies to both materials having particle size of not less than 2 micrometers and to the family of minerals that have similar compositions and structural characteristics (Olorunsogbon, 2007).

Clay is a material resourceof major industrial importance for production oftiles, bricks, pottery, from the coarsest to finest. (Ampiam, 1985).Nearly all civilizations have used some form of clay for different applications. Clay deposits occur as a mixture of different clay types with one group or type normally being dominant.

Clay is composed of mainly alumina-silicates, but it also includes fine-grain deposits of non-alumina silicates such as shale and some argillaceous soils. When most clay are wet they become "plastic" meaning that they can be formed and molded into shapes when they are fired, and as water is removed they become as hard as stone.

Colour is important in most structural clay products particularly the maintenance of uniform color. The color of the products is influenced by the rate of oxidation of iron, the state of the division of the minerals, the firing temperature and thedegree of verification, the proportion of alumina, lime and magnesia in the clay material, and the composition of the fired glass during the burning operation.(Onyeji, 2010).

II. MATERIALS AND METHODS

2.1 Materials

The clay and silica sand samples for this work was obtained from Abinsi-Makurdi clay deposit in Makurdi local government area of Benue State-Nigeria.

The clay and silica samples were soaked for two days in other to remove alkalis and organic matter in the materials and then sun -dried, and crushed and ground to 200 diameter particles size.

2.2 Methods

2.2.1 Chemical composition

The chemical composition of both the clay and silica sand was determined using X-ray florescence spectrometer (XFS). This is a non-destructive analytical technique used to identify and determine the concentration of elements in solid, powdered and liquid samples. The spectrometer was switched on and allowed to warm up and also to stabilize the optics and the X-ray tube. It was calibrated to determine the expected elements present in the samples. The samples were there run using a prepared program (calibration) and the concentration of the elements present in the sample were automatically calculated and displayed by the spectrometer.

2.2.2 SieveAnalysis

Sieve analysis was then carried out on the clay and silica sand materials to check the particle size distribution accordingly by shaking the samples downward through a set of standard sieve having increasing fines.

2.2.3 Sample preparations

The clay and silica sand were made to pass through 200μm and used in the production of the test bricks.The ground clay and silica sand were mixed together to produce a plastic mass. During mixing, the proportion of silica sand was varied from 0-100% (with 10% increments). For each mixture blend bricks of standard (same) dimension (100×50×50mm) were produced using a metal mould. However, the percentage water content in each mixture was maintained at 25%. The produced plastic mass were packed into a metallic mould box and pressed with hydraulic press to a uniform pressure of 25 kN. This was for uniformity in the production of the test bricks. The bricks were sundry for two weeks to drain off the remaining water, and were then fired in the electric furnace at a temperature of 800^0C and allowed to cool for 24 hours, and air dried again. For each sample three specimens were casted and average value obtained. Also, the colours of the bricks were noted using colour chart before and after firing.

2.2.4 Mechanical and Physical Tests

The following mechanical and physical properties were then carried out on the bricks: - Cold crushing strength; bulk density, shrinkage, apparent porosity, thermal shock resistance, permeability and refractoriness.

2.2.4.1 Cold crushing strength (kN/m^2)

This was done to determine the compression strength to failure of each sample, an indication of its probable performance under load. Each sample was placed between two plates of the compression strength tester. This was followed by the application of a uniform load to it. The load at which a crack appears on the sample was noted and the cold crushing strength calculated from the equation:

$$CCS = \frac{load\ to\ fracture}{Surface\ area\ of\ sample} kN/m^2$$

2.2.4.2Bulkdensity (g/cm^3)

This was done to determine the volumetric firing density of the fired samples. The weight of the samples was taken on a digital weigh balance as $W_{(g)}$, The specimen was saddle lowered on the surface of mercury in a beaker and volume taken as V_1(cm^3), it was further re-immersed into the mercury to soak for 10 minutes and was quickly removed and recorded as soaked volume V_2 (cm^3).
The Bulk density (BD) was calculated from the equation:

$$BD = \frac{W}{V_1 - V_2}\ g/cm^3$$

2.2.4.3 Shrinkage

This was done to determine the linear shrinkage of the fired samples. The lengths before and after firing were measured using a vernier caliper.
The linear shrinkage was calculated from the equation:

$$Ls = \frac{l_1 - l_2}{l_1} \times 100\%$$

2.2.4.4 Apparent porosity

The weight of each fired sample was taken and recorded as D. Each sample immersed in water for 6 hours to soak and weighed while been suspended in air. The weight was recorded as W. Finally, the specimen was weighed when immersed in water. This was recorded as S. The apparent porosity was the calculated from the equation:

$$Ap = \frac{[W - D]}{[W - S]} \times 100\ \%$$

2.2.4.5 Thermal shock resistance (cycles)

Each sample was placed in electrically heated furnace to attain the test temperature of 1,100 ^{0}C. The sample was then withdrawn from the furnace and held for 10 minutes. The procedure was repeated until an appearance of a crack was visible. The number of cycles necessary to cause a crack was recorded for each of the samples and taken as a measure of its thermal shock resistance.

2.2.4.6 Permeability (AFN)

The specimens were placed on a motorized permeability-meter and were subjected to constant pressure. The equipment was calibrated directly in American foundry society (AFS) permeability number (pn) was calculated from the equation;

$$pn = \frac{vh}{pat}$$

where;

v= volume of air passing through the specimen (cm^3);
h= height of the specimen (cm);
p= pressure of air (g/cm^2);
a= area of cross section of specimen (cm^2); and
t= time of air to pass (minutes).

2.2.4.7 Refractoriness (^oC)

This was done determine the temperature at which each test sample would fused. Each test sample was placed in the furnace and the temperature was raised to 1,000 ^0C. The sample was then observed to check for fusion. The process was repeated by increasing the temperature at 50 ^0C interval until fusion was observed.

III. Results and Discussion

The result of the experimental analysis and test investigation are presented below:-

Table 1: Particle sizes distribution of Makurdi clay.

Diameter (mm)	Mass retained (g)	Retained %	Passing %
20	13	1.30	98.70
14	138	13.8	84.90
10	189	18.90	66.00
6.3	293	29.2	36.70
5.0	98	9.80	26.90
3.35	100	10.0	16.60
2.36	53	5.30	8.00
1.70	36	3.60	5.40
1.18	26	2.60	4.60
0.850	8	0.80	3.30
0.600	13	1.30	2.90
0.425	4	0.40	2.30
0.300	6	0.60	1.90
0.100	4	0.40	1.60
0.075	3	0.30	0.00
	16	1.60	–
	100	100	

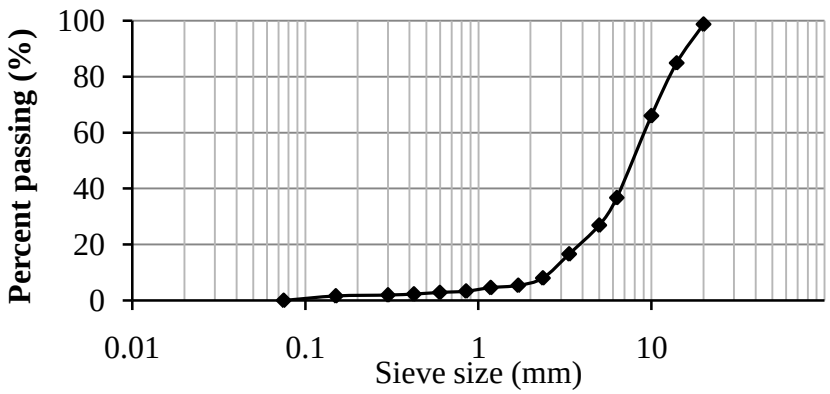

Figure1: Particle sizes distribution curve of Makurdi clay

Table 2:Particle sizes distribution of silica sand.

Diameter (mm)	Mass retained (g)	Retained %	Passing %
20	15	3.75	96.25
14	0	0.00	96.25
10	3	0.75	95.50
6.3	14	3.50	92.00
5.0	7	1.75	90.25
3.35	20	5.00	85.25
2.36	24	6.00	79.25
1.70	23	5.75	73.50
1.18	33	8.25	65.25
0.850	34	8.50	56.75
0.600	76	19.00	37.75
0.425	83	20.75	17.00
0.300	46	11.50	5.50
0.150	14	3.50	2.00
0.075	7	1.75	0.25
	1	0.25	0.00

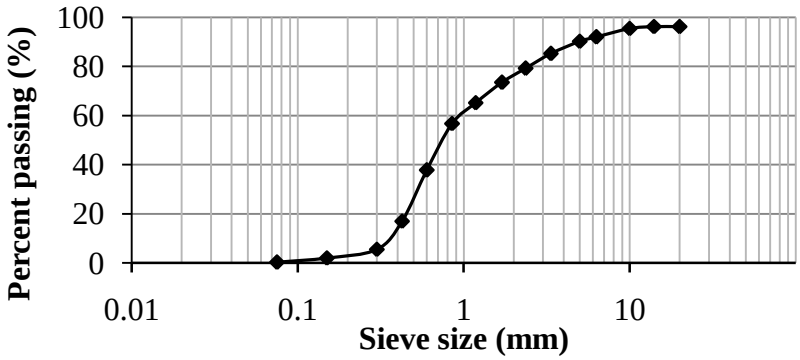

Figure2: **Particle sizes distribution curve of silica sand.**

Result of sieve analysis (Tables 1and 2), show that more than 98% and 96% aggregates respectively passed through 20mm sieve diameter that placed the aggregates as fine (ASTM D421).The assessments of sieve analysis curve indicate that the aggregates are fine and well graded with the limits zones, and therefore suitable for use as fire clay (Zainab,*et al.* 2007).Results of chemical analysis (Table 3) indicate that silica oxide (SiO_2) in the clay was as low as 27.70% buts could be blended with the silica sand of 86.18% silica oxide content (Table 4) to improve the silica content of the clay for better fire clay bricks applications (Onyeji, 2010). The colour of the bricks changed from grey to light brown when fired (Table 5). (Oroscо*et al,*2010).

Results of the mechanical and physical tests on the clay silica blends showed thatthe cold crushing strength of bricks produced from 100% Makurdi clay was 10,221.50 kN/m^2 (Table 6) which is less than the standard value of 15000 kN/m^2 for a typical fire clay brick (Table 7).On addition of silica sand, however, the cold crushing strength increased to the standard value at 20% silica sand addition (Table 6). This could bedue to the dense nature of the Silica sand (Amrane*et al*, 2011).

The bulk density at 100% clay was 1.52 g/cm^3 (Table 6) against the required standard range of 1.7-2.1 g/cm^3(Table 7). As the silica increased the bulk density to the standard range (Table 7) at 30% silica sand.

The shrinkage at 100% clay was 8.94% (Table 6) which is within the standard range of 7-10% (Table 7). Shrinkage further decreased on addition of silica sand. This is expected as the silica reduces the number of pores and water in the bricks (Mazen, 2009).

The apparent porosity at 100% clay was 65.85% (Table 6) higher than the standard range of 20-30% (Table 7). However, addition of % silica sand decreased the porosity of the test bricks. This is in agreement withFayomi*et al* (2011) at 50% Silica sand (Table 6).

The thermal shock resistance of bricks with 100% clay was 18 cycles (Table 6). As the silica sand was increased, the thermal shock resistance increased to the standard range of 20-30 cycles (Table 7) at 10% Silica sand. This is attributed to good sintering characteristics of Silica sand clay masses (Abolarin*et al.* 2004).

The permeability of bricks produced at 100% clay was 30AFN (Table 6) which attained the standard range of 25-90 AFN. The permeability number decreased on addition of silica sand in agreement with (Wazir*et al.,* 2011).

The refractoriness was less than 1,100^{0}C (Table 6) at 100% clay. This wentto the standard range of 1,500-1,700^{0}C at 50% Silica sand blend.

Table 3: Chemical composition of Makurdi clay

Oxides	**Makurdi (%)**
SiO_2	27.70
Fe_2O_3	10.11
Al_2O_3	13.60
MgO	3.15
CaO	16.60
Na_2O	1.55
K_2O	1.40
MnO	0.72
P_2O_3	2.71
TiO	1.38
LOI/Residue	21.08

Table 4: Chemical composition of Silica sand

Oxides	**(%)**
Fe_2O_3	1.2
TiO	-
Al_2O_3	5.63
SiO_2	86.18
MgO	0.2
CaO	Trace
Na_2O	0.36
K_2O	1.67
LOI/Residue	0.65

Table 5: Colour of Makurdi clay

Colour	**Before firing**	**After firing**
Makurdi	Grey	Light brown

Table 6: Average values for Mechanical and Physical properties of the clay Silica sand blends

Silica Sand (%)	**Cold crushing strength (kN/m^2)**	**Bulk density (g/cm^3)**	**Shrinkage (%)**	**Apparent porosity (%)**	**Thermal shock resistance (cycles)**	**Permeability (AFN)**	**Refractoriness (^{0}C)**
0	10, 221.50	1.52	**8.94**	65.85	18	**30**	< 1,100
10	13, 854.03	1.50	8.87	28.54	**28**	28	< 1,100
20	**15, 097.13**	1.58	8.79	33.12	38	26	< 1,200
30	20, 443.10	**2.04**	8.69	27.78	48	25	< 1,100
40	23, 702.44	3.31	7.05	31.25	58	25	1,450
50	27, 356.10	4.16	6.82	**26.77**	63	24	**1,500**
60	30, 611.20	4.16	6.14	27.40	65	23	1,530
70	33, 645.21	5.88	5.56	21.40	67	22	1,550
80	36, 993.25	7.97	5.16	28.00	68	19	1,580
90	40, 256.75	10.10	4.30	25.72	74	17	1,580

100	44, 665.45	12.12	4.16	23.41	76	15	1,600

Table 7: Standard values and Physical properties for a typical fire clay brick

Properties	Standard values
Bulk Density (g/cm^3)	1.7-2.1
Apparent porosity (%)	20-30
Permeability number	25-90
Linear shrinkage (%)	7-10
Thermal shock resistance (cycle)	20-30
Cold crushing strength (kN/m^2)	15, 000
Refractoriness (^0C)	1500-1700

IV. Conclusion

The 100% Makurdi clay is not suitable for the production of fire clay bricks because the chemical and mechanical/physical properties of test bricks are in most cases below or far above the minimum standard requirements. Addition of silica sand improved sufficiently most of the chemical and mechanical/physical properties to posses standards required for refractory applications.

REFERENCES

[1] Abolarin M.S., Olugboji O. A. and Ugwuoke I.C (2004).Determination of Moulding properties of locally available clays for casting operation.Proceedings 5th*Annual Engineering Conference*.2nd Ed. Federal University of Technology Minna, Nigeria Pp.82-85.

[2] Ampiam, S.G. (1985): "Clays; Minerals fats and problems" Washinton Dc, us Bereau of mines (B 1-13)

[3] Amrane B. Ouedraogo E, Mamen B, Djaknoun S, Mesratic N. (2011). Experimental study of the thermo-mechanical behavior of Alumina-Silicate refractory materials base on a mixture of Algerian Kaolinitic clays.*Ceramic International Journal* Vol. 37. No.12. Pp. 3217-3227.

[4] Fayomi O.S.I., Ajayi O.O and Popoola A.P.I (2011).Suitability of local binder compositional variation of Silica sand for foundary core-making.*International Journal of Physical sciences* Vol.6.No.8. Pp.1940-1946.

[5] Mazen A.A., (2009) production of fire-clay Refractory Bricks from local materials. *European Journal of Scientific Research*.Vol. 26. No.3. Pp. 386-392.

[6] Olorunsogbon, B. (2007): Beneficiation, Calcination and characterization of Kutigi clay, "unpublished undergraduate project. FUT Mina, Pp. 14-15.

[7] Onyeji, (2010): Analysis and characterization of Nyikangbe day, chanchaga L.G.A, Niger State *Journal of Metallurgy and materials Engineering* Vol. 5, No. 2. Pp. 55-62.

[8] Orosco, Perino E, Del M, Ruiz C. and Gonzaleze J. A. (2010).A thermogravimetric study of refractory clays chlorination.International *Journal of Mineral processing.*Vol.98, No.11 Pp. 195-201.

[9] Waziri,B. S.,Bukar A. G. and Gaji Y. Z. A. (2011): Application of Quarry sand as a fine Aggregate in the production of medium Grade concrete. *ContinentalJournal of Engineering Sciences* Vol.6. No.2 Pp. 1-6.

[10] Zainab, S.A., Ahuwan, A., Madugu, I.A. (2007): "The effect of zircon sand addition on the refractory properties of Kankara clay" proceeding of the 24th NMS conferences Pp.43-55.