PRODUCTION OF FIRE CLAY INSULATING BRICKS FROM A BLEND OF CLAYS AND RICE HUSKS

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Abstract

Fire-clay insulating bricks have been produced from a blend of two Nigerian clays (Nafuta and Nsu clays) and rice husks. The chemical compositions of the clays used in this work were carried out using Atomic Absorption Spectrometer (AAS) and Ultra Violent-Visible Range Spectroscopy (UV-VIS). The clays were blended in the ratio of 7:3 i.e. 70% Nafuta : 30% Nsu. The percentage of Nfuta clay was decreased in further samples in proportion to the quantity of rice husks addition. Test samples were produced from the blends and the clay-rice husks composite bricks using internationally accepted standard techniques. Physical properties tests: porosity, density, shrinkage, percentage water absorption and modulus of rupture were carried out at different firing temperature of viz: 900^oC 1000^oC, 1100^oC, and 1200^oC respectively. The results obtained showed that the insulating bricks produced have properties comparable with an international accepted standard for fire-clay insulating bricks. The bricks can therefore be used in the lining of crucible furnaces for the production of non ferrous metals, heat treatment furnaces, reheating and holding furnaces, salt bath, ovens, kilns, ladles, soaking pits, incinerators, boilers, etc.

Introduction

Refractories are defined as "nonmetallic materials for construction of lining of furnaces operated at high temperatures". Stability at high temperatures, both physical and chemical, is the primary requirement for refractory materials. They may be called upon, while hot, to withstand pressure from the weight of furnace parts or contents, thermal shock, resulting from rapid heating or cooling, other induced by temperature change, mechanical wear resulting from movement of furnace contents and chemical attack by heated solids, liquids, gases or fumes (McGraw-Hill, 1997, Harbison, 1979, Kivandin & Markov, 1980, Kingery, Bowen & Uhlmann, 2006).

It is appropriate to mention the role of refractories in the present day civilization, our national economy and our individual lives. Refractories are indispensable for sustainable technological and industrial development and advancement in everything that is manufactured in almost every area of human endeavours. Their need is obvious for the smelting of ores, refining of metals, industrial and transmission of electricity, mining, generation of steam power, production of glass and cement, space shuttle, bio- medical implants, etc. Directly or indirectly refractories are equally important in the production of paper, lumber, textiles, plastics, refining of petroleum, electronics, guided light wave transmission, automobile industries, food and chemical industries, packaging science, watch-making and nearly all other manufactured materials (Harbison, 1979, Kivandin & Markov, 1980, Richerson, 1992, Gohardani & Gohardani, 2012, Lin & Seki, 2008).

Refractory materials of various kinds are needed for the many widely diversified industrial applications. Those in greatest tonnage demand are classified on the basis of composition of properties into a few main types known as fireclay, high-alumina, silica, basic, acidic and insulating refractories (McGraw-Hill, 1997, Harbison, 1979, Kingery, Browen, & Uhlmann, 2006, Babero, 2010).

Insulating bricks are light weight, porous refractories having much lower thermal conductivity and heat-storage capacity than other conventional refractories. Insulating fire bricks are made of diatomite, expanded vermiculite, perlite, refractory fire-clay, kaolin, high-alumina mineral, bubble alumina, quartzite and other minerals. The most common method is to add to the brick mix a combustible material such as sawdust, or fine coke which burns out during firing process. Another common method is to induce in the brick mix materials of low bulk density such as diatomite or expanded minerals. In the production of some insulating fir bricks, foaming agents are used, generally in conjunction with burn-out material to achieve the desired pore structure (Harbison, 1979, Kivandin & Markov, 1980, China, 2006, Onoda & Hench, 1979, Ajay, Kalyani, Devendra & Om, 2012). According to Ajay, Kalyani, Devendra & Om, (2012), the presence of entrapped air in pores have thermal insulating characteristics and thus make the porous fire brick structure suitable for back-up insulation.

Insulating bricks are used most extensively as backing for brick of higher refractoriness and higher thermal conductivity. They are also used for inner linings of furnaces, petrol partitions kilns, metallurgical hot stoves, ceramic kilns, tunnel kilns and lining of main electric stoves, but only when they are not subjected to erosion by molten metal or slag, or to abrasion or corrosion (China, 2006, Richard, 2003, Walter, 1997, Singer & Singer, 1989, Kingery, Browen & Uhlmann, 2006).

The principal advantages in the use of insulating fire-clay bricks where they are applicable instead of the heavier fire clay bricks are: fuel economy through lower heat losses and lower heat-storage capacity of the furnace brick works; increased production due to shorter heating up time; closer control of operation because of rapid response of the furnace to temperature cycles; decrease in size and weight of furnace because of lighter weight of insulating bricks and economy of space because of thinner walls made practicable by higher insulating efficiency.

Materials and Methods

The raw materials: Nafuta clay was procured from National Metallurgical Development Centre (NMDC), Jos, Plateau State, while Nsu clay was obtained from Agbaghara, Nsu town in Mbano Local Government Area of Imo State. The rice husks were collected from Ezilo in Ishielu Local Government Area of Ebonyi State. The clay lumps as mined from their deposits, were crushed, ground, sieved, washed and passed through a 100μm mesh size into a container with some quantity of water. The slip was allowed to settle, de-watered and dried. The dried clay slurry was ground with mortar to increase compatibility and proper blending. The chemical compositions of the samples were determined using “Atomic Absorption Spectrometry Technique” (ASS) and Ultra Violent- Visible Range Spectroscopy (UV-VIS).

The clay samples and the rice husks were mixed in varying proportions as presented below:

JSA - 30% Nsu and 70% Nafuta to serve as a control
JSB - 5% rice husk, 30% Nsu and 65% Nafuta
JSC - 10% rice husk, 30% Nsu and 60% Nafuta
JSD - 15% rice husk, 30% Nsu and 55% Nafuta
JSE - 20% rice husk, 30% Nsu and 50% Nafuta
JSF - 25% rice husk, 30% Nsu and 45% Nafuta

Different clay, rice husks mixtures were thoroughly blended for the determination of the physical properties. Measurements of their green properties such as moisture content, and modulus of plasticity were thereafter made using International Standard Organization (ISO), American Society of Testing of Materials (ASTM) and Japanese Industrial Standard (JIS) accepted methods of testing insulating brick before firing.

The test specimens were fired to temperatures of 900^oC 1000^oC 1100^oC and 1200^oC

respectively and their physical properties such as shrinkage, porosity, density, percentage water absorption and modulus of rupture or transverse strength were determined using internationally accepted standard techniques according to American Society of Testing Materials (ASTM) and Japanese Industrial Standard (JIS).

Results and Discussion

The chemical analysis of the clays carried out indicated that Nafuta clay is a fire clay of the medium duty class while Nsu is a fire clay of the low duty class, (See Tables 1 and 2). From the green state tests of the clay-rice husks mixtures, it could be seen that the percentage making moisture increased with the increase in the rice husks percentage which resulted in the decrease in plasticity of the mixtures/composites.

The physical properties tests results as shown in Tables 4 - 9 indicated that shrinkage, density and modulus of rupture decreased with increase in rice husks addition, while porosity and percentage water absorption increased with increase in rice husks addition but decreased with increase in the firing temperature, Figures 1 - 6. This was because bricks made of rice husks develope plenty of pores during heat treatment due to burning off of the organic materials constituent of rice husk thereby increasing porosity and percentage water absorption. The more the percentage of the rice husks in the brick, the more porous would the brick become thereby enhancing better thermal insulation. The more porous the bricks, the lesser would be the density and hence the reduction in strength and shrinkage properties. The porosity of the clay-clay blend and clay-rice husks composite bricks studied fell within international standard fire clay bricks of 25 - 50% according to ASTM, JIS, Harbison, (1979), Richard, (2003), Ewurum, 1997, Harris, 2009, Halima & Bachir, (2013).

Density, strength and shrinkage increased with increase in the firing temperature while percentage water absorption and porosity decreased with temperature rise as indicated in Figures 1 - 6 respectively. Increasing the firing temperature ensures the completion of crystallization process of clay particles and melting of the low melting point constituents of the brick. The molten materials flows, penetrates the clay – rice husks composite body, closes the open pores, reacts with the alumino-silicate particles, sinters hard thereby increasing density, strength and reducing porosity and percentage water absorption. This is normal for good clay/ceramics products. The insulating brick sample JSD with mixing ratio 3:6:11 (rice husks – Nsu clay – Nafuta clay respectively in grams) gave the optimum performance values of an insulating brick in most of the properties tested which are porosity, density, shrinkage, effective moisture content, strength, percentage water absorption, etc. This could be attributed the reduction in the quantity of Nafuta clay which is highly more plastic than Nsu clay and addition of moderate quantity of rice husks which is the needed combustible material to produce the necessary porosity required of a good insulating brick. The insulating bricks produced by this study compare favourably with other insulating bricks made with clay – sawdust, clay – rice husk , clay – coal dust according to earlier studies on insulating fire brick by Ugheoke, Onche, Namessan & Asikpo, (2006), Halima & Bachir, (2013), BNZ, (2012) and Hegazy, Fouad & Hassanain, (2012).

Contribution to Knowledge

1. Utilization of rice husks in the production of insulating fire brick.
2. Production of insulating fire brick from local raw materials.
3. Production of an insulating fire bricks that can withstand temperature up to 1200^{o}C.
4. The use of rice husks as secondary raw materials for production of light-weight insulating ceramic bricks.
5. Reduction of the hazard of rice husks to the environment.
6. Provision of alternative solution to waste management issue.

Conclusion

Insulating fire clay brick has been produced successfully from Nigeria clays with the addition of rice husks as the combustible material to create the needed porosity. Porosity obtained, which is the most important property distinguishing insulating bricks from conventional dense bricks fall within the internationally recommended standard of between 25 and 50% porosity according to BNZ (2012), Halima & Bachir (2013) and Hegazy, Fouad, Haassanain, (2012). The insulating refractory bricks produced from this clay- rice husk composite blend can be used in the lining and back-ups of crucible furnaces for melting non ferrous metals, heat treatment furnaces, forge furnaces, glass tank regenerators and support structures, salt bath, incinerators, reheating and holding furnaces, lime/ceramic kilns, ovens, ladles, soaking pits, boiler fittings, oil refining equipments, sound-absorption cells, etc. The use of rice husks in the production of insulating fire bricks will help solve waste management problem, create job opportunity to the youths and serve as source of income to the host community.

Table 1. Chemical analysis of Nafuta clay

Oxides	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	SiO_2	Na_2O	K_2O	L.O.I
Percentage,%	30.78	1.16	1.90	0.11	0.12	56.15	0.03	0.17	9.41

Table 2. Chemical analysis of Nsu clay

Oxides	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	SiO_2	Na_2O	K_2O	L.O.I
Percentage,%	24.40	1.57	0.83	0.003	Nil	61.29	0.05	0.48	9.97

Table 3. Percentage making moisture and modulus of plasticity

Specimen	Modulus of plasticity	% Making moisture
JSA	3.47	23.30
JSB	3.25	23.60
JSC	3.18	23.90
JSD	3.15	25.29
JSE	3.11	25.89
JSF	3.08	25.94

Table 4. Physical properties test for JSA at various firing temperature, ^oC

Property/Temperature, ^oC	900	1000	1100	1200
Total shrinkage, (%)	5.80	7.60	8.70	10.80
Apparent porosity, (%)	38.74	36.81	34.65	25.72
Bulk density, Kg/cm^3	1.61	1.63	1.65	1.68
Apparent density, Kg/cm^3	2.35	2.38	2.42	2.47
% Water absorption	24.02	22.51	20.96	14.75
Modulus of rupture, Kg/cm^2	20.15	37.60	48.14	80.83

Table 5. Physical properties tests for JSB at various firing temperature, ^oC

Property/Temperature, ^oC	900	1000	1100	1200
Total shrinkage, (%)	5.60	7.60	8.40	10.00
Apparent porosity, (%)	40.79	39.29	37.29	27.85
Bulk density, Kg/cm^3	1.59	1.61	1.63	1.66
Apparent density, Kg/cm^3	2.32	2.35	2.38	2.42
% Water absorption	25.62	24.45	22.92	16.18
Modulus of rupture, Kg/cm^2	18.50	34.58	43.67	77.66

Table 6. Physical properties test for JSC at various firing temperature, ^oC

Property/Temperature, ^oC	900	1000	1100	1200
Total shrinkage, (%)	5.39	7.18	8.00	9.80
Apparent porosity, (%)	44.41	42.28	41.39	28.77
Bulk density, Kg/cm^3	1.56	1.57	1.59	1.64
Apparent density, Kg/cm^3	2.28	2.30	2.33	2.40
% Water absorption	28.46	27.03	26.09	16.80
Modulus of rupture, Kg/cm^2	17.30	32.04	39.58	51.69

Table 7. Physical properties test for JSD at various firing temperature, ^oC

Property/Temperature, ^oC	900	1000	1100	1200
Total shrinkage, (%)	5.15	6.10	7.70	9.60
Apparent porosity, (%)	46.70	44.34	43.24	34.51
Bulk density Kg/cm^3	1.53	1.56	1.58	1.60
Apparent density Kg/cm^3	2.23	2.28	2.31	2.34
% Water absorption	30.47	28.48	27.58	20.86
Modulus of rupture Kg/cm^2	16.53	30.12	36.20	56.20

Table 8. Physical properties test for JSE at various firing temperature, °C

Property/Temperature, °C	900	1000	1100	1200
Total shrinkage, (%)	4.90	6.50	7.40	9.50
Apparent porosity, (%)	51.40	48.78	47.12	37.62
Bulk density, Kg/cm^3	1.47	1.51	1.53	1.57
Apparent density, Kg/cm^3	2.15	2.21	2.24	2.30
% Water absorption	34.14	32.25	30.78	23.17
Modulus of rupture, Kg/cm^2	15.82	27.22	34.31	52.00

Table 9. Physical properties test for JSF at various firing temperature, °C

Property/Temperature, °C	900	1000	1100	1200
Total shrinkage, (%)	4.30	5.80	6.60	8.90
Apparent porosity, (%)	53.01	50.65	49.65	39.90
Apparent density, Kg/cm^3	1.45	1.47	1.50	1.56
Bulk density, Kg/cm^3	2.10	2.14	2.19	2.28
% Water absorption	36.06	33.91	31.91	24.54
Modulus of rupture, Kg/cm^2	14.51	22.10	31.15	44.23

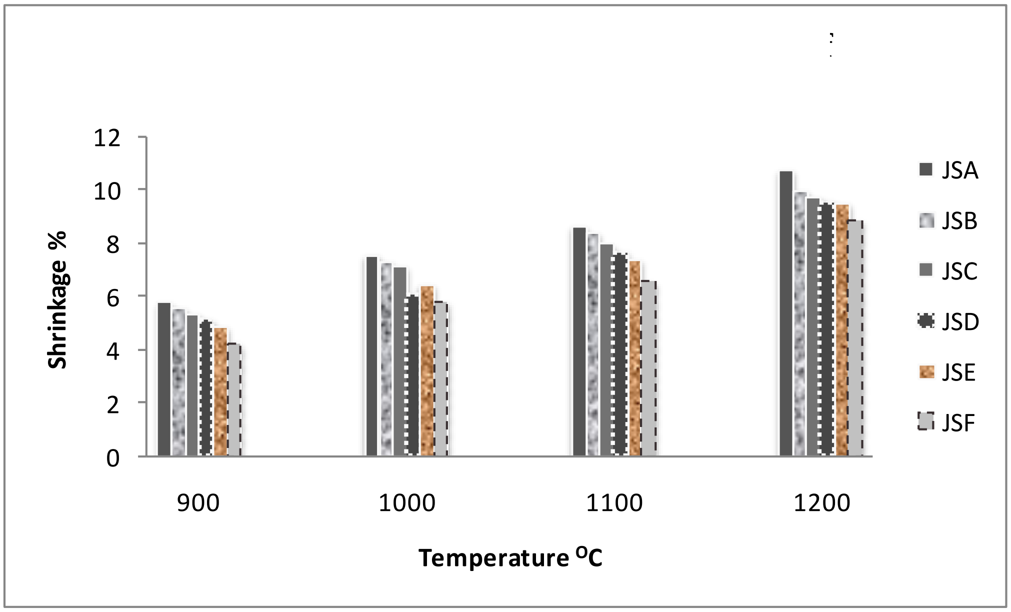

Figure 1: Shrinkage against firing temperature

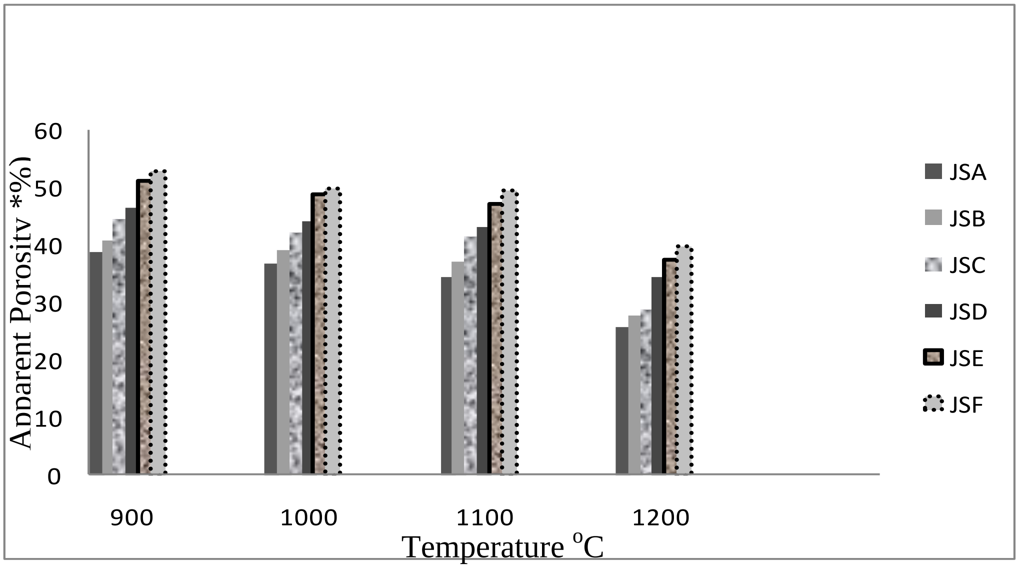

Figure 2: Apparent porosity against firing temperature

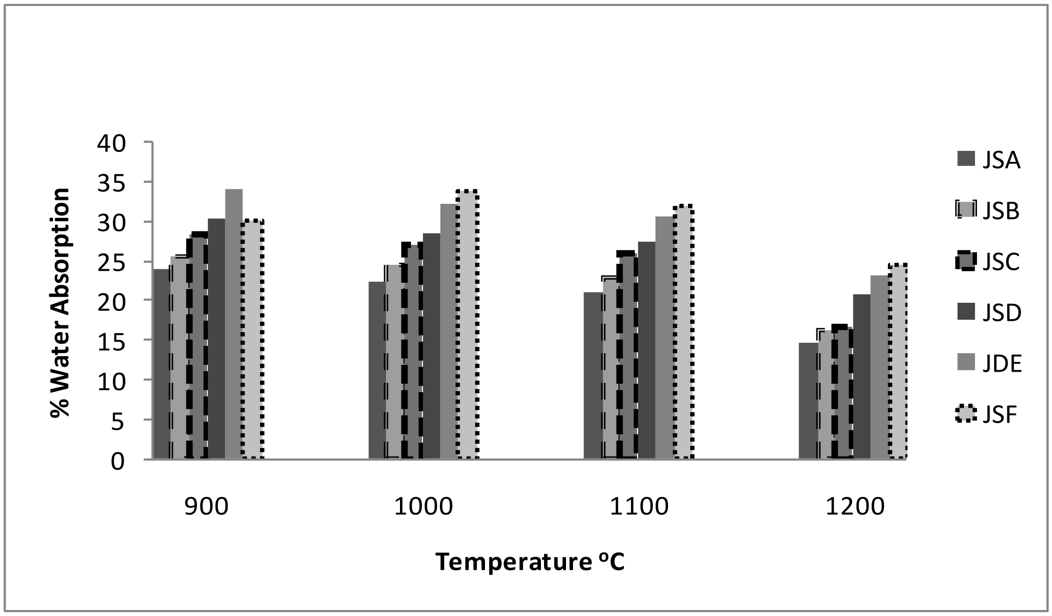

Figure 3: Water absorption against firing temperature

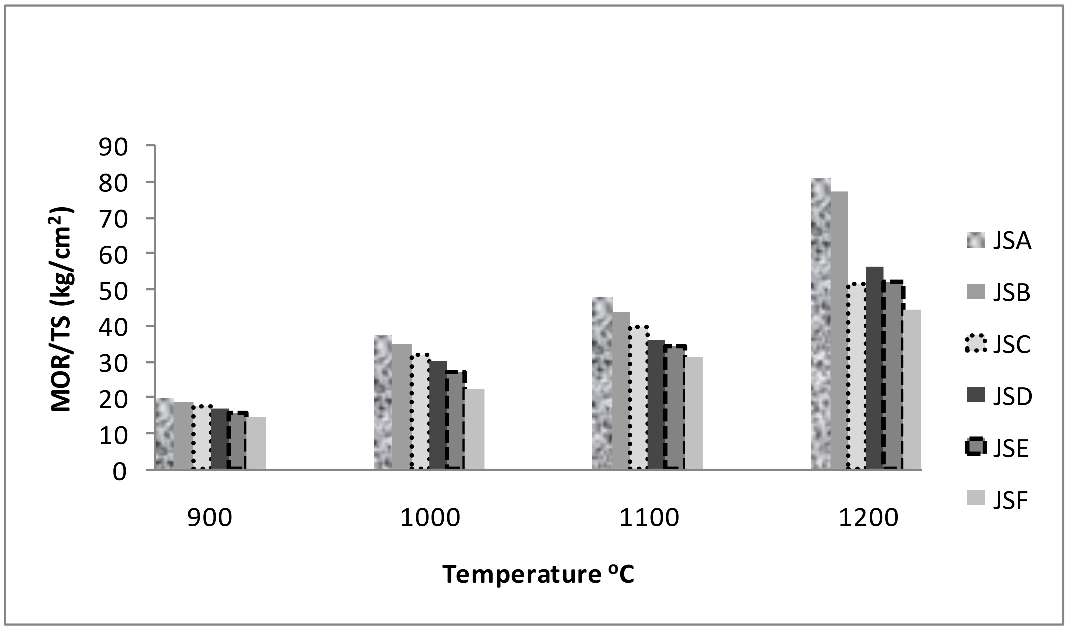

Figure 4: Transverse strength Kg/cm^2 against firing temperature

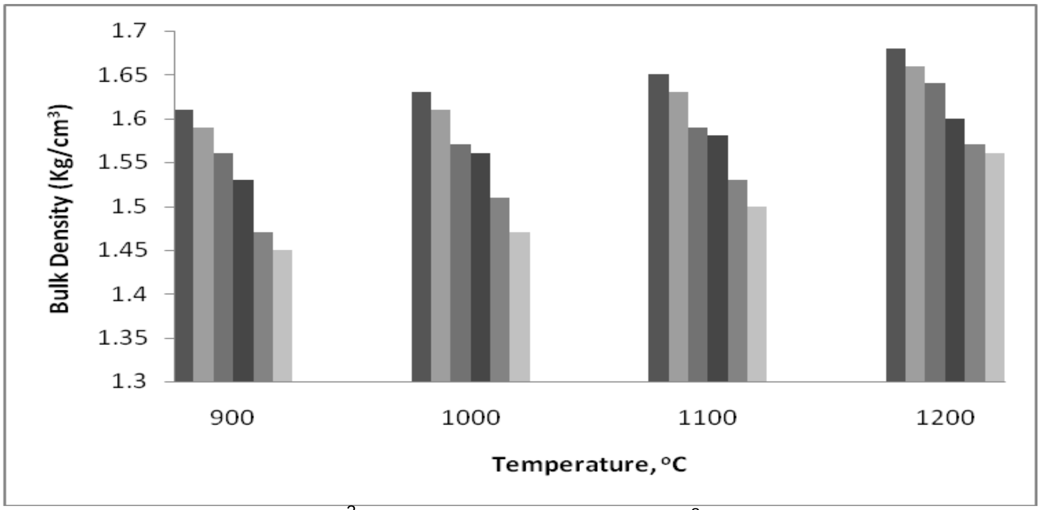

Figure 5: Bulk Density Kg/cm^3 against Firing Temperature ^{o}C

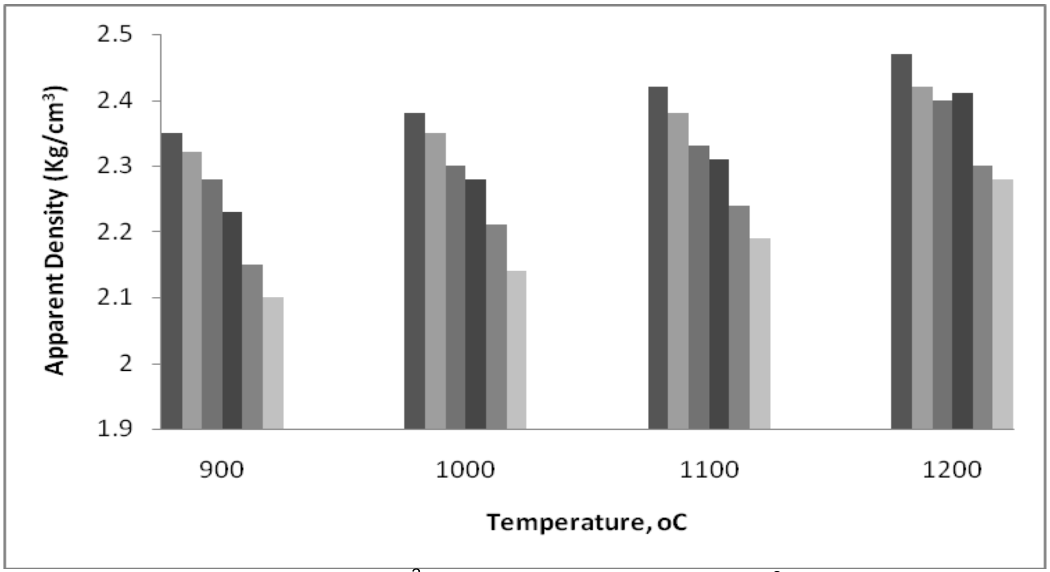

Figure 6: Apparent Density (Kg/cm^3) against Firing Temperature, ^{o}C

References

Ajay Kumar, Kalyani Mohanta, Devendra Kumar & Om Parkash, (212). Properties and Industrial Application of Rice husk. A Review. Vol. 2 Issue 10, pp. 18 - 35. International Journal of Emerging Technology and Advanced Engineering.

American Society of Testing Materials (ASTM).
http://www.astm.org.insulatingbricks.mechanical/physicaltests.asp?

Barbero, E.J. (2010). Introduction to Composite Materials Design, 2nd Edition, pp. 29 – 53. Boca Raton FL Palm Beach City, Florida, CRC Press.

BNZ Materials INC (2012). Insulating fire brick. pp. 2 – 12. Zelienople, PA 16063, Pennsylvania

China Manufacture of mullite heat institution bricks (2006). Mullite Heat Insulation, pp. 15 - 21. High temperature refractory materials Co. Ltd - Yixing City Nouming

Ewurum M.C. (1997). Development of fire clay insulating bricks from Nigeria clays, pp. 8 - 18. Technical Research Seminar Paper, PRODA, Enugu.

Gohardani Amir, S. & Gohardani Omid, (2012). "Ceramic engine consideration for future aerospace propulsion", Vol. 84 Issue: 2, pp. 75 DOI. Aircraft Engineering and Aerospace Technology.
Halima Chemani & Bachir Chemani, (2013). Valorization of wood sawdust in making porous clay brick, Vol. 8 (15), pp. 609 – 614. Academic Journals

Harbison-Walker Refractory Company (1979). Modern refractory, 4th Edition, pp. 124 – 132. Pesttsburgh, Pennsylvania

Harris, D.C. (2009)."Materials for Infrared Windows and Doors: Properties and Performance". 2nd Edition, Vol. PM70, pp. 20 – 28. International Society of Optical Engineers. Bellingham WA, SPIE PRESS.
Hegazy, B.E.E., Fouad, H.A. & Hassanian, A.M., (2012). "Brick Manufacturing from water treatment sludge and rice husk ash" Vol. 6 (3), pp. 453 – 461. Australian Journal of Basic and Applied Sciences

International Standard Organization (ISO).
http://www.iso.insulatingbricks/tests/shrinkage/porosity/density/modulus of rupture.co

Japanese Industrial Standard (JIS). http://www.jis.materialstesting.insulating/porous bricks

Kingery, W.D., Browen, H.K. & Uhlmann, D.R., (2006). Introduction to Ceramics, 2nd Edition, pp. 501 – 532. New York, Wiley-Interscience.

Kivandin, V.A. & Markov, B.L., (1980). "Metallurgical Furnaces", pp. 255 – 256. Moscow, Mir Publishers.

Lin, A.Y. & Seki, Y., (2008). "Biological Materials: Structure and Mechanical Properties", Vol. 53: pp. 1-206, Progress of Materials Science.

McGraw-Hill, (1997). Encyclopedia of science and technology, 15th Edition Vol. 3, pp. 1236 - 1252, New York
Onoda, G.Y. & Hench, L.L., (1979). Ceramic processing before firing, pp. 25 - 35. New York, Wiley & Sons Inc.
Richard Boy, (2003). Ceramics clay and insulating brick-ceramics for stoves Part I, II & III, pp. 50 - 123. Neosho.

Richerson, D.W., (1992). Modern Ceramic Engineering, 2nd Ed. Pp. 201 – 224. New York, Marcel Dekker Inc.

Singer Felix & Singer S. Sonja, (1989). Industrial ceramics, pp. 1294 - 1297. New York, Chapman and Hall.

Ugheoke, B.I., Onche, E.O., Namessan, O.N., & Asikpo, G.A., (2006). Use of Kaolin - Rice Husk - Plastic Clay to Produce Insulating Fire brick, Vol. 2 (4), pp. 136 - 147. International Journal of Environmental Science and Engineering
Walter, C. Rueekel, (1997). Physical properties of some insulating bricks, Vol. 18, pp. 30 - 15. Journal of the American Ceramic Society.