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Effect of Nigerian Rice Husk Ash on Some Engineering Properties of Sandcrete Blocks and Concrete

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Abstract: Sandcrete blocks have been in use in many nations of the world including Nigeria for a long time, playing a major role in the building and construction industry. In the investigation described in this study rice husk ash (RHA) has been used to partially replace cement in both concrete and sandcrete block manufacture. RHA having pozzolanic properties would reduce the demand of Portland cement whose cost has soared at the moment in Nigeria and hopefully help reduce the unit cost of both concrete and sandcrete block. Results suggested that the addition of RHA in the mix produced sandcretes of lower density, meaning that the density of the blocks actually decreased as the RHA content in the mix increased. In addition it was observed the compressive strength of the sandcrete blocks was not enhanced by the use of RHA. It was also observed that10% RHA content in the sand-cement mix is the optimum for improved structural performance. RHA however had a fairly significant effect on the compressive strength of the concrete cube specimens increasing the latter by nearly 17% (at 28 days) and at 5% RHA content. Concrete made with 20% RHA content is suitable for low-cost housing development.

Key words: Sandcrete blocks, concrete, rice husk ash, engineering properties

INTRODUCTION

Hollow sandcrete blocks containing a mixture of sand, cement and water are used extensively in many countries of the world especially in Africa. In many parts of Nigeria, sandcrete block is the major cost component of the most common building. However, it is pertinent to note that it is manufactured without reference to any standard specification either to suit local building requirements or for good quality work. The high and increasing cost of cement has contributed to the non-realization of adequate housing for both urban and rural dwellers. Alternatives to cement as a material for construction are very desirable in both short and long term as a stimulant for socio-economic development. In the short run, any material that can complement cement and is much cheaper will be of great interest. Over the past decade, the presence of mineral admixtures in construction materials has been observed to impart significant improvement on their strength, durability and workability (Mental, 1994; Falade, 1990, 1997; Oyekan 2001).

Rice husks are a residue produced in significant quantities on a global basis. While, they are utilized as fuel in some regions, they are regarded as waste thereby causing pollution and in others, problems with disposal. Hence, its profitable use in an environmentally friendly manner will be a great solution to an otherwise pollutant. When burnt under controlled conditions, the rice husk ash is highly pozzolanic and very suitable for use in lime-pozzolana mixes and for Portland cement replacement (Yogenda and Jagadish, 1988). When burnt in an uncontrolled manner however, the ash, which is essentially silica, is converted to crystalline forms and becomes less reactive. Partially replacing cement with rice husk ash (RHA) is not generally new. Effect of RHA as a partial substitute for cement in masonry units was investigated by Cook *et al*. (1977) and specifically in concrete manufacture by Zhang and Malhotra (1996), Mehta and Pitt (1996), Okpala (1987) and Sampalo *et al*. (2002). On sandcrete block, Cisse and Laguerbe (2000) observed that the mechanical resistance of sandcrete blocks obtained when unground ash was added increased in performance over the classic mortar blocks. Their studies in Senegal also revealed that the use of unground rice husk ash enabled production of a lightweight sandcrete with insulating properties and at a reduced cost. The ash pozzolanic reactivity was responsible for the enhanced strength obtained.

Okpala (1993) partially substituted cement with rice hush ash in the percentage range 30-60% at intervals of 10% while considering the effect on some properties of the block. His results revealed that a sandcrete mix of 1:6

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(cement/sand ratio) required up to 40% cement replacement and a mix of 1:8 ratio required up to 30% to be sufficient for sandcrete block production in Nigeria. However, it is worthy of note that replacing cement with such high volume of RHA could be economically counterproductive for local sandcrete block manufacturers thereby defeating the main purpose of the substitution which is to reduce the unit cost of the block. Also, hygrothermal properties which are important in areas prone to flooding are not considered in the investigation.

This study therefore, investigates the effect of partially replacing cement with the Nigerian rice husk ash on the structural, thermal and hygrothermal properties of sandcrete block in the percentage range 5-30% at intervals of 5%. Falade (1990) reported that the replacement of cement with sawdust ash reduced the strength of concrete produced. He also noted that the effect is more pronounced in the mixtures with high aggregate/cement ratios. It was also reported by Falade (1997) that the 28-day compressive and flexural strength values increased when cement was partially replaced with powdered glass in concrete manufacture. The 28 days compressive strength increased by 43.5% while the flexural strength increased by 11% at 5% replacement.

MATERIALS AND METHODS

This research was carried out at the University of Lagos, Nigeria in the year 2006. The material constituents, their mix, presence of admixtures and manufacturing process are important factors that determine the properties of sandcrete blocks. The materials used and method of manufacture employed in this investigation are thus presented.

Materials of sandcrete blocks: The sandcrete blocks are made of sand, cement and varying proportions of granite fines.

Sand: The sand used was clean, sharp river sand that was free of clay, loam, dirt and any organic or chemical matter. It was sand passing through 4.70 mm zone of British Standard test sieves. The sand had a specific gravity of 2.66 and an average moisture content of 0.90%. The coefficient of uniformity of the sand was 2.95.

Cement: The cement used was Ordinary Portland Cement from the West African Portland Cement Company, Ewekoro in Ogun State of Nigeria with properties conforming to BS 12 (1971).

Water: The water used was fresh, colourless, odourless and tasteless potable water that was free from organic matter of any type.

Table 1: Chemical analyses of rice husk ash and cement

Parameters	Rice hush ash results (%)	Cement results (%)
Moisture	0.27	-
Ash	11.28	-
Ferrous oxide (Fe_2O_3)	Not detected	4.75
Calcium oxide (CaO)	0.06	64.73
Magnesium oxide (MgO)		2.01
Sodium oxide (Na_2O)	1:18	0.19
Potassium oxide (K_2O)	0.10	0.42
Lead oxide (PbO)	Not detected	-
Silica (SiO_2)	16.0	21.0
Barium oxide (BaO)	0.24	-
Aluminium oxide (Al_2O_3)	0.03	5.22
Sulphite (SO_3^{2-})	Not detected	1.48

Grading of aggregates: The grading of an aggregate defines the properties of different sizes in the aggregate. This grading has a considerable effect on the workability and stability of the mix.

Wet sieving analysis which is in accordance with BS 1377 (1971) was used. Table 1 shows the results of the chemical analyses of the rice husk ash and cement.

Manufacture of sandcrete blocks: The blocks (all hollow) were manufactured with the use of a vibrating machine. Two mixes (1:6 and 1:8 cement-sand ratios) were used in this investigation. Two different sizes of block, namely, 450×225×225 mm and 450×150×225 mm (NIS 87 (2004)) were used. The standard mix proportion is 1: 6, that is one part by volume of cement to six parts by volume of coarse sand but a mix proportion of 1:8 is used by many commercial sandcrete block manufacturers. In this research effort, both mix proportions have been used.

In the manufacture of these blocks, hand mixing was employed and the materials were turned over a number of times until an even colour and consistency were attained. Water was added through a fire hose in just sufficient quantity and further turned over to secure adhesion. It was then rammed into the machine moulds, compacted and smoothed off with a steel face tool. After removal from the machine moulds, the blocks were left on pallets under cover in separate rows, one block high and with a space between 2 blocks for at least 24 hours and kept wet during this period by watering through a fine watering hose. Testing for compressive strength was then carried out at ages 7, 14, 21 and 28 days.

Manufacture of concrete cubes: The concrete cube specimens were made using approved cube moulds. A total of 12 cube specimens were made for each proportion of rice husk ash in the cement matrix for the compressive strength test. All the cubes were cured by immersion in water right from the moment they were removed from the moulds until the day for their testing when they were removed from the curing water tank and sun-dried before being tested for strength. The weight of each specimen was determined and recorded prior to the testing. The universal testing machine was used for this exercise.

Compaction

Sandcrete blocks: This can be done by the use of approved standard machine compaction but hand compaction can also be used when the blocks have been manually produced using metal moulds. In either case what is essential is that the approved strength must be attained. In this research effort standard machine compaction was utilized.

Concrete cubes: In order to remove trapped air in the concrete, which could reduce the strength of the cubes, the cube specimens were fully compacted by hand. For this, the 150 mm cube moulds were filled in three approximately equal layers and each layer was fully compacted before adding the next one. At least 35 tamps of the standard tamping bar were used to compact each layer. After the top layer had been tamped, the top surface was trowelled level with the top of the mould.

The hygrothermal properties: The properties are determined as follows:
Porosity, υ is given by:

$$\upsilon = \frac{V_f}{V} \times 100\% \quad (1)$$

Permeability: Darcy's law (1856) for fluid flow in a permeable medium expresses permeability in terms of measurable quantities and states that the steady state rate of flow is directly proportional to the hydraulic gradient. Thus, permeability, K can be expressed as:

$$K = \frac{Q}{A[h/l]} \quad (2)$$

For uni-axial penetration employed in this investigation, it is given as:

$$K = \frac{\upsilon\, d^2}{2\, t\, h} \quad (3)$$

Water absorption coefficient, A_w: This property is obtained using the partial immersion method as stipulated in the European Standard CEN/TC 89/WG10 N70 (1994). It is calculated as (Mukhopadhaya *et al*., 2002).

$$A_w = \frac{M_t - M_i}{A\sqrt{t}} \quad (4)$$

Sorptivity: It is a measure of the capacity of the medium to absorb liquid by capillary action. The absorption of water into concrete under capillary action is dependent on the square-root of time (Hall, 1989).

$$A' = S\sqrt{t} \quad (5)$$

In most cases, the test method chosen for a particular property is always the one appropriate to the predominant transport mechanism acting on the block. After evaluation of various methods, it was decided that capillary rise method in accordance with the ASTM E 514-90 (1990) be employed. Basically, a sample of sandcrete block is placed with one edge in contact with water surface. The height of capillary rise is measured. The fineness of the capillary pores in the sandcrete blocks causes absorption of water by capillary attraction. Hence, a measure of the rate of absorption provides a useful indication of the pore structure. If water is absorbed rapidly, it shows that the pores are large; if the absorption rate is slow, then, the pores are small. This is considered to be a useful measure of the durability of building materials.

Necessary precautions were taken while taking the readings and in ensuring that the specimens were as dry as possible before coming in contact with water.

RESULTS AND DISCUSSION

Results for the compressive strength and the hygrothermal properties are presented in graphical forms. While the results presented for the compressive strength are for both 1:6 and 1:8 mix ratios, the results for the thermal and hygrothermal properties are limited to the 1:8 mix ratio only.

Effect of RHA on compressive strength: The results are shown in graphical form. Fig. 1 shows the variation of compressive strength with percentage RHA content in the mix.

The strength test results show clearly that RHA does not appreciably enhance the compressive strength of the conventional sandcrete block. The graph shows that the blocks actually decreased in strength as the RHA percentage content in the mix increased. At a mix proportion of 1:8 and for the 450×150×225 mm blocks the compressive strength of the sandcrete blocks increased at 5% RHA content in the mix. This may be due to the

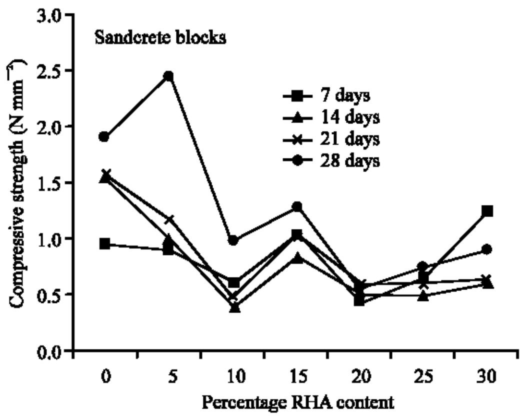

Fig. 1: Variation of compressive strength with percentage RHA content

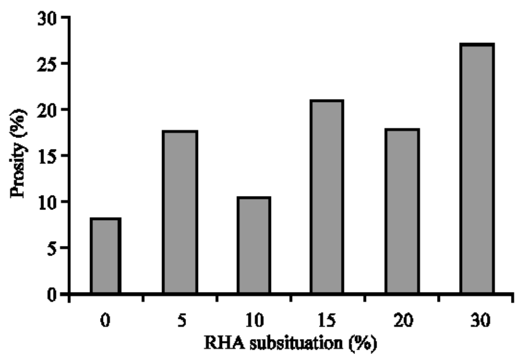

Fig. 2: Porosity against percentage substitution of RHA

reaction of the lime with silica (SiO_2). In the presence of moisture the lime in the cement reacts with the silica in the RHA to produce tricalcium silicate (C_3S) and dicalcium silicate (C_2S), the hydration products of these two compounds are tobermorite gel and calcium hydroxide. The tobermorite particles are responsible for the cementing properties as well as other important engineering properties such as strength and shrinkage.

The decrease in strength may be attributed to the fact that the partial replacement of cement with the RHA caused a reduction in the quantity of cement in the mix available for the hydration process and hence a reduction in the formation of the stable strength producing cementitious compounds. Another possible reason for the low strength obtained is the type of burning used to produce the ash.

The burning process has been known to affect the quality of the ash produced. Open field burning was used in the investigation and the ash obtained probably contained a high percentage of unburnt carbon with a consequent reduction in the pozzolanic activity of the ash. High pozzolanic RHA is created by maintaining husk combustion temperatures between 500 and 700°C for less than a minute.

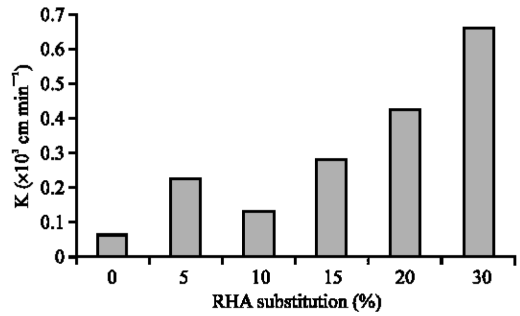

Fig. 3: Permeability against percentage substitution of RHA

Effect on porosity: Block units take in water due to their porous nature. The volume of water absorbed is an indication of the pore volume which depends on the interstitial arrangement of the particles of the constituent materials at micro level. When exposed to persistent flooding, a highly porous block will absorb and retain much water, become soaked and could eventually fail. The variation of porosity with percentage substitution of the rice husk ash is presented in Fig. 2.

The results show that all the blocks with admixtures are more porous than the control (0%). The closest in value to that of the control is the block with 10% RHA substitution. While, the most porous is that with 30% replacement. The fluctuating values of the porosity with the percentage substitution may be probably due to non-uniformity in the RHA distribution. It can be concluded here that sandcrete block with RHA absorbs more fluid and hence, fails faster.

Effect on permeability: Figure 3 shows the variation of permeability with the increase in rice husk ash content. It is observed that replacing cement with RHA increases the permeability of the sandcrete block. This means that the inclusion of the admixture opens up the block in a way that encourages up flow of fluid.

Effect on water absorption coefficient: Determination of the water absorption coefficient is of relevance in knowing how the block will perform under moist or wet condition.

In Fig. 4, the water absorption coefficient, A_w, is plotted against percentage RHA content. 10% RHA substitution is seen to have lower A_w value than the control block.

Effect on average absorption and sorptivity: In using blocks for external wall in humid climate, the density and water-resistance ability of the blocks must be considered in order to minimize penetration of moisture or rain water

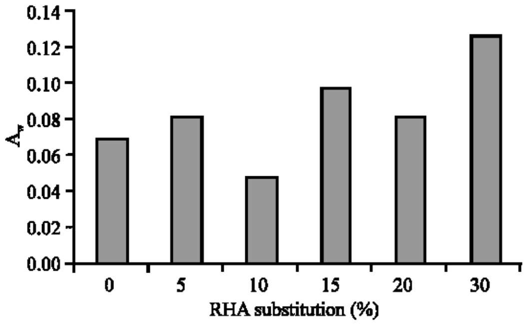

Fig. 4: Water absorption coefficient, A_w against percentage substitution of RHA

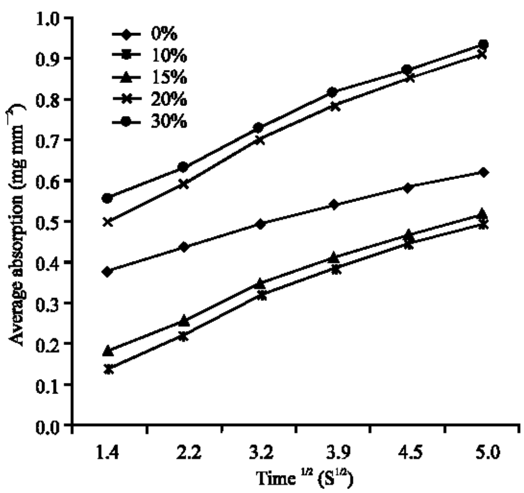

Fig. 5: Average Absorption for the Nigerian RHA against the square root of time

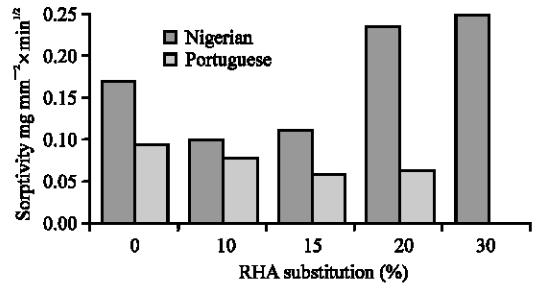

Fig. 6: Comparison of the sorptivity of sandcrete blocks made with percentage substitution of the Nigerian and Portuguese RHA

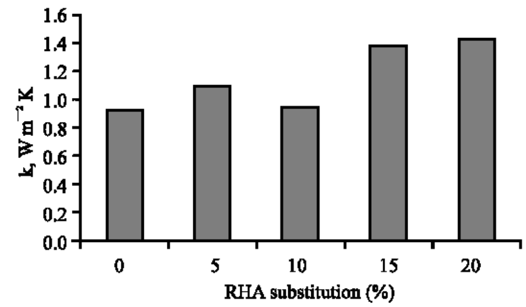

Fig. 7: Plot of thermal conductivity against % RHA substitution

into the interior of the building. Similarly, when block work is to be constructed as channels for drainage, blocks to be used must have a very low value of water absorption coefficient and hence, highly impermeable. Damp penetration weakens the blocks and can eventually result in the collapse of the block work

The plot of the average absorption of the block against time, Fig. 5 shows an almost linear relationship with the square root of time for each percentage of rice husk ash content in the mix. The results show that addition of the admixture makes the average absorption value to drop drastically at first and thereafter increases above that of the control block. The 10% RHA substitution block has the lowest values of the average absorption for each time interval. This makes it the most water resistant.

Sorptivity, on the other hand, is a measure of the capacity of the block to absorb liquid by capillarity. It is observed in Fig. 6 that the value of sorptivity for the sandcrete blocks initially reduces as the content of rice husk ash increases with the minimum value at the 10% substitution. It later increases with the RHA content. The results of the present study for rice husk ash are compared with the experimental data of Sampalo *et al.* (2002) on Portuguese rice husk ash (Fig. 6). Unlike the Nigerian rice husk ash, the sorptivity value for the Portuguese rice husk ash decreasess as the RHA content increases. The implication of this is that the addition of the Nigerian RHA forms a structure that encourages liquid absorption by capillary as the RHA content increases beyond 10%, whereas the Portuguese rice husk ash forms a more compact structure that reduces fluid absorption.

Effect on thermal conductivity: The effect of the substitution of RHA on the thermal conductivity of the sandcrete block with 1:6 mix ratio is presented in Fig. 7. The value of the thermal conductivity is seen fluctuating as the RHA content increases.

In a manner consistent with other properties, the value of the thermal conductivity of the block could be said to increase as the RHA content increases except that there was a drop in the value for the 10% RHA content. The low value of the thermal conductivity of the block with 10% RHA content makes it the most suitable when

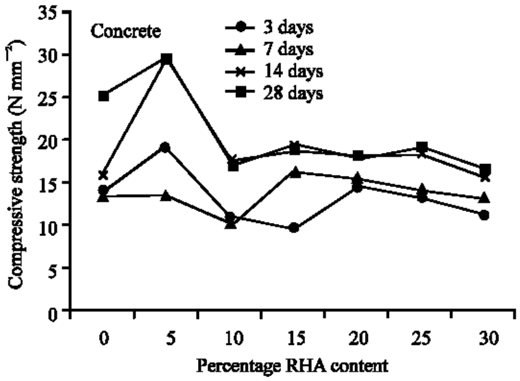

Fig. 8: Variation of compressive strength with percentage RHA content

reduction of heat transfer into the enclosed space or when reduction of heat loss from the enclosed space is desired. This would minimize the cooling load necessary to provide a given level of thermal comfort within the building over the annual climatic cycle. This would help in reducing the size of the air-conditioning system required to cool or heat the space, reduce the thickness of the thermal insulator and extend the period of human comfort without reliance on mechanical air-conditioning. The above qualities reduce the annual energy cost in addition to other energy conservation and environmental effects.

Effect of RHA on concrete: The results are presented in graphical form. Figure 8 shows the variation of compressive strength with the RHA percentage content at 28 days.

The results show that the highest compressive strength for the concrete cubes was attained at a RHA percentage content of 5% in the mix. The strength of 29.35 N mm^{-2} obtained represented a 16.8% increase over the strength at 0% ash content in the mix. As the percentage RHA content however increased the compressive strength of the concrete cube specimens decreased. The 28th day compressive strength decreased from 29.35 N mm^{-2} at 5% RHA content to 16.43 N mm^{-2} at 30% RHA content in the sand-cement mix. The initial increase in strength of the Sandcrete block could be attributed to the reaction of the lime (CaO) in the cement with the silica in the RHA resulting in the production of strength producing calcium silicate compounds. As the percentage RHA content in the mix increased, the amount of cement available for the hydration process decreased with a consequent reduction in the strength of the concrete cube specimens produced.

CONCLUSION

The main conclusions derived from this investigation are as follows:

- RHA has a fairly significant effect on the compressive strength of sandcrete blocks at low RHA content in the sand-cement matrix. A 29% increase in strength was obtained over the block without RHA and for a mix proportion of 1:8.
- As the percentage RHA content in the mix increased the compressive strength of the sandcrete blocks decreased. For the 1:6 mix proportion the compressive strength of the sandcrete blocks decreased throughout as the RHA content increase. For the 1:8 mix proportion, however and for the 450×150×225 mm blocks, the compressive strength increased at 5% RHA content and began to decrease as the RHA content in the cement-sand matrix increased.
- The sandcrete blocks containing RHA are not strong enough to be used as load-bearing Type A blocks or non-load bearing Type B blocks. But blocks made with mix containing 25-35% cement replacement with RHA is suitable for use as non load-bearing Type C blocks.
- The addition of RHA into the sand-cement matrix produced sandcrete blocks of lighter weight. The density of the blocks actually decreased as the percentage RHA content in the mix increased.
- The results of the hygrothermal properties show that 10% rice husk ash would be the optimum content to replace cement with in order to obtain a very compact block.
- The maximum compressive strength of 29.35 N mm^{-2} was obtained for the concrete cube specimens at a percentage RHA content of 5%.
- As the percentage RHA content in the mix increased the compressive strength of the concrete cube specimens decreased appreciably to a value of 16.43 N mm^{-2} at 30% RHA content.
- Concrete made with 20% replacement of cement with RHA is suitable for low cost housing development.
- Sandcrete blocks made with 10% rice husk ash content have the best heat resistant quality.

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Notations

A : liquid contact area of permeable medium perpendicular to flow (m^2).
A' : Cumulative infiltration.
A_w : Water absorption coefficient.
h : Hydraulic head (m).
K : Coefficient of permeability or hydraulic conductivity ($m\ s^{-1}$).
l : Length of flow path (m).
M : Specimen mass gain (kg).
M_t : Specimen mass after time, t (kg).
M_i : Initial mass of the specimen (kg).
P : Percentage substitution of admixture (%).
Q : Liquid flow rate ($m^3 s^{-1}$).
S : Sorptivity ($m/s^{1/2}$).
V : Volume of material sample (m^3).
t : Time taken for liquid to rise (s).
V_f : Volume of water absorbed (m^3).

Greek symbols

υ : Porosity of the material (%).

REFERENCES

ASTM E 514-90, 1990. American Society for Testing and Materials.

BS 12, 1971. Portland cement (Ordinary and Rapid-Hardening). Part 2, British Standards Institution.

Cisse, I.K. and M. Laguerbe, 2000. Mechanical Characterization of Filler Sandcretes with Rice Husk Ash Additions; Study Applied to Senegal. J. Cement and Concrete Res., 30 (1): 13-18.

Cook, D.J., R.P. Pama and B.K. Paul, 1977. Rice Husk Ash-Lime Cement Mixes for use in Masonry Units. J. Building and Environ., 12: 281-288.

Darcy, H.P.G., 1856. Les fontaines publiques de la ville de Dijon. V Dalmont, Paris, pp: 674.

European Standard: CEN/TC89/WG10N70, 1994. Thermal Properties of Buildings and Building Components-Determination of Water Absorption Coeffient Working Draft.

Falade, F., 1990. Effect of Sawdust Ash on the Strength of Laterized Concrete. West Indian J. Eng., 15 (1): 71-84.

Falade, F., 1997. The Use of Ground Broken Bottles as Partial Replacement of Cement in Concrete. Proc. 4th Int. Conf. Structural Eng. Analysis and Modelling, Ghana, pp: 473-486.

Hall, C., 1989. Water Sorptivity of Mortars and Concretes. A Review Magazine of Concrete Res., 41: 51-61.

Mehta, P.K. and N. Pitt, 1996. Energy and Industrial Materials from Crop Residues. In Resources Recovery and Construction, 2, Elsevier Scientific Publishing Company, pp: 23-38.

Mental, P.Q., 1994. Mineral admixtures for concrete –an overview of recent developments. Advances in Cement and Concrete, Proceedings of Engineering Foundation Conference, University of New Hampshire, Durham. American Society of Civil Engineers (ASCE), pp: 243-256.

Mukhopadhaya, P., P. Goudreav, M.K. Kumaran and Van Reenen, 2002. Influence of material properties on the hygrothermal response of an ideal stucco wall-result from hygrothermal simulations. 6th Nordic Building Physic Symposium, Trodheim, Norway, pp: 611-618.

Muskat, M., 1937. The flow of homogeneous fluids through porous media, McGraw-Hill, NY, pp:763.

Okpala, D.C., 1987. Rice Husk Ash (RHA) as Partial Replacement of Cement in Concrete. Proceedings of 1987 Annual Conference of Nigerian Society of Enginners, Port-Harcourt, pp: 83-90.

Okpala, D.C., 1993. Some Engineering Properties of Sandcrete Blocks Containing Rice Husk Ash. J. Building and Environ., 28 (3): 235-241.

Oyekan, G.L., 2001. Effect of Granite Fines on the Compressive Strength of Sandcrete Blocks, Proceedings of Conf. Construction Technol. Contect-Sabah, Malaysia, pp:14-17.

Sampalo, J., S.J. Coutiaho and M.N. Sampalo, 2002. Portuguese rice husk ash as a partial cement replacement. Technical Report, Department of Civil Engineering, FEUP, Universidade do Porto, Portugal.

Yogenda, M.R. and K.S. Jagadish, 1988. Pozzolanic Properties of Rice Husk Ash, Burnt Clay and Red Mud., J. Building and Environ., 23: 303-308.

Zhang, M.H. and V.M. Malhotra, 1996. High performance concrete incorporating rice husk ash as a supplementary cementing material. ACI Material J., pp: 629-636.