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Exploiting the Potentials of Rice Husk Ash as Supplement in Cement for Construction in Nigeria

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Abstract: This paper present the results of investigation on the use of rice husk ash as a partial substitute for cement in construction. One hundred and eighty specimens of concrete cubes were cast. 0, 5, 10, 15, and 20% partial replacement of cement with rice husk ash were carried at 1:2:4 mixes by weight with 0.60, 0.65, 0.70 water/cement ratio. The results indicated that compressive strengths of cubes at 0.6, water/cement were higher than 0.65 and 0.70. Also 5% partial replacement cement with rice husk ash at 28^{th} day average compressive strength value of 25.4 N/mm^2 compared well with 0% partial replacement of cement with rice husk ash of 26.28 N/mm^2. This shows that at 5% partial replacement of cement with rice husk ash can be used for structural concrete and at 15% replacement or more it can be used for non - structural construction works or light weight concrete construction. The cost analysis shows substantial amount of savings for the country.

Keywords: rice husk ash, pozzolan, environmental pollution, new construction material, cost saving technology.

1. Introduction

According to Food and Agricultural organization,[1] Nigeria is the 17th largest producer of rice in the world with over 3.3 million tonnes of paddy rice produced annually and 637, 400 tonnes of rice husk generated with a potential for production of at least 121,212 tonnes of rice husk ash from rice husk generated. This enormous waste is presently not being harnessed productively in the country other than burning, which is a major air pollution activity and indiscriminate dumping that cause environmental hazard. Rice husk ash, a product of rice husk when burnt under controlled temperature has been found to be rich in silica. Rice husk are being put into various uses from the manufacture of refractory bricks to use as light weight insulating boards. The benefit of high silica content makes it very useful pozzolan and a good admixture in concrete production. Conversion of wastes to wealth is the new vogue all over the world; this is not only to reduce environmental degradation and pollution but also to effectively put these wastes into use that would be beneficial to mankind. Reducing environmental pollution and alleviating poverty in less developed countries are important goals of sustainable development. The challenge that poses to civil engineering profession is to execute projects in harmony with nature using the concept of sustainable development involving the use of high performance economic friendly materials produced at reasonable cost with lowest possible environmental impact. In the context of concrete as building material, it is necessary to identify less expensive cement substitutes. In recent years researchers have established that the use of supplementary cementation materials (SCM) like fly ash, blast furnace slag, silica fume, rice hush ash, e.t.c which can improve the various properties of fresh and hardened states of concrete as well as curb the rise in cost of construction.[2] World Commission on Environment and Development[3] first coined the term sustainable development to mean: "Development which meets the needs of the present without compromising the ability of future generations to meet their own needs."[4]

Dong et al.[5] reported the potential of utilization of rice husk in manufacturing rice husk ash (RHA) for industrial applications, especially as a super reactive pozzolanic material in cement and concrete productions. El-Sayed and El-Samni[6] also reported that rice husk ash and rice straw ash contain high percentage of silica dioxide (SiO_2) that make these ashes very reactive pozzolan. Rodríguez de Sensale et al. [7] noted that another good quality of rice husk ash is that it greatly decreases the autogenous shrinkage as well as produces an autogenous relative humidity change. An increase in the rice husk ash content in cement decreases the autogenous deformation. Safiuddin[8] also demonstrating the use of rice husk ash concluded in his work that the hardened properties of the self-consolidating high performance concrete improved at later ages due to greater hydration of cement and enhanced pozzolanic activity of rice husk ash. The hardened properties also improved with lower water/binder ratio due to improved paste densification resulting from greater hydration products in the presence of higher binder content. The hardened properties of the self-consolidating high performance concrete were improved with higher RHA content due to the microfilling and pozzolanic effects of rice husk ash. Muthadhi et al.[9] also pointed out that generally

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RHA performs better than other pozzolans in general and silica fume in particular. It was observed by Zhang et al.[10] that reduced porosity in RHA concrete also increases resistance to chloride ion penetration which is an advantage in prevention of corrosion of reinforcement in marine environment. Another reason that makes rice husk ash a unique pozzolan is its multilayered, microporous surface, which differs from fly ash's and silica fume's spherical particles. The surface is thought to reduce bleeding through absorption when RHA is used in concrete.[11] Despite producing less bleeding in fresh concrete, RHA particles' absorbency reportedly maintains the workability of fresh concrete used for flatwork finished in hot, windy conditions. In contrast, Aberdeen Group[12] reported that, silica fume has a higher water demand due to a smaller particle size, tempting finishers to increase slump by adding water, thus increasing the water – binder ratio and reducing strengths in hardened concrete. These afore – mentioned properties make RHA a good admixture in cement and concrete production.

Presently in Nigeria, rice husk ash is not used in the construction industry but is often disposed as waste; managing rice husks waste is therefore, a major challenge. The ever rising cost of building materials especially cement, Nigeria with a population of 140 million people and an annual growth rate of 2.8% according to the Population Council,[13] makes affordable housing out of reach of the poor majority in the country. However, the quest for affordable housing for both rural and urban populations of Nigeria and other developing countries made focusing on wastes as inevitable option.[14-16] The need for effective utilization of this material in order to bring down the cost of cement which is a major building material necessitated this work with a view to determining the percentage utilization of partial replacement of cement with rice husk ash in structural concrete.

2. Materials and methods

The materials that were used for the execution of this work were:

Cement- Portland Cement that meets the requirement of Standard Organization of Nigeria[17] was used.

Fine and coarse aggregates-river sand and granite from local quarry in Ile Ife, Nigeria were used.

Rice husk ash-Rice husk was sourced from a local rice mill at Erin-Ijesha about 51 km from Ile-Ife, Nigeria. The rice husk was burnt under a controlled atmosphere in a muffle furnace. Burning was at a temperature between 550~800°C for about one hour to preserve the amorphous form of the ash. This is similar to the process of production of rice husk ash described by Muthadhi et al.[9] and Allen.[18] The fully burnt rice husk ash was later grounded and sieved to ensure proper fineness of the ash.

Potable water-The potable water was used for this study.

2.1 Determination of properties of aggregates

The following physical properties were carried out: moisture content, absorption capacity, specific gravity, setting time, and sieve analysis. Water absorption capacity for fine aggregates was determined by measuring the decrease in mass of the saturated surface-dry samples after oven drying for 24 hours. The ratios of the decrease in mass to the mass of the dry samples were expressed in percentage. The moisture content fine aggregate was determined by weighing specific quantities of the samples oven dried at a constant temperature of 105°C until a constant weight was obtained

2.2 Mixing of materials

Cement, sand and granite were properly mixed together in accordance with British Standard Code of Practice (BS 8110)[19] in the ratio 1:2:4 by weight before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing. Muthadhi et al.[9] reported the blending of rice husk ash (RHA) in cement is recommended in most international building codes now. Hence, cement was replaced in percentages of 0, 5, 10, 15 and 20 with rice husk ash and 150 × 150 × 150 mm^3 moulds were used for casting. Compaction of concrete in three layers with 25 strokes of 16 mm rod was carried out for each layer. The concrete was left in the mould and allowed to set for 24 hours before the cubes were demoulded and placed in curing tank. The concrete cubes were cured in the tank for 7, 14, 21 and 28 days. Sixty cubes each were cast for 0.60, 0.65 and 0.70 water/cement ratios and crushing tests were carried out using ELE compression machine. Target mean strengths for average compressive strength values obtained for each curing day in different water/cement ratios were calculated using:

$$f_{cm} = f_{cu} + 1.64\sigma \tag{1}$$

Where

f_{cm} = the target mean strength
f_{cu} = the characteristic strength
σ = the standard deviation of strength test

3. Results and discussion

The results of preliminary tests for properties of fine aggregate and rice husk ash is presented in Table 1 and mix proportions used for the concrete is as shown in Table 2. The results of statistical parameters: average compressive strength values, standard deviation, coefficient of variation and target mean strength values for different curing days in different water/cement ratios 0.60, 0.65 and 0.70 respectively are shown in Tables 3 to 5. Figures 1~3 displayed the results of the Target mean strength values of the concrete cubes for water/cement ratios 0.60, 0.65 and 0.70 respectively. Generally, it was observed that concrete strengths increased with curing age. However, there was a progressive decrease in strength with increase in the percentage replacement of cement with RHA for all the water/cement ratios. Also with increase water/cement ratios there was a decrease in strength for all the partial replacements including that of the control. In Table 2, and Fig. 1, after twenty eight days of curing, at 5% replacement of cement with RHA it is noted that compressive strength decreased when compared with 0% control; however, both fall within the same

Table 1 Properties of fine aggregate and rice husk ash.

Type of test	Fine aggregate	Rice husk ash
Absorption capacity (%)	2.8	0.72
Moisture content (%)	2.29	-
Specific gravity	2.6	2.31

Table 2 Mix proportion.

Coarse aggregate (mm)	Slump range (mm)	Air content range (%)	Water binder ratio (w/b)	B:S:G ratio by weight	Quantity of material per unit concrete					
					Water	Cement	Fine aggregate	Coarse aggregate	Admixture	
									Rice husk ash	Chemical admixture
20	58	2.0	0.60	1:2:4	185	308	616	1232	0	0
					185	293	616	1232	15	0
					185	277	616	1232	31	0
					185	262	616	1232	46	0
					185	246	616	1232	62	0
20	73	2.0	0.65	1:2:4	200	308	616	1232	0	0
					200	293	616	1232	15	0
					200	277	616	1232	31	0
					200	262	616	1232	46	0
					200	246	616	1232	62	0
20	80	2.0	0.70	1:2:4	216	308	616	1232	0	0
					216	293	616	1232	15	0
					216	277	616	1232	31	0
					216	262	616	1232	46	0
					216	246	616	1232	62	0

Table 3 0.6 water/cement ratio statistical parameters.

Curing days	Concrete (percentage replacement)	Average compressive strength (N/mm^2)	Standard deviation (σ)	Coefficient of variation	Target mean strength (f_{cm})
7	control	15.24	0.97	6.33	16.82
14		21.03	1.58	7.51	23.62
21		23.78	0.78	3.28	25.06
28		26.26	0.72	2.75	27.45
7	5%	15.59	1.20	7.67	17.56
14		19.48	1.20	6.14	21.44
21		21.22	1.06	5.00	22.96
28		25.40	0.85	3.36	26.80
7	10%	14.08	0.63	4.44	15.11
14		18.02	0.44	2.44	18.74
21		19.94	1.19	5.95	21.89
28		23.44	1.30	5.56	25.58
7	15%	13.51	0.87	6.44	14.94
14		17.08	0.74	4.35	18.29
21		18.88	0.57	3.02	19.82
28		21.24	1.76	8.29	24.13
7	20%	12.86	0.46	3.58	13.61
14		15.58	0.68	4.37	16.70
21		18.07	0.97	5.37	19.66
28		19.42	0.57	2.92	20.35

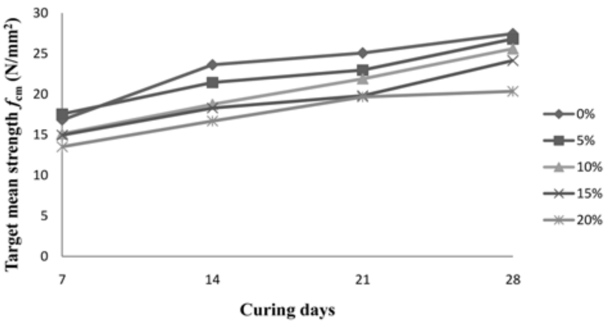

Fig. 1 Target mean strength versus curing days for 0.6 water/cement ratio.

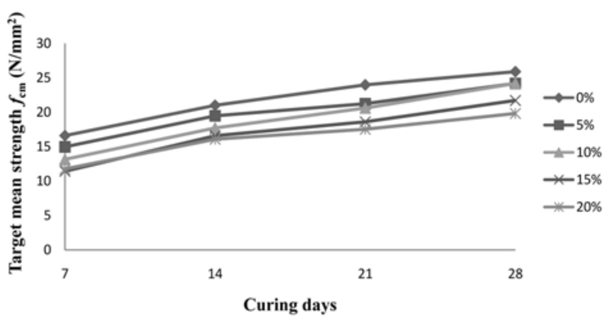

Fig. 2 Target strength versus curing days for 0.65 water/cement ratio.

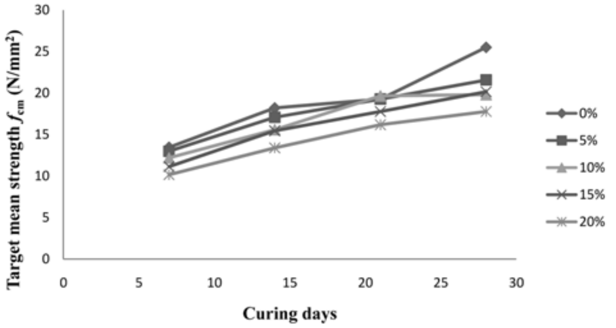

Fig. 3 Target strength versus curing days for 0.7 water/cement ratio.

strength range of 25.00 N/mm^2 which is the minimum strength for structural concrete in use in Nigeria. For the control, compressive strength value at the end of 28th day curing is 26.26 N/mm^2 and standard deviation is 0.72 utilizing 0.6 water cement ratio

Therefore, using Eq. (1);

$$26.26 + 1.64 \times 0.72 = 27.47 \text{ N/mm}^2 \quad (2)$$

$f_{cm} = 27.47$ N/mm^2

From Table 3 and Fig. 1, for 5% partial replacement of cement with RHA, compressive strength value obtained after twenty eight days of curing using 0.6 water cement ratio is 25.40 N/mm^2 and standard deviation is 0.85, also applying Eq. (1);

$$25.40 + 1.64 \times 0.570351 = 26.79 \text{ N/mm}^2 \quad (3)$$

$f_{cm} = 26.79$ N/mm^2

Also, for 10% partial replacement of cement with RHA, obtained value compressive strength at the end of twenty eighth day curing applying 0.60 water cement ratio is 23.44 N/mm^2 and the target strength value still came up to 25.58 N/mm^2. This showed that for both control and 5% replacement of cement with RHA using 0.60 water/cement ratio the results of the tests obtained are comparable to the target mean strength of grade 25.00 N/mm^2. From Tables 4~5 and Figs. 3~4, at 15% replacement of cement with RHA, average compressive strength values recorded are 20.21 and 18.95 N/mm^2 for 0.65 and 0.70 water/cement ratios respectively. The target mean strength values were 21.71 and 20.15 N/mm^2 in that order. The result of compressive strength of 15% partial replacement of cement with RHA indicated that it can be used for non structural concrete construction.

The prices of cement and cement products are always on the rise in Nigeria, average cost of 50 kg bag varies from \$11.50~\$15.00 depending on location and there is nothing on ground that indicates that prices will not keep rising. This is because the demand for cement in the country is put at 14 million metric tonnes and the installed capacity of the seven cement factories now operating in the country is 10 million metric tonnes. However, none of the cement factories is operating at installed capacity. This is due to epileptic power supply among other reasons. Tell,[20] reported the total output from the five cement factories in the Nigeria as at December 2005, to be 2.94 million metric tonnes although they have a combined capacity of 5.15 million metric tonnes. Punch[21] also reported that cement factories spend 40% of their cost on energy and one of the cement factories, West Africa Portland Cement Company (WAPCO) reported a loss of huge sum as a result of gas cuts and epileptic power supply in the first half of 2007. This cost implication brings to the fore the necessity to source for cheap alternatives for cement in Nigeria. The result of the experimental work carried out on Rice Husk Ash (RHA) proves to be a good alternative. The country's annual requirement is put at 14 million metric tonnes and if all the cement factories with the new one coming on stream produce at full capacity it would only amount to 10.2 million metric tones.[22] There is still a shortfall of 3.8 million metric tonnes.

4. Cost analysis

A typical cost analysis of production of rice husk ash is given in Table 6. The raw material (rice husk) is available for free since it is waste from milling of rice and is disposed off afterwards. The

Table 4 0.65 water/cement ratio statistical parameters.

Curing days	Concrete (percentage replacement)	Average compressive strength (N/mm^2)	Standard deviation (σ)	Coefficient of variation	Target mean strength (f_{cm})
7	control	15.34	0.78	5.06	16.62
14		19.04	1.20	6.30	21.01
21		21.84	1.30	5.95	23.97
28		24.42	0.91	3.71	25.90
7	5%	13.46	0.92	6.85	14.97
14		18.60	0.54	2.88	19.48
21		20.22	0.62	3.05	21.23
28		23.44	0.45	1.90	24.18
7	10%	12.02	0.69	5.76	13.16
14		16.53	0.73	4.40	17.72
21		18.46	1.31	7.11	20.61
28		22.11	1.28	5.77	24.20
7	15%	10.52	0.56	5.29	11.43
14		15.72	0.53	3.36	16.59
21		17.71	0.55	3.12	18.62
28		20.41	0.80	3.90	21.71
7	20%	10.39	0.83	7.99	11.75
14		14.57	0.92	6.33	16.08
21		17.08	0.27	1.59	17.53
28		19.00	0.51	2.69	19.84

Table 5 0.7 water/cement ratio statistical parameters.

Curing days	Concrete (percentage replacement)	Average compressive strength (N/mm^2)	Standard deviation (σ)	Coefficient of variation	Target mean strength (f_{cm})
7	control	12.79	0.41	3.17	13.46
14		16.78	0.87	5.17	18.20
21		18.02	0.76	4.22	19.27
28		21.92	2.18	9.96	25.50
7	5%	11.88	0.68	5.70	12.99
14		15.96	0.68	4.27	17.08
21		17.98	0.79	4.39	19.27
28		20.83	0.45	2.17	21.57
7	10%	10.92	0.77	7.08	12.19
14		15.03	0.34	2.24	15.58
21		17.05	1.59	9.30	19.65
28		19.54	0.17	0.85	19.81
7	15%	9.84	0.79	8.04	11.14
14		14.05	0.85	6.04	15.45
21		16.82	0.58	3.43	17.76
28		18.95	0.73	3.87	20.15
7	20%	9.13	0.62	6.83	10.16
14		12.54	0.51	4.08	13.38
21		15.44	0.45	2.88	16.17
28		17.01	0.45	2.67	17.76

use of two furnaces are proposed with each having capacity to produce 750 kg/hr. The breakdown is as adapted from Grover and Mishra[23] and Oke.[24] It was modified to suit the present purpose.

Basis:

Two furnaces each 750 kg/hr
Two sieving machines
Production capacity = 1.5 T/hr (20 hrs/day operation)

Operating days per year	300
Operating hours per year	6000
Capacity utilization	80%
Raw material	36,000 tonnes per year (TPY)
Rice husk ash produced (about 20% of raw material)	7,200 TPY
Infrastructural facilities	
Power	150 kW
Land area	3,000 m²
Operational shed area	240 m²
Packaged rice husk storage (covered area)	250 m²

Based on capacity utilization, twenty four tonnes of rice husk ash will be produced a day at the cost $ 78.60. The cost of a tonne of RHA, therefore, is $ 3.23 which is far less than the cost of a bag of cement.

The equivalent cost savings on 5% replacement of cement with RHA for a 50 kg bag of cement is presented below:

A 50 kg bag of cement costs $ 11.50

Cost of 5% replacement of cement with RHA in a bag is as follows:

$$\frac{2.5}{50} \times 11.50 = \$0.575 \tag{4}$$

A million tonne of cement will cost $230,000,000.00

If 5% replacement of cement with RHA is done for utilization in low cost housing

Cost savings on a million tonne will be,

$$\frac{0.575}{11.5} \times 230,000,000.00 = \$11,500,000.00 \tag{5}$$

5. Conclusions

The compressive strengths of the test cubes increased with age with the control having the highest values for the three different water/cement ratios. This was closely followed by cubes with 5% replacement with RHA. However, compressive strengths for both control tests cubes and 5% replacement with RHA were above 25.00 N/mm^2. This shows that 5% replacement of cement with RHA as new construction material can be utilized for structural concrete with satisfactory strength. The cost saving technology indicated that over $11.5 million would be saved on a million metric tonne of cement with 5% replacement with RHA and this would bring down the cost of housing for the ever increasing population of Nigeria, majority of whom cannot afford shelter because of increasing cost of construction materials. The money saved with the addition of 5% RHA to cement can be diverted to other sectors of the economy. UNFCCC,[25] puts emission of CO_2 from cement industry in Nigeria at 1.345 million metric tonnes in 1998, this would have greatly increased now with the coming on stream of more cement factories. This contributes significantly to

Table 6 Cost analysis.

Items	Naira (Nigerian) ₦	USD **₦147 = $1	Item	Naira (Nigerian) ₦	USD ₦147 = $1
Plants and machineries	1,000,000.00	6802.72	Raw materials (free)	0.00	0.00
Building	250,000.00	1,700.86	Utilities (water and electricity)	1,500.00	10.20
Land	100,000.00	680.27			
Contingencies	20,000.00	136.05	Labour	5,500.00	37.41
Total	1,370,000.00	9319.72	Depreciation	100.00	0.68
Average per year*	137,000.00	931.97	Maintenance (including consumables)	2,500.00	17.00
Average per day (Capital cost)	456.67	3.11	Other expenses	1,500.00	10.20
			Sub-total (running cost per day)	8,500.00	75.49
Grand total	(i.e capital cost plus running cost per day)				78.60
Cost per tonne					3.23

*Capital cost divided by an economic life of 10 years. **Based on exchange rate of ₦ 147.00 to $ 1.00 from Central Bank of Nigeria.

effect of greenhouse gases in the country. A reduction in the quantity of cement used may also reduce this effect significantly.

References

1. Food and Agricultural Organization, Statistical Database Available at www.fao.org*(2002) accessed on 25th June 2008.*

2. Natarajan, C., "Characterization of Permeability of Fly Ash Concrete," *Journal of Corrosion Science and Engineering, V*ol. 7, 2005 (preprint 34).

3. World Commission on Environment and Development, "The Bruntland Report," United Nations Department of Economic and Social Affairs (DESA), 1987.

4. Harris, R. A., Eatmon, T. D., Jr., and Seifert, C. W. A., Natural Pozzolans for Sustainable Development: Mapping out Poverty in the Philipines, 2006.

5. Dong, D. V., Huu, P. D., and Lan, N. N., "Effect of Rice Husk Ash on Properties of High Strength Concrete," *The 3rd ACF International Conference-ACF/VCA*, 2008.

6. El-Sayed, M. A. and El-Samni, T. M., "Physical and Chemical Properties of Rice Straw Ash and Its Effect on the Cement Paste Produced from Different Cement Types," *J. King Saud Univ.*, Vol. 19, *Eng. Sci.* (1), 2006, pp. 21~30.

7. Rodríguez de Sensale, G., Ribeiro, A. B., and Gonçalves, G., "Effects of RHA on Autogenous Shrinkage of Portland Cement Pastes," *Cement & Concrete Composites,* Vol. 30, Issue 10, 2008, pp. 892~897.

8. Safiuddin, M., "Development of Self-consolidating High Performance Concrete Incorporating Rice Husk Ash," A Thesis Presented to the University of Waterloo in Fulfillment of the Thesis Requirement for the Degree of Doctor of Philosophy in Civil Engineering, Waterloo, Ontario, Canada, 2008.

9. Muthadhi, A., R, Anitha, R., and Kothandaraman, S., Rice Husk Ash - Properties and its Uses: A Review, *IE(I) Journal–CV,* Vol. 88, 2007.

10. Zhang, M. H. and Mohan, V., "High-Performance Concrete Incorporating Rice Husk Ash As a Supplementary Cementing Material," *ACI Materials Journal, Vol. 93, No. 6,* 1996, pp. 629~636.

11. Hwang, C. L. and Wu, D. S., "Properties of Cement Paste Containing Rice Husk Ash," *ACI 3rd International Conference Proceedings,* Vol. 114, 1989, 738 pp.

12. The Aberdeen Group, The Best-Kept Secret to High-Performance Concrete? *imgs.ebuild.com/woc/J970499.pdf. (1997). Accessed on the 8th of March. 2009.*

13. The Population Council, Inc., "Report of Nigeria's National Population Commission on the 2006 Census," Population and Development Review, www.accessmylibrary.com/*(2007*), Accessed on 25th March 2009.

14. Akindahunsi, A. A. and Ojo, O., "Recycling Billet Scales as Fine Aggregate in Concrete Production," *Journal of Civil Engineering Science and Application,* Vol. 10, No. 2, pp. 59~62.

15. Ayangade, J. A., Olusola, K. O., Ikpo, I. J., and Ata, O., "Effect of Granite Dust on the Performance Characteristics of Kernelrazzo Floor Finish," *Building and Environment,* Vol. 39, 2004, pp. 1207~1212.

16. Olanipekun, E. A., Olusola, K. O., and Ata, O. A., "Comparative Study of Concrete Properties Using Coconut Shell and Palm Kernel Shell as Coase Aggregates," *Building and Environment, Vol.* 41, 2006, pp. 297~301.

17. SON, NCP1, *The Structural Use of Concrete in Buildings*, Nigerian Code of Practice, Part 1, Nigerian Standard Organization, Lagos, 1973.

18. Allen, M. L., The Manufacture of a Cement Extender from Rice-Husks Using a Basket-Burner, http://www.*Prince of Songkla University/ JourneyToForever.org*, Date accessed 8th March, 2009.

19. British Standard Code of Practice BS 8110, *Part 1. The Structural Use of Concrete*, Her Majesty Stationary Office, London, 1997.

20. Tell magazine, *Why Cement Price Is Rising*, Tell Communications Ltd., Nigeria, 2005.

21. Punch Cement Importation: Nigeria may lose $647 m, Punch Newspapers Nigeria Ltd., 2007.

22. Thisday, *Nigeria: Cement Prices Set to Crash*, Thisday Newspapers Nigeria Ltd., 2007.

23. Grover, P. D. and Mishra, S. K., *Biomass Briquetting: Technology and Practices*, Food and Agriculture Organization of the United Nations, Bangkok, 1996.

24. Oke I. A, "Influence of Carbonisation on Selected Engineering Properties of Carbon Resin Electrodes for Electrochemical Treatment of Wastewater," *The Canadian Journal of Chemical Engineering,* Vol. 87, 2009, pp. 801~811.

25. UNFCCC, Climate and Atmosphere in Nigeria, United Nations Framework for Climate Change http://www.unfccc.int/resource/conv/ratlist.pdf *(2001)*, accessed on 12th August 2008.