The Use of Rice Husk Ash in Low - Cost Sandcrete Block Production

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Abstract

The compressive strength of some commercial sandcrete blocks in Minna, Nigeria was investigated. Rice Husk Ash (RHA) was prepared using Charcoal from burning firewood. Preliminary analysis of the Constituent materials of the ordinary Portland Cement (OPC) / Rice Husk Ash (RHA) hollow sandcrete blocks were conducted to confirm their suitability for block making. Physical test of the freshly prepared mix was also carried out. 150mm×450mm hollow sandcrete blocks were cast cured and crushed for 1, 3, 7, 14, 21, and 28 days at 0, 10, 20, 30, 40 and 50 percent replacement levels. Test results indicate that most commercial sandcrete blocks in Minna town are below standard. The compressive strength of the OPC/RHA sandcrete blocks increases with age at curing and decreases as the percentage of RHA content increases. The study arrived at an optimum replacement level of 20%.

Keywords

Sandcrete Blocks; Ordinary Portland Cement (OPC); Rice Husk Ash (RHA)

Introduction

Sandcrete blocks comprise of natural sand, water and binder. Cement, as a binder, is the most expensive input in to the production of sandcrete blocks [1]. This has necessitated producers of sandcrete blocks to produce blocks with low OPC content that will be affordable to people and with much gain.

The poverty level amongst West African Countries and particularly Nigerian has made these blocks widely acceptable among the populace so as to minimize the cost of construction works. The improper use of these blocks leads to microcracks on the walls after construction. The use of alternative cheaper local materials as stabilizer will greatly enhance the production of sandcrete blocks with the desired properties at low cost. It will also drastically reduce the cost of production and consequently the cost of construction works.

A survey by raw materials research and development Council of Nigeria on available local building materials reveals that certain building materials deserve serious consideration as substitute for imported ones [2]. Few of these materials includes: cement / lime stabilized bricks /blocks, sundried (Adobe) soil blocks, burnt clay bricks/ blocks, cast in-situ walls, rice husk ash (RHA), mud and straw, lime and stonecrete blocks.

In the urban and rural areas of Nigeria, local milling is being done mostly by women. They mainly use firewood as heat source and as such one hundred percent of the rice husk from the mill is a waste. It occupies 20 –24% of the rough rice produced, although the ratio differs by variety. About 10^8 tonnes of rice husks are generated annually in the world [3]. In Niger State, Nigeria about 96,660 tonnes of rice grains were produced in year 2000 [4]. In developing countries like Nigeria, proper utilization of agricultural waste has not been given due attention. The rice husk thereby constitutes an environmental nuisance as they form refuse heaps in the areas where they are disposed. The use of rice husk ash as a partial replacement to cement will provide an economic use of the by – product and consequently produce cheaper blocks for low cost buildings.

Previous Research Efforts

The followings shed light on the research works on the utilization of rice husk and rice husk ash as a partial replacement material or stabilizing agent in building works.

In [5] was carried out an extensive work on some characteristics of acha husk ash/ordinary Portland cement concrete. Test results indicate that the compressive strength for all the mixes containing AHA increases with age up to the 14-day hydration period but decreases to the 28-day hydration period while the conventional concrete increases steadily up to 28-day hydration period.

In [6] was worked on rice husk as a stabilizing agent in clay bricks. In his work clay bricks were produced with 0%, 1%, 2%, 3%, 4%, 5%, and 10% rice husk. Some of the bricks were burnt in an electric furnace to a temperature of 1005°C for about 3-4 hours. Compressive strength and absorption tests were carried out. It was concluded that the addition of husk reduces the compressive strength of the bricks and the husk clay bricks becomes lighter as the percentage of husk clay increases.

Followings were said [7] on the effect of rice-husk on the compressive strength and durability of burnt-clay bricks. Test results show that rice husk has a decreasing effect on the compressive strength of the brick and increasing effect on the water absorption of the bricks.

In [8] was carried out a research work on the use of rice husk ash in concrete. Test results indicate that the most convenient and economical temperature required for conversion of rice husk into ash is 500°C. Water requirement decreases as the fineness of RHA increases. The higher the percentage of RHA contents, the lower the compressive strengths

Materials and Methods

For the purpose of this work 150mm×450mm hollow blocks were produced at the concrete laboratory of the Department of Civil Engineering, Federal University of Technology, Minna, Nigeria. The mix ratio used was 1:8 (one part of binder to eight part of sand) at different replacement levels of OPC and rice husk ash. For each replacement levels about 18 block samples were cast. The replacement levels and water/binder ratios used are as shown in table 1.

Table 1. Percentage Replacement Levels & Water / Binder Ratio

Replacement level [%]	Water/binder ratio
100% OPC, 0% RHA	0.50
90% OPC, 10% RHA	0.54
80% OPC, 20% RHA	0.55
70% OPC, 30% RHA	0.56
60% OPC, 40% RHA	0.57
50% OPC, 50% RHA	0.58

The materials used for the production of the blocks were sand, rice husk ash (RHA), water and cement (Burham cement). Commercial sandcrete blocks were collected from different areas in Minna town to determine their compressive strength. Husk Ash (RHA) was prepared using Charcoal from burning firewood. The average temperature attained was 483°C. Preliminary analysis was conducted on the constituent materials of the OPC/RHA hollow sandcrete blocks to determine their suitability for block making. Tests conducted include: chemical analysis of rice husk ash, particle size analysis of sand, specific gravity test on RHA and sand, Bulk density test on RHA and sand, silt content test on sand, constituency test, setting times test, free moisture content test and slump test. Mix design was carried out by absolute volume method to select the most suitable materials (cement, RHA, sand and water) that will produce blocks with the desired properties. Compressive strength and density of the OPC/RHA sandcrete blocks were also determined.

Production of the Block Samples

For the purpose of this study, about one hundred and eight 150mmx450mm hollow sandcrete blocks were produced. The quantities of materials obtained from the mix design were measured in each case with the aid of weighing balance. The cement and rice husk ash (RHA) was mixed thoroughly. The sand was poured on to the concrete floor in the concrete laboratory. The cement, RHA and sand were then mixed together to obtain a homogeneous mixture. The measured quantity of water was then sprayed on to the mixture using bucket. The mixture was further turned with shovels until a mix of the required workability was obtained. Slump test was conducted to measure the workability of the mix.

The resulting mortar was transferred to the steel hollow mould to half the depth. This was tamped uniformly over the cross section of the mould with 25 strokes with a tamping bar. More mortar was added and tamped until the mould was completely filled to the brim. The content was demoulded in the concrete laboratory as a fresh hollow block. The block samples were cured by sprinkling water twice in the morning and evening daily.

Compressive Strength Test

The compressive strength of the block samples was determined in accordance with the standard procedure for pre-cast concrete blocks. The weights of the block samples were always taken before the compressive strength test was conducted. Three sample blocks were crushed each at 1, 3, 7, 14, 21 and 28 days after casting at different replacement levels using the compressive testing machine in the concrete laboratory of department of civil engineering, Federal University of Technology, Minna, Nigeria.

Results and Discussions

Commercial Sandcrete Blocks

Table 2 shows the compressive strength of some commercial sandcrete blocks in Minna, Nigeria.

Table 2. Compressive Strength of Commercial Sandcrete Blocks

Batch No.	Failure Loads [KN]				Compressive Strength [N/mm^2]			
	Block A	Block B	Block C	Block D	Block A	Block B	Block C	Block D
1	48	38	44	28	1.01	0.80	0.93	0.59
2	46	30	48	22	0.97	0.63	1.01	0.47
3	42	34	46	30	0.89	0.72	0.97	0.63
AVERAGE					0.96	0.72	0.97	0.56

The maximum value of the compressive strength obtained was 0.97 N/mm^2 which does not comply with the minimum standard of 3.5 N/mm^2. These blocks are therefore below standard.

Chemical Analysis of Rice Husk Ash

Table 3 shows the chemical composition of rice husk ash. The total percentage composition of iron oxide ($Fe_2 O_3$ = 0.95%), Silicon dioxide (SiO_2 = 67.30%) and Aluminum Oxide (Al_2O_3 = 4.90%) was found to be 73.15%.

Table 3. Chemical Composition of Rice Husk Ash

Constituent	% Composition
Fe_2O_3	0.95
SiO_2	67.30
CaO	1.36
Al_2O_3	4.90
MgO	1.81
L.O.I	17.78

This value is within the required value of 70% minimum for pozzolanas [9]. The value is higher than the value obtained in [5] for acha husk ash (48.36%) and as such the rice husk ash is more pozzolanic. Also this value is less than the 87.55% obtained in [8]. The slight difference in percentage composition might have resulted from the method of preparation of the ash and the species of the rice used.

The loss on ignition obtained was 17.78%. This value is slightly more than 12% maximum as required for pozzolanas. It means that the RHA contains little unburnt carbon and this reduces the pozzolanic activity of the ash. The unburnt carbon it-self is not pozzolanic and its presence serves as filler to the mixture. The value obtained is higher than 3.30% obtained in [8] and as such the pozzolana is less effective compared to that obtained in [8]. The loss on ignition obtained is less than the value obtained in [5] for acha husk ash (43.57%). This indicates that Acha husk produces greater unburnt carbon compound compared to rice husk. Therefore rice husk is a better material for making pozzolana compared to acha husk. The magnesium oxide content was 1.81%. This satisfies the required value of 4 percent maximum.

Particle Size Analysis

Table 4 shows the result of particle size analysis performed on the sand sample.

Table 4. Particle Size Analysis

Sieve Size [mm]	5	2.36	1.18	0.6	0.15	0.075	PAN
Weight of Sieve [g]	478.78	420.24	391.29	336.47	295.85	287.22	306.1
Weight of Sieve + Sample Retained [g]	487.76	530.84	606.66	722.94	551.52	305.23	310.9
Weight of Sample Retained [g]	8.98	110.6	215.37	386.47	255.67	18.01	4.8
% of Sample Retained	0.9	11.06	21.54	38.65	25.57	1.8	0.48
% of Sample Passing	99.1	88.04	66.5	27.85	2.28	0.48	-

The sand was obtained from natural source by dredging from the Maikunkele riverbed Maikunkele, Nigeria. The results obtained comply with the grading limit of zone 1 and therefore are suitable for construction work [10].

Specific Gravity

Table 5 shows the result for the specific gravity test of RHA and sand. The specific gravity of Rice husk ash was found to be 2.13. This value is close to the values obtained by in [8] of 2.12 for Acha Husk Ash, and in [8] was reported a value of 2.14 for rice husk ash. The value is within the range for pulverized fuel ash (pfa), which is between 1.9 and 2.4 as reported in [11a]. The value of specific gravity is, however, less than the value for cement, which is 3.15. Further, the specific gravity of sand was found to be 2.64. The value obtained falls within the limit for natural aggregates with value of specific gravity between 2.6 and 2.7 as reported in [11a].

Table 5. Specific Gravity of RHA and Sand

	Rice Husk Ash		Sand	
	Test1	Test 2	Test 1	Test2
Mass of gas jar, plate, soil (RHA) and water (m_3) [g]	1612.6	1611.40	1631.40	1629.60
Mass of gas jar, plate and soil (RHA) (m_2) [g]	751.80	749.60	751.80	750.00
Mass of gas jar, plate and water (m_4) [g]	1507.0	1506.0	1507.00	1506.8
Mass of gas jar and plate (m_1) [g]	551.80	551.8	551.8	551.8
($m_2 - m_1$) [g]	200.00	197.80	200.00	198.20
($m_4 - m_1$) [g]	955.20	954.20	955.20	955.00
($m_3 - m_2$) [g]	860.80	861.8	879.60	879.60
($m_4 - m_1$) - ($m_3 - m_2$) [g]	94.40	92.40	75.60	75.40
Specific gravity of the particles $G_s = (m_2 - m_1)/((m_4 - m_1) - (m_3 - m_2))$	2.12	2.14	2.65	2.63
Mean of specific gravity	2.13		2.64	

Bulk Density

Table 6 shows the result for compacted and uncompacted bulk densities for RHA and sand.

Table 6. Bulk Density of RHA and Sand

	RHA		Sand	
Uncompacted Bulk Density	Test 1	Test 2	Test 1	Test 2
Weight of empty cylinder (w_1) kg	4.24	4.24	4.24	4.24
Weight of empty cylinder + weight of loose materials (w_2) kg	4.69	4.71	5.73	5.75
Weight of loose materials (w_3) kg	0.45	0.47	1.49	1.51
Volume of Cylinder (V) Liter	1	1	1	1
Uncompacted Bulk density (w_3/V) Kg/m^3	450	470	1490	1510
Mean Bulk density Kg/m^3	460		1500	
Compacted Bulk Density				
Weight of empty cylinder (w_1) kg	4.24	4.24	4.24	4.24
Weight of empty cylinder + weight of compacted materials (w_2) kg	4.78	4.76	5.83	5.85
Weight of compacted materials (w_3) kg	0.54	0.52	1.59	1.61
Volume of Cylinder (V) Liter	1	1	1	1
Compacted Bulk density (w_3/V) Kg/m^3	540	520	1590	1610
Mean Bulk density Kg/m	530		1600	

The compacted and uncompacted bulk densities of rice husk ash are 530 kg/m^3 and 460kg/m^3. In [8] was reported obtained the compacted bulk density of 740kg/m^3 for Acha

Husk Ash. Test result indicates that both materials are lightweight materials. Bulk density depends on how densely the practices are packed. The silica in pozzolana can only combine with calcium hydroxide when it is in a finely divided state. Pozzolana in this state have uniform particles which cannot be packed very closely consequently leading to allow compact bulk density.

The compacted and uncompacted bulk densities of the sand are 1600kg/m^3 and 1500kg/m^3. These values are reasonably close to the value given for bulk density before excavation for sands and sandy soils with ranges from 1650kg/m^3 to 1850kg/m^3 as reported in [12]. The difference in the values is due to sample disturbance.

Silt Content

The result for silt content is presented in table 7.

Table 7. Silt Content

Description	Sand Layer	Silt Layer	Silt Content
Quantity	775 ml	25 ml	3.23 %

The silt content was found to be 3.23%. According to [13], are permitted silt content to be within the range of 3-8%. This implies that there is an adequate fine to occupy the voids between the sand particles and this reduces the cement content required for a given workability.

Consistency Test

Table 8 shows the result for the consistency test. Test result indicates that the water required to achieve the desired consistency increases with the percentage increase in Rice-husk ash.

Table 8. Consistency Test

Replacement of OPC with RHA (%)	0	10	20	30	40	50
Opc (g)	400	360	320	280	240	200
Rha (g)	0	40	80	120	160	200
Water (ml)	112	116	120	128	140	152
Water/Binder Ratio (%)	28	29	30	32	35	38

The increased water demand is as a result of increased carbon content. The loss on ignition for Burham cement is very small compared to the loss on ignition of rice husk ash.

This is because the carbon content of Burham cement is very small compared to that in rice husk ash. So as ash is introduced in to the mix, the carbon content increases and the water requirement also increases. The carbon content of acha husk ash as reported in [5] is very high and as such greater amount of water was needed compared to RHA to achieve the same consistency. This is in agreement with the results obtained in [8].

Setting Times

Table 9 shows the result for setting times test.

Table 9. Setting Times Test

RHA replacement of OPC (%)	0	10	20	30	40	50
Initial Setting Time (minutes)	95	189	191	305	374	429
Final Setting Time (minutes)	150	323	510	685	756	811

The initial and final setting times increases with increase in rice husk ash content. The reaction between cement and water is exothermic leading to liberation of heat and evaporation of moisture and consequently stiffening of the paste. As rice husk ash replaces cement, the rate of reaction reduces, and the quantity of heat liberated also reduces leading to late stiffening of the paste. As the hydration process requires water, greater amount of water was also required for the process to continue. This result is in consonant with the work [5].

Slump Test

Table 10 shows the result for slump test.

Table 10. Actual Water/Binder Ratio and Slump Values

Replacement of OPC with RHA (%)	0	10	20	30	40	50
Actual Water/Binder Ratio	0.5	0.54	0.55	0.56	0.57	0.58
Slump (mm)	15	30	20	25	20	25

Test result indicates that mixes with greater RHA content requires greater water content to achieve a reasonable workability. This was due to the carbon content of the rice husk ash. This was in agreement with the findings in [5].

Compressive Strength

The variations of compressive strength with age at curing are presented in Table 11. The compressive strength generally increases with age at curing. The reaction between the cement particle with water or cement / RHA with water is known as hydration. Hydration proceeds with the presence of evaporable water. Water was continuously provided in the course of curing and the hydration process continued. This ensured an increase in the value of compressive strength. In the absence of the evaporable water there can be no gain in strength according to [11b]. This result is in line with the submission made in [8]. However in [5] was reported that the compressive strength of concrete for the mix with partial replacement of acha husk ash is not directly related to its maturity. He found that at 7 and 14 days hydration period the 10% and 20% AHA / OPC concrete strength was higher than that of conventional concrete. The deviation might be due to the different material composition in the samples.

Table 11. Compressive Strength of Blocks

Age At Curing % Replacement Level	Compressive Strength (N/mm^2)						Remarks
	1 Day	3 Days	7 Days	14 Days	21days	28 Days	
100%OPC, 0%RHA	0.51	0.91	1.60	2.78	3.63	4.60	The compressive strength generally increases with age at curing and decreases as the RHA content increases.
90%OPC, 10%RHA	0.40	0.70	1.31	2.43	3.35	4.09	
80%OPC, 20%RHA	0.25	0.55	1.14	2.02	2.91	3.65	
70%OPC, 30%RHA	0.15	0.36	0.74	1.35	1.79	2.07	
60%OPC, 40%RHA	0.00	0.15	0.38	0.65	0.91	1.05	
5O%OPC, 50%RHA	0.00	0.06	0.30	0.40	0.42	0.59	

At the 28 days hydration period only blocks made with 100% OPC (4:60N/mm^2), 90% OPC (4.10 N/mm^2), and 80% OPC (3.65 N/mm^2) met the minimum required standard for sandcrete blocks (3.5 N/mm^2 - 10 N/mm^2), other percentage replacement level fell bellow the minimum standard. The 20% replacement is then the optimum replacement level of OPC with RHA. This is so because it is the cheapest block that met the minimum compressive strength required for sandcrete blocks at 28 days. At the 28 days hydration period the range of strength obtained was 4.6 N/mm^2 (for 0%RHA content) to 0.59 N/mm^2 (for 50% RHA content). These values were greater than the maximum value obtained for commercial sandcrete blocks in Minna (0.97 N/mm^2) except for 50% RHA content which gave a compressive strength of 0.59N/mm^2 at 28 days.

Furthermore, the variations of compressive strength with the mix proportions at various ages at curing are shown in table 12. Test result indicates that the compressive strength decreases with increase in RHA content for all ages at curing.

Table 12. Compressive Strength of Blocks

Mix ratio	Age at curing (days)	Average weight of blocks (Kg)	Density (Kg/m^3)	Failure loads (KN)			Average failure load (KN)	Compressive strength (N/mm^2)
100% OPC, 0% RHA	1	20.1	1884.19	23	22	27	24	0.51
	3	21.4	2006.06	41	45	43	43	0.91
	7	20.32	1904.82	78	77	76	76	1.6
	14	20.8	1949.81	130	134	132	132	2.78
	21	20.9	1959.19	170	169	167	172	3.63
	28	21.08	1976.06	221	217	216	218	4.6
90% OPC, 10% RHA	1	19.34	1812.95	18	19	20	19	0.4
	3	20.25	1898.25	29	34	36	33	0.7
	7	20.32	1904.82	58	64	64	62	1.31
	14	18.9	1771.7	118	116	116	115	2.43
	21	19.42	1820.45	159	160	160	159	3.35
	28	19.58	1835.45	191	193	193	194	4.09
80% OPC, 20% RHA	1	19.22	1801.7	10	12	11	12	0.25
	3	19.14	1794.2	29	24	25	26	0.55
	7	19.18	1797.95	54	55	53	54	1.14
	14	18.36	1721.08	97	93	98	96	2.02
	21	19.38	1816.7	141	137	136	138	1.91
	28	19.28	1807.32	172	170	177	173	3.65
70% OPC, 30% RHA	1	19.18	1797.95	6	8	7	7	0.15
	3	18.44	1728.58	17	18	16	16	0.36
	7	19.84	1859.82	36	32	37	35	0.74
	14	19.56	1833.57	64	66	62	64	1.35
	21	19.34	1812.95	86	89	80	85	1.79
	28	19.14	1794.2	98	100	96	98	2.07
60% OPC, 40% RHA	1	19	1781.08	0	0	0	0	0
	3	19.28	1807.32	7	8	6	7	0.15
	7	19.84	1859.82	17	20	17	18	0.38
	14	19.04	1784.82	32	31	30	31	0.65
	21	18.88	1769.83	44	42	43	43	0.91
	28	18.94	1775.45	48	50	52	50	1.05
50% OPC, 50% RHA	1	18.96	1777.32	0	0	0	0	0
	3	19.58	1835.45	3	3	3	3	0.06
	7	19.36	1814.82	13	15	14	14	0.3
	14	19.2	1799.83	19	20	18	19	0.4
	21	19.27	1806.39	20	21	19	20	0.42
	28	18.74	1756.7	26	30	28	28	0.59

The chemical reaction involves fixing of $Ca(OH)_2$ in liquid phase from the hydrating cement with the silica in the pozzolana. For lower percentage replacement level such as 10%RHA and 20%RHA the silica from the pozzolana is in required amount. This aids the

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hydration process producing blocks with high compressive strength. For higher percentage replacement level such as 30%RHA 40%RHA and 50%RHA, the amount of rice husk ash in the mix is higher than required to combine with the liberated calcium hydroxide in the course of the hydration. The excess silica substitute part of the cementitious materials and consequently causing a reduction in strength. The values obtained for the density of OPC/RHA hollow sandcrete blocks falls within the range specified for sandcrete blocks (500-2100 kg/m^3). The RHA content does not affect the density of the hollow blocks. Rice husk is a lightweight material and its inclusion is in minute quantity, as such it has no noticeable effect on the density of the hollow blocks.

Conclusions

From the tests conducted on OPC/RHA hollow sandcrete blocks as presented in the various sections, the following conclusions are made:

- The rice husk ash produced using charcoal from firewood is pozzolanic and therefore is suitable for use in block making;
- The Specific gravity, Uncompacted bulk density, and Compacted bulk density of rice husk ash were found to be 2.13, 460 Kg/m^3 and 530 Kg/m^3;
- For a given mix, the water requirement increases as the rice husk ash content increases;
- The setting times of OPC/RHA paste increases as the ash content increases;
- The density of OPC/RHA is within the range for sandcrete blocks (500 to 2100kg/m^3);
- The compressive strength of the blocks for all mix increases with age at curing and decreases as the RHA content increases;
- Rice husk is available in significant quantities as a waste and can be utilized for making blocks. This will go a long way to reduce the quantity of waste in our environment;
- The optimum replacement level of OPC with RHA is 20%.

References

[1] Hornbostel C., *Construction materials: types, uses, and applications*, John Wiley & Sons Inc., USA, p. 271, 1991.

[2] Oluremi A. A., *Input of local Materials in Buildings as a Means of Reducing Cost of Construction*, Journal of the Nigerian Institute of Quantity Surveyors, p. 12-14, 1990.

[3] Nakoo Y., *Rice: Post Harvest Technology*, ACE Corporation, Tokyo, p. 431, 1999.

[4] Edodzigi M., *Cropped-Area and Yield Survey (CAYS)*, Report 2000 Wet Season, Agric. Development Project (A.D.P), Niger State, Nigeria p. 2, 2001.

[5] Dashan I. I. and Kamang E. E. I., *Some characteristics of RHA/OPC Concretes: A Preliminary Assessment*, Nigerian Journal of Construction Technology and Management, 2(1), p. 22-28, 1999.

[6] Michael K. O., *Rice Husk as stabilizing agents in Clay Bricks*, Higher National Diploma Project, Department of Civil Engineering, Federal Polytechnic Bida, Nigeria, 1994.

[7] Mbiminah G. Y., *Effects of Rice Husk on the Comprehensive Strength and Durability of Burnt - Clay Bricks*, B. Eng. Project., Department of Civil Engineering, Ahmadu Bello University Zaria, Nigeria, 1992.

[8] Al-Khalaf M. N. and Yousif H. A., *Use of Rice Husk Ash in Concrete*, The International Journal of Cement Composites and Lightweight Concrete, 6(4), p. 241-248, 1984.

[9] American Standard for Testing Materials, *Specification for fly ash and Raw or Calcium Natural Pozzolana for use as a mineral admixture in Portland Cement Concrete*, ASTM C 618-78, 1978.

[10] British Standards Institutions, Specification for aggregate from Natural Sources for Concrete, BS 882, London, 1992.

[11] Neville A.M., *Properties of Concrete*, John Wiley & Sons, Malaysia, 1981 & 1995.

[12] Jackson N. and Dhir R. K., *Civil Engineering Materials*, Macmillan Education Ltd, Hong Kong, p. 294, 1998.

[13] British Standards Institution, *Testing aggregates. Guide to sampling and testing aggregates*, BS 812-101, London, 1984.