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Effects of Rice Husk Ash on the Non Autoclaved Aerated Concrete

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***Abstract* – This paper describes an investigation of the use of rice husk ash in corporation with cement for the production of rice husk ash cement based non-autoclaved aerated concrete block. Rice husk ash was used as an aggregate with different replacement amounts viz., 0%, 20%, 30%, 40%, 50%. To determine the effect of rice husk ash incorporation on the final product properties such as compressive strength, Water absorption and density have been investigated. Results show that using rice husk ash in aerated concrete formulations caused weight decrease in the produced aerated concrete for all concerned rice husk ash replacement ratios and the compressive strength and water absorption of specimen consisting rice husk ash has been always higher (Up to optimum level of replacement) as compared to Ordinary Portland Cement aerated concrete. The optimum replacement level of Ordinary Portland cement with rice husk ash is 30%.**

***Keywords* – Rice Husk Ash, Non-Autoclaved Aerated Concrete, Aluminium Powder Etc.**

I. Introduction

Bangladesh is one of the largest rice producing country and per capita rice consumption is higher than that in any other countries (Ahiduzzaman, M. 2007) [(1)]. There are main three biomass by-product comes from rice viz, rice straw, rice husk, and rice bran. Rice straw and rice bran are used as feed for cattle, poultry, fish etc. Rice husk is one of the waste materials in this region. Since rice husk has negligible protein content, it is not useful for animal feeding. Nor as cellulose product because of high lignin content. It has little value to the agriculture since it can not be used as manure due to its slow rate of biological decomposition, high content of silica and cellulose. Rice husk content with a high concentration of silica, generally more than 80%-85% (Siddique [(2)] 2008). It can contribute about 20% of its weight to rice husk ash (RHA) after incineration (Anwar et al., [(3)]2001). RHA is a highly pozzolanic material (Tashima et al.,[(4)]2004) and could be suitable partly replacement for Portland cement (Smith et al.,[(5)]1986; Zhang et al.,[(6)]1996; Nicole et al.,[(7)]2000; Sakr [(8)] 2006; Sata et al.,[(9)]2007; etc). Simultaneously, rice husk ash recycling has received a great deal of attention in the recent years. Numerous patents, publications,[(10)] reviews[(11)] and reports [(12),(13.)] have appeared during last two decades but its effective utilization in bulk quantities has not been commercially established in our country. In developing country like Bangladesh proper utilization of agricultural waste has not been given due attention. The rice husk ash thereby constitutes an environmental nuisance as they form refuse heaps in the areas where they are dispose. So, attempt has been made to 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. Laboratory scale investigation have suggested the possibility of making good use of this waste in powdered form, as a raw material in the manufactured of aerated concrete block. This work initiated Housing and Building Research Institute in the recent past. One of the earlier reference to the potential benefits of using rice husk ash for making cement was publication in 1956, where the author report the successful production of building blocks using rice husk ash cement as early as 1923[(14)]. So the present study and investigation has been carried out toward production of rice husk ash based non-autoclaved aerated concrete which may cause saving of cement through partial replacement by rice husk ash.

The concrete without coarse aggregates and a large number of air voids induced with the help of some aeration agents, within the concrete mass is known as aerated concrete. Generally aerated concrete is cured under steam curing regime. thus called as autoclaved aerated concrete (AAC). Aerated concrete can be autoclaved (AAC) or non- autoclaved (NAAC) based on the method of curing.

Comprehensive researches had been carried out to find out the effectiveness of waste materials such as slate waste, coal bottom ash, shredded rubber waste, tin cal ore waste, fly ash and coal bottom ash, air cooled slag, quartz particle, pulverized fuel ash as partial replacement of Portland cement in AAC (N.B.Eden et. at; [(15)]1980 . H Kurama et al; [(16)] 2009, A Benazzouk et al;[(17)] 2006, i Kula etal;[(18)] 2002, N.Y. Mostafa [(19)] 2005, Norifumi Isu etal;[(20)] 1995, N Narayanan et al; [(21)]2000). A very little research is reported in the literature to investigate the non-autoclaved aerated concrete (Richard et al.,[(22)] 2005, Arresh,[(23)]2002,Arresh and Fadhadli,[(24)]2002;Arresh et al.,[(25)]2005).

This experimental study is aimed at to investigate the suitability of rice husk ash as partial replacement of cement in non- autoclaved aerated concrete. The attempt is made to replace cement partially with rice husk ash to produce non-autoclaved aerated concrete. The main objective of the study is to determine the effect of the incorporation of different percentages of rice husk ash on compressive strength and the density of the specimens at 28 days. The effect of curing regime by applying water curing is investigated. In addition, attempt is also made to examine the strength development of the specimens by testing those at 3, 7, and 28 days of curing.

II. EXPERIMENTAL

Materials:

The cement used was a Portland cement CEM I 42. 5 N production in accordance with BDS EN 197-1, [26] 2003.its chemical composition is given in Table-1. Rice husk ash used in the present investigation collected from a rice mill where rice husk was using as a fuel for the parboiling operation for paddy. The collected ashes were dried in the oven at the temperature of 110ºc ±5 for 24h to remove moisture in it before sieved and ground to obtain finer particles. RHA used in this study has been identified as pozzolanic material that conforms with the requirement in ASTM C618-05 [27] (ASTM 2005b). The physical and chemical analysis of RHA is shown in Table-1 and Table-2.Aluminium powder with 99% aluminium and fineness of 100 µm (Synthetic, silver grey).

Preparation of test specimens:

Two sets of specimen which are OPC aerated concrete and RHA cement based aerated concrete were used through out this investigation. One set containing 18 cubes of standard size 70.6×70.6×70.6mm are cast and tested. Over all 20%, 30%, 40%, 50% cement replacement adopted for all the mixes. Cement replacement is adjusted by RHA. One set of control specimen without cement replacement is also cast to compare the values. Based on the previous research conducted at UTM, Malaysia (Arresh 2002)[24] and with the subsequent modification made through trial mix series, aluminium powder content is fixed at .2% by weight of the binder. Specimens were prepared by dry mixing of the solid component approximately two minutes (in mortar mixture) then mixing with water and mixing is continued approximately three minutes before they were cast in the form of cubes(70.6×70.6×70.6mm). All specimens were left in the mould for 24h before being demolded and subjected to water curing until it is time to be tested. The replacement levels, water /binder ratio and aluminium powder content used are shown in Table- 3.

Produced samples were retained in water for 28 days to complete hydrolysis and hydration reactions of the cement. With this test specimens a comparative study on density, water absorption and compressive strength were carried out. Compressive strength test was conducted in accordance to BS1881:116 [28] (British standard Institution 1983). The density of specimens was taken by drying the specimen in the oven for 24h based on the procedure enlisted in AAC 4.1 [29] (RILEM 1994a). Results are given in Table -4.

Table 1: Physical properties of Ordinary Portland cement and rice husk ash.

Sample	Specific gravity	Blaine Fineness (cm^2/g)
OPC	3.15	3600
Rice husk ash	2.12	4200

Table 2: Chemical composition of materials used

Chemical composition (% by weight)	Ordinary Portland cement (OPC)	Rice husk ash
Silicon dioxide (SiO_2)	19.85	85.20%
Aluminum oxide (Al_2O_3)	4.49	0.59%
Iron oxide (Fe_2O_3)	3.56	0.22%
Calcium oxide (CaO)	66.96	0.51%
Magnesium oxide (MgO)	1.36	0.41%
Sodium oxide (Na_2O)	0.68	0.05%
Potassium oxide (K_2O)	0.34	2.93%
Sulfur trioxide (SO3)	2.46	0.10%
Loss on ignition (LOI)	1.98	4.91%
SiO_2+$A1_2O_3$+ Fe_2O_3	-	86.01%

Table 3: Percentage Replacement levels, water/Binder ratio and aluminium powder content

Replacement level (%)	Water cement ratio	aluminium powder content (% by wt. of cement)
100% OPC, 0 % RHA	0.50	0. 2 %
80% OPC, 20 % RHA	0.57	0. 2 %
70% OPC, 30 % RHA	0.58	0. 2 %
60% OPC, 40 % RHA	0.59	0. 2 %
50% OPC, 50 % RHA	0.60	0. 2 %

Table 4: Compressive strength (MPa), Density and Water absorption of non- autoclaved RHA cement based aerated concrete with variation of Rice husk ash replacement

Aerated concrete	RHA content (% by weight of cement)	Density (Kg/m^3)	Compressive strength (MPa)					Water absorption (% by weight)
			3 Days	7 Days	14 Days	21 Days	28 Days	
100% OPC, 0% RHA	0	670	0.91	1.6	2.78	3.63	3.84	25
80% OPC, 20% RHA	20	580	0.55	1.14	2.02	3.65	3.92	35
70% OPC, 30% RHA	30	570	0.66	1.78	2.75	3.87	4.27	39
60% OPC, 40% RHA	40	560	0.15	0.38	0.65	1.05	1.58	45
50% OPC, 50% RHA	50	553	0.06	0.3	0.4	0.59	0.98	47

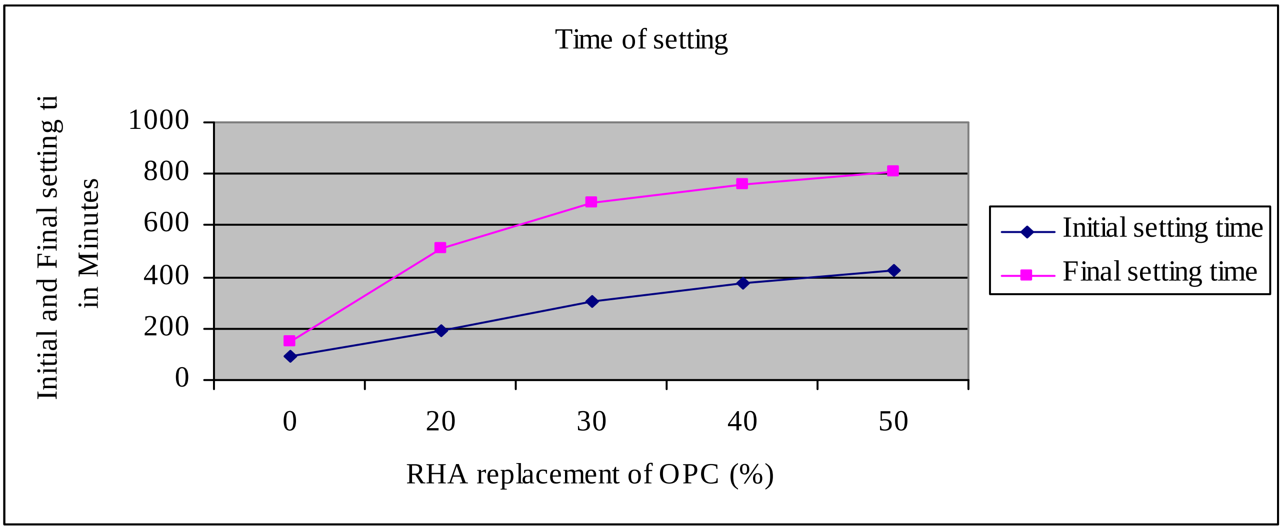

Fig.1. Initial and Final setting times of RHA cement based with different replacement percentage.

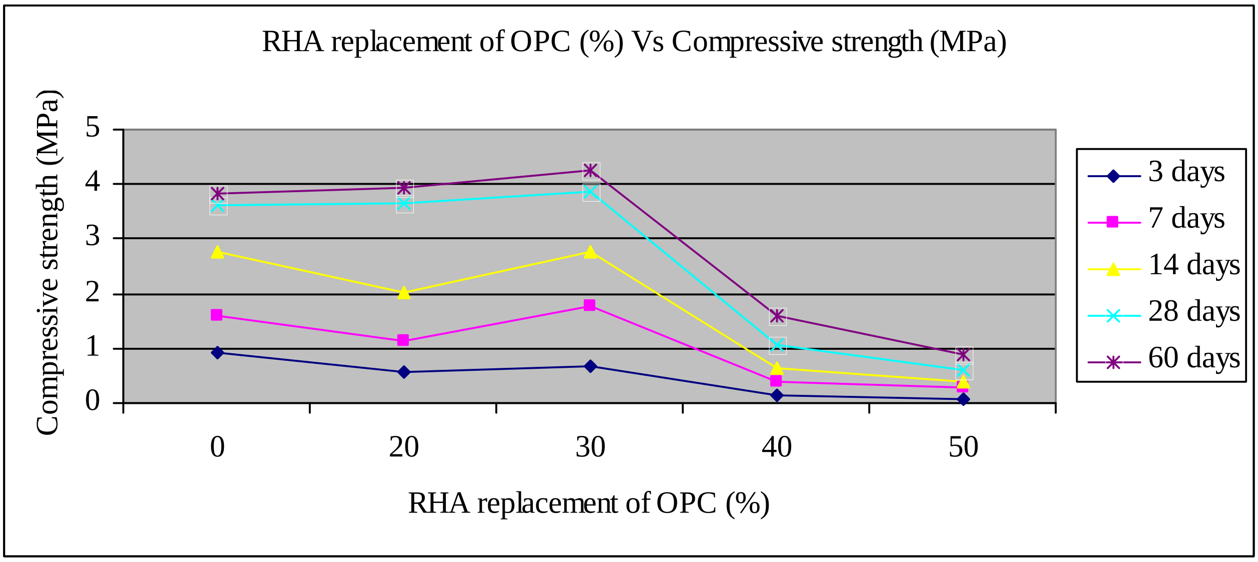

Fig.2. Compressive strength of RHA cement based non-autoclaved aerated concrete specimens with different replacement percentages.

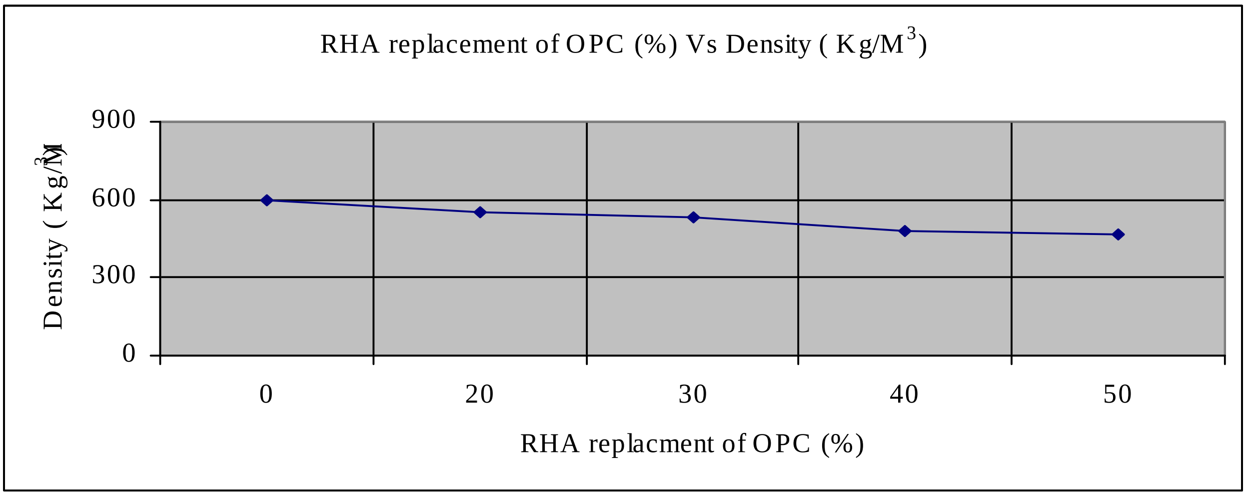

Fig.3. Density of RHA cement based non-autoclaved aerated concrete specimens with different replacement percentages.

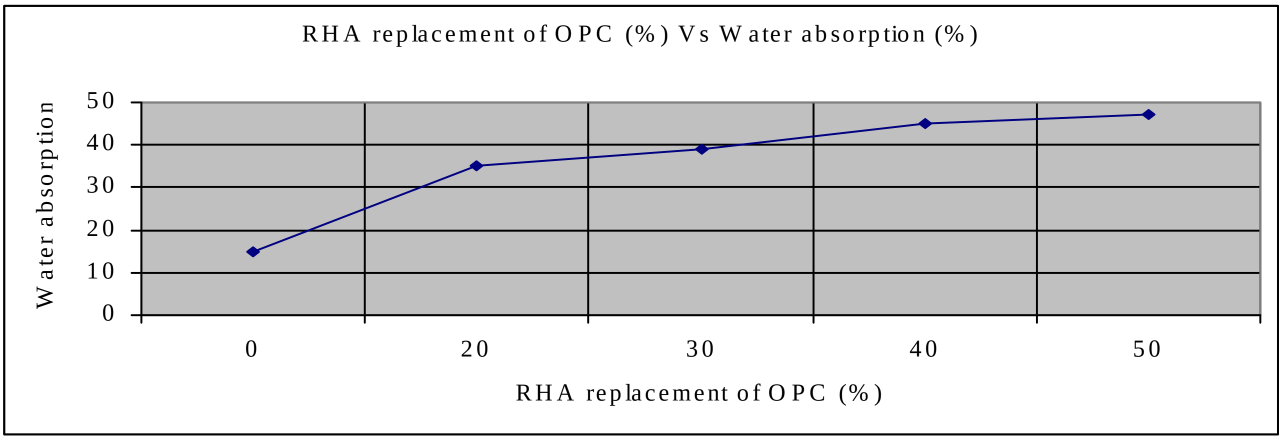

Fig.4. Water absorption of RHA cement based non-autoclaved aerated concrete specimens with different replacement percentages.

III. Results and Discussion

The study reported in this paper was undertaken to investigate the properties of aerated concrete composite with rice husk ash waste particles in order to produce usable materials in aerated concrete application. The material containing different amounts 20%, 30%, 40%, 50% of rice husk ash particles as partial replacement of cement (by weight of cement), was aerated by aluminium powder method. Physical and chemical properties of the materials are shown in Table-1 and Table-2. From Table -1, the specific gravity of OPC 3.15 indicates that cement particles is heavier than RHA which is 2.12. Results of RHA having smaller Blaine fineness 4200 cm^2/g shows that this RHA is very much finer than OPC of 3600 cm^2/g. So, RHA is finer and lighter particles as compared to OPC Table-2, Shows the chemical composition of OPC and RHA. From Table-2. The oxides analysis of RHA that is Silica, aluminium and iron oxide contents are approximately 86.01% of total composition. This value is within the required value of 70% minimum for Pozzolanas [30]. The loss of ignition is 4.91%, which is within the required value of maximum 12%. The magnesium oxide content was 0.41%. This satisfies the required value of 4% maximum. So, RHA used in this study as an active pozzolana. Fig-1 shows the result of setting time test. From the study, it is observed that, the initial and final setting times increases with increase in rice husk ash content.The studies by Ganesan et al. [31] (2008), Cook [32] (1986), and Bhanumathidas et al. [33] (2004) showed that RHA increases the setting time of pastes. The reaction between cement and water is exothermic, leading to liberation of heat and evaporation of moisture and consequently stiffing 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, So, more water was also required for the purpose to continue. This result is in consonant with the work [34].

The most obvious characteristic of aerated concrete is its lower density (300-1800Kg/m^3) compared with the density of ordinary concrete (up to 2600 Kg/m^3).From Table-4, it is noted that using rice husk ash in aerated concrete formulations caused weight decrease in the produced aerated concrete block for all concerned rice husk ash replacement ratios. It is obvious that almost all mixes are within the range of light weight aerated concrete.

The variations of compressive strength with age at curing are presented in Table-4.Throughout the study, it is observed that the strength performance of specimen consisting RHA has been always higher (Up to optimum level of replacement) as compared to OPC aerated concrete. Integration of RHA, which is finer and is able to be involved in pozzolanic reaction forming C-S-H gel while at the same time acts as filler, has created a newly modified microstructure for this agro cement-based aerated concrete. The influence of RHA in modifying the internal structure of this lightweight concrete to be denser and different than OPC specimen. Conclusively, this finding is in line with the results obtained by Narayanan and Ramamurthy [21] (2000b) who have mentioned that variation in the composition used will definitely affect the aerated concrete pore structure. The compressive strength generally increases with age at curing. At the hydration period only block made with 100%OPC (3.84MPa), 80% OPC (3.92MPa), and 70%. OPC (4.27MPa) met the minimum required standard. Other percentage replacement level fell below the minimum standard. The 30% replacement is then the optimum replacement level of OPC with RHA. For higher percentage replacement level such as 40% RHA, 50% RHA, the amount of rice husk ash in the mixture is higher than required to combine with the liberated calcium hydroxide in the course of the hydration. The excess silica substitute part of the cementatious materials and consequently causing a reduction in strength.

From Table-4, it is also noted that, unlike conventional concrete, water absorption increases with compressive strength and decreases with RHA content increases. A possible explanation can be that, increased density corresponds to an increase in paste volume of capillary pore and reduction in foam volume of artificial pore. Therefore, water absorption mainly depends on capillary pore volume and the volume of artificial pores governs the compressive strength and density (Narayanan and Ramamurthy, [35] 2000) reported similar conclusions on strength of artificial pore dependency for autoclaved aerated concrete.

IV. Conclusions

Based on the study, the following conclusions are made:

- Physical characteristic of RHA in terms of fineness and chemical composition plays vital role in determining the strength development of this agro blended cement based aerated concrete.
- Since Percentage of SiO2 is higher in rice husk ash which reacts with Ca(OH)2 and produce additional CSH minerals resulting in a 15-20% higher strength in later age. The reaction reduces the amount Ca(OH)**2** from concrete. CSH is the glue that provides strength in concrete and gives a dense concrete matrix due to reducing the capillary pores those results in lower permeability and higher durability.
- 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 rice husk ash content increases;
- The density of OPC/RHA is within the range for RHA based aerated concrete block (553-670kg/m^3);
- The compressive strength of the blocks for all mix increases with age at curing and decreases as the RHA content increases;
- Unlike conventional concrete, water absorption increases with compressive strength and decreases with 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 30%;
- So, replacement of cement up to 30% by the RHA can be accommodated to produce rice husk ash cement based non autoclaved aerated concrete block suitable for low cost construction. Such development has to be implemented in Bangladesh to provide suitable housing structures for low income group particularly in rural areas. So, the development of new constructional materials using waste rice husk ash is important to both the construction and the environment.

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