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Influence of Rice Husk Ash on the Properties of Concrete

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Abstract

This research was carried out to investigate various physical properties of Rice Husk Ash (RHA) and, some physical and mechanical properties of concrete incorporating RHA in different proportions. The concrete specimens were tested at 7, 21 and 28 days after curing. Test results revealed that the specific gravity of RHA was found lower than that of sand. The density of concrete containing RHA was recorded between 80-110 lb.ft^{-3}, which is lower than conventional concrete. Water absorption was found increasing with the increase of RHA content in concrete specimens. There were significant variations in compressive strength values of concrete containing 5%, 10% and 20% volume of RHA. The compressive strength of 5% RHA specimen was 150-200% higher than that of other specimens. Hence, upto 5% replacement of RHA could be recommended for making normal lightweight concrete. The splitting tensile strength was about 9-10% of compressive strength. It was concluded that upto 5% RHA can be used effectively in making normal lightweight concrete. The higher percentage of RHA could be used in making non-structural concrete where the strength of concrete is not concerned.

Key words: Lightweight concrete, Physical properties, Rice husk ash, Strength properties

Introduction

Rice is a heavy staple in the world market as far as food is concerned. It is the second largest amount of any grain produced in the world. For every 1000 kg of paddy milled, about 200 kg (20%) of husk is produced (Anwar *et. al.*, 2001). The husk of the rice is removed in the farming process before it is sold and consumed. Rice husk ash RHA is a by-product from the burning of rice husk when this husk is burnt in the boilers, about 50 kg (25%) of RHA is generated. In global context, annual rice husk production is about 148 million tones whereas in Bangladesh about 10 million tons of rice husk is produced (FAOSTAT, 2012). Out of 37.08 million tons of total biomass produced from agro-residues, rice husk contributes about 26% by mass in Bangladesh (BBS, 2009). At present about 67-70% of rice husk is consumed for steam producing in rice mills (Ahiduzzaman, 2007; Ahiduzzaman *et al.*, 2009). Rice husk constitutes about 20% of the weight of rice. It contains about 50% cellulose, 25-30% lignin, and 15-20% of silica (Hwang and Chandra, 1997). On burning, cellulose and lignin are removed leaving behind silica ash. As the production rate of rice husk ash is about 20% of the dried rice husk.

Disposal of rice husk ash is an important issue in those countries which cultivate large quantities of rice. Rice husk has a very low nutritional value and as they take very long to decompose are not appropriate for composting or manure. Therefore, 100 million tons of rice husk produced globally begins to impact the environment if not disposed of properly. One effective method used today to rid the planet of rice husk is to use it to fuel kilns. The controlled temperature and environment of burning yields better quality of rice-husk ash as its particle size and specific surface area are dependent on burning condition.

RHA is a potential source of amorphous reactive silica, which has a variety of applications in materials science. When completely incinerating, the husk in controlled conditions, the residue, RHA, contains 90-96% silica in amorphous form. The average particle size of RHA ranges in general from 5 µm to 10 µm with a very high specific surface area, even more than 250m^{-2}g (Bui, 2001). Silica is the basic component of sand, which is used with cement for plastering and concreting. This fine silica will provide a very compact concrete. The ash also is a very good thermal insulation material. The fineness of the ash also makes it a very good candidate for sealing fine cracks in civil structures, where it can penetrate deeper than the conventional cement sand mixture. A number of possible uses for RHA include absorbents for oils and chemicals, soil ameliorants, a source of silicon, insulation powder in steel mills, as repellents in the form of "vinegar-tar" release agent in the ceramics industry, as an insulation material. More specialized applications include the use of this material as a catalyst support (Chumee *et al.*, 2009). The main aim of this study was to determine various physical properties of RHA and important mechanical properties of concrete containing different amount of RHA. The influence of RHA on strength properties of concrete was also investigated.

Materials and Methods

Rice husk ash (RHA)

The rice husk ash is the substance which was found after burning the rice husk in the rice mill. It looks like powder and light dark in color. The RHA was collected from different rice mills where the rice husk was burned after boiling and ultimately the burned ash was waste product (Fig. 1).

(i) (ii) (iii)

Fig. 1. (i) Rice husk before burning, (ii) Waste RHA after burning at a rice mill (iii) RHA for use in concrete

RHA was collected from the local Rice mill and prepared in the laboratory for its physical properties. The size of ash particles ranges between 0.15 to 1.25mm. River sand and khoa (brick chips) were used as fine and coarse aggregates. The gradation of RHA, sand and brick-chips are presented in Fig. 2.The physical properties of RHA, fine and coarse aggregate are given in Table 1.

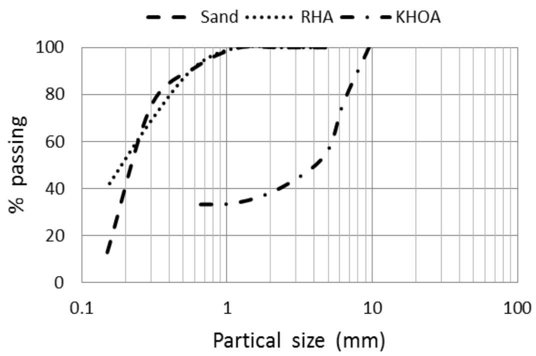

Fig. 2. Gradation curve for RHA, sand and Khoa

Table 1. Physical properties of fine and coarse aggregates

Properties	Fine aggregate	Coarse aggregate	RHA
Bulk specific gravity (OD)	1.22	1.42	1.09
Bulk specific gravity (SSD)	--	1.45	--
Apparent specific gravity	1.19	1.50	1.23
Water absorption (%)	35.6	9.30	42.30
Size range (mm)	<4.75	4.75-9.5	0.15-1.25
F.M.	1.97	--	--

Preparation of concrete specimens

Mix design of concrete was performed according to British (DOE) method (Neville A.M., 1981). The prepared mixed proportions are given in Table 2. The fine aggregate was replaced by 5%, 10% and 20% volume of concrete mix with the RHA aggregate. Four types of concrete specimens were prepared maintaining the same water-cement ratio of 0.45. The specimens are named as CC0RHA, CC5RHA, CC10RHA and CC20RHA containing 0%, 5%, 10% and 20% RHA, respectively. The densities of fresh mix concrete were measured immediately after each mixing. A cone of 12 inch length and 6 inch diameter was used to measure the slump. After 24 hours of casting, all the specimens were transferred into a curing tank at room temperature till the day before testing (Fig.3). The specimens were cured for 7, 21 and 28 days.

Table 2. Mix proportions for different concrete specimens

Types of specimen	W/C ratio	Sand (%)	RHA (%)	Slump (mm)
CC0RHA	0.45	100	0	13
CC5 RHA	0.45	95	5	16
CC10 RHA	0.45	90	10	19
CC20 RHA	0.45	80	20	21

Fig. 3. Concrete specimens in a curing tank

Fig. 4. Compression test setup

Testing of concrete specimens

The tests of compressive strength, splitting tensile strength, modulus of elasticity and flexural strength were performed according to ASTM C39, ASTM C496, ASTM C469 and ASTM C78 standards, respectively. Fig. 4 shows the compression testing machine used in the laboratory. The load was applied continuously until the specimen failed. The load and deformation were measured at a fixed interval.

Results and Discussion

Water absorption

The percentage of water absorption for different concrete specimens is presented in Fig. 5. It was found that the percentage of water absorption was higher with the increase of RHA. For concrete specimen containing 20% volume of RHA, the water absorption was higher than the specimen without RHA aggregate.

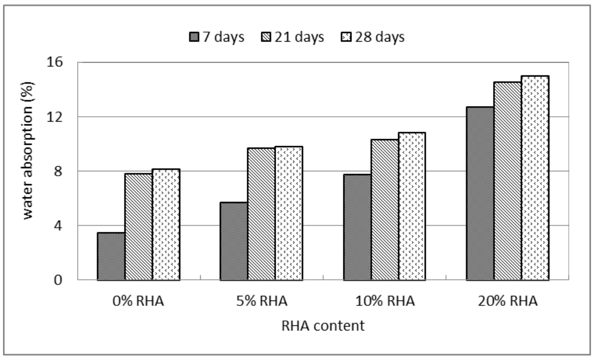

Fig. 5. Water absorption rates of the concrete specimens with RHA

Strength properties

The compressive strength values for various concrete specimens containing different percentage of RHA are presented in Fig. 6. It is observed that the fresh concrete specimen without RHA provided highest compressive strength which is about 60-70% higher than the strength of 5% RHA specimen. However, a significant change in compressive strength of the specimens containing 10% and 20% RHA is seen from Fig. 6. The compressive strength of 5% RHA specimen is found about 150-200% higher than 10% and 20% RHA specimens. In a previous study, as a replacement of cement, 8% RHA provided the higher compressive strength (Kah Yen Foong *et al.*, 2015). The splitting tensile strength tests were performed at 7, 21 and 28 days of curing. From Fig. 7, it is seen that the tensile strength with 0% RHA concrete was higher than the other

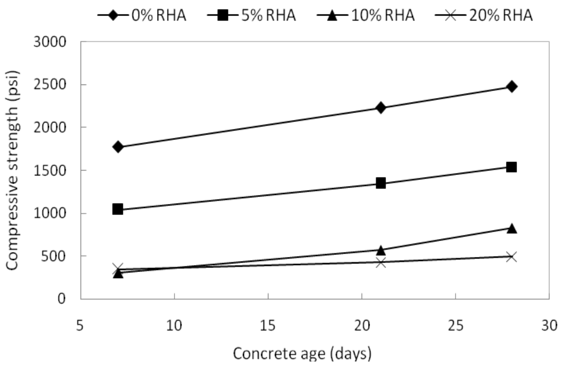

Fig. 6. Compressive strength variations with time and amount of RHA

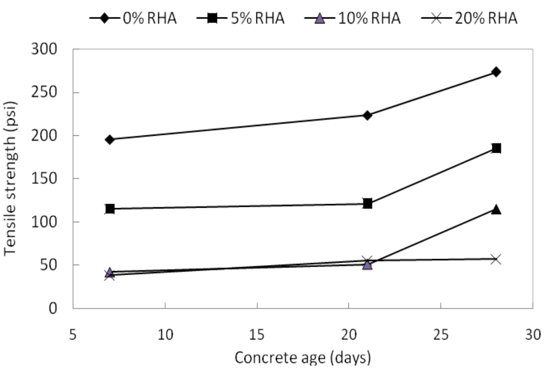

Fig. 7. Tensile strength variations with time and amount of RHA

specimens containing 5%, 10% and 20% volume of RHA. The nature of increasing tensile strength is found similar to the compressive strength. The 5% RHA specimen achieved better tensile strength value at 28 days. The strength of 20% RHA specimen was very low and this was happened because of higher absorption of water by RHA. The strength decreased as the more amount of RHA added. Splitting strength of concrete increased with time, but not more than conventional concrete at early stage. The flexural strength tests were conducted on 2×2×8in. specimens using three point loading method. The flexural strength values of different concrete specimens are presented in Fig. 8. It was observed that the flexural strength of concrete specimens without RHA aggregate was higher than other specimens with RHA content. But, the flexural strength with 5% RHA was found better than the specimens with 10% and 20% RHA.

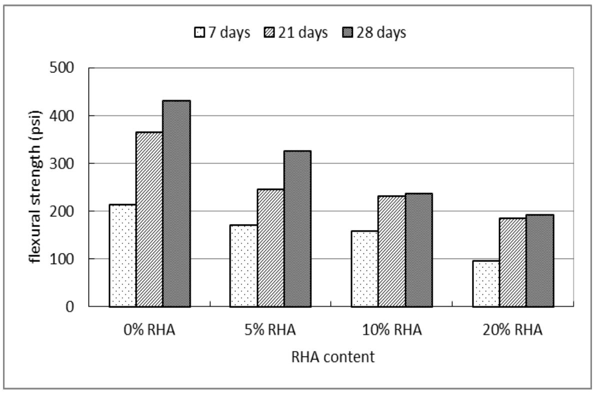

Fig. 8. Variation in flexural strength with time and different RHA content.

Stress-strain behavior

The stress-strain behaviour of the concrete specimens was recorded during compression testing at the age of 7, 21 and 28 days of curing. From Fig.9, it was found that the initial slope of the stress-strain curve for 0% RHA and 5% RHA specimens is almost same. But the elastic range of 0% RHA specimen was higher than others containing 5%, 10% and 20% RHA. At 7 days, the fresh concrete was more brittle than others and concrete containing 5% RHA was more brittle among other specimens containing different percentages of RHA. Almost similar trend was observed in case of 21 and 28 days specimens. It was also observed that the stiffness of 5% RHA concrete is found decreasing gradually with time. No significant change is observed in stress-strain relationships for 20% RHA specimens with time (Fig. 9 to Fig. 11). However, there was inconsistency found in case of the stress-strain behaviour for the 10% RHA specimens.

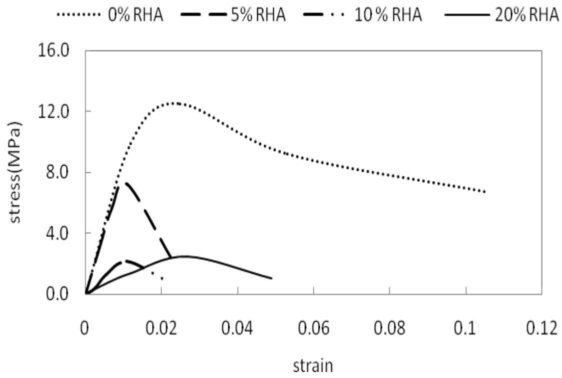

Fig. 9. Stress-strain behavior of concrete after 7 days

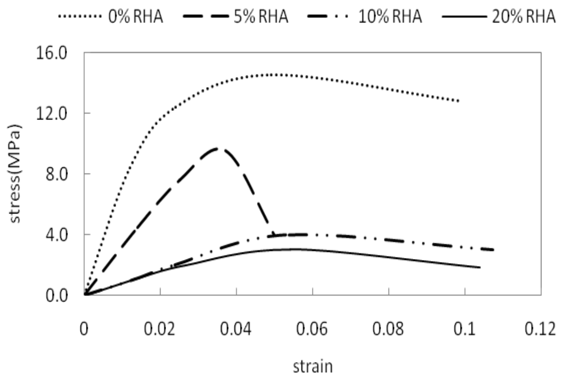

Fig. 10. Stress-strain behavior of concrete after 21 days

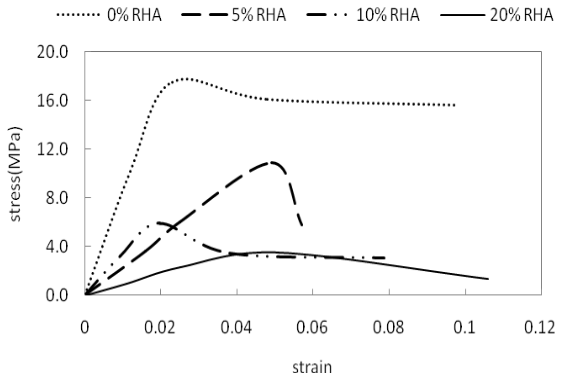

Fig. 11. Stress-strain behavior of concrete after 28 days

Conclusions

The ultimate goal of this research was to investigate the influence of different proportion of RHA over the mechanical properties of concrete. The physical properties of RHA and fresh concrete were identified. This study showed the potential of using RHA by analyzing different properties of hardened concrete. From this study, some conclusions are drawn as follows;

1. Since the specific gravity of RHA is found lower than conventional fine aggregate, sand, it falls under the category of lightweight aggregate. So, it can be used partially in making lightweight concrete.
2. The water absorption rate is higher for concrete with RHA content. The water absorption rate increases with the addition of more RHA aggregate.

3. The compressive strength of concrete without RHA aggregate is about 60-70% higher than that of 5% RHA concrete. And, the compressive strength of 5% RHA specimen is found about 150-200% higher than 10% and 20% RHA specimens. Hence, upto 5% replacement of RHA could be recommended for making normal lightweight concrete.
4. The concrete with 0% RHA is found more brittle than all other specimens. And, the concrete containing 5% RHA was more brittle among other specimens RHA content at all ages. The stiffness of 5% RHA concrete decreases gradually with time. No significant change in stress-strain relationships observed for 10% and 20% RHA specimens with time.

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