POTENTIAL OF INDIGENOUSLY PRODUCED RICE HUSK ASH IN CONCRETE

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ABSTRACT

After aluminium and steel, portland cement is the most energy-intensive product and efforts are being made to find cement replacement material. The use of Rice husk ash offers one such possibility. Due to growing environmental concerns and the need to conserve energy and resources, efforts have been made to burn the rice husk at a controlled temperature and atmosphere, and to utilise the ash so produced as a supplementary cementing material Rice husk ash, being available as a waste product, is very cheap in comparison to cement. It is expected that if replacement of a certain portion of cement with indigenously produced Rice husk ash does not adversely change the strength and durability of concrete, it would be cost effective. In the present study, investigation was carried out using Rice husk ash as cement replacement of 0%, 5%, 10% and 15% with both brick- and stone-chips as coarse aggregates. Mix proportions of both 1:1.5:3 and 1:2:4 by volume were adopted. In some of the samples superplasticizer was used to have slightly higher strengths and more workability. Strength properties of concrete produced by using rice husk ash as a supplementary cementing material have been compared with their plain concrete counterpart. Results from tests on about 300 cylinders at different ages have shown that unrefined rice husk ash has a moderate potential of economically producing good quality concrete.

Keywords: rice husk ash, indigenous production, concrete strength, brick- and stone-aggregates, superplasticizer, cement replacement, cost effectiveness.

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INTRODUCTION

Rice husk, an agricultural waste, constitutes about one-fifth of the 300 million metric tons of rice produced annually in the world. This requires a storage space of well over 600 million cubic meters. Because of their poor nutritive and high silica content, rise husks are not suitable for animal fodder and are considered as an agricultural waste. Rice husk ash (RHA) having a low bulk density and an abrasive character, also poses some disposal problems. On the other hand, due to high silica content, rice husk ash has been regarded as a cementitious material in making concrete. In developing countries, where rice husk is abundant, the use of RHA can help in partially solving the scarcity of cement, relieve the disposal problem and at the same time meet the demand for low cost materials.

Many efforts have been made to produce good quality ashes. Mehta [1] obtained patents on his discovery that active RHA could be produced by maintaining the combustion temperature for prolonged period below 500^0C under oxidizing condition or, alternatively, combustion temperature upto about 680^0C may be used provided the hold time is short, viz., less than 1 min. Along with the production of good quality ashes, an efficient grinding process is essential for an RHA cement industry of any scale. In view of effective utilisation of active RHA, it is essential that it is made on a mass scale and economically. The most simple and inexpensive way to mass-produce RHA would be to burn rice husks in open air without using sophisticated equipment or high capital investment.

Swamy [2] contains a detailed account of various studies on cement replacement materials. The objective of this research (see Sultana [3] for details) is to gain information on the utilisation of RHA as a supplementary cementing material. The effect of the percentage of RHA, as a material replacing part of cement content, on the strength of concrete was investigated. In the local rice mills of Bangladesh, rice husk is used as a fuel. The ash that is left has been used in the present study without treatment. This was done in order to find out the suitability of indigenously produced RHA as a possible cement replacement material.

EXPERIMENTAL PROGRAM

In this study, mix proportion (by volume) of 1:1.5:3 (Cement:FA:CA) and 1:2:4 were adopted. Apart from using both brick- and stone-chips as coarse aggregates, the amount of RHA as a cement replacement material was varied. Mixes with lower water/binder ratio but incorporating superplasticizer and RHA were also tried. A test programme of casting about 300 cylinders having 150 mm x 300 mm size, forming 32 batches of different mixes, were undertaken. The proportions of various ingredients of concrete mixes are summarised in Table 1. All the mixes had a water/binder ratio of 0.45 when superplasticizer is not added. Superplasticizer was used to adjust the flow of paste, slump of concrete and to compare the effect of superplasticizer on plain concrete and RHA concrete.

Table 1: Mix proportions of concrete

Conditions	FA (lb.)	CA (lb.)	Water (lb.)	SP (ml)	% of cement replaced by RHA	RHA (lb.)	Cement (lb.)	Cylinder number
Agg = Brick	94.7	142.3	26.1	0	0%	0	58.0	1-9
Mix prop = 1:1.5:3					5%	2.9	55.1	10-19
W/(C+RHA) = 0.45					10%	5.8	52.2	20-29
SP/Binder = 0					15%	8.7	49.3	30-39
Agg=Stone	95.2	199.2	23.5	0	0%	0.0	52.2	40-49
Mix prop = 1:1.5:3					5%	2.6	49.6	50-59
W/(C+RHA) = 0.45					10%	5.2	47.0	60-69
SP/Binder = 0					15%	7.8	44.4	70-79
Agg=Brick	84.8	126.7	17.4	0	0%	0.0	38.8	80-88
Mix prop = 1:2:4					5%	1.9	36.8	89-97
W/(C+RHA) = 0.45					10%	3.9	34.9	98-107
SP/Binder = 0					15%	5.8	32.9	107-115
Agg = Brick	80.9	120.9	16.3	671	0%	0.0	49.3	116-124
Mix prop = 1:1.5:3					5%	2.5	46.9	125-133
W/(C+RHA) = 0.33					10%	4.9	44.4	134-142
SP/Binder = 0.03					15%	7.4	41.9	143-151
Agg = Stone	87.3	182.6	18.0	0	0%	0.0	39.9	152-159
Mix prop = 1:2:4					5%	2.0	37.9	160-168
W/(C+RHA) = 0.45					10%	4.0	35.9	169-177
SP/Binder=0					15%	6.0	33.9	178-186
Agg = Stone	83.3	174.3	117.8	461	0%	0.0	50.8	187-195
Mix prop = 1:1.5:3					5%	2.5	48.3	196-204
W/(C+RHA) = 0.35					10%	5.1	45.7	205-213
SP/Binder = 0.02					15%	7.6	43.2	214-222
Agg = Brick	87.3	130.4	14.0	352	0%	0.0	39.9	223-231
Mix prop = 1:2:4					5%	2.0	37.8	232-240
W/(C+RHA) = 0.35					10%	4.0	35.9	241-249
SP/Binder = 0.02					15%	6.0	34.0	250-258
Agg = Stone	84.8	187.2	13.6	352	0%	0.0	38.8	259-267
Mix prop = 1:2:4					5%	1.9	36.8	268-276
W/(C+RHA) = 0.35					10%	3.9	34.9	277-285
SP/Binder = 0.02					15%	5.8	32.9	286-294

Preparation of concrete specimens

For the determination of compressive strength of concrete cylinders were cast in two layers and compacted by vibrator following ASTM specifications. At least nine cylinders were cast from each of the mixes, for testing at 7-, 28- and 60-days; three cylinders for each test date. Mixing of concrete was performed using a mixing machine. The specimens were left in the moulds in the casting room at 20 ± 3°C for 24 hours then demoulded and cured in water continuously until the compression tests were performed.

Testing

Sulphur mortar was used as capping material. The sulphur mortar was prepared by heating it to about 130°C and then was poured into lightly oiled steel capping plates. The cylinders were set into the sulphur in such a way that the caps ended up being 6 mm thick and were aligned so that the deviation of each cap from the perpendicular with the axis of the specimen was less than 0.5°. Both the top and bottom ends of each of the cylinders were provided with Sulphur capping. The whole operation was conducted in accordance with ASTM guideline. Before crushing, the diameter of each cylinder was recorded and the test was carried out in Universal Testing Machine according to relevant ASTM specifications.

Materials

Rice husk ash was collected from a rice mill in Savar near Dhaka city. The rice husk was burnt by farmers without using any sophisticated, or highly mechanised instrument and without maintaining a constant burning temperature. The ash which was found in the field was directly used in this investigation without any refinement. Ordinary Portland cement, Type I, of unit weight 90.3 lb/cft and specific gravity 3.15 was used. Strength of 100 mm x 100 mm x 100 mm cubes made from cement mortar as per ASTM standard was tested at 3, 7 and 28 days and the average compressive strength at these days were 28, 37 and 43 MPa, respectively. Sylhet sand of bulk specific gravity 2.77 (SSD), 2.73 (OD), bulk unit weight 98.8 pcf and fineness modulus of 2.42 was used. Stone chips of unit weight of 103.3 pcf & fineness modulus 6.98 was used. Again, brick chips of bulk specific gravity 1.92 (SSD), 1.53 (OD), unit weight 73.8 pcf and fineness modulus 7.03 was used. Sikament 280 (M), high range water reducing concrete admixture, which is a highly effective dual action liquid plasticizer for the production of free flowing concrete or as a substantial water reducing agent for promoting high early and ultimate strengths has been used. This reduces water by 20% and 28 days compressive strength is increased by 30%.

RESULTS AND DISCUSSION

The findings of cylinder test results at 7-, 28- and 60-days are as follows:

At mix proportion of 1:1.5:3 compressive strength of brick aggregate concrete at 0% RHA has been found to be higher than that of the stone aggregate concrete at 7 days, 28 days and 2 months. The strengths either remained similar or increased slightly for RHA up to 5%. It showed a sudden decrease beyond 5% for brick aggregate concrete, as shown in Figs. 1, 2 and 3. This is due to the fact that w/c ratio remaining constant, concrete with 10%-15% RHA becomes quite dry and that the workability and consistency of the concrete were adversely affected.

In the case of stone aggregate concrete, at mix proportion of 1:1.5:3, strength increased at all ages for up to 10% RHA, but beyond that a decline in strength, as shown in Figs. 1, 2 and 3, has been observed. As stone absorbs less water than brick, it makes concrete less dry (more workable) than brick aggregate concrete and shows increase in strength up to 10% of RHA, whereas such increases in brick aggregate concrete can be seen for RHA up to 5%. Water-binder ratio, W/(C+RHA), was kept constant with the main purpose of comparing strengths between plain concrete and concrete incorporating RHA.

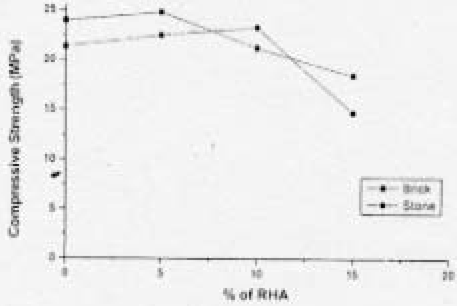

Fig. 1: Compressive strength (7 days) vs. % RHA at mix proportion of 1:1.5:3 and w/(c+RHA) = 0.45

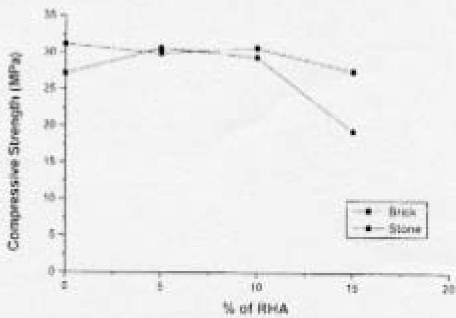

Fig. 2: Compressive strength (28 days) vs. % RHA at mix proportion of 1:1.5:3 and w/(c+RHA) = 0.45

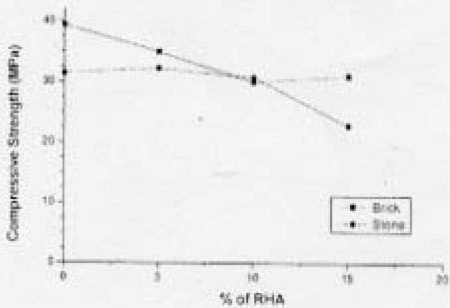

Fig. 3: Compressive strength (2 months) vs. % RHA at mix proportion of 1:1.5:3 and w/(c+RHA) = 0.45

At mix proportion of 1:2:4 strength gain at 7 days, 28 days & 2 months has been found to be higher for stone aggregate concrete than that for brick aggregate concrete with no RHA as shown in Figs. 4, 5 and 6. Although strength increases with 5% RHA, beyond that there is a sudden decrease in strength, in the case of stone aggregate concrete. However, for brick aggregate concrete, strength increased upto 10% of RHA and the rate of decrease in strength beyond 10% RHA was less than its brick aggregate counterpart. At mix proportion of 1:2:4 concrete becomes comparatively much drier than the mix of 1:1.5:3.

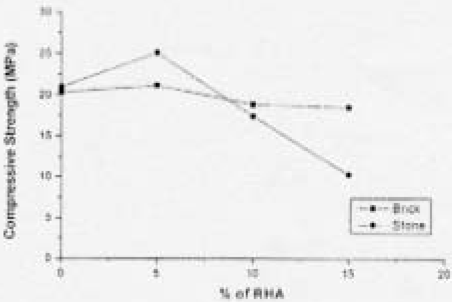

Fig. 4: Compressive strength (7 days) vs. % RHA at mix proportion of 1:2:4 and w/(c+RHA) = 0.45

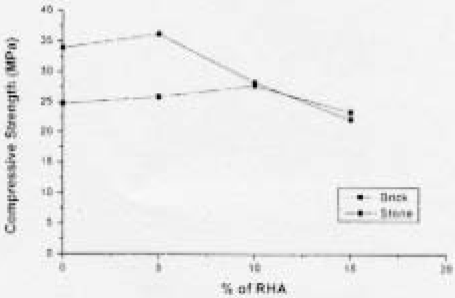

Fig. 5: Compressive strength (28 days) vs. % RHA at mix proportion of 1:2:4 and w/(c+RHA) = 0.45

At mix proportion of 1:2:4 strength increases due to addition of RHA up to 10%, but beyond that strength decreases rapidly in both the cases of brick- and stone-aggregate concrete having super plasticizer (SP). For brick aggregate concrete, strength increased by 32% at 7 days, 61% at 28 days and 95% at 2 months when cement was replaced from 0% to 10% by RHA as shown in Figs. 7, 8 and 9. For stone aggregate strength decreased by 4.8% at 7 days, increased by 5.4% at 28 days and decreased 2.2% at 2 months as cement was replaced by 0% to 10% by RHA (see Figs. 7, 8 and 9).

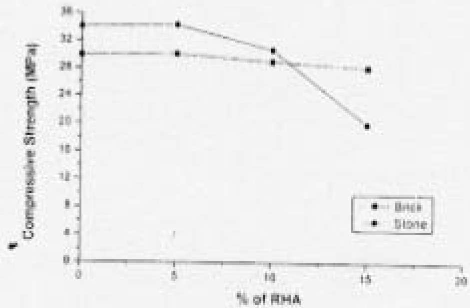

Fig. 6: Compressive strength (2 months) vs. % RHA at mix proportion of 1:2:4 and w/(c+RHA) = 0.45

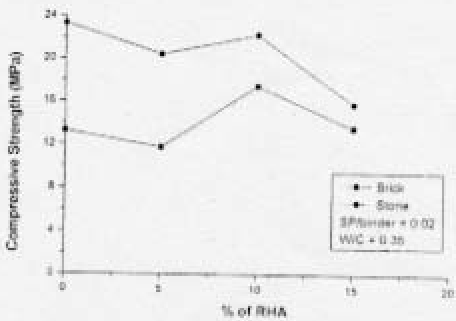

Fig. 7: Compressive strength (7 days) vs. % RHA at mix proportion of 1:2:4, SP/binder = 0.02 and w/(c+RHA) = 0.35

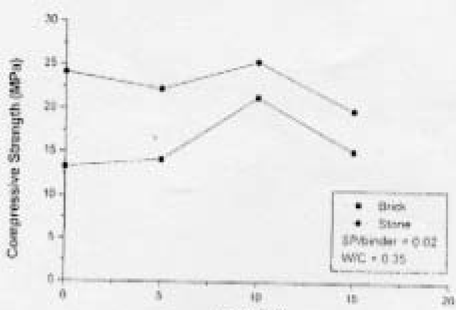

Fig. 8: Compressive strength (28 days) vs. % RHA at mix proportion of 1:2:4, SP/binder = 0.02 and w/(c+RHA) = 0.35

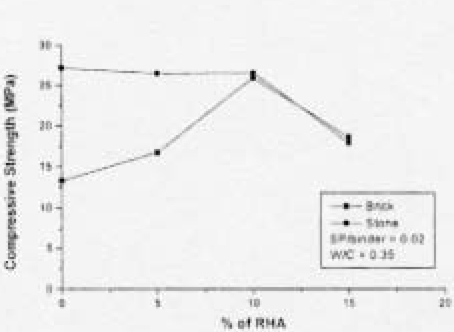

Fig. 9: Compressive strength (2 months) vs. % RHA at mix proportion of 1:2:4, SP/binder = 0.02 and w/(c+RHA) = 0.35

It has been found that concrete with 15% RHA, at mix proportion of 1:1.5:3, and SP to binder ratio of 0.02, compressive strength either increases or remains virtually similar. Such curves for stone aggregate concrete are shown in Fig. 10.

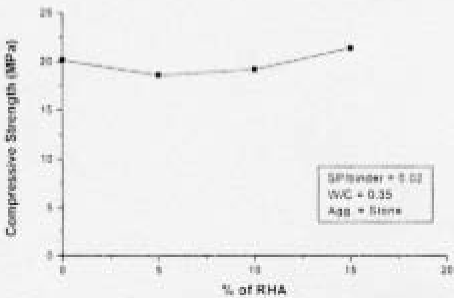

Fig. 10(a): Compressive strength (7 days) vs. % of RHA at mix proportion of 1:1.5:3, SP/binder = 0.02, w/(c+RHA) = 0.35 and stone aggregate

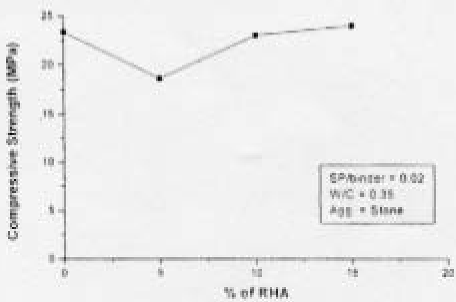

Fig. 10(b): Compressive strength (28 days) vs. % of RHA at mix proportion of 1:1.5:3, SP/binder = 0.02, w/(c+RHA) = 0.35 and stone aggregate

From the plot of compressive strength against age, it is evident that at mix proportion of 1:1.5:3, both brick- and stone-aggregate concrete, with up to 10% RHA, show higher strength at 7 days, 28 days and 2 months, in comparison to plain concrete without RHA as shown in Figs. 11 and 12.

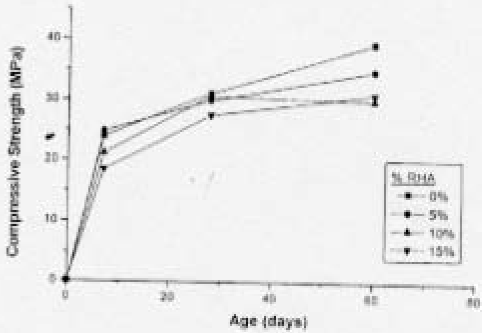

Fig. 11: Compressive strength vs. age at mix proportion of 1:1.5:3, w/(c+RHA) = 0.45, SP/binder = 0 and brick aggregate

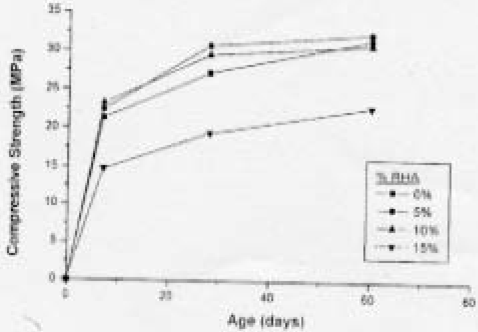

Fig. 12: Compressive strength vs. age at mix proportion of 1:1.5:3, w/(c+RHA) = 0.45, SP/binder = 0 and stone aggregate

At mix proportion of 1:2:4, brick aggregate concrete shows higher strength at 5% to 10% RHA, but for stone aggregate concrete it is true for RHA of 5% only. Again, strength at 15% RHA is much lower than that of plain concrete as concrete almost looses its workability (see Fig. 13 and 14).

Due to the addition of super plasticizer at mix proportion of 1:1.5:3, both brick- and stone-aggregate concrete with 15% RHA show higher strength with age than that of plain concrete. However, for concrete up to 10% RHA but with the same superplasticizer to binder ratio, concrete had very high slumps and also yielded lower strengths, as can be seen in Figs. 15 and 16.

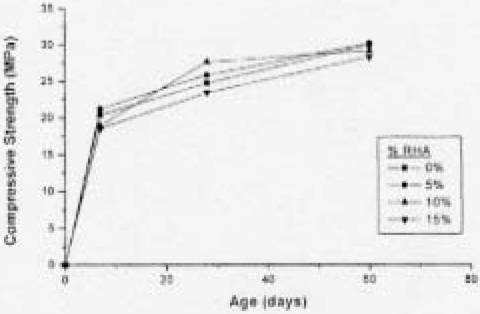

Fig. 13: Compressive strength vs. age at mix proportion of 1:2:4, w/(c+RHA) = 0.45 SP/binder = 0 and brick aggregate

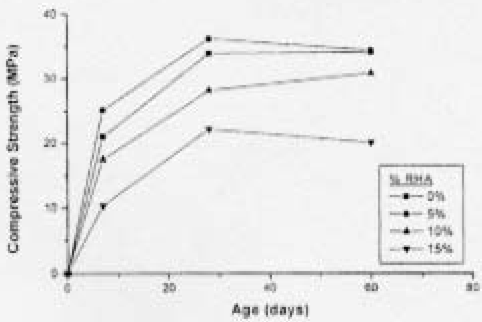

Fig. 14: Compressive strength vs. age at mix proportion of 1:2:4, w/(c+RHA) = 0.45 SP/binder = 0 and stone aggregate

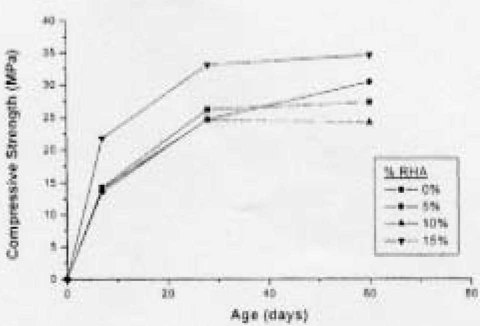

Fig. 15: Compressive strength vs. age at mix proportion of 1:1.5:3, w/(c+RHA) = 0.35, SP/binder = 0.03 and brick aggregate

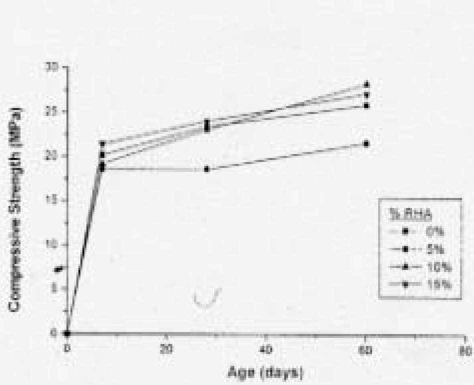

Fig. 16: Compressive strength vs. age at mix proportion of 1:1.5:3, w/(c+RHA) = 0.35 SP/binder = 0.02 and stone aggregate

At mix proportion of 1:2:4 with super plasticizer both for brick and stone aggregate, rate of increase in strength with age is higher for 10% RHA concrete than for plain concrete. Brick aggregate concrete of 5% and 15% RHA showed a slight increase in strength with age than for plain concrete but stone aggregate concrete shows lower strength at 5% and 15% RHA concrete (see Figs. 17 and 18).

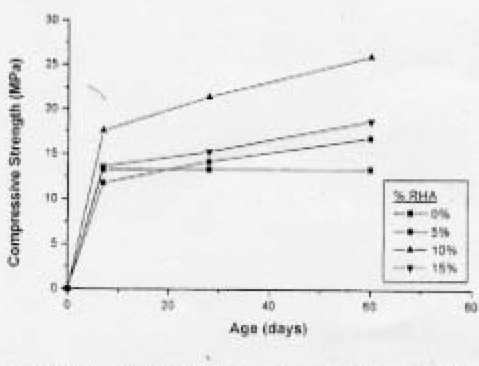

Fig. 17: Compressive strength vs. age at mix proportion of 1:2:4, w/(c+RHA) = 0.35 SP/binder = 0.02 and brick aggregate

CONCLUSION

The extensive laboratory test data indicate that the indigenously produced RHA, the production process of which does not involve any treatment, grinding and temperature control, may be suitably used as a cement replacement material in the production of concrete. The optimum amount lies in the range of 5 to 10 percent of the total cementitious content within the limitations that constant water-binder ratio is to be maintained for all percentages of cement replacement by RHA.

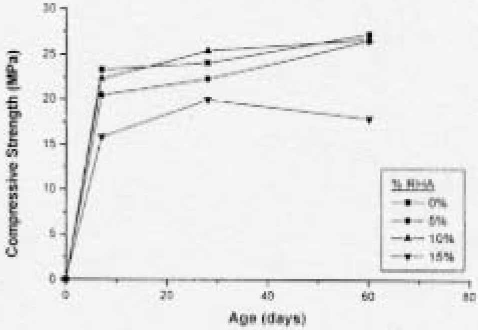

Fig. 18: Compressive strength vs. age at mix proportion of 1:2:4, w/(c+RHA) = 0.35 SP/binder = 0.02 and stone aggregate

The limited study reported here shows that such a replacement of cement, which is quite expensive in developing countries like Bangladesh, by RHA, which is abundantly available at no cost, may lead to cost reduction of structural concrete members using both stone chips and (light weight) brick chips as coarse aggregates. Addition of super plasticizer allowed the use of lower water-binder ratio and increase in the compressive strength. It is apparent that in the majority of the cases studied, 15% of cement could be replaced by RHA, for both stone- and brick-aggregate concrete, and yet satisfactory strength values could be obtained.

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FPS TO SI CONVERSION FACTORS

To convert	To	Multiply by
Pound (lb.)	Kg	0.4536
C	F	1.8
Inch	cm	2.54
Pounds per cubic feet (pcf)	Newton per cubic meter	156.84