EFFECTIVENESS OF RICE HUSK ASH (RHA) AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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ABSTRACT

An experimental investigation has been carried out to observe the efficacy of Rice Husk Ash (RHA) as a partial replacement of binding materials in concrete construction. Bangladesh, being an agro-based country, has plenty of RHA production as an agricultural by-product. Previous studies reported that about 400 pounds of rice husk can be obtained after milling approximately 2000 pounds of paddy. In this study, compressive strength of 4-inch concrete cubes has been determined to see the variation in strength of concrete with the partial replacement of cement by RHA. After a rigorous review on related available research articles, RHA to Cement ration are selected as 10:90, 15:85, 20:80, 25:75, 30:70, 40:60, 50:50 and then, compared with the controlled concrete sample. Curing periods of 7, 14, 28, 60, 90 days are considered for all the combinations and a constant mixing ratio of 1:1.5:3 for binder, fine aggregate & coarse aggregate, respectively, and a w/c ratio of 0.45, are chosen. RHA is collected from a rice mill in Bogra district, where a temperature of about 300-350 degree Celsius is maintained usually. Results depict that with the inclusion of RHA as partial binders, the strength of concrete expectedly decreases. It is observed that addition of 10% and 15% RHA to cement by weight (curing period 60 days) yields nearly the same compressive strength of controlled concrete sample (curing period 28 days). Besides, it is found that addition of RHA by 40% and 50% to cement by weight, on an average, reduces more than 50% of the concrete compressive strength. Based upon the results, usefulness of different fusions for different types of permanent and interim constructions are recommended.

Keywords: *RHA, concrete, compressive strength, curing periods, mixing ratio*

1. INTRODUCTION

Buildings and any other similar constructions in Bangladesh chiefly depend on reinforced cement concrete (RCC) that requires a large amount of cement along with other construction materials. Ample amount of brick manufacturing, large amount of readily available stones and sands made the civil engineering building works economic and most popular in this country. But, cement, which needs proper and relatively expensive manufacturing cost, remains a matter of concern. Hence, it is a topic of interest to find out how the construction cost of concrete, cost of cement to be specific, can be optimized keeping the quality of construction almost unhampered. In general, Ordinary Portland Cement (OPC) remains the popular choice despite its high production cost. In search of an alternate material, Rice Husk Ash (RHA) which is richly available in Bangladesh, becoming the choice of cement replacement, partially though. RHA, which is an agricultural by-product, is a woody sheath surrounding the kernel or grain and consists of two interlocking halves. According to Food and Agricultural Organization (FAO), world rice production in the year of 2009 is about 678 million tons and according to Bangladesh Bureau of Statistics (BBS), annual production of all kind of rice in Bangladesh in year 2009-2010 is about 31 million metric tons. That means a large amount of RHA is available, which was previously considered just a waste material. According to Hossain (2011), yearly RHA production in Bangladesh is nearly 1.15 million metric tons. Besides, RHA has some good quality ingredients to be considered as binder

material in concrete construction. Typical chemical composition of RHA found in Bangladesh is given in Table 1. It can be seen that the silica is predominant in RHA. Materials those are rich in siliceous or siliceous and aluminous contents are known as pozzolans. Pozzolans, itself possesses little or no cementitious value, however, if divided into very fine powder and in the presence of water, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. Therefore, RHA is becoming one of the best replacement materials to reduce the dependency on cement in many countries of the world where paddy production is substantial. RHA possesses adequate bonding quality and imparts additional strength if added to concrete as partial replacement of cement, under proper justification (Chindaprasirt et al., 2007; Ganesan et al., 2008; Givi et al., 2010; Ikpong & Okpala, 1992; Ismail & Waliuddin, 1996; Rodrguez, 2006; Van Tuan et al., 2011).
Although RHA has been reported as good material to be used in concrete construction, yet, it is not in international best practice. In Bangladesh, large amount of paddy construction is available and we need to reduce the construction cost and need to recycle this agricultural by-product (RHA). So, many more solid evidences are required to make people aware of the use of RHA in all kinds of civil engineering constructions.

Table 1: Chemical composition of RHA found in Bangladesh (Givi et al., 2010)

Contituent	**Percentage Composition**
$Fe2O3$	1.38
$SiO2$	90.20
$Al2O3$	0.85
CaO	1.18
MgO	1.21
Loss on Ignition	3.95

This study is carried out to see the performance of RHA blended concrete. To look into the behaviour of concrete, particularly the compressive strength of concrete prepared with various ratios of RHA to cement, this study is undertaken, so that huge amount of RHA produced all over Bangladesh, can be utilized at its best and optimum level of RHA to be used as partial replacement of cement in concrete can be determined.

2. METHODOLOGY

2.1 Materials

Type-1 (CEM-1) Ordinary Portland Cement (OPC) collected from one of the famous cement factories in Chittagong, is used in casting the concrete. According to the company provided guidelines, the 52.5 N strength class cement has 95-100% clinker and 0-5% gypsum. RHA is collected from an Auto Rice Mill in Bogra district, Bangladesh. It was out of the scope of this study to personally burn the RHA within laboratory facilities. Rather, RHA are burnt in the above mentioned rice mill under a controlled temperature of 300°C to 350°C. Sylhet sand with FM (fineness modulus) value of 2.5-2.7 and ¾" down size stone chips (Sylhet boulder) are used as fine aggregate and coarse aggregate, respectively. The water used is plain water collected from the supply line of Chittagong WASA.

2.2 Casting and Testing

This study considers 7 different percentages of RHA to be partially used with cement. These are 10%, 15%, 20%, 25%, 30%, 40% and 50%. Previous studies considered a RHA replacement of up to 35% in investigating various aspects of RHA blended concrete (Saraswathy & Song, 2006; Ganesan et al., 2007; Obilade, 2014). In this study it was targeted to see the effectiveness of RHA to be replaced in regular civil engineering works as well as temporary civil engineering works, hence, a large range of RHA replacement is considered. Considering the time constraint, concrete mix design was not carried out rather a commonly used mix ration of 1:1.5:3 is adopted. Because this study considered all the usual construction materials commonly used in Bangladesh for construction works e.g. Sylhet sand, OPC cement, Stone chips and RHA, it is technically good to go with the above mentioned mix ration. Having said that a water-cement ration of 0.45 is used and cubic specimens of 100×100×100 mm are prepared. For each combination, 3 samples are cast and tested. Concrete compressive strength for curing periods of 7 days, 14 days, 28 days, 60 days and 90 days are obtained using the UTM (capacity of 1000kN) owned by the Strength of Materials Laboratory of department of Civil Engineering, Southern University Bangladesh, Chittagong. Alongside the concrete cast and tested for several RHA combinations, separate controlled samples (with 0% RHA replacement) are also cast with the same mixing ratio and water content and tested to compare the results.

3. RESULTS AND DISCUSSION

Compressive strengths of concrete for all the blending combinations are reported in this section. Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5 depict the outcomes from this study for the curing periods of 7 days, 14 days, 28 days, 60 days and 90 days, correspondingly. From the results presented, it is evident that for any of the curing periods employed in this study, compressive strength of concrete in general decreased with the increase in percentages of RHA replacement. In a similar type of study, Obilade (2014) have reported the identical behaviour of concrete.

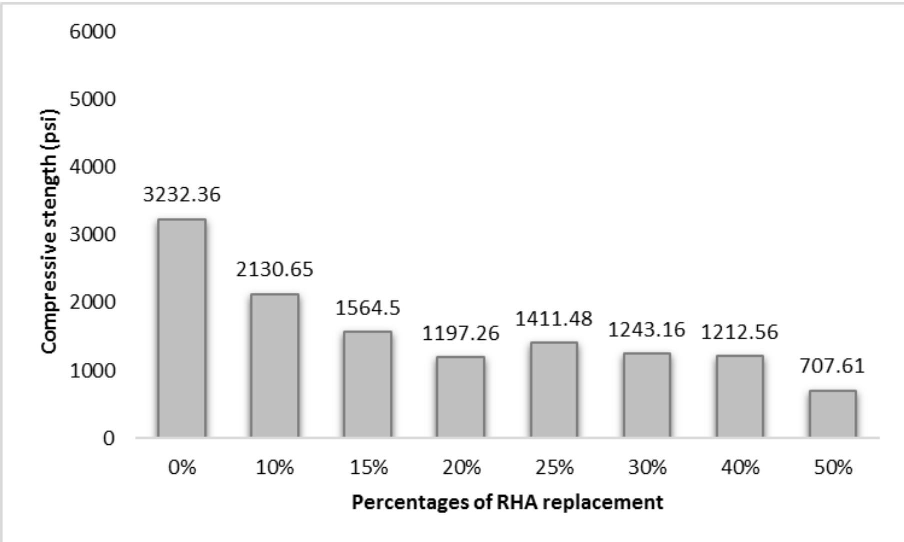

Figure 1: Compressive strength of RHA blended concrete for 7 days curing period

In reference to 28 days' compressive strengths (Figure 3), nearly 96% of controlled sample's (0% RHA) strength is gained for a RHA replacement of 5% and, 94% of controlled sample's (0% RHA) strength is gained for a RHA replacement of 10%. Even for a 15% of RHA replacement, around 88% of controlled sample's compressive strength is attained. Compressive strength is significantly reduced when the amount of RHA replacement is beyond 20%.

For a 10 % and 15% RHA replacement in cement, reasonable compressive strength is attained. Although, results of 10% RHA replacement is not uniform for all the curing periods but yielded satisfactory compressive strength for 28 and 90 days curing. Results of 15% RHA replacement showed somewhat uniform and adequate compressive strengths for all the curing periods considered for the problem in hand (Figure 1 to Figure 5).

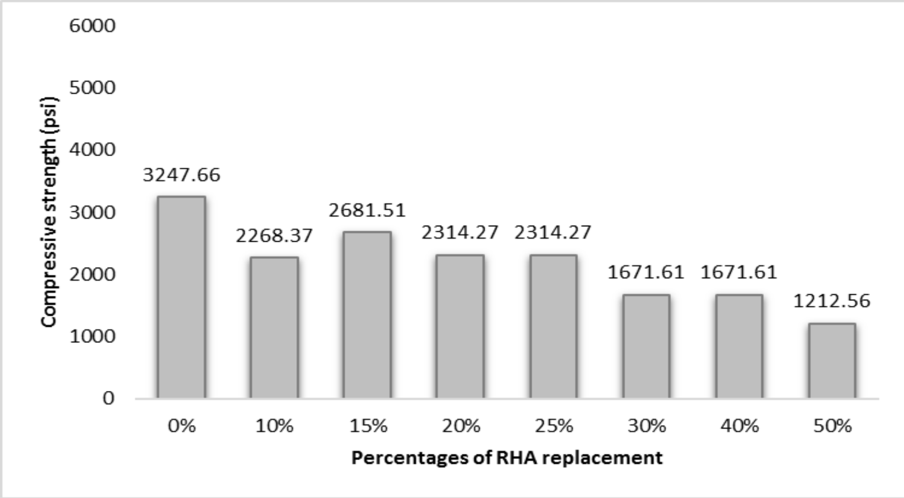

Figure 2: Compressive strength of RHA blended concrete for 14 days curing

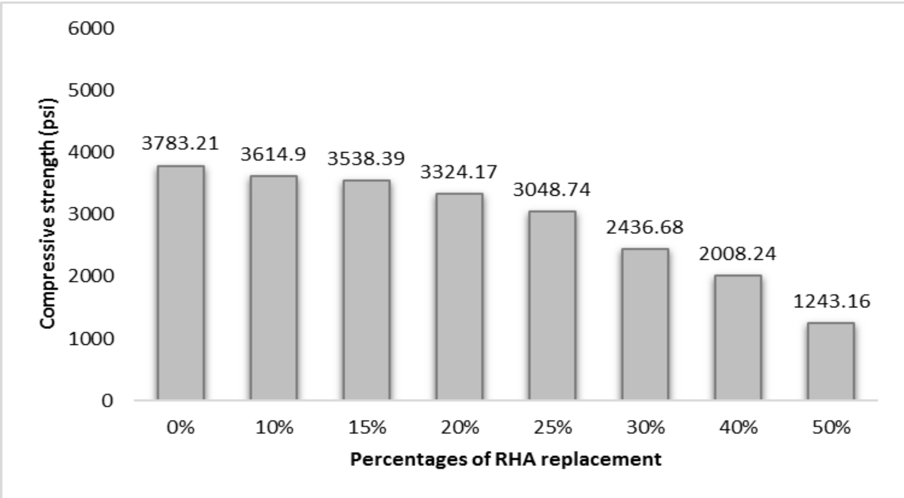

Figure 3: Compressive strength of RHA blended concrete for 28 days curing

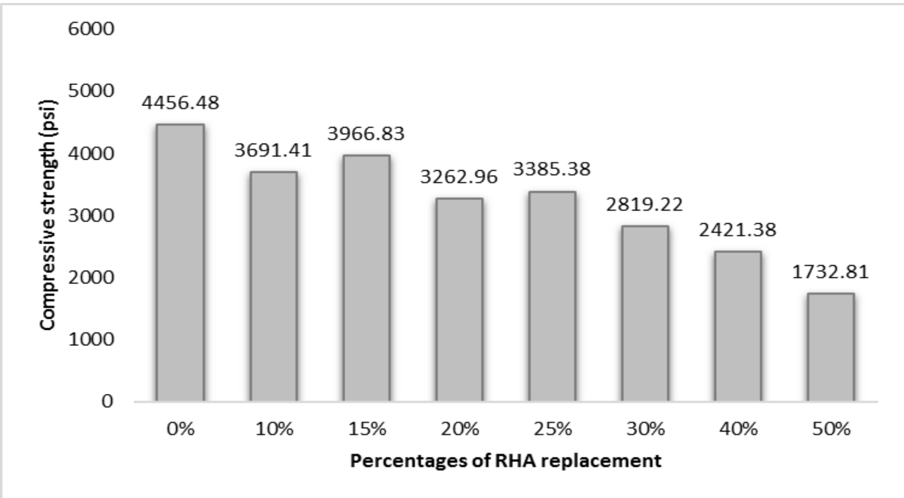

Figure 4: Compressive strength of RHA blended concrete for 60 days curing

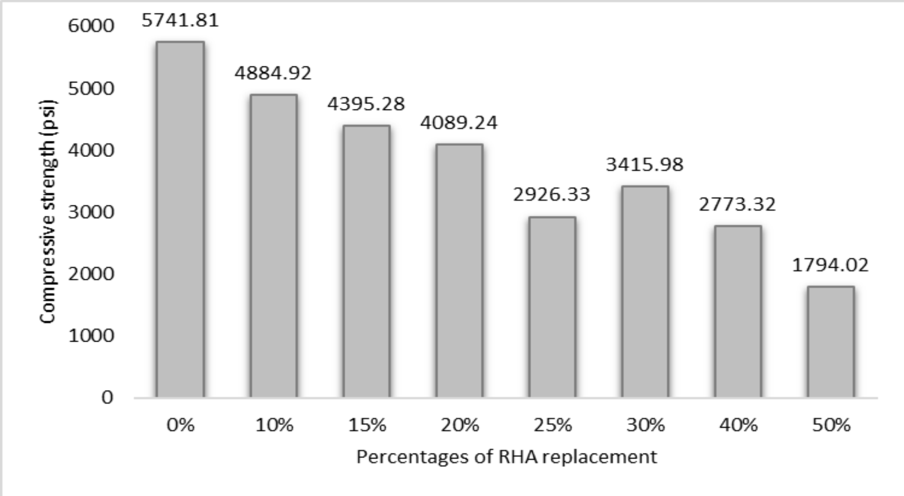

Figure 5: Compressive strength of RHA blended concrete for 90 days curing

A summary of the compressive strength of concrete studied, is illustrated in Figure 6. The general decreasing trend of compressive strength with the addition of RHA for a particular curing period is precisely understood. The typical strength gaining with curing periods 7 days, 14 days, 28 days, 60 days and 90 days is also obvious. Based upon the results of this study, it is clearly understood that for the regular civil engineering construction practice, partial replacement of RHA up to 15% can be undoubtedly considered, provided that RHA is properly burnt and suitably mixed in concrete. In a study carried out by Chik et al. (2011) somewhat similar conclusion is made.

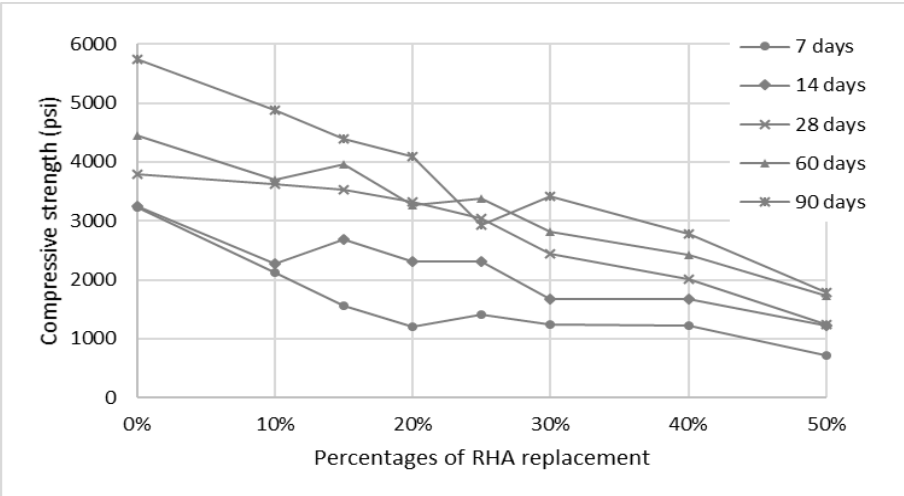

Figure 6: Compressive strength of concrete for varying percentages of RHA replacement to cement and different curing periods

Civil engineering construction types vary widely based upon the purposes of the construction and requires rich to lean concrete depending on the construction purpose. For example, a very good quality concrete is essential for normal residential building or bridges or other hydraulic structures where as a lean concrete can be used for less durable or temporary constructions. As can be seen from the results presented in Figure 6, for 50% RHA replacement, compressive strengths of concrete for 28 days and 60 days are 1243.16 psi and 1732.81 psi, respectively, which necessarily state that a great amount of RHA can be consumed in concrete for casting lean concrete. Such lean concrete can be used for less important civil engineering works which in turn will substantially reduce the problem associated with rice husk ash because typically it is a waste material that needed to be disappeared from the environment.

4. CONCLUSIONS

Current study considered replacement of locally available RHA in cement to be used in casting concrete. Seven different replacement ratios of RHA to cement are considered e.g., 10:90, 15:85, 20:80, 25:75, 30:70, 40:60, 50:50 and then, compared with the controlled concrete sample (with no addition of RHA in concrete). Curing periods of 7, 14, 28, 60 and 90 days are considered for all the blending combinations. The following conclusions are addressed based on the experimental results of this study:

- Compressive strength of concrete with 10% and 15% RHA replacement for a curing period of 60 days is similar to the result of control sample for 28 days' curing.
- Reasonable compressive strength of RHA blended concrete is attained. For few particular cases, compressive strength very near to the controlled concrete sample is available. For example, the 28 days' optimum concrete compressive strength for 10% RHA replacement is 3614.90 psi, which is 0.96 times the value for control sample. And, 60 days' optimum concrete compressive strength for 15% RHA replacement is 3966.83 psi, which is 0.89 times the value for control sample.
- In general, compressive strengths of concrete get reduced with the increase in replacement percentages of RHA.
- Overall, based upon the results it can be said that optimum RHA replacement of cement falls within a range of 0 to 15%, where, above 75% of controlled sample's compressive strength is available in RHA blended concrete, almost for all the curing periods, which can still be considered for good quality construction works
- A maximum of 50% RHA replacement yields a compressive strength of 1732.81 psi (60 days). Such a low strength is not recommendable for primary construction works but can be effective in temporary construction works.

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