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Influence of High Volume RHA on Properties of Cement Mortar

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Abstract. This work study the impact of partial cement replacement by high volume Rice Husk Ash (RHA) on some characteristics of cement mortar like compressive strength and flexural strength at different ages. In this research, RHA was used in three different ratios (20, 40, and 60)% as a cement substitution and the findings were compared with control mixture (0% RHA). The findings demonstrated that the replacement of cement by RHA reduced the compressive strength of all selected ratios and the increase in the content of RHA lead to reduce compressive strength comparative to control sample with 100% cement as a binder at all ages. However, the flexural strength results indicated that the RHA in 20% showed approximately same results as control sample at early ages while increasing the curing period lead to improve flexural strength. Increasing RHA higher than 20% lead to decrease Flexural strength at all selected ages.

Keywords: Compressive strength, Cement replacement; Flexural strength; RHA.

1. Introduction

Cement is a heavily used binder material in mortars to act as a bonding layer between construction parts. Conventionally, mortar mainly relies on cement, sand and water for their composition [1]. Cement being one of the essential traditional materials made by humans in construction that plays a part in the growing enormous demand on cement around the world [2]. The energy intensive production process of cement raised concerns due to their cost and environmental effect. Currently, the cement production is considered as the third energy demanding industry and that subsequently raise costs [3-8]. On the other side, cement production contributes annually in a range of between 7 - 10% of greenhouse gases emissions to the world, especially, Carbon dioxide (CO_2) [9-21]. Therefore, companies and governments have decided to look for other alternatives that would decrease the impact on the environment with a decrease of cost, while attaining similar chemical and physical characteristics of the conventional cement used in construction [22-26]. As a result of that, Mineral additives or Supplementary cementitious materials (SCMs) were encouraged to be used in order to create advanced construction technologies. Materials including fly ash, Ground Granulated Blast Furnace Slag (GGBS), dust of cement kiln, silica fume; bagasse ash, palm oil fuel ash, and RHA from the agriculture industry, which considered as wastes, are always taken under consideration and experiments to act as a cheaper and eco-friendlier supplement to the Portland cement in the making of mortar or concrete structures [27, 28].

An essential source of food on earth is rice. Approximately it covers around 1% of the earth. A residue from the milling process of rice is called Rice husk [29], this waste is extracted from outer crust of rice grain [30], and is calculated to be one fifth of the annual total of rice produced globally[29]. In order to produce the ash from the rice husk, a slow burning process is needed to the husk at a temperature of 500 to 700 ºC [31]. It was found that approximately 20% of rice husk can be turned into rice husk ash (RHA) [31]. The content of silica in RHA is the cause of experimenting the material as a SCM, the content could range from 80-95% of silica. This made it to be categorized as a pozzolanic material. Materials which act as siliceous and aluminous substances are considered to be pozzolanic. In the hydration stage of the Portland cement and the exposure of moisture, RHA will chemically react with the calcium hydroxide at an ordinary temperature [30, 32].

The quality of mortar is highly crucial for construction, as the cementitious mixture is used to bind and protect elements of construction or structure. Therefore, strength, durability and protection from acid attacks are the measure of quality for mortars [1]. RHA in mortar was found to improve the compressive strength and also chloride resistivity when compared with regular cementitious or controlled mixes of mortar [32]. Furthermore, many studies were conducted to replace ordinary Portland cement with rice husk ash and observe the influence on its various characteristics. It has been reported by [27] that the previous studies have found that the replacement was only partially and the optimal substitution of OPC with RHA in mortars to be in the range between 10-30%. Additionally, [29] experimented the addition of RHA and nano-silica hydrosols in mortar mixture by adding them separately and together. The samples were tested for their electrical resistivity, capillary absorption, chloride permeability and compressive strength. Results of the samples showed that adding RHA alone didn't attain to higher strength and durability during the early ages but even recorded lower levels of strength unlike adding nano-silica separately, which recorded an improvement to the performance of the mortar. Also, incorporating RHA and nano-silica have demonstrated steep reduce in the compressive strength of the early ages but managed to display the most compelling results for durability and strength at the later ages (28 and 90 days). Another investigation by [30], where authors replaced cement with RHA and investigated the influence of 5, 10, and 15% adding to both the density and compressive strength of mortar samples. The consequences demonstrated that the use of untreated RHA will decrease the density and subsequently will lessen the strength of the mortar as well to almost half of the strength when the 15% is added. This was attributed to the carbon residue and impurity found in RHA. Therefore the authors have advised to acid treat the RHA by adding a more environmentally friendly citric acid to the rice husk before the process of burning it, to partially remove the impurities that could hinder the strength of the mortar. As pointed previously, the studies that investigated RHA incorporation for the replacement of cement didn't exceed 30% of replacement, due to the nature of RHA properties which will require the cement to react chemically with it. Therefore, this research was conducted to explore the influence of using high volume RHA on mechanical performance of cement mortar.

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2. Experimental Part

2.1. Materials

2.1.1. Cement

Ordinary Portland cement (CEM-II/A/LL 32.5-N) Factory Warwickshire, UK has been utilized in this work. The physical characteristics and chemical analysing of cement have been demonstrated in Table 1. The BET specific surface area (SSA) of cement is 6.7 m^2/g.

2.1.2. Rice Husk Ash (RHA)

Rice Husk Ash (RHA) that utilized in this investigation has been delivered by Company of NK Enterprises, Jharsuguda, Orissa, India Group. The elemental composition of RHA has been analysing by an Energy Dispersive X-ray Florescence Spectrometer (EDXRF) brand Shimadzu EDX-720. Table 1 demonstrates the chemical analysing of the RHA. The BET SSA of RHA is 26.7 m2/g

Table 1. RHA and PC Chemical composition

Oxide composition (% by mass)	PC	RHA
$Si0_2$	20.99	88.32
Al_20_3	6.19	0.46
Fe_20_3	3.86	0.67
Ca0	65.96	0.67
Mg0	0.22	0.44
Na_20_3	0.17	0.12
K_20	0.60	2.91
L0I %	1.73	5.81
Specific Gravity	2.94	2.11

2.1.3. Sand

The natural sand was utilized as a fine aggregate. Figure 1, illustrate the grading of sand used throughout this work.

2.1.4. Water

Tap water has been utilized as mixing water for all mixtures.

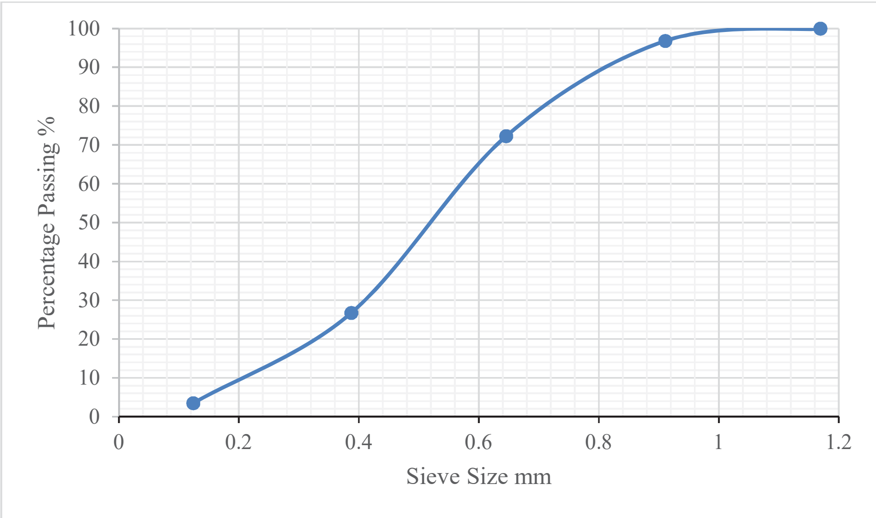

Figure 1. Grading of sand.

2.2. Designing the mixtures

The effect of replacing 0, 20, 40, and 60% of cement by RHA on compressive strength and flexural strength was studied and compared with control mix.

The mix proportion of samples tested for compressive strength flexural strength was 1 cement: 2.5 sand by weight. The compressive strength test has been performed on prisms of (40x40x160) mm size at (7, 14 and 28) days.

Table 2. The proportions of Mixing

Sample ID	OPC %	RHA %	Sand to binder Proportion	Water to binder Proportion
Con	100	0	2.5	0.4
R1	80	20	2.5	0.4
R2	60	40	2.5	0.5
R3	40	60	2.5	0.55

2.3. The Applied Testes

The flexural strength and compressive strength tests of all the mixture has been performed depending on BS EN 196-1 [33]. For each blending proportion at any curing time, two samples with dimensions of 40x40x160 mm have been tested for flexural strength using three points loading of the prism samples to split each sample into two sections and the four sections resulted from this test were utilized to measure the compressive strength. Equation 1 represent the formula followed to calculate the flexural strength.

$$fr = 3PL/2bd2 \qquad (1)$$

Whereas:
fr, (MPa) : Strength of flexural;
P, (N): Max. applied load specified by testing machine;
L, (mm): Sample's length Span;
b, (mm) : Sample's average width.
d, (mm) : Sample's average depth.

3. Results and Discussion

3.1. Compressive Strength Finding

The influence of replacement of cement by (0, 20, 40, and 60%) weight with RHA on compressive strength of mortars can be seen in Figure 2. Figure 2 clearly demonstrate that the compressive strength of all specimens increase with the increase of age of curing as a result of the progress of the hydration reaction. Additionally, it could be detected from Figure 2 that the compressive strength decreases with the increase in the amount of RHA, which may be due to low activity of RHA compared to reference cement mortar and also to the higher water content that cased an increasing in the porosity of the mixtures. The percentage of decrease in compressive strength at 7 curing days reaches 88% when replacing 60% of the cement by RHA, which is considered the worst condition comparison with control samples without any RHA. Figure 2 also shows that for all mixtures, most of the compressive strength were acquired at 7 curing days and after that the enhancement in strength with increasing the age of curing was very small.

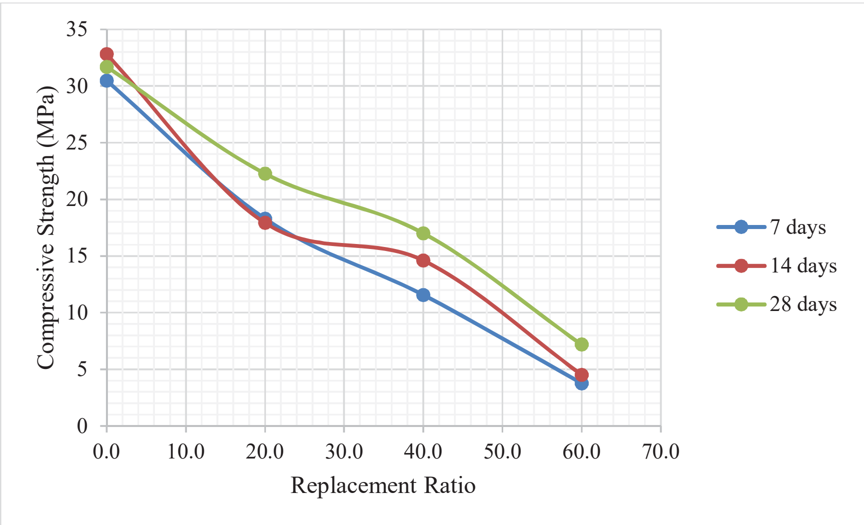

Figure 2. The Effect of Replacing OPC by RHA on compressive strength after 7, 14 and 28 curing days.

3.2. Flexural strength Results

The results of the flexural strength of all mixtures are presented in Figure 3. Figure 3 demonstrates that there is an improvement in the flexural strength of all samples with time due to cement hydration and develop the effect of Pozzolanic. The applying of RHA in the mortar has a varying behavior on the flexural strength, such as using 20% of RHA increased flexural strength at 14 and 28 curing days, but it has been reduced the flexural strength at 7 curing days by about 5% relative to control sample without replacement. Increasing RHA content to 40 and 60 lead to a reduce the flexural strength by 34% and 74%, respectively at 7 days associated to the control sample. At 28 curing age, the decreasing in flexural strength was about 13% and 61% for samples with 40% RHA and 60% RHA, respectively.

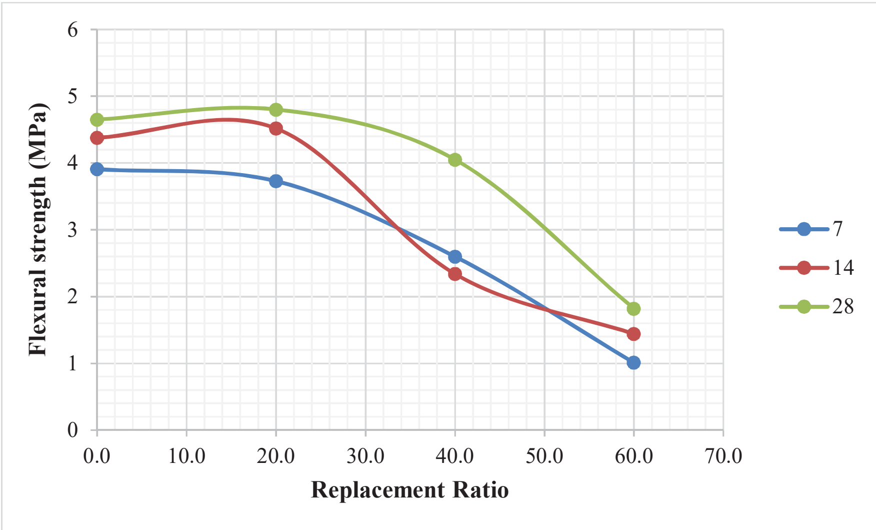

Figure 3. The Effect of Replacing OPC by RHA on Flexural strength after 7, 14 and 28 curing days.

4. Conclusion

Depending on the experimental work and results gained in this exploration, the following facts could be presented:

1. The usage of high volume rice husk ash in mortar mixtures could be used as a cement substitution materials as a result of existence of high amount of SiO_2 approximately 88%.
2. In compressive strength, the applying of RHA in any of the selected ration (20, 40 and 60) % by the weight of cement was lead to reduce the compressive strength comparative with controlling mix without replacement.
3. In flexural strength, the applying of RHA in any of the selected ration (40 and 60)% by the weight of cement was lead to reduce the flexural strength of samples (R2 and R3), while applying 20% RHA improved the flexural strength in comparison with control specimen at after 14 and 28 days of curing.

For future studies investigations, authors highly recommending the use of other waste and by/producted materials in combination with RHA to develop the features of the produced mortars. For example, industrial wastes [34-57] municipal solid wastes [58] and waste from water and wastewater planes [59-62].

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