

Use of Rice Husk Ash as Partial Replacement of Cement in Sandcrete Blocks

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ABSTRACT

This paper presents the outcome of a research study aimed at the performance evaluation of rice husk ash as partial replacement of cement in sandcrete blocks used as masonry units. Rice husk from the rice cultivated in the North of Pakistan was used in the study. It was first combusted in a locally manufactured incinerator to convert it into rice husk ash (RHA) and then finely ground to powder form for use with cement. Blocks with the size of 305×203×152 mm were molded with 0, 10, 30, 40 and 50% replacement of cement with RHA to find compressive strength at 3, 7, 14 and 28 days age of curing. The results showed that water requirement for the required workability of the sandcrete increased along with the RHA content, whereas the compressive strength decreased with increase in RHA content. However, the comparison of compressive strengths of RHA sandcrete blocks with the strength of commercial concrete blocks available in the market and used as masonry units in Pakistan showed that sandcrete blocks having the sand to binder ratio of 1:8 and using up to 40% of RHA as replacement of cement gave larger compressive strength than that of commercial concrete blocks and only marginally lower strength for 50% replacement.

Keywords: Rice husk ash, sandcrete blocks, compressive strength, masonry units, pozzolanic.

INTRODUCTION

The rising concern for environmental protection, energy source conservation and economy in the current times has created a pressing demand for the search of cement alternatives because of its very high carbon footprint, source depletion and high cost. Rice husk ash (RHA) is one of the materials that has been studied for their potential use as partial replacement of cement and have been placed by ASTM in the category of materials called pozzolans [1]. RHA is obtained by burning rice husk; the external hard covering of paddy rice grain received as waste material during rice milling process. The proportion of rice husk in paddy rice is 22% by weight that on burning loses 75% of the weight and the balance 22% is left as rice husk ash that was believed to have pozzolanic properties [2]. The global paddy rice production in year 2019 was 782 million tons [3] which implies

172 million tons of rice husk and 43 million tons RHA. These figures show that the use of RHA as partial replacement of cement can significantly contribute to environmental protection and fight against the climate change by reducing the cement demand and alleviation of the environmental hazards associated with dumping of waste RHA. Therefore, a good amount of research has been devoted to the use of RHA as cement replacement in concrete during the past decades.

Rahman [4] concluded that the water demand of mix increased along with RHA content and 40% of cement content can be replaced with RHA without significant change in 60 days compressive strength of sandcrete blocks. Okpala [5] found that the addition of RHA in cement paste increased both initial and final setting times, whereas the mix of 1:6 ratio with up to 40% cement replacement with RHA and the mix of 1:8 ratio with up to 30% replacement with

RHA had adequate compressive strength for urban and rural dwellings in Nigeria. Cissea [6] used ground as well as unground RHA as partial replacement of cement in sandcrete blocks. The study revealed that the strength of the sandcrete with ground RHA was almost twice as high with unground RHA at all ages of curing; and the sandcrete utilizing both ground and unground sandcrete gave better strength as compared to sandcrete made with filled limestone or chert for same cement contents. Oeytola [7] studied the use of rice husk ash for the preparation of low cast sandcrete blocks in Nigeria. The strength of 150×450 mm hollow concrete blocks was determined at 1, 3, 7, 14, 21 and 28 days for 10, 20, 30, 40 and 50 percentage replacement of cement with RHA. The study concluded that the compressive strength increased with the age at curing and decreased with the percentage of RHA. The study recommended 20% as an optimum level of RHA usage as cement replacement. Agbede [8] studied the effect of partial substitution of Ordinary Portland Cement (OPC) with RHA on the compressive strength of hollow sandcrete block. The hollow blocks with the dimensions of 150×22×450 mm were crushed at 7, 14 and 28 days of curing for 0, 10, 20, 30, 40, 50 and 60 percent replacement levels. The study recommended 17.5 per cent of cement replacement with RHA for sandcrete blocks used as building units. Aho [9] tested the hollow sandcrete blocks produced with 0, 10, 20, 30, 40 and 50% of RHA replacement for cement at 1, 3, 7, 21 and 28 days of curing and recommended 30% RHA for cement replacement for the production of hollow sandcrete blocks for use in Nigeria.

Olutoge [10] studied the effect of rice husk ash as a component of hollow sandcrete blocks. Two sizes 226×225×450 mm and 150×225×450 mm were tested for various proportions of rice husks ash i.e. 0%, 4%, 10%, 20%, and 30%. The compressive strength of the samples were determined after 28 days. The study concluded that 10% ash replacement gave the strength required by the standard for building construction and it reduced the cost by 5.3%. Oyekan and Kamiyo [11] investigated the physical and mechanical properties of concrete for 5 and 10% of RHA replacement. The study showed that water absorption increased along with the RHA content and the compressive strength of concrete decreased with the addition of RHA. It also showed that the difference of strength for 10% and 5%

replacement with respect to the control mix was larger at 14 days than 28 days that proved that the gain of strength at old age decreased with increase in RHA content. The RHA content showed no relation to the splitting tensile strength and modulus of elasticity. Ettu [12] investigated the compressive strength of ternary blended cement sandcrete containing Afikpo RHA and sawdust ash (SDA) for 5%, 10%, 15%, 20%, and 25% of cement replacement. The study suggested that very high sandcrete strength values could be obtained with OPC RHA-SDA ternary blended cement with richer mixes, high quality control, and longer days of hydration. Sangeetha [13] worked on replacement of OPC with 10%, 20%, 30% & 40% RHA in sandcrete blocks in India and investigated the compressive strength, setting time, consistency, workability and specific gravity of the blocks as well as performed a cost analysis. The study recommended 15-20% as optimum level of cement replacement with RHA in sandcrete blocks. Mayooraan [14] studied the performance of high and low carbon content rice husk ash waste generated from open air burning of rice husk as partial replacement of cement in 215×105×65 mm sized blocks cast with the mix proportion of 1:5 cement and sand. The blocks prepared with 5%, 10%, 15% and 20% replacement levels were analyzed on the parameters of workability (water/binder ratio and setting time), strength (compressive, flexural bending and splitting tensile) and durability (water absorption, sorption, acid attack resistance and alkaline attack resistance). The study concluded that both types of RHA gave satisfactory results as per the standard for the maximum level of replacement used i.e., 20%.

This paper presents the outcome of a study on the use of RHA produced in Pakistan as partial replacement of cement in sandcrete masonry blocks. Sandcrete is a building material made of Portland cement and sand in the ratio of 1:8. It is similar but weaker than mortar which normally has a ratio of 1:5. Since only moderate compressive strength is required for the sandcrete blocks used as masonry units; therefore, the block manufactured with higher proportion of RHA in place of cement are expected to possess sufficient compressive strength for practical use as masonry units and will open the way for commercial use of RHA as cement replacement in Pakistan and worldwide. This study is aimed at exploring this potential.

MATERIALS AND METHODS

The research was organized on following lines to investigate the performance of RHA as partial replacement of cement in sandcrete blocks for use as masonry units:

- Rice Husk from the Swat variety of rice cultivated in Swat, Pakistan was used for the study.
- The husk was incinerated in a locally manufactured incinerator under controlled temperature and the ash was then allowed to cool at slow rate.
- The RHA was ground to the required fineness as per ASTM C618 requirement for use of pozzolanic material with cement and pozzolanic activity index was determined as per ASTM C311/C311M Standard.
- Sandcrete blocks with cement-sand ratio of 1:8 were cast and tested to find their compressive strength at 3, 7, 14 and 28 days age of curing for 0, 10, 20, 30, 40 and 50% of cement replaced with RHA and the strengths were compared with that of commercial concrete blocks to analyze the performance of RHA as cement replacement and find optimum level of replacement.

Incineration of Rise Husk

The process of rice husk ash incineration is very important for its microstructure and later performance as pozzolanic or cementing agent. The reactivity of rice husk ash is greatly influenced by the temperature and duration of burning; and the cooling regime [15]. The incineration of rice husk for the study was carried out under controlled temperature conditions in the laboratory



Fig. 1. Whitish grey rice husk ash produced by incineration

Table 1. Chemical composition of RHA by slow cooling

S. No.	Component	Percentage
1	SiO ₂	73
2	Fe ₂ O ₃	3.1
3	CaO	1.20
4	Al ₂ O ₃	22.80
5	NaO	0.16
6	MgO	0.54
7	K ₂ O	0.16

with subsequent slow cooling during 10 hours after achieving the maximum temperature of 800 °C. The white grey RHA achieved from the incineration process is shown in Figure 1.

Chemical Composition of RHA

The chemical composition of RHA after going through the slow cooling is given in Table 1. X-ray fluorescence analysis was used for determination of chemical composition. The silica content in the RHA was 73% that was in agreement with the previous published research and indicated high possible reactivity of RHA as pozzolanic/cementing agent [16, 17].

Grinding of RHA

The RHA was ground to obtain the required fineness specified by ASTM 618-05 [18] for the use of pozzolanic materials with cement. The ground RHA gave only 15% retention on ASTM Sieve No. 325 when wet sieved against the minimum requirement of 34% retention.

Conformity of RHA used in the Study to ASTM Standards

Before ASTM C 618-05 [18] specifies minimum requirements for use of natural pozzolana as cementing agent in concrete, the standard specifies the minimum chemical composition requirement as well as physical properties for determining the conformability of a material for use as pozzolanic material in concrete.

The RHA used in the study satisfied the chemical composition criterion as the sum of silica (SiO₂), alumina (Al₂O₃), and iron oxide (Fe₂O₃) content was 98.90%, significantly larger than the specified minimum of 70% as per ASTM C 618-05.

Table 2. Physical requirements for pozzolanic material as per ASTM C 618-05

S. No.	Property	ASTM limit	Test value	Test (passed/failed)
1	Fineness: Amount retained when wet-sieved on 45 µm (No. 325) sieve (max %)	34	15	passed
2	Strength activity index: • with Portland cement at 7 days, min % of control • with Portland cement at 28 days, min % of control	75	93.67	passed
		75	80.09	passed
3	Water requirement, max % of control	115	113	passed
4	Soundness: • autoclave expansion or contraction, max %	0.8	0.5	passed

The physical conformability of RHA used in the study was also checked by performing the tests specified in the standard and comparing the results with the ASTM specifications. The physical conformability of the RHA as per ASTM C 618-05 is summarized in Table 2.

The description of materials used in the preparation of sandcrete blocks for the study is given hereunder:

Cemenet

Ordinary Portland cement conforming to ASTM C150-07 [19] standards from Cherat Cement Factory Nowshera, Pakistan was used in the preparation of blocks and cubes. The chemical composition of the cement is given in Table 3.

Fine Aggregate

Locally available fine aggregate (sand) having fineness modulus 2.7 was used in the preparation of blocks and cubes. The sand was free of silt and organic material and was washed before use.

Water

Clean drinking water free of any physical impurity and chemical compounds, having near to room temperature was used for mix preparation.

Table 3. Chemical composition of cement

S. No.	Constituent	Percentage
1	SiO ₂	19.8
2	CaO	62.45
3	Al ₂ O ₃	6.9
4	Fe ₂ O ₃	3.85
5	SO ₃	2.95
6	MgO	2.35

For control mix, the water binder ratio of 0.45 was used. The water binder ratio used for different RHA replacements are shown in the Table 4.

Superplasticizers

Superplasticizers were used in the range of 2-4% to gain adequate workability of the mix and water-binder (cement + RHA) ratio. Superplasticizer was also used for higher degrees of RHA replacement i.e., for 30% and above to obtain a workable paste. The percentage of superplasticizer used for each level of RHA replacement is shown in the Table 4.

Casting of Sandcrete Blocks

The sandcrete blocks with the size of 305mm×203mm×152mm were prepared as per standard ASTM C90 procedure [20]. The fine

Table 4. Water/binder ratio and quantity of superplasticizer

RHA replacement level (% of binder by weight)	Water/binder ratio	Quantity of superplasticizer (% of binder weight)
0	0.45	0
10	0.485	0
20	0.5	0
30	0.55	2
40	0.55	3
50	0.55	3

Table 5. Compressive strength of sandcrete blocks

Age of curing (days)	Compressive strength (MPa)					
	Control mix	10% RHA	20% RHA	30% RHA	40% RHA	50% RHA
3	2.73	2.75	2.17	2.10	1.58	0.81
7	4.49	3.38	2.84	2.10	1.96	1.74
14	5.76	5.64	4.53	3.00	2.91	1.96
28	7.02	5.69	4.73	4.47	3.85	3.32

aggregate (sand) having a fineness modulus of 2.7 was first washed with water to make it saturated and to make the silt and other impurities rise to the surface. The water along with silt and impurities was removed by tilting the pot, and the upper surface of the sand containing a thin layer of silt was scratched with spatula to make it free of all impurities. Sand was then spread in a large tray to bring it to the surface dry condition. Sand took 24 hours to become saturated and surface dry. Saturated and surface dry sand was then used for making sandcrete blocks. Each block was tamped in three layers; tamping each layer at least 25 times. The blocks were demolded after 24 hours and kept in water thereafter till the time of testing. The molding and storage of blocks was carried out at room temperature nearing 25 °C.

Compressive Testing of Sandcrete Blocks

The compression testing of the blocks was carried out in Material Testing Laboratory, University of Engineering & Technology Peshawar, Pakistan. A 2000 kN digital Universal Testing

Machine (UTM) was used for finding the compressive strength of blocks. The specimen were tested under slow rate of loading.

RESULTS AND DISCUSSIONS

The results of the compression testing of sandcrete blocks are summarized in Table 5, whereas the graph in Figure 2 shows gain of strength of blocks with age of curing for different replacement levels of cement with RHA. It is evident from Figure 2 that the compressive strength of sandcrete blocks decreases with the increase of the RHA content. The figure further shows that the gain of compressive strength with age of curing is almost linear for all replacement levels and gives same shape of graph as the control mix but of lower peaks. The difference of strength between the control and RHA sandcrete grows up with age of curing for all replacement levels suggestive of the higher pozzolanic activity of RHA during the early days of curing.

The variation of 28 days compressive strength of sandcrete blocks with the RHA

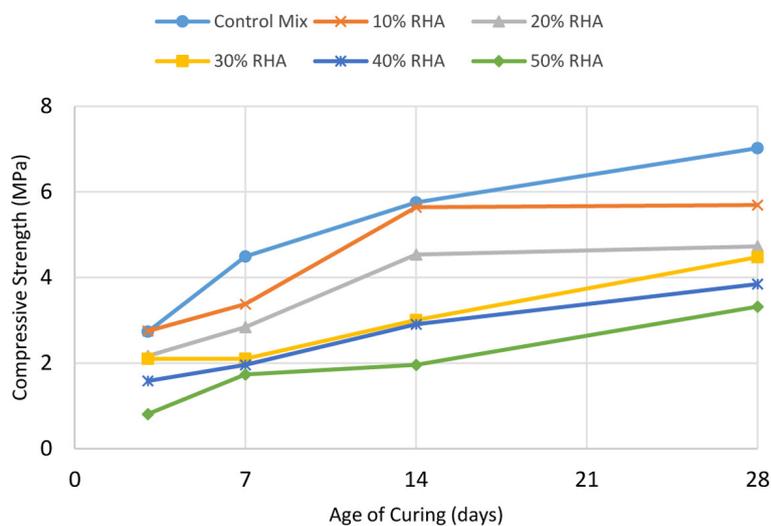


Fig. 2. Variation of compressive strength of blocks with age of curing

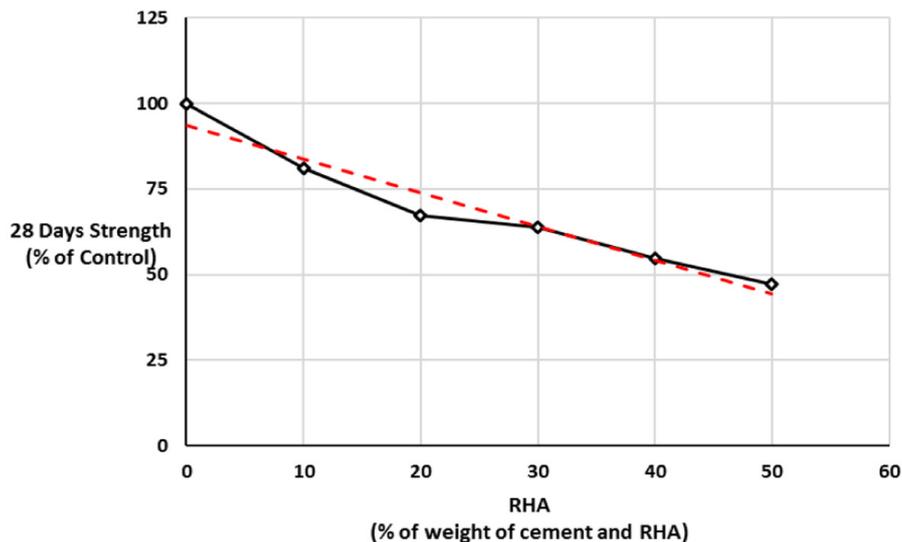


Fig. 3. Percentage decrease in compressive strength with addition of RHA

content of the mix as shown in Figure 3 exhibits an almost linear decrease in strength with the increase of RHA content. The 50% replacement of cement with RHA reduces the 28 days compressive strength to half the 28 days strength of control mix.

The comparison of 28 days strength of sandcrete blocks with that of the commercially available concrete masonry blocks in the market is shown in Figure 4. The graph shows that the strength of the sandcrete blocks having 50% of RHA was slightly lower than that of the commercial concrete blocks, whereas all the other replacement levels gave the strength greater than that of the commercial concrete masonry blocks.

CONCLUSIONS

The RHA given by the incineration (under controlled conditions) of the husk obtained from the Swat variety of rice grown in the North of Pakistan met all the requirements of chemical composition as specified by ASTM C 618-05. The RHA obtained met all physical requirements of a material to be used as pozzolana as specified by ASTM C 618-05 including pozzolanic activity index which is the direct measure of the activity of RHA as cementing agent. The water requirements of the paste for a given slump increased along with the increase of the RHA content used as cement replacement. Addition of superplasticizer was needed for making the paste workable

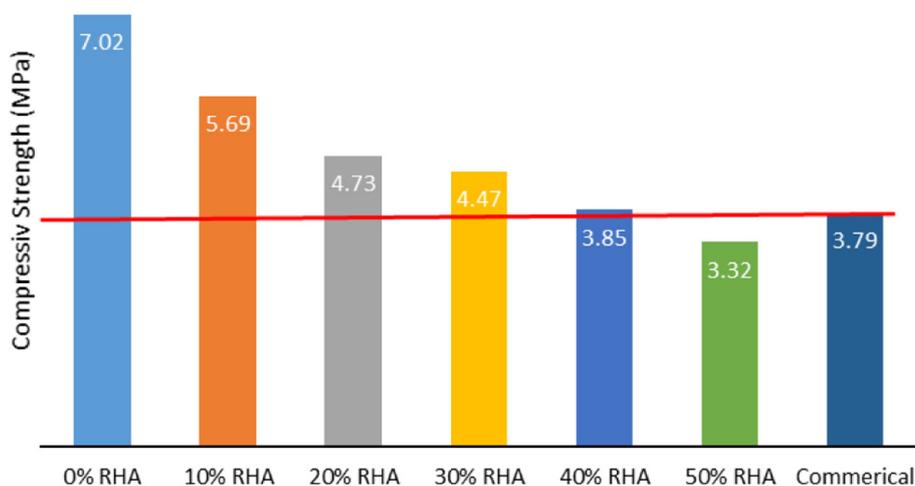


Fig. 4. Comparison of 28 days compressive strength

for 30% and above level of the RHA content. The superplasticizer was used in 2 to 4% by weight of mix water. The compressive strength of RHA sandcrete at all ages of curing decreased with increase of the RHA proportion in the mix.

The comparison of compressive strengths of RHA sandcrete blocks with the strength of commercial concrete blocks available on the market and used as masonry units in Pakistan showed that sandcrete blocks having the sand to binder ratio of 1:8 and using up to 40% of RHA as replacement of cement gave larger compressive strength than that of commercial concrete blocks and only marginally lower strength for 50% replacement.

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