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Effect of mechanical properties of concrete containing rice husk ash

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Abstract

This paper presents a study on the utilization of rice husk ash (RHA) to enhance concrete properties, in which RHA from byproduct of brick-kilns in Sri Lanka. The rice husk ash (RHA) is a pozzolanic material that can be blended with the portland cement in concrete to obtain a high-performance of normal concrete. This paper proclaims an experimental investigation on utilization of RHA for the concrete as it is a byproduct of brick-kilns in Sri Lanka. The results of three different replacement percentages of RHA in concrete (10%, 20% and 30% by mass of cement) were compared with the concrete contain without RHA. Those samples were compared for compressive strength, tensile strength, surface water absorption and the durability aspects. A comparative study on chemical composition and physical properties was implemented and the experimental results were discussed. A significant improvement on the compressive strength at early stage is identified and optimum strength was obtained at the 20% RHA replacement by mass of cement. The strength of the concrete with different sizes of RHA particles was compared to identify the effects of particle size of RHA. Around 50% of the RHA from the brick-kiln can be utilized for the concrete by a proper grinding. Possibility of adding fly ash mixing with RHA was investigated to overcome the reduction of workability of concrete with the addition of RHA.

Keywords: rice husk ash, compressive strength, brick-kiln, surface water absorption, fly ash

Introduction

In the present situation, concrete is one of the most widely used construction material in the world. The most common form of concrete is Ordinary Portland Cement (OPC) concrete, which consists of coarse aggregate, fine aggregate, cement and water.

In most of the countries, different cementitious materials such as Fly-Ash, Ground Granulated Blast-furnace Slag (GGBS), Silica Fume and Rice Husk Ash (RHA) to achieve high performance, good quality and low cost concrete mixtures. In here, rice husk is a byproduct of de-husking operation of paddy rice that is produced in about 115 million tons in all over the world annually. The total amount of rice produced in Sri Lanka in year 2002 is 2.79 million metric tons (Reddy and Alvarez, 2006). The total amount of rice needed in Sri Lanka over the year 2010 and 2020 are estimated at 3.46 and 3.83 million metric tons respectively (Thiruchelvam, 2005). Approximately 20 kg of rice husk are obtained for 100 kg of rice. Rice husks contain organic substances and 20% of inorganic material (Tashima *et al.*, 2004). Therefore considerable amount of rice husk is wasted annually and it may increase with the time.

Rice husk ash (RHA) can be used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in high-performance concrete (Saraswathy and Song, 2006). The utilization of rice husk ash as a pozzolanic material in cement and concrete provides several advantages, such as improved compressive strength and durability properties, reduced materials cost due to cement savings and environmental benefits related to the disposal of waste materials and reduced carbon dioxide emissions (Saraswathy and Song, 2006).

From 1980 to 1996, the world's annual consumption of Portland cements increased around 2 million tons to 1.3 billion tons. This was associated with major environmental problems since the cement manufacturing is the third largest CO_2 producer and for over 50% of all industrial CO_2 emissions (for every 1.0 ton of cement produced, 1.0 to 1.25 tons of CO_2 is released in the air) and 1.6 tons of natural resources is consumed to produce 1.0 ton of cement (Mihelcic *et al.*, 2005).

The reaction of the rice husk ash with the cement is dependent on several factors. Burning duration, burning temperature and the particle size of the ashes are the most significant. The optimum temperatures are around 600 ^{0}C for 2-3 hrs burning and 400 ^{0}C for 4 hrs burning. There is an optimum temperature for each burning time and burning at higher temperatures beyond a certain limit does not necessarily help to produce quality ash (Yamamoto and Lakho, 1982).

The grinding process would affect the water absorption capacity of concrete. Longer the grinding time, it may lower the water absorption rate (Tashima *et al.*, 2004). With the proper grinding process, the RHA can be converted to the ultrafine particles. Therefore, of ultrafine RHA in to concrete to reduce permeability, water absorption of concrete and many beneficial effects on concrete performance (Saraswathy and Song, 2006).

This paper proclaims an experimental investigation on possibility of utilization of RHA from the byproduct of brick-kilns in Sri Lanka. In the present investigation, rice husk has been blended with Ordinary Portland Cement (OPC) at various percentages and experiments were carried out to investigate the mechanical properties. The results were compared with conventional OPC concrete.

Materials and Methods

Rice husk ash

RHA for the experiment was obtained from the brick-kiln that used rise husk as a fuel. The burning temperature was within the range of 600^{0}C to 850^{0}C. The fully burnt ashes and the partially burnt ashes are separated by 10 minutes sieving. The ash passing 300 μm sieve size are considered as fully burnt ashes and it may be around 60% of the ashes collected from the brick-kiln. The particle size of the RHA is limited to 75 μm and fineness of the RHA was increased by the grinding process. The particle size distribution of 75 μm passing RHA is as shown in Figure 1. The average particle size is 18 μm and specific gravity is 2.16. Since more than 40% of RHA is finer than cement, it can be expected to have micro-filler effect as well as the pozzolanic reaction (Habeeb and Fayyadh, 2009).

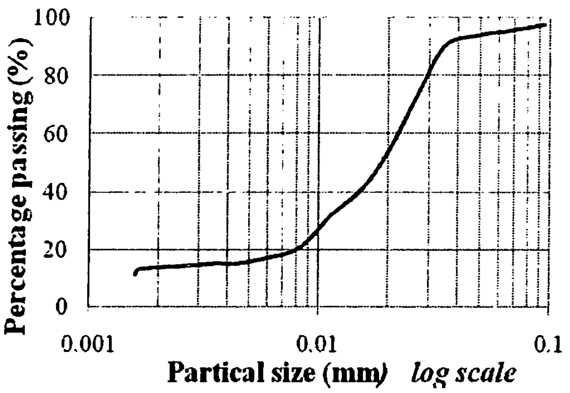

Figure 1: Particle size distribution for RHA obtained from 75μm passing

Fine and coarse aggregates

The fine aggregates that used for the experiment were natural river sand passing from 4.75 mm sieve. The specific gravity of the sand was tested according to BS 812: Part 2: 1995. The specific gravity of fine aggregate was tested as 2.65.

The coarse aggregate that used for the experiment were crushed granite with maximum size of 20 mm. The specific gravity of the coarse aggregate was tested according to BS 812: Part 2: 1995. The specific gravity was tested as 2.65 for coarse aggregates.

Compressive strength of concrete

The Compressive strength of the concrete was measured by preparing cubes of 150x150x150 mm mould size. Concrete with 0.75 W/C ratios was used for the experiments to maintain high water content in fresh concrete (RHA may absorb higher amount of water in fresh concrete). Mechanical vibrator was used to compact the concrete during casting. The moulds were removed after 24 hours and placed in the curing tank until the testing dates. The specimens were tested after 3, 7, 14, 28, 56, and 91 days with the loading rate of 0.3 $N/mm^2/s$. The average value of compressive strength was obtained by testing of three specimens.

Split tensile test

Split tensile test for the concrete was carried out according to the BS 1881:Part117:1983. Concrete cylinders of 150 mm diameter and 300 mm height were cast by using concrete with W/C ratio of 0.75. Mechanical vibrator was used to compact the concrete during casting. The moulds were removed after 24 hours and placed in curing tanks until the testing dates. The specimens were tested after 91 days with the loading rate of 0.03 N/mm^2s. The average value of tensile strength was obtained by testing of three specimens.

Surface water absorption test

The surface water absorption test was carried out with a concrete cube of 150x150x150 mm size. The W/C ratio of 0.75 was used for concrete mixture. The test was conducted after 28 days and the variation of the results were discussed as percentage deviation with reference to the control sample. All cubes were subjected to oven dry under 100 ^{0}C before testing. The surface water absorption of concrete was tested at 10, 30 and 60 min after the water head was released to the concrete surface.

Workability of concrete

In this experiment, it was expected that there would be a significant reduction in workability of fresh concrete with the increases of RHA content in concrete. Therefore some admixture has to be used to maintain the workability of concrete contain RHA.

The fly-ash is pozzolanic material that wasted product from the coal power plant and it has some properties to increase the workability of concrete. Therefore it was decided to compare the performance between fly-ash and RHA to find out a solution to workability reduction in concrete contain RHA. The replacement percentages of each material were as follows:

Results and Discussion

Compressive strength of concrete

The compressive strength of concrete cubes containing different amount of RHA (75μm passing) was tested according to BS 1881: Part 116:1983. The variation of compressive strength of concrete with days is shown in Figure 2.

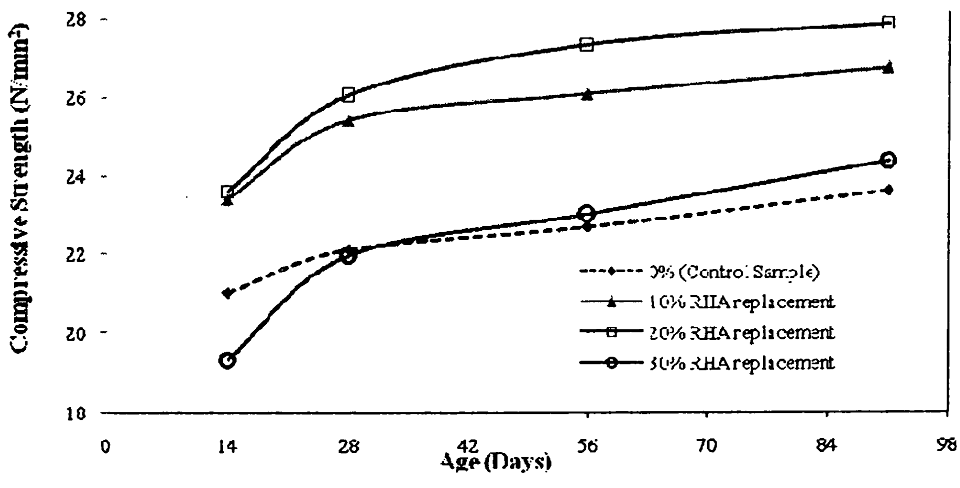

Figure 2: Variation of compressive strength of concrete with varying percentages of RHA

The maximum strength is achieved with 20% replacement of RHA for the cement in concrete. The maximum increment is around 17.9% than the control sample. Therefore 20% of RHA can be identified as the optimum percentage to replace the cement in concrete.

The effect of the particle size also tested during this experiment. The sieve sizes of 75 μm and 150 μm passing RHA mixed concrete specimens were compared with the control sample. The variation of compressive strength of concrete containing two different sizes of particles of RHA is shown in Figure 3.

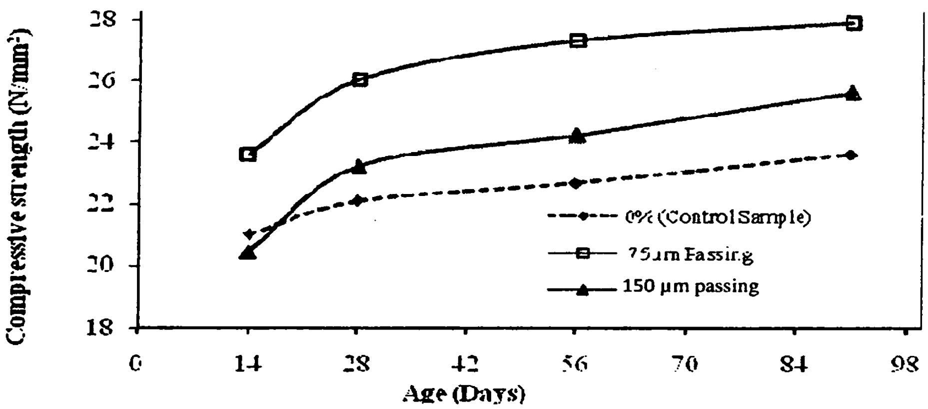

Figure 3: Variation of compressive strength of concrete with different sizes of particles of RHA

Splitting tensile strength

The tensile strength of the concrete was tested according to the BS 1881: Part 117: 1983 by using the concrete cylinder. The experimented results are as follows (Table 1):

Table 1: Results of splitting tensile strength

Sample No.	Replacement (%)	Splitting tensile strength (N/mm^2)
1	0	1.86
2	10	2.60
3	20	3.01
4	30	2.56

Figure 4 shows that significant increment in the tensile strength in concrete containing RHA. The maximum tensile strength is resulted with 20% replacement. Therefore tendency of cracking of concrete containing RHA can be considered as low compared to the normal concrete.

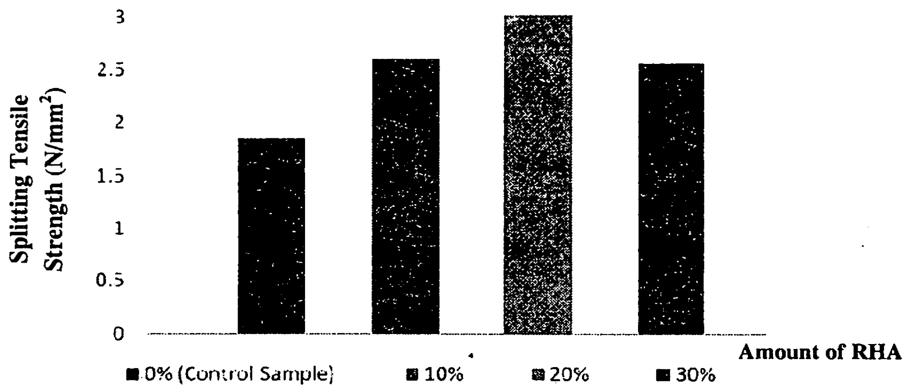

Figure 4: Variation of splitting tensile strength

Surface water absorption test

The result of surface water absorption test is shown in Table 2. Around 15% reduction in water absorption was observed with the 20% replacement of fly ash. Around 11% reduction in water absorption with 20% replacement of RHA and around 10% reduction with combination of same amount of RHA and Fly Ash were observed.

Table 2: Surface water absorption test results

Time (min)	Control Sample	Percentage water absorption compared to control sample		
		Fly-Ash10 and RHA10	RHA 20	Fly-Ash 20
10	100	88.24	91.18	86.76
30	100	91.11	88.89	86.67
60	100	88.57	85.71	82.86
Average	**100**	**89.31**	**88.59**	**85.43**

The concrete containing RHA has shown a considerable reduction in surface water absorption in concrete. Further addition of fly ash has given better result than the 20% RHA replacements. It may be due to higher fineness of fly ash than the RHA particles. However, according to the degree of replacement of RHA, the rate of water absorption can be different (Figure 5). Therefore, number of experiments consisting different percentage of RHA is required to find out the optimum level of RHA to minimize the surface water absorption of concrete.

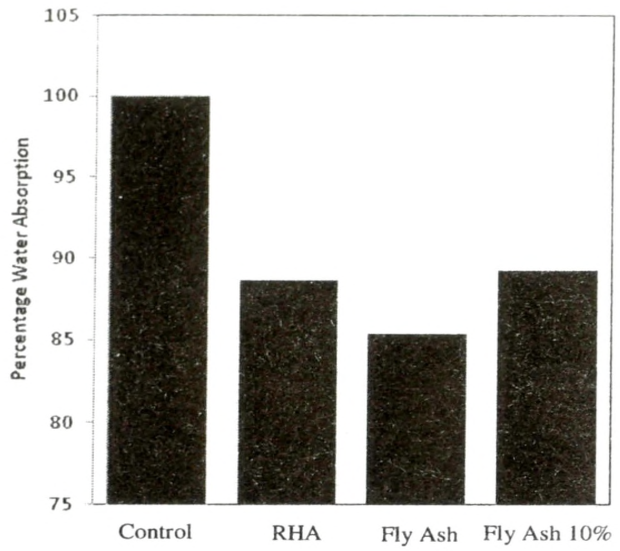

Figure 5: Surface water absorption test results

Workability of concrete

The concrete contain Fly Ash was verified a 27% workability improvement compared to the control sample. It was tested by 20% replacement of cement by the fly ash (Figure 6). Therefore it was decided to find the possibility of adding RHA to improve the workability of concrete contain RHA.

The concrete contains 10% Fly Ash and the 10% RHA instead of the pure cement in concrete was resulted an almost same workability as control sample. It was verified an increment in compressive strength of the concrete contain RHA without reduction in workability.

Therefore further studies are required to find out an optimum mixing percentage of RHA and Fly Ash, to maximize the degree of replacement and improve compressive strength without any reduction in workability.

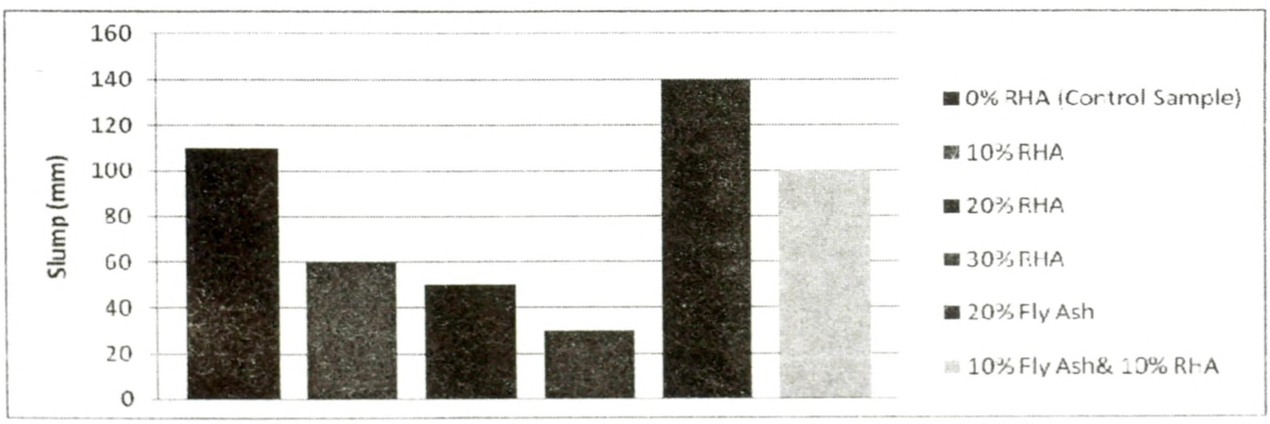

Figure 6: Variation of workability of concrete

Conclusion

- It is possible to use the RHA that is produced as waste material from the clay brick production process in Sri Lanka to improve the properties of concrete.
- 20% replacement of RHA by mass of cement shows about 18% increment of compressive strength of concrete.
- There is a considerable increment in splitting tensile strength with 20% replacement of cement by RHA.
- There is a significant reduction of workability in fresh concrete with the increase amount of RHA content in concrete. The Fly Ash can be used with the RHA to increase the workability of concrete.
- The performance of the concrete would depend on the fineness of the RHA. The finesses of RHA would increase the compressive strength of concrete.
- The addition of RHA for the concrete decreases the water absorption of concrete. There was around 11% reduction in surface water absorption with 20% of RHA replacement compared to control specimen.

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