SECM/15/175

Behaviour of Concrete Produced with Cement and Rice Husk Ash

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Abstract: Disposal of rice husk and its ash has been identified as a major problem in areas where rice production is abundance. Cement is an expensive material which plays a major role in the construction industry. This study shows the utilization of Rice Husk Ash (RHA) in concrete by conducting the laboratory experiments. Replacement of cement with RHA enhances both compressive and tensile properties of concrete. For this study, RHA was obtained from Bio-Energy power plant located in Ampara, Sri Lanka. As received RHA was sieved in order to prepare two types of samples with different particle sizes. Enhanced performances of Ordinary Portland Cement (OPC) can be achieved with 10% replacement of OPC by RHA regardless of particle sizes. Moreover, the adverse environmental impacts associated with RHA can also be reduced by utilizing the RHA in cementitious systems.

Keywords: Compressive strength, Concrete, Rice husk ash, Tensile strength

1. Introduction

Rice husk is an agricultural waste that is produced during the rice milling process. Rice husk is widely used as a fuel in several industries such as brick industry, rice mills and power plant industry.These process converts the rice husk into ash. The disposal of rice husk and its ash has been identified as a major problem in areas where rice production is abundance, for example, Ampara district in Sri Lanka. According to theFood and Agriculture Organization of the United Nations [6] database, Sri Lanka produced 4.62 million tons of rice in the year of 2013. However, annual rice production has dramatically increased in last 15 years.

RHA is one of the promising pozzolanic material which can be used in lime-pozzolan mixture and as a replacement material of Portland cement. Pozzolanic reactivity of RHA is influenced by silica content and crystallization phase, particle sizes, large surface area governed by the porous structure of the ash and less amount of carbon content in the ash [8].

However, siliceous and aluminous are pozzolanic materials. Pozzolans have either little or no cementitious material.Addition of RHA into concrete starts the pozzolanic reaction in the presence of Calcium Hydroxide (CH) that obtains from the cement hydration. Calcium Silicate Hydrate (C-S-H) gel is produced by the dissolution-precipitation process at the ordinary temperature. In the presence of moisture, RHA rapidly dissolves in the high pH of Calcium Hydroxide then precipitates the form of C-S-H (secondary) gel which has cementitious property[9].This process leads to producehighly dense and less porous, and it increases the strength of harden concrete against cracking [6].

Several researchers have interested in utilization of waste materials. Most of the studies in various parts of the world illustrate that RHA can be used as a supplementary cementitious material in concrete because of its pozzolanic activity and very high silica content, where rice plant absorbs silica from the soil and assimilates it into its structure during the growth. RHA is a competitive additive to Portland cement because it enhances primary characteristics such as cost reduction, performance, durability, eco-friendly and environmental concerns [7,10].

For the purpose of this research, RHA was obtained from Bio-Energy power plant located in Ampara, SriLanka. As received RHA was sieved in order to prepare two types of ash samples with different particles size.This research investigates the workability, compressive strength and split tensile strength on concreteproduced with cement having partial replacement of RHA.However, tests were conducted on concrete at constant a water/binder ratio and superplasticizer content.

2. Experimental Programme

2.1 Materials

Cement: The Ordinary Portland Cement that compliances with SLS107:2000 which equivalents to BS EN197 was used for this study.

Rice husk ash: RHA which is dark grey in colour was obtained from the biomass power plant in Ampara. Rice husk was burnt at approximately 650°C by continues supply of natural air. As received ash was sieved for 10 minutes. Thereafter, particles passing through 75µm and 150µm sieve sizes were denoted by "P" and "Q" respectively. Both RHA samples showed almost equal bulk densities. The bulk densities of P and Q are 215.8 kg/m^{3}and 215.9kg/m^3 respectively.

Aggregates: Locally available natural river sand was used as fine aggregate. This sand was 100% passed through 5mm sieve size. On the other hand, coarse aggregate was obtained from crushed rock with maximum size of 20mm. Moreover, the water absorption and specific gravity tests were conducted according to BS 812: Part 2 [4] and these properties are shown in Table 1.

Table 1 Properties of Aggregates

Parameter	Fine Aggregate	Coarse Aggregate
Specific gravity	2.60	2.70
Water absorption (% by mass)	0.98	0.45

Chemical admixture:RHEOBUILD®1000 Super plasticizer was used to obtain high workability of the fresh concrete. This water reduces admixture compliances with ASTM C494 type-A&F. It is dark brown, water-soluble and chloride free sulphonated naphthalene. According to the manufacturer's instruction, the dosage was limited to 950ml per 100kg cement.

Water: Potable tap water which comes from pipe supply for the drinking purpose of public was used in this study to make concrete.

2.2 Preparation of concrete

Seven series of samples were prepared including the control mixture. Control mixture was prepared only with the OPC, natural river sand, coarse aggregates and water. The rest of the mixtures were prepared with RHA, which is passing through 75µm and 150µm sieves. Concrete prepared with RHA samples passing 75µm and 150µm sieves are denoted by "P" and "Q" respectively.

For each particle size of RHA, mixtures were produced by replacing OPC with 10%, 12.5% and 15% of RHA by weight. Water/binder ratio was fixed at 0.53 for each and every mixtures. Also fine and coarse aggregates were used in 875 kg/m^3 and 975kg/m^{3}respectively. Notation of mixtures and RHA replacement levels are given in Table 2.

Table 2Mix Design of Control Mixture

Series	Notation	RHA replacement	Cement kg/m^3	RHA kg/m^3
control	C1	0%	360.0	00.0
P	AP	10%	324.0	36.0
P	BP	12.5%	315.0	45.0
P	CP	15%	304.0	54.0
Q	AQ	10%	324.0	36.0
Q	BQ	12.5%	315.0	45.0
Q	CQ	15%	304.0	54.0

After the batching of raw materials coarse and fine aggregates, OPC and RHA were placed in the titling drum mixer .Each mixtures was mixed for 8 minutes duration that included three minutes mixing after adding of water to the concrete. Moreover, the admixture RHEOBUILD® 1000 was dissolved in water before adding it into the concrete to ensure the homogeneous mixing.

2.3 Compressive Strength Test

The test specimens were cast in 150mm cubic mould. The casting process was conducted accordance with BS1881-108-1983 [1]. All the test specimens were cured in water for 28 days.

Figure 1: Compressive strength testing

Compressive strength was measured according to the BS1881-116-1983 [2]as shown in Figure 1. Load was applied continuously at 0.3MPa/s without shocking until the crack propagation.

2.4 Split tensile test

Standard cylinder moulds were used with the diameter and height of 150mm and 300 mm respectively. Test was carried out in accordance with BS 1881-117-1983 [3]as shown in Figure 2. The loading rate was 0.03 MPa/s that was applied continuously without shocking until the crack propagation in the test specimen.

Figure 2 Split tensile test

2.5 Slump test

The slump test was conducted immediately after the completion of mixing process to determine the workability of concrete. Slump Test was conducted according to the BS1881-102-1983as shown in Figure 3.

Figure 3 Measuring the Slump

3. Test results and analysis

3.1 Compressive strength variations

According to Figure 4, P and Q series indicate that the compressive strength increment at 10% replacement level than the control. However, P series test specimens show the highest compressive strength at the age of 28 days. Both P and Q series exhibit the normalized strength of 107% and 105% respectively.

These favourable results show for finer RHA particles which consumes more $Ca(OH)_2$ formed during the hydration of Portland cement and it has high pozzolanic reactivity than the coarser RHA. Also the fine RHA particles improve the particle packing density of the RHA concrete.

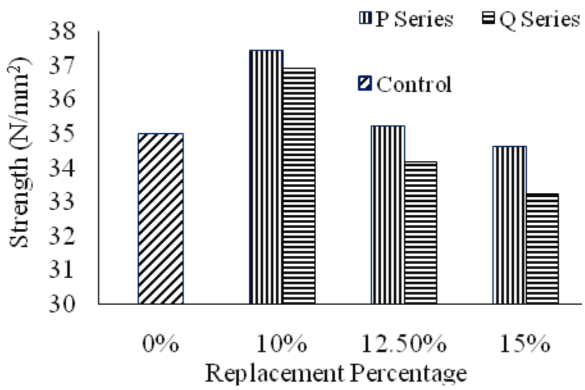

Figure 4 Compressive strength variation at 28 days

3.2 Tensile strength variations

According to Figure 5, the highest tensile strength is obtained for 12.5% cement replacement with RHA at the age of 28 days. Also the strength relevant to 15% replacement level is less than that of 10% replacement level.

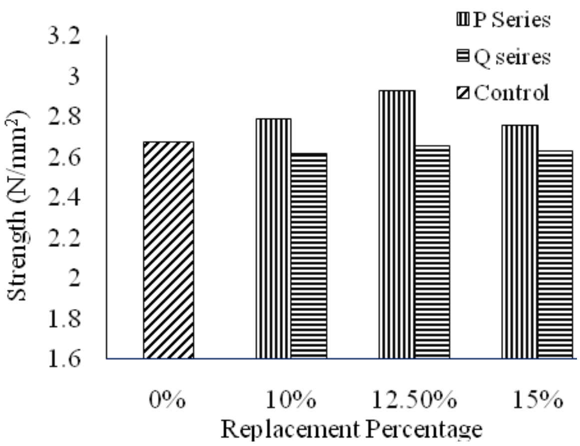

Figure 5

In an overall sense, the finer RHA replaced concrete is stronger than the control concrete. Although, the development in split tensile strength is in very small range, the higher variability in the result due to the senility the fabrication, curing and testing of concrete specimens.

3.3 Slump test

The slump test results are shown in Figure 6.It illustrates thatthe workability of concrete with RHAis low. Moreover, it is observed that slump reduction increases as the RHA percentage increases.Especially, concrete with Q-type RHA has a lower workability than the concrete with P-type RHA. The lowest workability is seen from the concrete with 15% replacement of Q-type RHA and this attributes to the highest water consumption of RHA due to its porous structure.

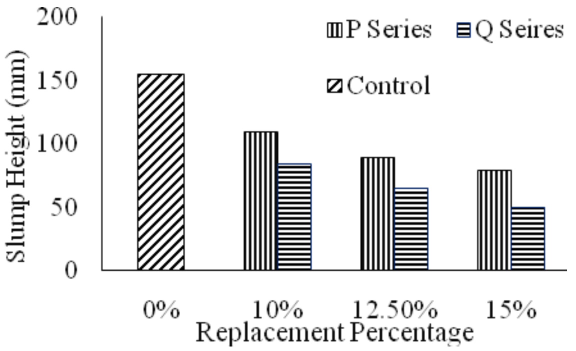

Figure 6 variation of slump height

4. The conclusions drawn from the tests are listed below.

Favourable results were obtained from the compression tests for concrete made with both typesof P (75 µm RHA) and Q (150 µm RHA). Concrete produced with 10% replacement of cement by P-type RHA shows the maximum normalized compressive strength of 107% while concrete with 10.0% replacement of Q-type RHA shows 105% normalized strength. Although P-type RHA replacement level shows a higher split tensile strength than that of the control mix, the maximum split tensile strength is obtained from the concrete produced with 12.5% replacement of cement by P-type RHA.

As a result, it can be concluded that an enhanced performance can be achieved with 10% replacement of cement by RHA regardless of the particle size of RHA.

Test results show that the workability of the concrete with RHA is low. Moreover, it is observed that slump reduction increases as the RHA percentage increases. Especially, concrete made with finer RHA has a lower workability than the concrete made with coarser RHA concrete.

Finally, this study suggests a proper way of disposal for the RHA produced from the Bio-Energy power plant by investigating the suitability of RHA to partially replace the cement. This brings an enormous amount of both environmental and economic benefits to Sri Lanka.

Future research can be carried out with partial replacement of cement with rice husk ash and fly ash in different levels to investigate the improvement of the workability and strength.

Moreover, it is recommended to grind as-received RHA from the power plant in order to produce ultrafine particles and then tests can be conducted to investigate the properties of such RHA replaced cement. Because it is possible to grind RHA in huge concrete plants, where the grinding process is cost effective.

Acknowledgement

The authors highly acknowledge the Colombo International Nautical and Engineering College, Malabe, Sri Lanka.

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