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Study on Strength Properties of Concrete made with Agrowaste Rice Husk Ash (RHA)

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ABSTRACT

Biomass is currently considered as an emerging technology to develop ecological sources of energy. Several studies have shown that and it is feasible to use biomass in concrete production. This paper presents results about the characterisation of the biomass rice husk ash (RHA) derived from combustion of an agricultural solid residue rice husk. The implementation of biomass in concrete will indirectly advance the renewable energy production and the economic development by decreasing CO_2 emission from cement industry and saving energy as well. The results also indicate that up to 20% of RHA incorporation could be advantageously blended with cement without adversely affecting the strength properties of concrete.

1.0 Introduction

Concrete, one of the most consumed material is not known to be an eco-friendly material as a significant amount of raw materials utilized for its production. Unfortunately, the production of Portland cement releases large amounts of CO2 and other harmful gases into the atmosphere, that cause environmental pollution. In addition to environmental pollution, Cement industry is one of the largest consumers of natural resources like limestone due to which sustainability of concrete industry is under threat.

Due to growing environmental concerns and the need to conserve energy and resources, considerable efforts have been made worldwide to utilize local natural waste and by-product materials in making concrete. It is imperative that supplementary cementing materials be used to replace large proportions of cement. By reducing the demand of cement, natural reserves of limestone can be preserved, energy can be saved and pollution due to CO2 can be reduced. Previous studies indicate that the use of Fly Ash, Silica fume, Matakaoline, Ground Granulated Blast Furnace Slag as partial replacement of cement, reduces the cement consumption and also increases the strength and durability of concrete. Some natural products and waste resulting from the processing of agricultural products may be used for the manufacture of ecological concrete. One of such materials is the solid agricultural waste Rice husk ash (RHA) Fig.1(b). Indian Standard code of practice for plain and reinforced concrete, IS 456-2000[1], recommends use of RHA in concrete but does not specify quantities.

Approximately 134 million tonnes of rice husk are produced annually in the world [2]. India is a major rice producing country, and Rice husk is produced in about 100 million of tons. Each ton of paddy rice can produce approximately 200 kg of rice husk, which on combustion produces about 40 kg of ash [3]. The husk generated during milling can be used as a fuel in steam boiler to generate hot steam in the power plant [4], In addition, rice husks are able to be an ideal fuel for electricity generation [5] and mostly used as a fuel in the boilers for processing paddy. The solid biomass combustion is a proven technology for heat and power production [2,4].

RHA, a by-product of the biomass power plant. Rice husk which under controlled burning, and if sufficiently ground, the ash that produced is RHA, which contains more silica content in amorphous form. Therefore, it is a highly reactive pozzolanic material and more suitable replacement material for Portland cement [6,7]. The quality of the RHA depends on the type of rice husk, method of firing, the burning temperature, the duration of burning, the air supply requirement during burning, the cooling rate of the resulting hot ash, and the grinding time [8].

Figure.1(a). Rice husk

Figure.1(b). Rice husk

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In this document, the effects of RHA as partial replacement of cement on properties of concrete according to some experimental background is presented. Different levels of RHA addition from 0 to 20%, followed by some tests to examine the influence of additions on basic properties of concrete.

2.0 Materials and Methods

2.1 Cement

The Cement used in this work was Ordinary Portland Cement (OPC), 53 Grade confirming to IS:12269 [9]. The Specific gravity was 3.15. Normal consistency 25.0%, Initial setting time 46 minutes and the final setting time 335 minutes was observed for the cement.

2.2 Fine and Coarse Aggregates

River sand with Fineness Modulus of 2.73, absorption 3.0 %, unit weight 1.68 gm/cc and specific gravity 2.55 gm/cc was used as Fine Aggregate (FA). The crushed granite stone of maximum size of 20 mm with specific gravity of 2.83 and water absorption 1.53 % was used as Coarse Aggregate (CA). all these properties were arrived from the Laboratory tests conducted as per IS: 383 and IS:2386 [10,11]

2.3. Rice Husk Ash (RHA)

Rice Husk Ash used in this present experimental study was obtained from ASTRRA chemicals, Chennai,India. The Grey colour ash of the particle size was less than 45 microns. Specific gravity and bulk density of this ash was 2.3 and 0.39 gm/cc respectively. RHA particle having particle size below 45 µm in size can actively possess pozzolanic reaction [12]. Chemical properties of this ash is presented in Table.1, supplied by the manufacturer. Chemical compositions of RHA are affected due to burning process and temperature. Silica content in the ash increases with higher the burning temperature.

Table.1 Chemical Composition of Rice Husk Ash

Sl. No	Particulars	Proportion
1	Silicon Dioxide, SiO_2	88.94%
2	Aluminium Oxide, Al_2O_3	2.50%
3	Iron Oxide, Fe_2O_3	2.19%
4	Calcium Oxide, CaO	0.25%
5	Magnesium Oxide, MgO	0.2%
6	Sodium Oxide, Na_2O	0.3%
7	Potassium Oxide, K_2O	0.39%
8	Loss on ignition	4.14%

Rice Husk can be characterized as a biomass rich in Si, but poor in Ca, K. Generally, Portland cement contains 60 to 65% CaO and, upon hydration, a considerable portion of lime is released as free Ca $(OH)_2$, which is primarily responsible for the poor performance of concretes. When RHA is added with Portland cement in making the concrete, Silica present in the RHA combines with the calcium hydroxide and improve the performance of the concrete. The SP used is sulphonated naphthalene formaldehyde condensed polymer-based admixture.

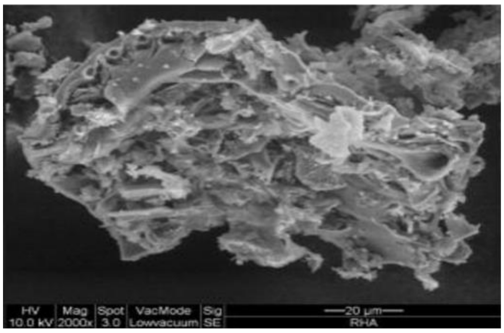

Figure. 2. SEM image of RHA

3.0 Results and Discussion

3.1 Mix Proportion

Mixture proportioning of conventional concrete (CC) was carried out according to the IS:10262-2009 [13]. The target mean strength was 40 MPa. RHA concrete (RHAC) mix proportions were arrived from 10% to 30% replacement levels of RHA in the volume of the cement for the CC mix. The water to binder ratio was kept constant as 0.40. A less workable (stiff) mix was obtained when RHA is used as a cement blender, and more water was therefore required to make a workable mix. The superplasticizer content had to be adjusted to maintain a slump of (200 – 240 mm) for all mixtures. The test specimens were cast and left for 24 hours. After that, samples were demoulded and placed in the curing tank until the testing time at the age of 7, 28 days. Mixture proportions are summarized in Table 2.

3.2 Compressive Strength

Compressive Strength test as per IS: 516 [14] was carried out on hardened 150mm concrete cubes after 7 and 28 days curing in water. The results showed that at 7 days, the strength increase with increasing percentages of RHA, but the strength was comparable with the strength of CC. At early ages, pozzolana acts as filler which dilutes the Portland cement. Hence the strength of pozzolanic cement pastes is less than that of OPC at early ages [15]. While at the age of 28 days, higher fineness of RHA allowed it to increase the reaction with Ca(OH)2 to produce more calcium silicate hydrate (C-S-H) resulting in higher compressive strength. The increase in strength may be due partially to the pozzolanic reaction as reported by many researchers and partially to the fine RHA particles contributed to the strength development by acting as a microfiller. high specific surface area and the presence of reactive silica in RHA are enhancing the cement paste pore structure [16].

28 days results showed that 15% replacement of RHA by volume of cement shows about 18% increment of compressive strength of concrete. Replacement level of 15% RHA in concrete perform well and shows better compressive strength than other replacements, which is in a good agreement with the previous studies [17]. At the replacement level of 20% RHA, the strength of RHAC is decreased but increased about 8% when compared to normal concrete. It is decrease to of the strength of CC when 25% RHA is added. Therefore the 20% RHA is the optimum content at which it is showing parallel result as compared to normal concrete.

Table.2. Mix proportions

		0%	5%	10%	15%	20%	25%	30%
Cement	kg/m^3	400	380	315	297.5	280	262.5	245
RHA	kg/m^3	0	14.60	25.56	38.33	51.11	63.89	76.67
FA	kg/m^3	691.97	691.97	691.97	691.97	691.97	691.97	691.97
CA(20mm)	kg/m^3	824.54	824.54	824.54	824.54	824.54	824.54	824.54
CA(12mm)	kg/m^3	484.25	484.25	484.25	484.25	484.25	484.25	484.25
water	lit/m^3	158	155.87	153.74	151.60	149.47	147.34	145.21
w/b		0.40	0.40	0.40	0.40	0.40	0.40	0.40

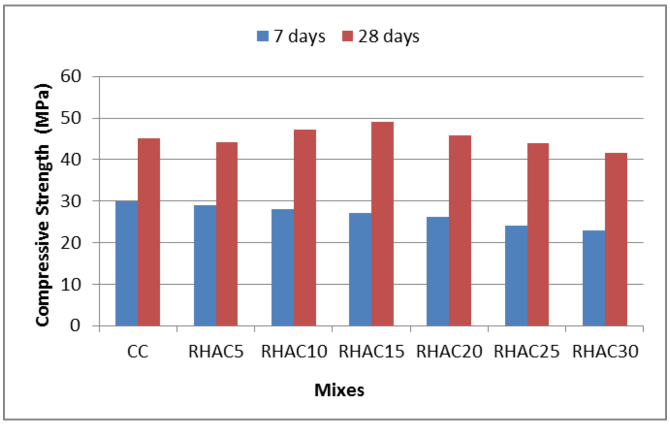

Figure.3. Compressive strength of CC and RHAC mixes

3.3 Flexural strength

The Figure.4 showing the flexural strength of concrete at the age of 28 days, with various percentages of RHA content. From the figure, it is clear that the flexural strength was gradually increased for the cement replacement values of 5% to 15% and reducing thereafter. So that the flexural strength increases with the increase of RHA up to 15%, the replacement level beyond this level the flexural strength decreases. Therefore, 15% replacement of cement by RHA is optimum in considering flexural strength.

However, 20% replacement of RHA gives higher strength than CC.

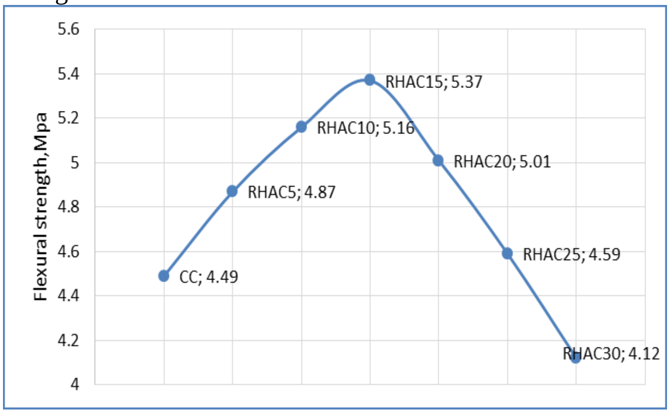

Figure.4. Flexural strength of CC and RHAC Mixes

3.4 Modulus of Elasticity

From the Figure.5, it is observed that the influence of RHA on the modulus of elasticity is same as that of its compressive strength. The increasing trend of compressive strength leading to increase of modulus of elasticity. The modulus of elasticity obtained is satisfied for all percentage of replacements.

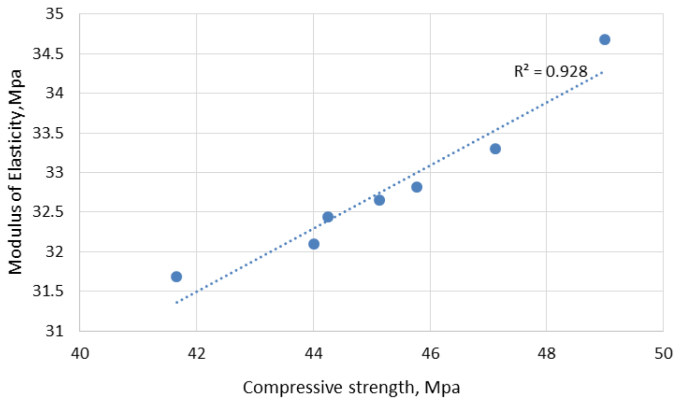

Figure.5. Relation between Compressive strength and Modulus of elasticity

4. Conclusions

Based on above results of concrete mixes, the following conclusions can be drawn,

1. It is an attempt made to develop the concrete using rice husk ash as a source material for partial replacement of cement, which satisfies the various structural properties of concrete like compressive strength.
2. Replacement of 15 % of volume of cement with rice husk ash in concrete causes reduction in utilization of cement and expenditures. Also, can improve quality of concrete at the age of 28 days.
3. Results indicate that, addition of pozzolans like rice husk ash to the concrete, can improve the mechanical properties of specimens. The pozzolanic reactions of rice husk ash in the matrix composite were low in early ages, but at the age of 28 days, considerable effect has been seen in strength.
4. Utilization of rice husk in concrete could solve the disposal problem and reduce the cost of waste treatment.
5. The compressive strength, flexural strength and tensile strength of concrete specimens with 20% cement replacement with RHA are comparable to the control specimens.

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