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AN INVESTIGATION OF ENGINEERING PROPERTIES OF HIGH STRENGTH CONCRETE CONTAINING RICE HUSH ASH AND RECYCLE AGGREGATES

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Abstract: Conventionally the concrete production is highly energy intensive and one of the main sources of greenhouse gas emissions in the World. The high strength concrete (HSC) is a trendy and effective solution for many structural applications. This concrete is particularly beneficial in compression members as it can endure higher stresses. In general the HSC requires the higher cement content and quality aggregates to achieve designated strength. However this process adds to the economy of the HSC production. Therefore replacement of supplementary cementitious materials and aggregates in HSC could lead to economical and sustainable manufacturing. Thus, the objective of this research is to investigate the effect of partial replacement of untreated rice husk ash (RHA) together with recycled coarse aggregate (RCA) on the engineering properties of HSC. Sixteen various mix propositions were examined by replacing the cement and natural coarse aggregates by RHA and RCA respectively to investigate the compressive and tensile strengths. Further the influences of untreated RHA and RCA on other engineering properties including air-entrainment, modulus of elasticity, workability were examined. Replacement of RCA up to 100 % did not significantly alter the strength properties of HSC. The addition of RHA up to 20% has reduce the compressive and tensile strength by only 10%.

Keywords: High strength concrete, Recycled coarse aggregate, Rice Husk Ash, Compressive Strength, Tensile Strength, Young's Modulus

1. Introduction

Concrete is a composite material composed of coarse aggregates bonded together with fluid cement that hardens over the time. Ordinary Portland cement (OPC) is widely used as the main binder in the concrete. Production of OPC is currently topping 2.6 billion tons per year [1]. Manufacture of 1 kg of OPC emits nearly equivalent amount of CO_2 in to the atmosphere. Therefore OPC production is one of the main contributor to the global warming. Also the extent of energy required to produce OPC is only next to steel and aluminium [1].

Therefore, it will be much worth, if another material is found instead of cement with equivalent properties or if cement is partly replaced by some other supplementary cementitious materials (SCMs). Search of such materials can lead to a sustainable development incorporating a minimum impact on the environment. Presently OPC is partly replaced with SCMs obtained by industrial by products such as Rice husk ash (RHA), Fly ash, Silica Fume, Ground Furnace Slag, High Reactive Meta kaolin etc. SCMs improve concrete properties mainly in two ways. These materials increase the generation of more Calcium Silicate Hydrate (C-S-H) through the pozzolanic reaction and they also contribute in providing denser concrete due to better packing of particles.

Traditionally, the application of concrete recycled coarse aggregate (RCA) is used as landfill. Nowadays, the applications of recycled aggregate is getting popular around the World. The objective of this research is to investigate the effect of RHA together with RCA on engineering properties of high strength concrete. Sixteen mix propositions are made by changing percentage of RHA and RCA to investigate the compressive and tensile strengths characteristics.

2. Literature Review

Rice milling industry generates a lot of rice husk during milling of paddy which comes from the fields. Rice husk ash (RHA) is a carbon neutral green product. Many ways are being practiced for utilising them by making commercial use of RHA. Additionally RHA is a good super-pozzolan. This super-pozzolan can be used in an efficient way to make cementitious mixes. Various levels of RHA replacement to cement was examined on compressive strength characteristics of concrete [2]. The test results indicated that the concrete mixed with 20% of ground RHA had a compressive strength at 7 days higher than that of concrete without RHA [2]. It is reported that the higher fineness of RHA could be used as a pozzolanic material in making high strength concrete. The maximum compressive of 80 MPa was reported in their study [3]. This indicates that ground RHA had highly pozzolanic property and could be used as a good supplementary cementing material in concrete.

It is studied that the incorporation of RHA in concretes results in improved compressive strength and flexural strength [4]. The addition of RHA in concrete becomes cohesive and more plastic and thus permits easier placing and finishing of concrete [5]. Adding 20% RHA also gives maximum tensile, flexure & compression strength over normal concrete. It is shown that 10% replacement of cement by RHA gives peak compressive strength. With the increase of rice husk ash percentage above 10% show the decline in compressive strength. Tensile strength of the concrete containing RHA is almost similar as the compressive strength variation. It is shown that an increase in tensile strength of concrete due to the addition of 10-20% RHA replacing cement [6].

Further RCA is obtained mainly by crushing and processing of old concrete structural elements. RCA may contain bricks, tiles, metals and other miscellaneous materials such as glass, wood, paper, plastic and other debris along with crushed concrete. It has been established in literature that increase in RCA amount at the same w/c ratio leads to decrease in compressive strength, generally up to 10% lower than that of natural aggregate concrete [7,8,9]. It was observed that the compressive strength of RCA added concrete was 20% less than compressive strength of conventional Concrete [10]. However some other researchers observed that the compressive strength of concrete remains unaffected, or increases slightly for replacement of Natural aggregate by RCA up to 25% [11,12,13]. However, research conducted in [14] showed that the rate of strength gain in RCA made with 20%, 50% and 100% RA was more after 28 days as compared to that of conventional concrete [14]. The split tensile strength of RCA has been observed to be dependent on a variety of factors such as RCA replacement, water-binder ratio, mixing methods, type of cement, curing age and RA quality [?].

It is reported that the split tensile strength of RCA were 6%, 10% and 40% less than that of conventional concrete when RAC was made with 25%, 50% and 100% RA replacement, respectively [15]. Many studies show that the tensile strength of RCA for replacement ratio of up to 30% is same or even exceeds the tensile strength of natural aggregate concrete [14]. The possible reason for the behaviour can be due to the water absorption capacity of RCA which creates higher bonding between aggregates and cement matrix [11].

However no studies have been reported about partial replacement of untreated RHA together with RCA on the engineering properties of HSC. It is worth to find out the influencing factors and its effects on concrete containing both RHA and RCA to determine the sustainable mix design of designated concrete. Therefore this research study examines the engineering properties of concrete containing RCA and RHA for the sustainable development of modern concrete industry.

3. Materials and Testing

OPC, RHA, RCA and NA were used as raw materials in this research. The specific gravity, fineness and specific surface of the OPC were 3.05, 13% and 3500 m^2/kg respectively. The RHA was collected from a biomass power plant "Bio Energy Solution (Pvt) Limited", Sri Lanka. It was heated between 600ºC to 800ºC during the Biomass production and used in this research without further treatment. Local river sand with the fineness modulus of 2.54 was used as fine aggregate in this research.

RCA was obtained from COWAM Center, Galle. The mean values of AIV, specific gravity and water absorption of RCA were 19, 2.71, 4.68 respectively.

The process of proportioning of concrete mix involves the selection of ingredients and determining their amounts to produce specified fresh and hardened properties, while achieving economic and sustainability targets. Various methods are available for selecting mix proportions. Each method has its merit in certain types of concrete. Among them ACI-211 method is used to determine the proportions of the ingredients as given in table 01. Sixteen mix propositions were made by changing percentage RHA and RCA on the primary engineering properties of high strength concrete.

Table 1: Mix proportions

Mix	Mix proportion (kg/m³)					
	Cement	Rice Husk Ash (RHA)	Coarse aggregate (CA)	Recycled Coarse Aggregate (RCA)	Fine aggregate	Mixing Water
CON	488.1	–	992	–	687.2	205
LCA	488.1	–	992	–	687.2	205
LCAR5	463.695	24.405	992	–	687.2	205
LCAR10	439.29	48.81	992	–	687.2	205
LCAR15	414.885	73.215	992	–	687.2	205
LCAR20	390.48	97.62	992	–	687.2	205
MCA	488.1	–	496	496	687.2	205
MCAR5	463.695	24.405	496	496	687.2	205
MCAR10	439.29	48.81	496	496	687.2	205
MCAR15	414.885	73.215	496	496	687.2	205
MCAR20	390.48	97.62	496	496	687.2	205
HCA	488.1	–	–	992	687.2	205
HCAR5	463.695	24.405	–	992	687.2	205
HCAR10	439.29	48.81	–	992	687.2	205
HCAR15	414.885	73.215	–	992	687.2	205
HCAR20	390.48	97.62	–	992	687.2	205

Three specimens of each mix proportions were casted in cube mould and filled with concrete in three layers to analyse the compressive strength variation. Hand compaction was applied with tamping rod and after curing was carried out on ambient temperature pond for 28 days. After 28 days, specimens were tested under 3000 kN uniaxial compression testing machine as shown in Figure 01.

Figure 01: Compression testing.

Three cylindrical specimens (100mmx200mm) of each mix proportions were casted to investigate the split tensile strength variation with respect to ASTM C496. Splitting tensile load was recorded by testing the cylinder under diametric compression as shown in the Fig 02.

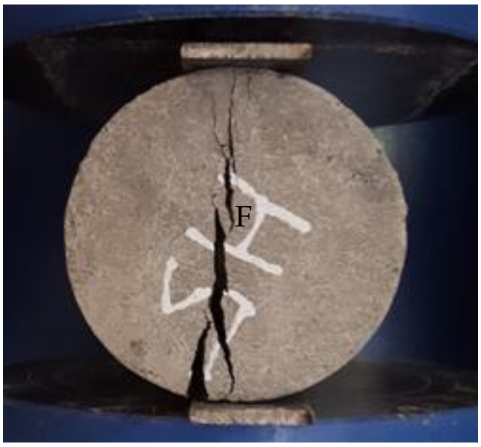

Figure 2: Splitting tensile loading.

Modulus of Elasticity was calculated by the ultrasonic wave transmitting through the concrete. The main objective of this test is to determine void pattern and determine the dynamic and static modulus of elasticity of concrete. The pulse velocity can be calculated using the measured path length through the concrete with respect to ASTM C597. The average value of pulse velocities obtained along different path as shown in Fig 03 were used for the calculation of modulus of elasticity.

Figure 3: Pulse velocity measurement.

4. Results and Discussion

Workability of concrete has been measured by performing slump cone to investigate the effect of RHA and RCA on workability of concrete. Workability of concrete is reduced with the percentage increment of RHA and RCA due to the poor bonding issues associated with RCA and RHA as shown in Figure 4.

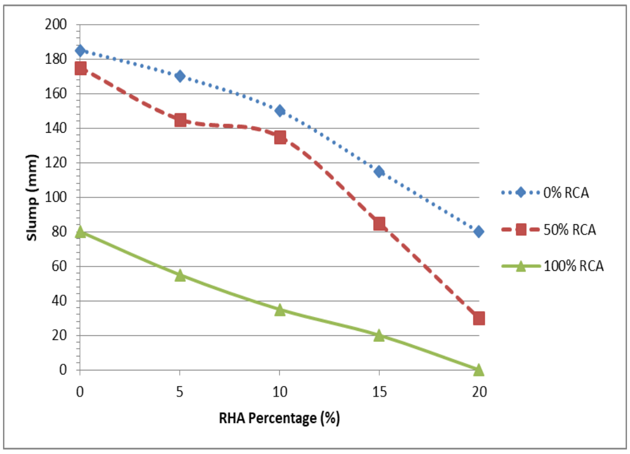

Figure 4: Variation of workability

Compressive strength of concrete decreased as the percentage of replacement of RHA and RCA increased as shown in Figure 5. Similar trends were observed even in the previous research works [7, 8, 9]. This might be due to the poor bonding property of RCA and poor cementitious property of RHA.

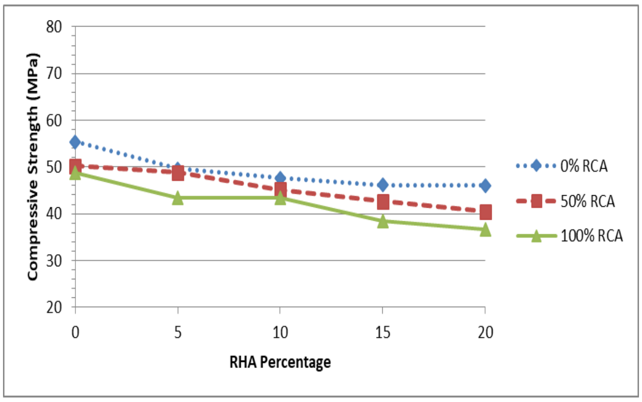

Figure 5: Variation of compressive strength.

The trend of tensile strength of the concrete containing RHA and RCA is almost similar as the compressive strength variation. Results from the of split tensile strength test shows that there is a reduction in tensile strength of concrete due to the addition of RHA and RCA as shown in Figure 6.

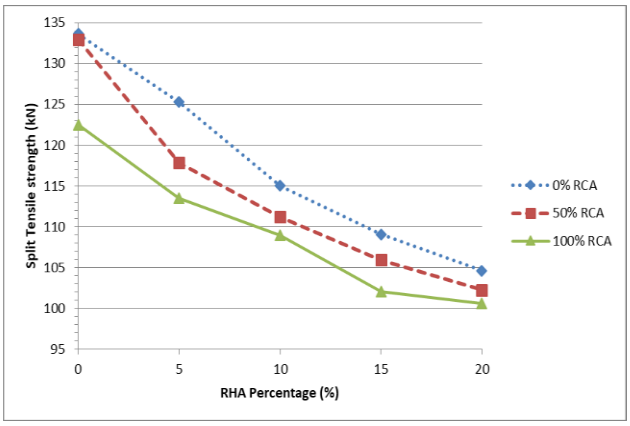

Figure 6: Splitting tensile strength.

Modulus of Elasticity of the concrete containing RHA and RCA at 28 days is almost similar as the compressive strength variation. Results shows that there is a reduction in Modulus of Elasticity of concrete due to the addition of RHA and RCA as shown in Figure 7.

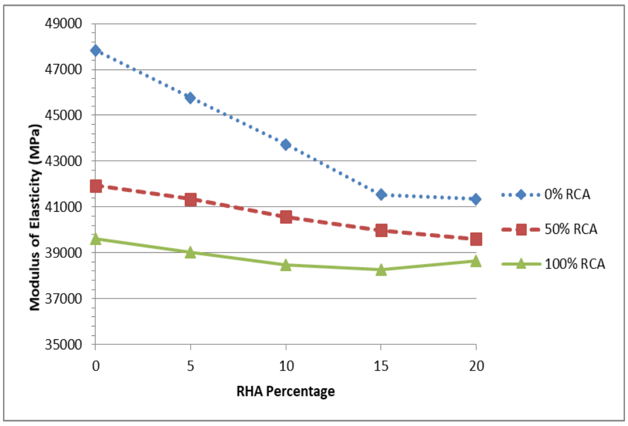

Figure 7: Modulus of elasticity.

5. Conclusion

Effect of partial replacement of untreated rice husk ash (RHA) together with recycled coarse aggregate (RCA) on engineering properties of high strength concrete (HSC) was investigated in this research. This research shows that the use of RHA and RCA for the concrete production is feasible. From the results of this study, the following conclusions can be drawn.

- Compressive strength and splitting tensile strength of concrete at 28 days was decreased as the percentage of replacement of RHA improved.
- No significant changes in the compressive strength was noted in replacing only course aggregates by RCA up to 100%.
- There is a significant reduction of workability in fresh concrete with the increase amount of RHA and RCA content in concrete.
- Results shows that there is a reduction in modulus of elasticity of concrete due to the addition of RHA and RCA.
- The use of industrial wastes such as of RHA and RCA as raw materials for the concrete production could contribute to the sustainable development.

The results of this research can be used to carry out the mix design of designated concrete with industrial wastes such as RHA and RCA.

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