Experimental study on partial replacement of cement with Rice Hush Ash and Sugar Cane Bagasse Ash

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Abstract: Rice husk constitutes 20% of the 500 million tons of paddy produced in the world. India, one of the largest producers of sugarcane in the world, produces 300 million tons per year. Rice husk ash (RHA) and bagasse ash (BA) are used as pozzolanic materials for the development of blended cements. Very limited information is available on the permeability and corrosion resistance characteristics of RHA blended concrete. Few studies have been reported on the use of bagasse ash as pozzolanic material in cement pastes and no detailed study for strength and durability properties of BA blended concrete has been made. The objective of the present investigation is to evaluate the RHA and BA as supplementary cementitious materials with reference to strength, and permeability properties in blended cement concrete and to identify the optimal level of replacement of OPC with RHA or BA. Boiler fired rice husk and bagasse residues were collected from the mills. The mill fired residues were further burnt at 650°C over a period of one hour and pulverized before they were used as cement replacement materials. Blended cements were prepared by replacing OPC with RHA or BA (5 to 35% by weight of cement) in dry condition.

INTRODUCTION

Construction has been an important element in the rapidly changing modern society. Innovation in construction is highly linked with the development of advanced construction materials. Cementitious materials are the major class of construction materials that have been used for several millennia. The ancient cementitious materials were lime alone or lime in combination with natural pozzolan, as well as gypsum, while the modern ones are largely portland cement. Many countries are in severe shortage of cement, in spite of higher demand. There would be an increase in the use of combination of Portland cement with large contents of mineral additives. Therefore, the search for alternative binder or cement replacement materials has become a technological interest and there is an urgent need to develop newer concrete as a reliable and durable construction material. From ecological point of view one has

(1) to produce binders that consume less energy and emit less greenhouse gases, in particular carbon dioxide,

(2) to incorporate industrial by-products and recycled materials in the cementitious binder as well as in the concrete and

(3) to produce structures that would function more efficiently over time, in terms of their durability performance.

Blended cements are produced by the addition of well known cement replacement material to ordinary Portland cement. Many of these cement replacement materials or mineral admixtures are industrial wastes. Agricultural wastes such as rice husk ash and sugarcane bagasse ash are also considered as mineral admixtures due to their pozzolanic property. The amount of Portland cement replaced with the pozzolanic materials depends not only on the physical and chemical properties of the pozzolanic materials, but also on the characteristics of the Portland cement and pozzolan. These include control of the alkali – aggregate reaction, improvement in durability properties, enhancement of resistance against the corrosion of steel in concrete and reduction in the heat of hydration. While 40 to 50% replacement is permitted by many standards, optimum replacement from a strength point of view appears to be less than 30%. With this amount of replacement for what can be referred to as good reactive pozzolan, the 28 days compressive strength with at least be comparable (if not greater) than the strength of the unsubstituted Portland cement. For poor pozzolanic materials, the amount of replacement could reduce to 10% to achieve strength equivalence at 28 days.

LITERATURE REVIEW

Many studies were carried out on the utilization of RHA, obtained from the controlled burning of raw husk as per the procedure laid down in the literature and most of the studies are focused on the improvement of physical and mechanical properties of rice husk ash in concrete. The Bureau of Indian standard for concrete, IS 456-2000 included for the first time RHA as one of the pozzolanic admixtures that may be blended with cement. Only a few studies have been reported on the use of bagasse ash as partial cement replacement material in respect of cement mortars. 89 Even though many studies have been reported on the use of RHA, there is a need to study specifically the performance of RHA prepared from uncontrolled boiler burnt rice husk residue available in rice mills. Systematic and detailed studies on the utilization of BA prepared from uncontrolled boiler burnt bagasse residue of sugar mills for strength and durability properties of concrete are scare.

Very little information is available on the chloride impermeability and corrosion resistant properties of concrete blended with these ashes. In this research work, an experimental investigation for the evaluation of RHA and BA prepared from the mill residues as cement replacement materials and assessment of optimal level of replacement to the blended cement concrete system for the strength and resistance against chloride penetration and corrosion of steel are considered. Optimal level refers to the maximum favourable percentage of replacement of OPC with RHA or BA up to which strength, impermeability and corrosion resistance properties of blended concrete become equivalent or more than that of OPC concrete. Comprehensive and systematic evaluation of RHA blended cement concrete and BA blended cement concrete would lead to its widespread application in corrosion prone reinforced concrete structures.

NEED FOR RHA AND BA BLENDED CONCRETES

Fly ash, ground granulate blast furnace slag and condense silica fume are well-established mineral admixtures. The improvements in the properties of fresh and hardened concrete resulting from the pozzalanic behavior of these admixtures are well understood. Among the mineral admixtures, only fly ash is available readily from thermal power plants. BFS and silica fumes require excessive processing before they are used as a mineral admixture. These materials are not available in many countries. Rice husk ash and bagasse ash have special relevance to many countries. Some 500 million tons of paddy and 1500 million tons of sugar cane are produced worldwide annually, from which some 20 million tons of rice husk ash and 10 million tons of bagasse ash as pozzolanic materials could be extracted.

Cement production is associated with the utilization of large amount of energy. Replacement of cement with RHA and BA results in energy saving as RHA and BA do not need addition of energy input before use and they are local waste materials. The salient features in the production of cement based on RHA and BA are the conversion of the husk or bagasse to ash and the grinding them to a suitable particle size. However the conversion of husk or bagasse may be undertaken in different ways.

Rice husk and bagasse represent valuable sources and are used as fuel in the mills. When used as boiler fuel or for any commercial application, the pyroprocessing is not controlled and the ash so produced contains crystalline components (hard burnt ash). The alternative process in the conversion of hard burnt rice husk residue and bagasse residue obtained from the mills into reactive amorphous ash is controlled burning using the fuel value of these residues and pulverizing them to required fineness with less energy compared to that of grinding in ball mills for several hours. The amount of cement replacement with RHA or BA, favour energy saving. Thermodynamic computation indicates that 1 ton of cement replacement with RHA and BA saves approximately 5000 MJ of energy which is equivalent to a barrel of oil or 0.25 ton of coal. Utilization of RHA and BA as cement replacement material in construction, they will provide economical benefit by way of energy saving.

The Portland cement production is also associated with carbon dioxide emission, which is a major source of global warming, and the use of Portland cement with cement replacement materials carbon dioxide emission is controlled. A typically efficient cement plant will release about 0.65 ton of carbon dioxide for each ton of cement produced. If carbon fuel is used to burn the clinker, an addition of 0.35 ton of carbon dioxide is released. Each cement plant releases at an average of 1 ton of carbon dioxide to the atmosphere to produce 1 ton of cement. RHA typically replaces 30 % of cement and BA typically replaces 20 % of cement and thus, at an average a 25 % replacement of 1 ton of cement would result in a reduction of 0.25 ton of carbon dioxide.

The use of RHA and BA in the blended concretes is expected to enhance the strength and durability properties of concrete for technical benefits :

1. Reduced bleeding and segregation
2. Reduced heat of hydration
3. Improved early strength development
4. Lower water permeability
5. Less shrinkage
6. Increased resistance to cracking
7. Higher compressive strength
8. Lighter colour
9. Reduced chloride ion permeability and diffusion
10. Increased resistance against corrosion of steel in concrete.

A number of tests and processing of rice husk and bagasse ash for cement replacement have to be carried out before they can be suitably blended with cement. Hence in this research work experimental investigations have been planned for the evaluation of RHA and BA prepared from the mill residue as cement replacement materials for strength and durability properties of concrete and to find an optimal level of replacement on the blended cement concrete system for the strength and resistance against chloride penetration and corrosion of steel.

It is felt that a more comprehensive and systematic evaluation on RHA blended cement concrete and BA blended cement concrete carried out in this report will lead to its widespread application in the corrosion prone reinforced concrete structures. Apart from reducing demand for Portland cement, its cost, ecological, economical and technical benefits, rich husk ash and bagasse ash will provide substitute for cement to rural areas which are traditionally deprived of cement.

METHODOLOGY AND EXPERIMENTAL WORK

MATERIALS

Cement: Ordinary Portland cement (OPC) of 43 grade, conforming to Indian standard IS 8112 – 1989 was used.

Sand: Screened river sand passed through 1.18mm sieve with fineness modulus of 2.85 and specific gravity of 2.55 (conforming to IS 383- 1970) was used in concretes.

Coarse aggregate: Locally available crushed granite aggregate, passing through 12.5mm sieve while being retained on 3.75mm sieve with fineness modulus of 6.26 and specific gravity of 2.7. (Conforming to IS 383- 1970) was used as coarse aggregate.

Rice husk ash: Boiler-fired rice husk residue was collected from a modern rice mill at Puduvayal, Sivaganga district in TamilNadu, India. The uncontrolled fired husk residue ash was black in colour due to excess amount of carbon content.

Bagasse ash: Boiler burnt bagasse residue was collected from Perry sugar mill, Hyderabad, India. The uncontrolled fired bagasse residue was also black in colour obviously due to excess amount of carbon content.

Two types of ashes namely, boiler burnt and reburnt ashes had been prepared from the above rice mill and sugar mill fired residues for the assessment of strength and permeability properties of blended cement mortars and concretes .The rice husk residue and bagasse residue as received from the mills were sieved to remove coarser and foreign particles. The sieved particles were then pulverized into fine powder. The boiler fired black rice husk residue powder and bagasse residue powder before reburning were named as boiler burnt rice husk ash (BRHA) and boiler burnt bagasse ash (BBA) respectively.

The finely ground uncontrolled mill fired black rice husk and bagasse residue powders were further burnt in an industrial furnace at a temperature of 650˚C over a period of one hour. Preparation of reburnt ashes is described below:

Black rice husk and bagasse residue powders prepared from the mills waste were placed in the furnace. The temperature of the furnace was increased at a rate of 200˚C per hour until it reached 650˚C over a period of 3 hours and 15 minutes. At 650˚C, the temperature was kept constant for a burning time of one hour and then cooled. During this process, the unburnt carbon present in these ashes was removed. The rice husk ash was pulverize before it was used as a cement replacement material. The bagasse ash was also pulverized before it was used as a cement replacement material. This rice husk ash and bagasse ash obtained by controlled reburning processes were termed as simply rice husk ash (RHA) and bagasse ash (BA) respectively and were used throughout this present investigation.

Steel: Cold twisted Carbon – steel of Fe 415 grade conforming to IS 1786-1979 and 12 mm in diameter was used as reinforcement for pullout test and for all corrosion tests.

RESULTS AND DISCUSSION

The experimental result of strength tests on RHA and BA blended concretes are presented.

Compressive Strength of Concrete

The compressive strength of RHA and BA blended concrete specimens are shown. The control concrete exhibited a compressive strength of 37.05 MPa and 38.30 MPa at 28 and 90 days of curing respectively. Comparison of blended concrete compressive strength data for 7, 14, 28 and 90 days of curing times showed that the compressive strength increases with RHA up to 20% (1.15 times) and then at 30% RHA, the compressive strength attained equivalent value (37.58 MPa at 28 days and 38.71 MPa at 90 days of curing) as that of control concrete specimens. At 35% RHA, the compressive strength decreased to a value which was less than that of control concrete. Therefore 30% RHA was considered the optimal limit.

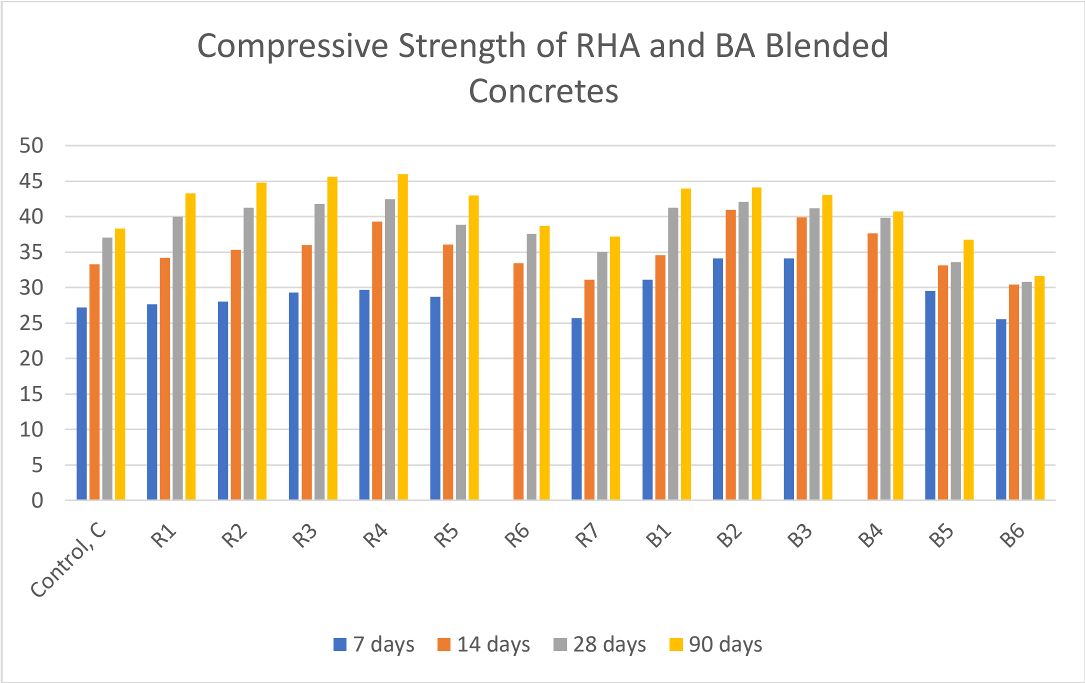

Figure 1 Compressive Strength of RHA and BA Blended Concretes

Splitting Tensile Strength of Concrete

The splitting tensile strength values of RHA and BA blended concretes after 28 days of curing are shown in Figure 4.6. The control concrete exhibited a splitting tensile strength of 4.49 MPa at 28 days of curing. The splitting tensile strength increased with RHA up to 20% and then at 30% RHA, the splitting tensile strength attained equivalent value (4.25 MPa at 28 days of curing) as that of control concrete specimens. At 35% RHA, the splitting tensile strength decreased to a value which is less than that of control concrete. Therefore 30% RHA was considered as the optimal limit.

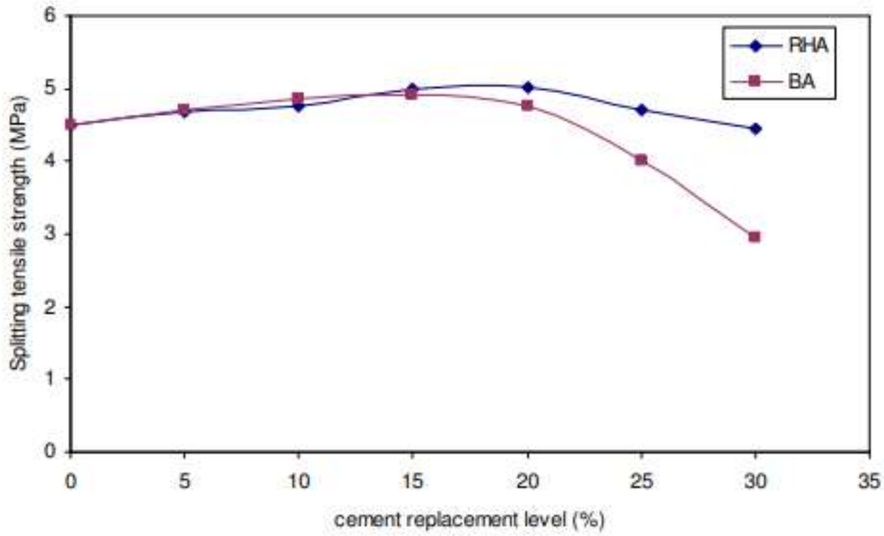

Figure 2: Splitting Tensile Strength of RHA and BA Blended Concretes

Water Absorption

Water permeability property as indicated by saturated water absorption of RHA blended concrete specimens after 28 and 90 days of curing are given in Table 4.4. The control concrete exhibited a saturated water absorption value of 4.71 % at 28 days of curing. The 48 hours saturated water absorption value of RHA concrete at different replacement levels were in the range of 4.83 to 6.92 % at 28 days of curing. Saturated water absorption of

RHA concrete increased with RHA contents at all replacement levels at 28 days of curing as these ashes were finer than OPC and they were hygroscopic in nature. The percentage of water absorption values reduced considerably (more than 50%) after 90 days of curing. This was due to gradual closing of pores. Obviously with prolonged curing, addition of RHA led to reduction of permeable voids.

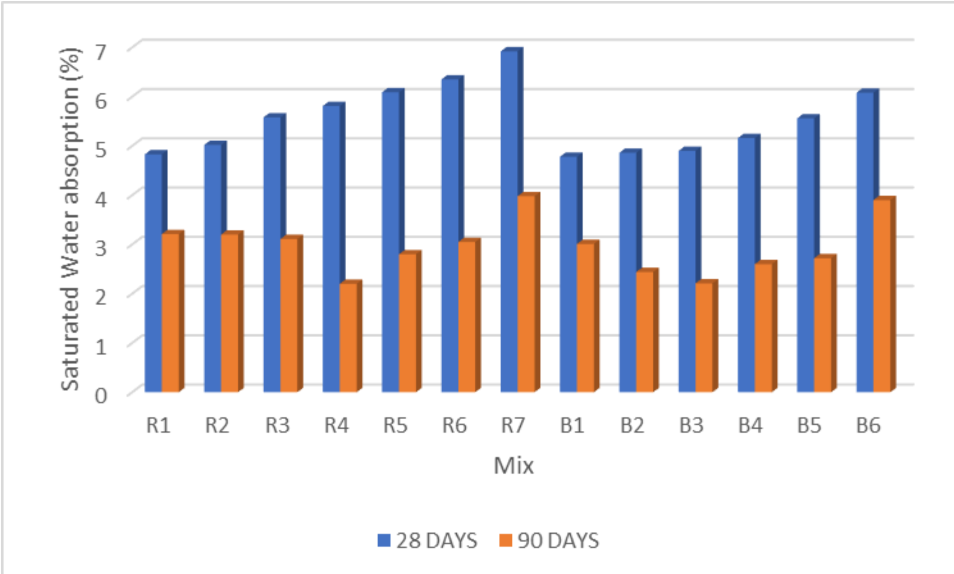

Figure 3:Permeability Related Properties of RHA and BA Blended Concretes

Water absorption values of BA blended concrete specimens after 28 and 90 days of curing are also given in Table 4.4. The 48 hours saturated water absorption values for BA concrete were found to be in the range of 4.78 to 6.08 % at 28 days of curing. It may be seen that at 28 days of curing the percentage of water absorption increased with BA content at all replacement levels. This was due to the fact that BA was again finer than OPC and also it was hygroscopic in nature. The percentage of water absorption values reduced considerably after 90 days of curing. This was due to gradual refinement of the C-S-H gel formed and closing of pores. Obviously with prolonged curing, addition of BA also led to reduction of permeable voids.

CONCLUSIONS

RHA consisted of 87% and BA consisted of 64% of silica respectively, mainly in amorphous form and the density, specific gravity and mean grain size of both RHA and BA were lower than OPC.

The resulting RHA and BA were whitish grey in colour. The water required for standard consistency linearly increased with both RHA and BA contents. The initial and final setting time measured up to 30% RHA and 20% BA were found to be within the permissible limit.

Higher carbon content in boiler burnt rice husk ash (18.4%) and boiler burnt bagasse ash (23.6%) had adverse effect on the strength and impermeability properties. RHA and BA reburnt at 650°C for one hour enhanced strength and impermeability properties of mortars and concretes.

Compressive strength and splitting tensile strength, increased with RHA content up to 30% and BA content up to 20% replacement level than OPC concrete.

The percentage of water absorption, values considerably reduced in RHA and BA concrete pores.

As high as 30% by weight of OPC can be optimally replaced with reburnt rice husk ash and 20% by weight of OPC can be optimally replaced with reburnt bagasse ash without any adverse effect on strength, permeability properties

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