

Use of Rice Husk Ash as Partial Replacement with Cement In Concrete- A Review

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Abstract:*Rapid increase in construction activities has resulted in shortage of conventional construction materials. In the present scenario, the high cost of conventional building materials is a major factor affecting housing delivery in the world. This has necessitated research into alternative materials of construction. The effective housing techniques deal with reduction in cost of construction as well as providing strength to buildings. Mainly gravel, sand and cement are used in the preparation of conventional concrete. While the use of agricultural by-product i.e. rice husk as a partial replacement with the conventional fine aggregates is expected to serve the purpose of encouraging housing developers in building construction. Rice husk is produced in about 100 million tons per annum in India. Twenty kg of rice husk are obtained from 100 kg of rice. It contains organic substances and 20% inorganic material. Ash from rice is obtained as a result of combustion of rice husk at suitable temperature. Proper utilization of it aims to save the environment, encourages the Government to find solutions regarding disposal of landfills of waste materials, and provides new knowledge to the contractors and developers on how to improve the construction industry by using rice husk, to sustain good product performance and to meet recycling goals. The rice husk ash concrete aims to prepare light weight structural concrete which may reduce considerably the self load of structures and permits large precast units to be handled. The main objective is therefore to encourage the use of these 'seemingly' waste products as construction materials in low cost housing. The various basic properties of rice husk concrete are reviewed in this paper.*

Keywords: Rice Husk Ash, Agricultural Residues Utilization, Light Weight Structural Concrete, Cost Effective Housing

I. Introduction

The construction industry relies heavily on conventional materials such as cement, sand and granite for production of concrete. Concrete is the basic civil engineering composite. The quality of concrete is determined by the quality of paste/mix. It is the world's most consumed man made material. Its great versatility and relative economy in filling wide range of needs has made it a competitive building material. The demand for concrete for today's infrastructural development is rising day-by-day. In light of this, the non-availability of natural resources to future generation has also been realized. Concrete production is not only a valuable source of societal development but also a significant source of employment. Following a natural growth in population, the amount and type of waste materials have increased accordingly creating thus environmental problems. Historically agricultural and industrial wastes have created waste management and pollution problems. Different

alternative waste materials and industrial by-products such as fly ash, bottom ash, recycled aggregates, crumb rubber, saw dust, brick bats etc. were replaced with natural aggregates. Although these materials are traditionally considered as "primitive" and therefore inferior to more highly processed materials in terms of safety, durability, performance, occupant's health and comfort with respect to environmental issue, consumption of environmental products and energy within the construction industry has created a significant demand for raw materials and for production thereby contributing to the many environmental problems associated with diverse ecosystem.

The wastes have generally no commercial value and are locally available at a minimal transportation cost. The use of these wastes has complemented other traditional materials in construction and hence provides practical and economic advantages. Also proper utilization of these wastes conserves the natural resources and protects the environment. Apart from the above mentioned waste materials, the rice husk can also be used in concrete due to the following points:-

- (i) Large scale production of rice in the coastal states of India and in the other countries of Asia.
- (ii) It is the staple food in majority of the countries of the world and thus generates the husk in Mega-tonnes per year.
- (iii) After the rice grain is collected, the husk or the ash is thrown away here and there causing environmental pollution.
- (iv) Some percentage of husk serves as eatables for the domestic animals, while majority are being wasted.
- (v) Little part of it when mixed with cow dung and other organic wastes serves as good manure to the plants.
- (vi) Helpful in cost effective housing and low rise buildings.
- (vii) Serves as an environment-friendly construction material.

With the quest for affordable housing system for both the rural and urban population of India and other developing countries, various proposals focusing on cutting down conventional building material costs have been put forward. Finding a substitute for the aggregate used today is a task that is worth studying because it helps in preserving conventional materials for future.

II. Review of Literatures

The literatures regarding the potential uses of rice husk as one of the suitable aggregates for concrete have been reviewed and are presented below.

Mehta and Pirth (2000) investigated the use of RHA (Rice Husk Ash) to reduce temperature in high strength mass concrete and concluded that RHA is very effective in reducing temperature of mass concrete compared to OPC concrete. RHA which is an agricultural by-product has been reported to be a good pozzolanic material by numerous researchers. RHA is obtained after burning of rice husk at a very high temperature.

Malhotra and Mehta (2004) reported that ground RHA with fine particle size than OPC improves concrete properties, including higher substitution amounts in lower water absorption values and the addition of RHA caused an increment in the compressive strength.

Adeyuyi and Ola (2005) have carried out research on the binary blends of OPC with different pozzolanic material in making cement composites. Supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete.

Habeeb and Fayyadh (2009) have investigated the influence of RHA average particle size on properties of concrete and found out that at early ages the strength was comparable, while at the age of 28 days, the finer RHA exhibited higher strength than the sample with coarser RHA.

Lee et al (2005) in their study concluded that some of the waste products like Rice husk which possess pozzolanic properties and used in the blended cements include fly ash, silica fume, volcanic ash, corn cob ash hence providing good strength properties to concrete.

Gunduz and Ugur (2004) in their study concluded that the greatest advantages of light weight concrete are its low density, allowing for construction on the ground with only moderate bearing capacity, the use of less reinforcement, the ability to construct taller structures, greater economy in lifting and use of more thermally efficient material. The unit weight of rice husk concrete can be lowered by either using porous materials, therefore lightweight aggregates instead of ordinary ones, introducing air into mortar or removing the fine fraction of aggregate and then by partially compacting the concrete. In all cases, the main goal is to introduce voids into aggregates and mortar or between mortar or aggregate.

Khedari et al (2001) have studied the characteristic properties of various light weight aggregates like pumice, coal slag, flying ash, rice husk, straw, saw dust, cork granules, wheat husk, coconut fiber and coconut shell used in partial replacement for concrete production. The organic waste used in light weight concrete is mainly of plant origin. They concluded that by using plant waste that is abundantly found in rural areas, it may be possible to construct cheaper and good quality agricultural constructions.

Sari and Pasamehmetoglu (2004) have concluded that rice husk as an organic waste, is a significant problem in rice cultivating areas because it is not used profitably and is generally burned after harvest, which causes environmental problems. Generally concrete with a unit weight of less than 2000 kg/cum is classified in the light concrete class. According to ACI (American Concrete Institute) Committee, light weight concrete is divided into three categories on the basis of its strength and density.

Properties	Lightweight Concrete Category		
	Low	Moderate	Structural
Unit weight (kg/m ³)	<1000	1000-1500	1500-2000
Compressive Strength (MPa)	0.70-2.00	2.00-15.00	16.00-42.00

Obilade and I.O.(2014) in their experimental study on rice husk as fine aggregates in concrete concluded that, there exists a high potential for the use of rice husk as fine aggregate in the production of lightly reinforced concrete. Weight-Batched Rice Husk Concrete and Volume-Batched Rice Husk Concrete showed similar trends in the variation of bulk density, workability and compressive strength. Loss of bulk density, workability and compressive strength is slightly higher for Weight-Batched Rice Husk Concrete than Volume-Batched. They made the following recommendations:

-The long term behaviour of rice husk concrete should be investigated.

-Volume batching should be used in works involving rice husk.

-Similar studies are recommended for concrete beams and slab sections to ascertain the flexural behaviour of light weight concrete made with rice husk.

Sisman et al (2011) have analysed the effects of rice husk on concrete properties for farm buildings and arrived at the following conclusions,

-The unit weight of the produced concrete samples varied between 1797-2268 kg/m³. When the RH amount in the mixture was greater than 15%, concrete should be classified as lightweight concrete with respect to their unit weights.

-The compressive strength of the samples at 7 and 28 days ranged from 15.2-31.3 MPa and 18.1-37.5 MPa respectively. The concrete produced in their study were defined as structural lightweight concrete when considering their unit weight and compressive strength.

-The water absorption of the samples on the 28th day varied between 3.03-5.48% and the use of RH as an aggregate replacement increased water absorption.

-The thermal conductivity decreased with increase in rice husk content. The thermal conductivity varied between 0.79-1.53 W/mK. Their research showed that the thermal conductivity of the RH aggregate concrete was approximately two times lower than that of an equivalent normal weight concrete.

Tomas U. Ganiron Jr (2013) experimented on the effects of rice husk as substitute for fine aggregate in concrete mixture and made the following inferences:-

-The results revealed that higher substitution amounts results into lower water absorption values due to more fineness property of RHA than cement. Adding 15% of RHA to the concrete, a reduction of 32.4% in water absorption value is observed.

-The addition of RHA causes an increment in the compressive strength due to the capacity of the pozzolana towards fixing Ca(OH)₂ generated during the reactions of hydration of cement. All the replacements degrees of RHA increased the compressive strength. For a 7% of RHA, 15% of increment in compressive strength is observed.

-According to the results of the splitting tensile test, all the replacement degrees of RHA research, achieved similar results. This may be realized that there is no interference of adding RHA in the splitting tensile strength.

-The rice husk is applicable to concrete for interior concrete walls.

-The wet weather conditions cause deterioration of husks that affect the stability of concrete. Based on their studies about Rice

Husk, K.S. Low and C.K.(1997) and W.T. Tsai et al(2007) have concluded that RHA as pozzolona is an effective admixture for cement and used as additives to reduce corrosion and increase durability of concrete structures.

M.Fang(2004) in his study concluded that the use of RHA contributed not only to the production of concrete of higher quality and lower cost but also reduced carbon-dioxide (CO₂) emissions from the production of cement.The partial replacement of cement by RHA would result in lower energy consumption associated with the production of cement.

Premalal(2002) et al have made comparison of the mechanical properties of rice husk powder and hence concluded that chemical compositions of RHA are affected due to burning process.Silica content in the ash increases with higher temperature.RHA produced by burning rice husk between 600⁰C-700⁰C for 2 hours contains 90-95% SiO₂,1-3% K₂O and <5% unburnt carbon.RHA contains silica in amorphous form and are cellular in nature with 50-1000 m²/g surface area.So use of RHA with cements improves workability and stability, reduces heat evolution, thermal cracking and plastic shrinkage.This increases strength development, impermeability and durability by strengthening transition zone, modifying the pore structure, blocking the large voids in the hydrated cement paste through pozzolanic reaction.RHA minimizes alkali-aggregate reaction, reduces expansion, refines pore structure and hinders diffusion of alkali ions to the surface of aggregate by micro porous structure.

V.M. Srivastava et al (2006) and A.H. Mahvi et al (2004) in their studies concluded that the use of RHA in the production of high performance and high durable concrete has been analysed in several works undertaken by the researchers.The significant findings were as follows:-

-Substantial reduction in mass loss on exposure to hydrochloric solution.

-Considerable reduction in alkali-silica and sulphate solutions.

-Higher frost resistance of non-air entrained RHA concrete compared to similar mixtures of silica.

Also studies have shown that RHA resulting from the burning of rice husk at control temperatures have physical and chemical properties that meet ASTM (American Society for Testing and Materials) Standard C 618-94a.At burning temperatures of 550⁰C-800⁰C, amorphous silica is formed, but at higher temperatures crystalline silica is produced.The silica content is in between 90-96%.Some particular chemical and physical properties shows diffraction analysis, which indicates that the RHA mainly consists of amorphous materials.

T.G. Chuah (2005) in his study of rice husk analysis found that, -Portland cement contains 60-65% 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 Portland cement concrete in acidic environments.Silica present in the RHA combines with Ca(OH)₂ and results in excellent resistance to the material at acidic environment.

-RHA replacing 10% Portland cement resists chloride penetration, improves capillary suction and accelerates chloride diffusivity.

R Sathish Kumar (2012) in his experimental study on the properties of concrete made with alternative construction materials concluded that,

-Compressive strength of Rice Husk Concrete was found to be 70-80% more than that of conventional concrete for areplacement of cement upto 20%

-Early strength of Rice Husk Ash Concrete was found to be less and the strength increased with age.

-Due to lower density of RHA concrete, the self weight of structure gets reduced which results in overall savings.

-The RHA concrete occupies more volume than cement for same weight. So total volume of RHA concrete increased for a particular weight as compared to conventional concrete which results in economy.

-From the cost analysis it was found that cost of RHA concrete was less than conventional Concrete.

Smita Singh and Dilip Kumar (2014) in their studies regarding use of rice husk concluded that,

-At all the cement replacement levels of RHA, there is a gradual increase in compressive strength from 0-7 days. However there is a significant increase in compressive strength from 7-14 days.

-At the initial ages with the increase in percentage replacement of RHA, compressive strength increases.

-By using RHA in concrete as replacement, the emission of green house gases can be decreased to a greater extent. As a result there is greater possibility to gain more number of carbon credits.

-The technical and economic advantages of incorporating RHA in concrete should be exploited by the construction and rice industries, more so for growing nations of Asia.

-Moreover with the use of RHA, weight of concrete reduces, thus making concrete lighter which can be used as light weight construction material.

Khassaf et al (2014) have established the following facts about RHA replacement concrete in lining canals.

-There is a significant reduction in workability in fresh lining concrete with increase in RHA content in concrete.

-The partial replacement of cement by RHA indicated that at long term ages the RHA concrete showed higher compressive strength in comparison with that of concrete without RHA.

-It is convenient to state that there is a substantial increase in tensile strength due to addition of RHA.

-As the percentage of RHA increased, there is decrease in drying shrinkage.

Sheth et al (2014) in their investigation with RHA and Styrofoam (Polymer Materials) in concrete preparation arrived at the following conclusions,

-With the addition of RHA to concrete, there is a significant decrease in water absorption.

-The concrete mixes under consideration produced strength in the range of 17-26 MPa at 7 days which is beyond the minimum requirement for structural lightweight concrete applications.

-The replacement degrees of RHA trials showed an increase in compressive strength to a particular level of replacement, but decreased if replaced to a higher degree.

-The use of smaller size aggregates of styrofoam showed strong compressive strength at the corner of the concrete cubes and remained soft at the faces.

-The highest compressive strength was obtained using minimum RHA content with minimum Styrofoam content of size roughly 10 cubic mm.

III. Conclusion

Rice husk ash is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Rice husk ash is an agricultural waste product which is produced in large quantities globally every year and due to the difficulty involved in its disposal, RHA is becoming an environmental hazard in rice producing countries. India alone produces around 120 million tons of paddy per year, giving around 24 million tons rice husk per year and 6 million tons of rice husk ash per year. As rice husk is piling up everyday, there is a pressure on rice industries to find a solution for its disposal. It is most essential to develop eco-friendly concrete from RHA. RHA can be used in concrete to improve its strength and other durability factors. From the review of above literatures from the various researchers, it can be well concluded that RHA can be used as cement in lightweight structural concrete preparation. Sustainable utilization would preserve conventional materials for future. To opt for green construction, RHA is a right choice, as it doesn't produce environmental pollution and accelerates speed of construction.

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