International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (IJEMHS)
Volume 30, Issue 03, Quarter 03 (July-August-September 2018)
An Indexed and Referred Journal with Impact Factor: 2.75
ISSN (Online): 2347-601X
www.ijemhs.com

Research on Utilization of Rice Husk Ash and Waste Paper Sludge Ash as Partial Replacement of Cement in Concrete

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Publishing Date: July 15, 2018

Abstract

Due to growing environmental awareness, as well as regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial wastes and finding solutions on using their valuable component parts so that those might be used as secondary raw material for other industrial applications. Presently large amounts of RHA are generated in Rural and Small Scale Industries with an important impact on environment and humans. In recent years, many researchers have established that the use of supplementary cementitious materials (SCMs) like fly ash (FA), blast furnace slag, silica fume, metakaolin (MK), and rice husk ash (RHA), hypo sludge etc. can, not only improve the various properties of concrete - both in its fresh and hardened states, but also can contribute to economy in construction costs. RHA, by controlled burn and/or grinding, has been used as a pozzolanic material in cement and concrete. Using it provides several advantages, such as improved strength and durability properties, and environmental benefits related to the disposal of waste materials and to reduced carbon dioxide emissions. Up to now, little research has been done to investigate the use of RHA as supplementary material in cement and concrete production in Vietnam. The main objective of this work is to study the suitability of the rice husk ash as a pozzolanic material for cement replacement in concrete. However it is expected that the use of rice husk ash in concrete improve the strength properties of concrete. Also 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. From the entire experimental work & studies it is concluded that mix M2 (M0+20%RHA) is the best combination among all mixes, which gives max, tensile, flexure & compression strength over normal concrete. Several mixes were created to check application suitability for RHA to determine the product best application. 10% RHA cement replacement gave a very near 28 days compressive and tensile strength values to control concrete specimens. The 20% RHA replacement using dolomite as coarse aggregate attained the minimum limit for structural concrete. Increasing cement replacement ratio slightly decreases the water absorption of RHA specimens. Paper sludge production is a by-product of paper making in the Paper Mill Industries and Rice Husk is a by-product of rice processing. In the present scenario, these by-products are being used in other industrial branches and in the field of civil constructions, such as in cement manufacturing along with clinker and in masonry work for civil works. This research work demonstrates the possibilities of using rice husk ash and waste paper sludge ash together as partial replacements of cement in concrete. This research work presents an investigation of compressive strength, and split tensile strength of concrete by adding rice husk ash and waste paper sludge ash as partial replacement of cement in various percentages. In this project Rice Husk Ash (RHA) and Waste Paper Sludge Ash (WPSA) obtained from uncontrolled combustion are used as an alternative construction material for concrete. In the present investigation, a feasibility study is made to use Rice Husk Ash and Waste Paper Sludge Ash as an admixture to Ordinary Portland Cement in Concrete, and an attempt has been made to investigate the strength parameters of concrete (Compressive and Splitting Strength). For control concrete, IS method of mix design is adopted and considering this a basis, mix design for replacement method has been made. Four different replacement levels namely 5%,10%, 15%and 20% are chosen for the study concern to replacement method. Large range of curing periods starting from 7days and 28days are considered in the present study. Cubes (150×150×150mm) and Cylinders (150ø×300mm) with varying ratios of RHA, WPSA and mix of both will be casted. Total no of cubes casted would be 78 and cylinder would be78. The various tests would be performed to evaluate the action of these materials will be normal consistency, setting time, compressive strength, splitting strength and water absorption. The study would be conducted in the framework of a research project aiming at improving the utilization potential of Rice Husk &Waste paper Sludge Ash.

Keywords: *Rice husk ash, Cement, CO2, Material selection, Environment, Sulphates Concrete, Waste materials, Partial replacement.*

I. Introduction

Concrete is one of the most widely used construction products in the world. It is mixture of cement, fine aggregate, course aggregate and water. Concrete construction does not require highly skilled labour. The durability of concrete depends upon proportioning, mixing and compacting of the ingredients. The cost of construction materials is increasing day by day because of high demand, scarcity of raw materials, and high price of energy. Agricultural waste (rice husk ash) and industrial by – product (silica fume) (waste paper) have been widely used as partial replacement materials or cement replacement materials in concrete works. Any improvement in these properties is likely to aid durability.

Addition of a pozzolanic material to concrete mix may lead a considerable improvement in the quality of the concrete and its durability. A pozzolanic material or pozzolan has been described as a siliceous and aluminous material. At ordinary temperature and with the presence of moisture it chemically reacts with calcium hydroxide (lime) to form compounds possessing cementitious properties. Rice husk ash (RHA) and silica fume (SF) waste paper sludge ash (WPSA)are considered as rich-silica materials or pozzolanic materials used to replace a portion by mass basic of Portland cement in order to modify the physical and engineering properties of cement and concrete.

When these materials blended with cement and in the presence of water, they can react with Calcium Hydroxide ($Ca(OH)_2$) which forms in hydrated Portland cement to produce additional Calcium Silicate Hydrate (C-S-H). With the addition of the these pozzolanic materials, many aspects of concrete properties can be favorably influenced, some by physical effects associated with small particles which have generally a finer particle size distribution than ordinary Portland cement and others by pozzolanic and cementitious reactions resulting in certain desirable physical effects. Concrete mix proportion and rheological behavior of plastic concrete are caused by the physical effects associated with the particle size and morphology of pozzolans. Strength and permeability of hardened concrete are the main effects associated with the pozzolanic and cementitious reactions. Several studies in developing countries, including Guyana, Thailand, Pakistan and Brazil, have shown that rice husk ash (RHA) can be used as a partial replacement for cement in concrete.

The ability to use an agricultural waste product to substitute a percentage of Portland cement would not only reduce the cost of concrete construction in these countries, but would also provide a means of disposing of this ash, which has little alternative uses. Additionally, cement manufacturing is an energy-intensive process, so in addition to reducing the cost of concrete construction and providing a means for disposing of an agricultural waste product, incorporating RHA into concrete as a partial substitute for Portland cement would also stand to reduce the amount of energy associated with concrete construction.

The rapid industrialization has resulted in generation of large quantities of wastes. Most of the wastes do not find any effective use and create environmental and ecological problems apart from occupying large tracts of valuable cultivable land. It has been observed that some of these wastes have high potential and can be gainfully utilized as raw mix / blending component in cement manufacturing. The utilization of the industrial solid wastes in cement manufacture will not only help in solving the environmental pollution problems associated with the disposal of these wastes but also help in conservation of natural resources (such as limestone) which are fast depleting. The other benefits to cement industry include lower cost of cement production and lower greenhouse gas emission per ton of cement production. This may also enable cement industries to take benefits of carbon trading.

II. Review of Literature

Lots of researcher has been done a research on concrete. This paper covers some of the paper based on partial replacement of cemen.

Kartini.K (Nov.2011) studied the effect of partial replacement of OPC cement by RHA from 10% to 30% for M30, M40 and M50 and tested the cubes at 28, 60, 90 and 120 days after curing in water. For the durability performance he conducted the water permeability, water absorption and rapid chloride ion penetration (RCPT).

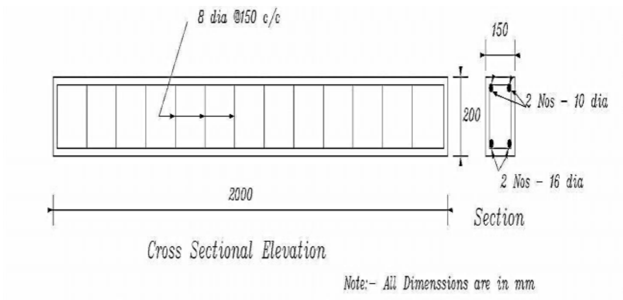
The results showed that:-Increased in the amount of RHA in the mix results indry and unworkable mixtures unless Super plasticizer (Sp) is added. The inclusion of Sp in RHA concrete while maintaining the w/b ratio increased the slump and improved the cohesiveness of the concrete. The optimum replacement of OPC with RHA taken at 28 days strength for Grade 30 and Grade 40 was 30%, while for Grade 50 was 20%. Replacement of OPC with RHA reduced the water permeability of the concrete. The water absorption values of RHA concrete are lower than the OPC control concrete. These results emphasize the beneficial effect of incorporating RHA to increase the durability of concrete, irrespective of their concrete grade. The percentage of water absorption obtained for all the grades are between 3% - 5% which can be considered as average absorption.

Satish Kumar et al (Sept-Oct, 2012) experimental study was carried out to find the suitability of the alternate construction materials such as, rice husk ash, sawdust, recycled aggregate and brickbats as a partial replacement for cement and conventional aggregates. For this concrete cubes of six 150mm x150mm were casted with various alternate construction materials in different mix proportion and with different water cement ratios. Their density, workability and compressive strengths were determined and a comparative analysis was done in terms of their physical properties and also cost savings. Test results indicated that the compressive strength of the OPC/RHA concrete cube blocks increases with age of curing and decreases as the percentage of RHA content increases. It was also found that the other alternate construction materials like saw dust, recycled aggregates and brick bats can be effectively used as a partial replacement for cement and conventional aggregates.

From the results: - The compressive strength of rice husk ash concrete was found to be in the range of 70-80% of conventional concrete for a replacement of cement up to 20%. The rice husk ash concrete occupies more volume than cement for the same weight. So the total volume of the rice husk ash concrete increases for a particular weight as compared to conventional concrete which results in economy. Due to the lower density of RHA concrete the self-weight of structure gets reduced which results in overall savings. The compressive strength of recycled aggregate concrete was found to be in the range of 70 to 80 % of conventional concrete. The compressive strength of brick bat concrete was found to be nearly 35 % of conventional concrete. The compressive strength of saw dust concrete was found to be nearly 10 to 15% of conventional concrete. So the concrete made with alternate construction materials like brick bats and saw dust can be used for partition & filling purposes & nailing purposes where the strength is not the criteria. Wherever compressive strength is not a criteria, the concrete made with alternate construction materials can always be preferred.

Jayanti Rajput et al (May-June2013) have studied on the effect of RHA used as supplementing cementing material on the strength of mortar by partial replacement of OPC. Cement mortar paste were proportioned with varying dosages of RHA as partial replacement of OPC in the range of 5% to 30% by weight of cement. From the test results they concluded that: This paper concluded that if approximately 10% of cement is replaced by equal amount of RHA, there is not any significant depreciation in the compressive strength.

Thandavamoorthy et al (2013) Investigated RHA concrete as a structural material on rectangular concrete beams of size 150 mm × 200 mm × 2000mm in the laboratory by casting with concrete containing 10 per cent RHA and testing the same under monotonic loading up to failure. The capacity of the beam, and its failure and crack pattern were studied. The paper presents the details of the experimental program as well as a comparison of the behaviour of RHA concrete beams with that of the conventional concrete.



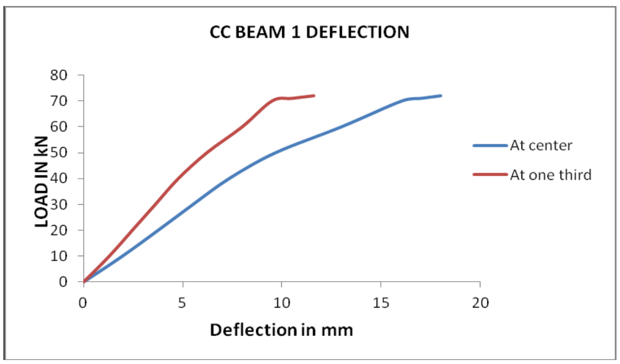


Figure 2.1: Typical Load deflection curve of normal concrete beam

Mix design of concrete for M-20 grade for mild exposure with w/c 0.45 was done acc. to IS 10262. Three rectangular beams of size 150 mm × 200 mm × 2000 mm with 2 nos. of 16 mm diameter rods were cast using control concrete. Another three beams of similar size were cast using RHA concrete. The beam was supported over a distance of 1800 mm between their centers. Load was applied on the beam using a 500 KN hydraulic jack arranged at mid-span. Dial gauges were arranged beneath the beam at mid-span as well at third points to measure the deflection. Load was applied in increment of 10 KN and dial readings were taken for each increment of load.

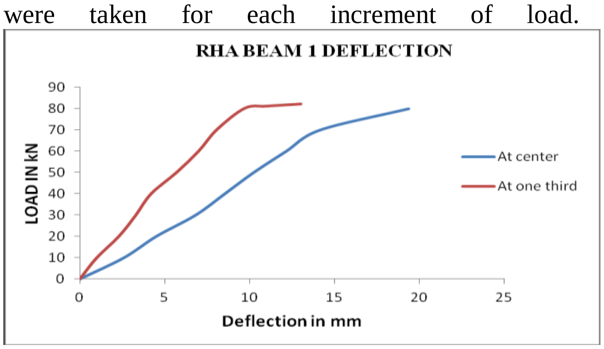


Figure 2.2: Typical Load Deflection of RHA concrete

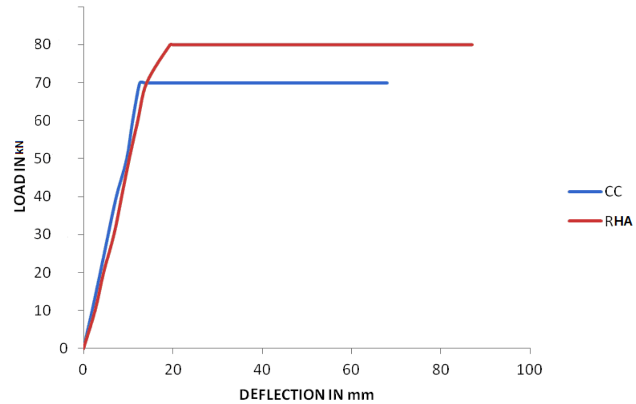


Figure 2.3: Superimposition of Load-deflection relations

Result showed that: - The first crack load observed in the case of conventional concrete beam was 20 KN and that of RHA concrete was 30 KN. This clearly establishes that the RHA concrete is superior in resisting the crack than the conventional concrete. The crack resistance capacity was increased by a factor of 1.5 over the conventional concrete beam. The increase in ultimate load capacity of RHA concrete beam was observed to be 14 per cent over its conventional counterpart. It has been observed that initially conventional concrete beams were marginally stiffer than the RHA concrete beams. At about 75 – 80 per cent of ultimate load the trend reverses and RHA concrete beams becomes stiffer than conventional concrete. This is because nearer the ultimate load cracking becomes extensive and their width increases. As RHA is fibrous it is able to bridge the crack and reduces the width. Thus the stiffness increases. This mechanism is absent in conventional concrete. So it loses its stiffness. The ductile nature of the RHA concrete beam in the service load regime is highly advantageous. This comparison categorically establishes the supremacy of RHA concrete beams over that of the conventional concrete beams. As Rice husk is an organic and fibrous material, its use in concrete improved the ductility of the RHA beams. This clearly establishes that RHA concrete can be used in structural applications with confidence.

Padma Rao et al (2014) have studied the use of RHA in concrete. RHA is a highly pozzolanic material .They studied the behavior of RHA as an admixture to an already replaced cement with fly ash and also studied the strength parameters of

concrete(Compressive and Flexure). According to the arrangement of different percentage of RHA, the cubes were classified into 5 groups. Each group includes one control mix cube and the curing period was form 3 days to 56 days.
The result showed that:- At all the cement replacement levels of Rice husk ash; there is gradual increase in compressive strength. At the initial ages, with the increase in the percentage replacement of both Rice husk ash, the flexural strength of Rice husk ash concrete is found to be decrease gradually till 7.5% replacement. By using this Rice husk ash in concrete as replacement the emission of greenhouse gases can be decreased to a greater extent.

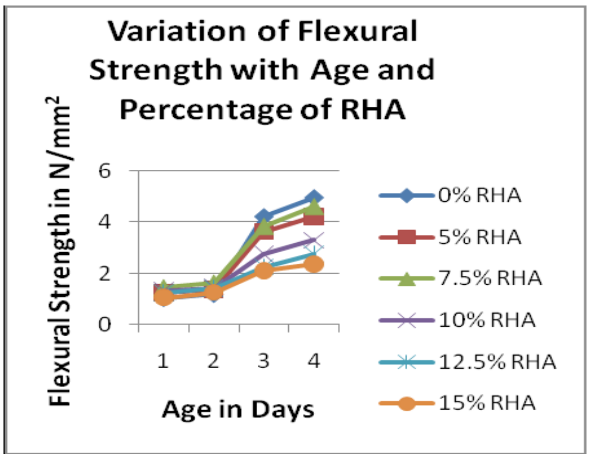


Figure 2.4: Variation of Flexural Strength with Age and Percentage of RHA

Satish Kene et al have studied on assessment of concrete strength using fly ash and RHA. They used proportioning form 30% fly ash and 0% RHA mix together in concrete by replacement of cement. They gradually increase the quantity of RHA by 1% and gradually decrease the quantity of FA by 1%.
From the results: -Compressive strength increases with the increase in the percentage of Fly ash & Rice Husk Ash up to replacement (21%FA and 9% RHA) of Cement in Concrete for different mix proportions. Rate analysis shows that as the percentage of RHA and FA added on the concrete the cost goes decrease up to 29%.RHA when added in the concrete reduces the weight of the concrete up to 15% after 90 days of curing. Rice Husk Ash can be used with admixtures, plasticizers, and super plasticizers, for increasing the strength of concrete with partial replacement of cement.

Jinan Jawad Hassan Alwash His research deals with the effect the effects of using rice husk ash (RHA) as a partial weight of cement replacement materials in cement mortar mixes. This work is based on an experimental study of mortar made with ordinary Portland cement (OPC) and 5%, 10%, 15% and 20% (OPC) replaced by RHA. The rice husk ash used was produced by burning the rice husk at 500° C, then grinding it to a fineness of 11200 cm^2/gm.
Results showed that:-The water demand for standard consistency linearly increases with an increase of cement replacement level by RHA. The addition of RHA to cement paste at all replacement level causes increase in the initial and final setting time. The use of RHA significantly improves the cement mortar strength at the 15% replacement level at the age of 90 days. The use of RHA at the 5% .10% and 15% replacement level decrease the porosity of cement mortar in comparison with controlled mortar samples at ages 7, 28 and 90 days. But at 20% cement replacement level by RHA, the porosity of mortars increased with that of the controlled one in all ages.

III. Methodology

In the present performance studies on concrete with Rice Husk ash as been used as partial replacement of cement as an additional ingredient in concrete mixes. On adding cement with different weight percentage of RHA the compressive strengths are studied at different ages of concrete cured in normal water. The details of experimental investigations are as follows.

Rice Husk Ash

This research is aimed at putting into effective use Rice Hush Ash (RHA) a local additive which has been investigated to be super pozzolanic in a good proportion to reduce the high cost of structural concrete. Rice Husk Ash (RHA) is an agricultural waste product, and how to dispose of it is a problem to waste mangers. While Concrete today has assumed the position of the most widely used building material globally. The most expensive concrete material is the binder (cement) and if such all-important expensive material is partially replaced with more natural, local and affordable material like RHA will not only take care of waste management but will also of concrete and housing. There is an increasing importance to preserve the environment in the present day world. RHA from the parboiling plants is posing serious environmental threat and ways are being thought of to dispose them. This material is actually a super Pozzolana since it is rich in Silica and has about 85% to 90% Silica content.

Important Reactions in RHA

These husks that are removed during the refining of rice have no commercial interest as such. Another relevant factor is its low cost compared to its large applicability, and its growing demand also reduces the disposal and environmental pollution problems. Rice husk contains silica in hydrated amorphous form and cellulose which yields carbon when thermally decomposed. When such a product is further heated at high temperature (> 1400°C) a reaction no occurs between silica and carbon resulting in the formation of SiC. The possible reactions of such a process can be written as

$C(s) + SiO_2(s) = SiO(g) + CO(g)$,

$SiO_2(s) + CO(g) = SiO(g) + CO_2(g)$,

$C(s) + CO_2(g) = 2CO(g)$,

$2C(s) + SiO(g) = SiC(s) + C(g)$ resulting in the overall reaction

Table 3.1: Specifications of Rice Husk Ash

1.	Silica	90% minimum
2.	Humidity	2% maximum
3.	Mean Particle size	25 microns
4.	Colour	Gray
5.	Loss of Ignition	4% maximum

Table 3.2: Compressive Strength Results for Cubes Cured In Water

Sample Designation	% of RHA	compressive strength at 7days (N/mm^2)	compressive strength at 28 days (N/mm^2)	compressive strength at 60days (N/mm^2)
W-0	0	36.89	45.83	55.69
W-05	5	37.72	46.75	56.16

W-10	10	38.79	47.69	58.63
W-15	15	35.86	44.78	56.43
W-20	20	35.78	43.79	55.57

Table 3.3: Split Strength Results Cured In Water

Sample Designation	% of RHA	Split strength at 28 days (N/mm^2)	Split strength at 60days (N/mm^2)
W-0	0	5.20	5.59
W-05	5	6.25	5.16
W-10	10	7.25	7.63
W-15	15	3.80	6.43
W-20	20	3.79	5.57

IV. Conclusion

(1) The specific surface area of RHA is 420 m^2/kg greater than 330 m^2/kg of cement. The workability of RHA concretes have decreased in compared with ordinary concrete. It is inferred that reduction in workability is due to large surface area of RHA.

(2) The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20%, weight replacement of cement with RHA) cured in Normal water for 7, 28, 60, 90 and 180 days have reached the target mean strength.

(3) The compressive strengths of concrete (with 0%, 5%, 10%,15% and 20%, weight replacement of cement with RHA) cured in different concentrations of (1%,3%,5%).

(4) The split strengths of concrete (with 0%, 5%,10%,15% and 20%, weight replacement of cement with RHA) cured in different concentrations.

(5) Due to slow pozzolanic reaction the Rice Husk Ash (RHA) concrete achieves significant improvement in its mechanical properties at later ages.

(6) In concretes cement can be replaced with 20% RHA without sacrificing strength.

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