CURRENT WORLD ENVIRONMENT

ISSN: 0973-4929, Vol. 13, No. (2) 2018, Pg. 224-231

# Current World Environment

Journal Website: www.cwejournal.org

# The Effect of Utilizing Rice Husk Ash on Some Properties of Concrete – A Review

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**Abstract**

World environmental pollution is having direct and visible influence of construction industry. Relatively, 10 quintal of $CO_2$ emitted by the manufacturing of 10 quintal of ordinary portland cement (OPC), which accounts almost seven percent of the global $CO_2$ emissions. Averagely, ten thousand million cubic meter of concrete is produced yearly. Byproducts like rice husk ash (RHA), fly ash, blast-furnace slag, metakaolin and silica fume will be able to utilize as supplementary cementitious material because of their pozzolanic behavior. Rice husk cannot be used as animal's feed due to the low nutritional value. Neither can it be discarded as landfill nor by burning because it arise a great environment challenge. By converting rice husk into rice husk ash (RHA), it can be used in concrete as a fractional substitution of cement because of high silica quantity in RHA. In this present paper, the result of some authors with the use RHA as a fractional substitution of cement on the properties of concrete like workability, permeability, compressive and tensile strength are reviewed.

**Article History**

Received: 04 April 2018
Accepted: 26 June 2018

**Keywords**

Pozzolanic Material,
Rice Husk Ash,
Cement Concrete.

## Introduction

The major environmental issues emerge these days are change in the climate, drain of the resources and so on. The climatic changes are increasing air contamination such as smog, depletion of ozone layer, greenhouse effect etc., which is a fundamental concern for researchers nowadays. The utilization of cement for urbanization and industrialization is significant cause for the air contamination because 10 quintal of $CO_2$ emitted from the manufacturing of 10 quintal of cement, which contributes to 5–7% of $CO_2$ emissions in global warming[1-3]. Several industrial and agricultural by-products such as blast furnace slag, rice husk ash (RHA), fly ash, condensed silica fume (SF), wood waste ash, coconut shell & fibers etc. might be adopted as an add-on cementitious substantial in order to reduce $CO_2$ emissions[4-9].

Rough rice consist of 20–25% husk by mass i.e. approximately, 40 kg of rice husk is obtained from 200 kg of rice[10-11]. In Asia, roughly 90% of the world's rice has been produced and consumed out

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Doi: http://dx.doi.org/10.12944/CWE.13.2.07

of which India is one of the major rice producing country. Main problems tackled by these countries are in the disposal of husk because it cannot be utilized as animal's feed due to the low nutritional value. Also, neither can it be discarded as landfill nor by burning because it arise a great environment challenge. Therefore, rice husk is generally utilized as a fuel in the boilers for processing paddy either by gasification or by direct combustion which create pollution[12-16]. Rice husk ash (RHA) is a pozzolanic material consists of more than 75% by weight as silica[17]. It was found that by burning at a temperature lesser than 800 $^0$C, rice husk ash formed consist of nearly 90% silica, however crystalline silica is obtained beyond this temperature[18-22]. It was also observed by Nair et al. that by burning for more than 12 hours, at 500–700 $^0$C produced remarkably reactivity rice husk ash, whereas high carbon content rice husk ash was obtained for short period of burning i.e. for 15–360 min[23]. Size, fineness of the particle, surface area, silica crystallization phase, silica content, time required for chilling process, temperature of burning process etc. are the key factors the pozzolanic behavior of RHA and the fineness of RHA falls between that of silica fumes and cement[24]. It was found from the study that the mechanical strength of the mortar increases with 10% by weight RHA replacement with cement[25,26]. From the previous study, it was concluded that fractional substitution of cement by RHA reduces the heat of hydration, improves the strength which is making concrete more economical and also environmental friendly.

In the present review paper, the results and discussion of some researchers on using rice husk ash (RHA) as additional cementitious material on the properties of concrete like compressive strength, workability, permeability and tensile strength are reviewed.

**Properties of Rice Husk Ash**

The color of rice husk ash depends upon the source of raw material, process, time, duration and temperature of burning and varies from whitish grey to black. According to the code IS 456, RHA is categorized as N type pozzolana[27]. Table 1 enlists the chemical properties and table 2 depicts the physical properties of RHA respectively.

Table1. enlists the components of RHA and cement. It is well known fact that the main binding component of cement is CaO, which is also a constituent of RHA although lower in percentage that cement. It can be observed from the table that all other components are nearly similar in both RHA and cement. Therefore, RHA can also be used a fractional substution of cement in concrete.

**Table 1: Chemical Properties of RHA by weight % age 19,28-33 are:**

| Component | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $Na_2O$ | $K_2O$ | LOI* |
|---|---|---|---|---|---|---|---|---|---|
| RHA | 86.8 -95.1 | 0.2 - 0.5 | 0.1 -0.9 | 0.5 -2.9 | 0.3 -0.9 | 0.0 -1.2 | 0.1 -1.0 | 0.5 -3.1 | 0.5 -8.5 |
| Cement | 21.8-22.0 | 4.7-5.5 | 2.3-3.4 | 60.5 - 61.6 | 2.6 - 4.3 | 2.0 - 2.2 | 0.1 - 0.4 | 0.7 - 1.1 | 0.5 - 2.3 |

[*LOI – Loss on Ignition]

**Table 2: Physical Properties of rice husk ash given by various authors 33-40 are:**

| Property | Specific gravity | Specific surface area ($m^2$/kg) | Pozzolanic activity Index(%) | Bulk density (Kg/$m^3$) | Median particle size(μm) | Nitrogen adsorption ($m^2$/kg) | Surface area, ($cm^2$/g) |
|---|---|---|---|---|---|---|---|
| RHA | 2.1 - 2.2 | 240.0 - 376.8 | 81.3 - 88.9 | 420.0 - 429.1 | 5.0 - 7.4 | 24.3 - 28.8 | 4091 - 5685 |
| Cement | 3.1 - 3.3 | 3310 | - | 830 - 1650 | 4.6 – 10.5 | - | - |

## Properties of Concrete Containing RHA

### Workability

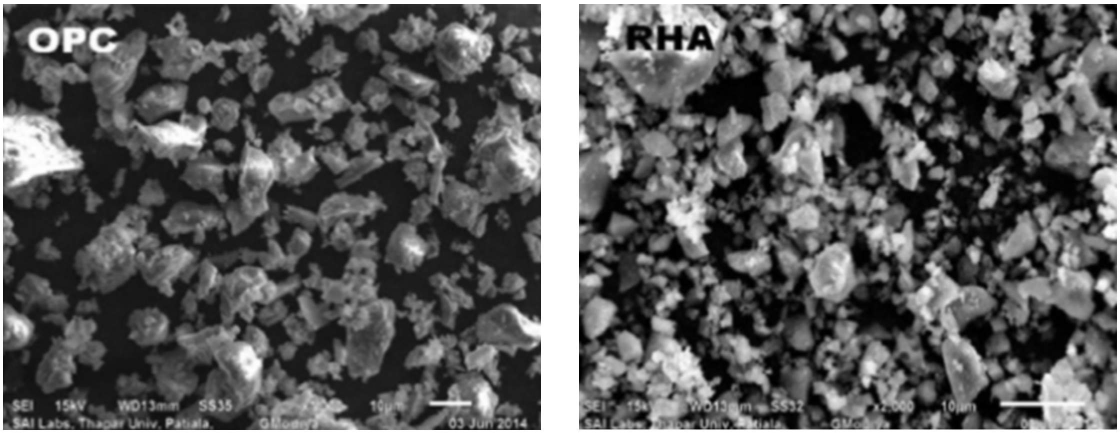
The effortlessness with which concrete can be mixed, transported and placed is known as workability. As a permeable material, fractional substitution of RHA in cement diminishes the workability of fresh concrete. Although, the workability can be improve by the use of high-quality superplasticizer. Salas *et al.,* determined that with 15 or 20% RHA, the mix becomes stiffer therefore extra super plasticizer has been required to keep up the vital workability[41]. Suaiam and Makul stated that by replacing RHA up to 25% gives the adequate results whereas if fine aggregates are partially replaced by the large quantity of RHA, workability is going to decrease[42]. Le *et al.,* find out the consequence of various percentage of RHA on high performance fine grained concrete and found that as the RHA content amplify workability decline because of huge specific surface area of RHA[43]. Due to huge surface area and carbon content in RHA, a large quantity of water reducing admixture to be used for maintaining the constant workability than that of the controlled concrete[43]. The workability of concrete containing two different RHAs, one controlled combustion rice husk ash from USA while the other uncontrolled combustion rice husk ash from Uruguay were explored and it was found that uncontrolled combustion rice husk ash concrete require less superplasticizer as compared controlled combustion rice husk ash concrete due to low unconsumed carbon content[44].

Safiuddin *et al.,* studied that the concrete made with super plasticizer (3.5 to 4.5%), RHA (5 to 30%) and water cement ratio (0.30 to 0.40) exhibited 265–280 mm slump which is same as of 0% RHA concrete, however the deformability of concrete enhanced significantly[17]. Sensale performed slump test and found that normal concrete exhibit medium workability (52mm), whereas for RHA concrete possesses low workability (45-48mm). Nagrale *et al.,* stated that with increase in RHA in concrete the water required for workable mix increases due to increase of the fineness material in the concrete[45]. It was revealed from the literature that specific surface area, void size scattering, and water demand of RHA were the key factor controlling the flowability of mortar[46]. Moulick stated the reason for the low slump that with the increase in the RHA quantity by weight increase the concrete volume, as density of cement higher that the RHA i.e. 3.11g/cm$^3$ as compare to 2.1 g/cm$^3$ in RHA[47].

### Compressive Strength

From the previous study it had been found that the strength increases with partial substitution RHA in concrete[29,48,49]. Most suitable RHA replacement varies from 5% to 30% by weight of cement. Specific surface area and bulk density of RHA are the important parameters affecting cement properties. As the specific surface area increase, it displays a remarkable pozzolanicity by consuming calcium hydroxide present in concrete, whereas the bulk density escalates the mechanical strength due to less void fraction. Replacing cement with 10% RHA increase the compressive strength irrespectively to ages due to high pozzolanicity and silica content[23,30,50]. Lung *et al.,* examined RHA and normal concrete properties and concluded that at 7, 14 and 28 days strength are 47MPa,52 MPa, 61MPa and 50MPa, 54MPa, 56 MPa respectively[30]. Muthadhi *et al.,* and Ganesan *et al.,* detected that the existence of amorphous silica and fine particle size of RHA, 20%RHA concrete exhibits the maximum compressive strength[48,49]. Figure 1 depicts the SEM of ordinary Portland cement and rice husk ash[32].

Gastaldini *et al.,* and Chindaprasirt *et al.,* revealed that concrete with 20% RHA, 1% $K_2SO_4$ (chemical activator) and ratio of water to cement are 0.35, 0.50, 0.65 % respectively had exhibited 9%, 33% and 43% additional strength then conventional concrete after 91 days of curing[21,51]. Salas *et al.,* observed that compressive strength increase significantly by replacing 5–10% cement with RHA[41]. Suaiam and Makul detected diminution in the compressive strength with each replacement of fine aggregates with 0–100% RHA[42]. Siddique *et al.,* found 10.2%, 11.8% and 14.7% upsurge in the strength of RHA and (Bacillus aerius strain) bacteria concrete than normal concrete at 7, 28 and 56 days respectively because of the calcite generation in the voids of cement sand[22]. Kulkarni *et al.,* found that by varying RHA percentage from 0 to 30 % there was slight increase in the strength (0.75%-4%) at 7$^{th}$ day, whereas there was significant increase in the strength (7.5%-15.5%) except 30% RHA replacement gave same result as normal concrete at 28$^{th}$ day[52].




(a) (b)

**Fig 1: SEM image of (a) OPC and (b) RHA**

### Tensile Strength

Tensile strength is the resistance of a material to fail under tension. As the compressive strength increase with curing period, so do tensile strength. Alex J *et al.,* examined the split tensile strength of partially replaced RHA concrete to the conventional concrete by considering aspects such as bulk density, specific surface area, practical size, RHA percentage added and discovered that conventional concrete lacks in most levels of replacement to RHA composite concrete, apart from the 7-day strengths of samples with 15 and 20 wt% replacement[50]. Salas and group observed that RHA concrete exhibit remarkable results of flexural tensile strength than conventional concrete[41]. Another study was conducted by Saraswathy and Song with 15%, 20%, 25% and 30% RHA replacement in concrete on cylindrical samples and observed that split tensile strength of various percentages RHA concrete were 4.92, 4.60, 4.58 and 3.67 N/mm$^2$ respectively which is much greater than the normal concrete, but suffered a great fall with 30% RHA substitution[53]. Madandoust et al. observed that concrete with 20% RHA replacement had a splitting tensile strength 21% less than the normal concrete at 3 days that amplified to 4% higher after 1 year[25]. The failure component of RHA concrete were investigated by Giaccio *et al.,* and Akinwonmi *et al.,* which revealed that cracks develop under the stresses are higher than the control concrete due to the presence of RHA in concrete[39,54]. This can be attributed to the fact that with the increase in the percentage of RHA, the concrete become lighter and stiffer as compared to control concrete hence show more cracks[54].

### Permeability

The resistance from chloride is a significant factor for the concrete toughness because chlorides will initiate and accelerate the corrosion process of reinforcement in concrete. Madandoust *et al.,* observed that a pozzolanic material enhances the protection from chloride entrance and diminishes the corrosion start time of steel reinforcement[25]. Le *et al.,* stated that by increasing RHA percentage diminishes permeability of concrete and the lowest permeability value was obtained with 20 % RHA replacement[11]. Sensale studied that with 15% RHA replacement in concrete, tolerance to chloride ion infiltration was the best because of voids refining ability of RHA[44]. Ganesan *et al.,* concluded from his trial that upto 30% RHA replacement the total charge passing through concrete containing RHA consistently decreases[48]. Another researcher Ramasamy studied that with the use of RHA in concrete, chloride ion diffusion increases but yet remain in the “very low category”. The minimum charge passed was obtained in 15% RHA motar because voids ratio reductions which led to low permeability[55]. Hesami *et al.,* conducted a test with varying w/c ratio (0.27, 0.33 and 0.44) on pervious concrete pavement and found that permeability vary with w/c ratio ($0.33 < 0.27 < 0.44$) and ranges between 0.08-0.48 cm/s which is very high to be used as a drain layer[56].

**Industrial and Practical use of RHA**

RHA has been used in various industries of cement, steel, rubber, cosmetic, food etc. Presence of Silica and calcium oxide content govern the suitability of RHA for various applications. Rice husk ash was found to be better supplementary material than silica fumes, fly ash, furnace slag etc. for industrial use. In steel industry, RHA has been used as an excellent insulator due to its low thermal conductivity, low bulk density etc. RHA is also used for coating molten metal because it does not allow rapid cooling of metal. In cement industry, upto 10% RHA replacement with cement showed remarkable results in the strength for the mixture. Due to high presence of silica in RHA, extraction of silica is quiet economical. This silica can be used as reinforcing agent in rubber industry, it can also be used as cleaning agent in cosmetic industry and anti cracking agent in food industry[57,58]. RHA mixed with cement/lime can be used as a stabilizing agent for soil as it improve the index properties and particle size distribution of soil[59,60].

**Conclusion**

As per the literature review, the following closures are initiated:

- As the percentage of rice husk ash (RHA) increases in the mix, there is considerable decrease in the workability due to which good superplasticizer is mandatory to achieve the required workability.
- The compressive and tensile strength of the mix increase with the addition in the RHA percentage, whereas 20% RHA replacement could be considered optimal.
- As RHA percentage increases in the concrete, chloride ion penetration and permeability decreases because of voids refining ability of RHA.
- With the use of RHA in concrete, problems like resources depletion, solid waste disposal and$CO_2$ emission can be decrease to a greater extent due to $CO_2$ emission from rice husk burning is 10% which is little as compare to $CO_2$ emission from cement manufacturing[61].
- The above facts concluded that rice husk ash (RHA) is a great substitution component which can be used in concrete yet further investigation for the utilization of rice husk ash (RHA) in pervious concrete can be carried out.

**Acknowledgement**

This review was carried out and supported by the authors of this paper. Authors are thankful to PAU, Ludhiana resources and one of the author D S Aulakh would like to thank colleagues and staff of CGCTC, Mohali & Mandeep Kaur for their consistent support and valuable suggestions during the work.

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