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A REVIEW ON UTILIZATION OF RICE HUSK ASH IN CONCRETE

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Abstract

Rice husk ash (RHA), a by-product of rice processing, is produced in large quantities globally every year and due to the difficulty involved in its disposal, can lead to RHA becoming an environmental hazard in rice producing countries, potentially adding to air and water pollution. Therefore it is necessary to find out the alternative for consumption or disposal of the RHA. Utilization RHA in concrete is an effective way to solve the environmental and disposal problem of the ash. Due to its pozzolanic properties it can be use as supplementary cementitious material in concrete. This ability to use RHA to substitute a percentage of Portland cement would not only reduce the cost of concrete construction, but would also provide a means of disposing of this ash, which has little alternative uses. RHA in concrete as a partial replacement for the energy intensive Portland cement would also stand to reduce the amount of energy associated with concrete construction. Therefore, RHA has great a potential in concrete for its sustainable use.

Key Words: Compressive strength, Concrete, Ordinary Portland cement, Pozzolanic reaction, Rice husk ash (RHA)

INTRODUCTION

Rice husk ash is produced by incinerating the husks of rice paddy. Rice husk is a by-product of rice milling industry. During milling of paddy about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight of paddy is received as husk. This husk contains about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). For every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and/or by gasification. About 20 million tons of RHA is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. RHA contains around 85% - 90% amorphous silica, it exhibits pozzolanic properties (Mehta 1992). Utilization RHA by exploiting its inherent pozzolanic properties is an effective way to solve the environmental and disposal problem of the ash. Due to its pozzolanic properties it reacts with the calcium hydroxide, which is produced during cement hydration. Silica in RHA combines with calcium hydroxide to produce additional cementing compound calcium-silicate-hydrate which holds the concrete and increase the strength of concrete. . RHA in concrete as a partial replacement for the energy intensive Portland cement results the substantial energy and cost savings. The present paper reviewed the properties and different application of RHA in concrete.

PHYSICAL PROPERTIES OF RHA

The physical properties of RHA largely depend on burning conditions. Particularly, the period and temperature of burning affect the microstructure and characteristics of RHA (Nagataki 1994). The partial burning of rice husks produces black RHA whereas the complete burning results in either white or grey RHA (Ismail and Waliuddin 1996). Hwang & Chandra (1997) suggested that burning rice husk at temperatures below 700°C provides amorphous silica which has a high surface area as shown in Table 1. James and Rao (1986) have also reported changes in surface area with temperature and its duration. They state that at 500°C, the surface area reached a maximum value of 170m^{2}g. Within 500-600°C, the surface area decreased but actual values remained quite high (100-150m^2/g).

Table 1: Rice husk ash properties produced from different burning conditions
(Hwang & Chandra 1997)

Burning temperature	**Hold time**	**Furnace environment**	**Properties of rice husk ash**	
			Silica form	**Surface area (m^2/g)**
500-600° C	1 min	Moderately oxidizing	Amorphous	122
	30 min			97
	2 hr			76
700-800° C	15 min-1hr			100
	>1hr	Highly oxidizing	Partially crystalline	6-10
>800° C	>1hr		Crystalline	<5

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The burning condition also affects the relative density of RHA. The relative density of grey RHA obtained from complete burning is generally 2.05 to 2.11 (Ismail and Waliuddin 1996). The RHA particles are mostly in the size range of 4 to 75 µm (Mehta 2002). The majority of the particles pass 45-µm sieve. The median particle diameter typically ranges from 6 to 38 µm (Mehta 2002), which is larger than that of silica fume. However, unlike silica fume, the RHA particles are porous and possess a honeycomb microstructure (Zhang and Malhotra 1996). Therefore, the specific surface area of RHA is extremely high. The specific surface area of silica fume is typically $20 m^2/g$, whereas that of non-crystalline RHA can be in the range of 50 to 100 m^2/g (Mehta 1992).

CHEMICAL COMPOSITION OF RHA

Rice husk ash contains a high amount of amorphous silica, which originally comes from the surfaces of the husk (Jauberthie *et al* 2000) after burning in moderately oxidizing environment at controlled temperature (500^0C to 800^0C) for a suitable time length generally ranging from 15 minutes to 1 hour (Nagataki 1994). The silica content (SiO_2) of RHA ranges between 90 to 95%, which is similar to that of silica fume (Zhang *et al* 1996). The characteristics of rice husk ash vary depending on burning conditions and rice husk sources. Different chemical composition of RHA is given in Table 2.

Table 2: Chemical compositions of rice husk ash (Mehta 2002)

Component	Mass content (%)		
	Mehta (2002)	**Chatveera & Lertwattanaruk (2009)**	**Prasara (2004)**
Silicon dioxide (SiO_2)	94.37	92.5	93.41
Aluminum oxide (Al_2O_3)	0.06	1.20	0.08
Ferric oxide (Fe_2O_3)	0.04	2.10	0.31
Calcium oxide (CaO)	0.48	0.90	1.17
Magnesium oxide (MgO)	0.13	0.40	0.38
Sodium oxide (Na_2O)	0.08	0.00	0.00
Potassium oxide (K_2O)	1.97	2	-
Sulfur trioxide (SO_3)	0.01	0.10	0.17
Igneous loss	1.18	0.90	2.35

RHA IN CONCRETE

Numerous studies have been conducted on rice husk ash concrete in the last century. In his review of the work done as of 1984, Cook (1986) mentions two German patents, first reported in 1924, as being the earliest description of using of rice in concrete, although it is unclear in what form the rice was used. These patents were followed by the works of McDaniel (1946) and Hough (1955), which investigated the production and behavior of Portland cement and RHA concrete blocks in the United States. Starting in the 1970s, Mehta (1977) made significant contributions to the field of knowledge of rice husk ash concrete. Since then much work has been done to determine how to best utilize RHA as an admixture in concrete along with Portland cement, trying to determine the optimal combustion process for creating the ash, the optimal particle size, water/binder ratio, etc. Mehta (1977) has conducted investigations on Portland Rice Husk Ash cements up to 50% of Ash showed higher compressive strength than the control Portland cement even at as early as 3 days. Zhang and Malhotra (1996) investigated the influence of 10% RHA inclusion as partial replacement of ordinary Portland cement (OPC) on the compressive strength of concrete and compared it with the compressive strength of concrete containing 10% silica fume (SF). At 28 days, the RHA concrete had a compressive strength of 38.6 MPa compared with 36.4 MPa for the control concrete (100% OPC) and 44.4 MPa for SF concrete. Waswa-Sabuni *et al* (2002) examined the engineering properties of binder resulting from a mixture of OPC with RHA and established that the compressive strength of OPC/RHA concrete cubes increases with increased amount of RHA. Ramy *et al* (2003) studied the effects of using rice husk ash (RHA), as a cement replacement material, on compressive strength of cementitious materials in a controlled experimental program. It was found that the incorporation of RHA in OPC mixes led to a notable increase in the compressive strength.

The improvement in the compressive strength of cementitious material that is produced as a result of incorporating RHA in OPC is due to the pozzolanic reaction occurring between RHA and $Ca(OH)_2$. In the presence of water, the RHA actively reacts with $Ca(OH)_2$ liberated during cement hydration (pozzolanic reaction) and produces additional calcium silicate hydrate (CSH), as shown in Equation 1 and 2.

Hydration reaction: C_2S or $C_3S + H_2O \rightarrow$ primary CSH + $Ca(OH)_2$………………1

Pozzolanic reaction: $Ca(OH)_2$ + RHA (SiO_2) + $H_2O \rightarrow$ secondary CSH…………...2

The pozzolanic reaction product fills the pores existing between cement grains and results in dense calcium silicate hydrate, as shown in Figure 1. The secondary reaction between RHA and $Ca(OH)_2$ makes the microstructure of concrete denser and improves the interfacial bond between aggregates and binder paste. As a result, the strength, transport properties and durability of concrete are improved.

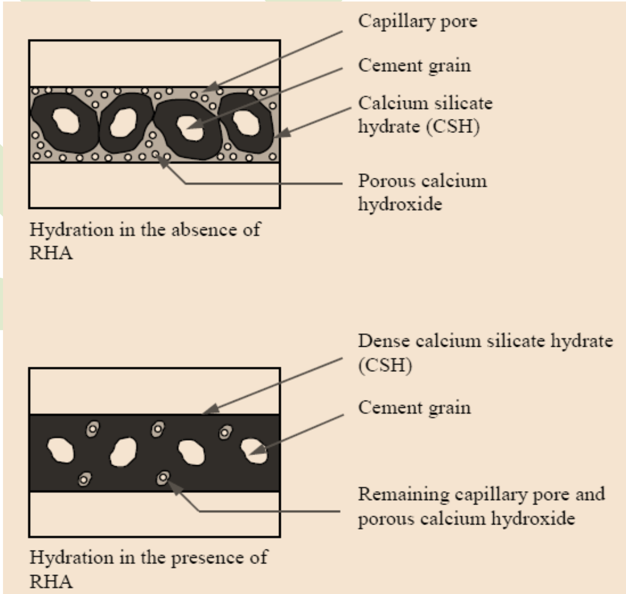

Figure 1: Pozzolanic effect of RHA

RHA IN CEMENT MANUFACTURING

Because rice husk can be a good source of energy and obviously the silica in its ash is beneficial in cement and concrete products, some research has attempted to make a good use of these two useful features of rice husk. Barkakati *et al* (1994) successfully used rice husk as raw material and fuel in cement manufacture. The rice husk was burned under set conditions to obtain the ash (to be used as a raw material) before being mixed with other raw materials to produce clinker by incineration (the husk was also used in this process to produce heat in clinker production). The cement produced from their process was of a similar standard as the ordinary Portland cement. Ajiwe et al (2000) successfully produced white Portland cement using rice husk as a raw material in the process of production (with the same standard as commercial white Portland cement). 24.5% rice husk ash was mixed with other raw materials (sourced locally) for producing white Portland cement and the cement produced was used to make a concrete slab. The formulated cement slab, commercial cement and slab were tested for their physical characteristics and chemical composition. They confirmed that produced cement was of similar standard to commercial cement. Rice husk has also been used as a fuel in cement manufacturing to substitute for fossil fuels. Murray and Price (2008) reported that the use of biomass (including rice husk) as a substitute fuel for fossil fuel in cement kilns had been widely used in countries like India, Malaysia and Thailand.

RHA IN CONCRETE BLOCKS

Apart from using high quality rice husk ash with amorphous silica in high strength concrete, rice husk ash can also be used to substitute cement in low cost building blocks. Rahman (1988) found no reduction in strength up to 40% replacement by RHA in the manufacture of sandcrete blocks Nair et al (2006) reported that rice husk ash can be successfully used to make low cost building blocks by mixing it with lime and/or cement and aggregates. This type of block normally contains a higher ratio of rice husk ash compared with the high strength concrete block. However, the concrete block that contains rice husk ash provides a lower strength than normal concrete block containing only Portland cement (without any rice husk ash substitution). Because in rural areas Portland cement is too expensive, the idea of using rice husk ash which is locally available to substitute for cement is believed to make affordable low strength building block with similar standard to the conventional masonry used in rural areas.

CONCLUSION

From the above review, it was found that utilization RHA in concrete is an effective way to solve the environmental and disposal problem of the ash. Due to its pozzolanic properties it reacts with the calcium hydroxide, which is produced during cement hydration. Silica in RHA combines with calcium hydroxide to produce additional cementing compound calcium-silicate-hydrate which holds the concrete and increase the strength of concrete. RHA can use as raw material and fuel in cement manufacture. RHA can also be used to substitute cement in low cost building blocks. RHA in concrete as a partial replacement for the energy intensive Portland cement results the substantial energy and cost savings.

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