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Use of Rice Husk Ash in Concrete: A Review

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Abstract : *Conventional building material like cement is both resource and energy-intensive material. Production of cement also emits CO_2 in atmosphere. In order to decrease this environmental pollution and cost of conventional building materials, alternative materials like fly ash, ground granulated blast-furnace slag, metakaolin, rice husk ash (RHA) and silica fume is used because of their pozzolanic behavior. RHA which contains high silica content produced by controlled incineration of rice husk can be used as supplementary cementitious material (SCM) in concrete production since it exhibits high pozzolanic characteristics and contributes to strength and impermeability of concrete. This paper presents an overview of the work carried out on the use of RHA as partial replacement of cement in concrete and its effect on workability, compressive strength and chloride permeability of concrete.*

Keywords - *Chloride Permeability, Concrete, Compressive Strength, Workability, Rice Husk Ash.*

I. Introduction

The construction industry has a direct and visible influence on world resources, energy consumption and on carbon dioxide emissions. Portland cement is both resource and energy-intensive material. The cement industry contributes to about 5% to global anthropogenic CO_2 emission making the cement industry an important sector of CO_2 emission mitigation strategies (Ernst Worrell et al. 2001)

Rice hulls (rice husks) are the coatings of seeds, or grains, of rice. To protect the seed during the growing season, the hull is formed from hard materials, including opaline silica and lignin. The hull is mostly indigestible to humans. When the rice husk is properly brunt it has high SiO_2 content and can be used as SCM in combination with cement to make concrete products. In 1978, Mehta obtained a patent for the production of RHA, which could be used as pozzolan. RHA contains a high amount of SiO_2, most of which is in amorphous form (Gambhir 1995; Mehta 1986). It is estimated that 1,000 kg of rice grain produced 200 kg of rice husk, after rice husk was burnt, about 20% of the rice husk or 40 kg would become RHA (Mehta 1986). India was the second largest rice producing country with 159.2 million tonnes of production in 2013 (FAOSTAT, 2014). In India where there is an abundance of rice husk, rice husk ash can be effectively used as a building material.

It is an active pozzolana and has several applications in the cement and concrete industry. RHA can be used as an economical substitute for silica fume as SCM having almost the same properties as that of microsilica. Therefore the use of less-expensive RHA is more desirable to decrease the overall production cost of concrete, reduce the cement requirement leading to less environmental pollution by cement factories thus providing economic and environmental benefits along with providing a way of disposing this agricultural waste product which otherwise has little alternative use.

This paper reviews the experimental studies carried on RHA as partial replacement of cement in concrete and its effect on properties of concrete.

II. Chemical properties of RHA

The chemical compositions of RHA from previous experimental studies by various authors are given in Table 1.

Table 1: Chemical properties of RHA (Wt. %)

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI*
H. Thanh Le et. Al (2014)	86.81	0.50	0.87	1.04	0.85	----	0.69	3.16	4.60
H. Chao-Lung et al.(2011)	91.00	0.35	0.41	----	0.81	1.21	0.08	3.21	8.50
R. Zerbino et al. (2011)	95.04	0.30	0.44	1.25	0.45	0.01	0.09	1.40	0.51
R. Madandoust et al. (2011)	90.90	0.83	0.60	0.80	0.56	----	1.55		----
V.-T.-A Van et al. (2014)	87.40	0.40	0.30	0.90	0.60	0.40	0.04		3.39
K. Ganesan et al. (2008)	87.32	0.22	0.28	0.48	0.28	----	1.02	3.14	4.60

(*LOI- Loss on Ignition)

III. Workability

RHA being a porous material, the partial replacement of cement by RHA reduces the workability of fresh concrete mix. However the workability of the mix can be improved using good superplasticizer. According to H. Thanh Le et al. (2014) from their experimental study on high performance fine grained concrete by varying percentage of RHA as partial replacement of cement have concluded that as RHA content increased, workability of the concrete mix decreased since RHA is a porous material with macro and meso-pores of the particles resulting in large specific surface area (SSA). Rossella M. Ferraro et al. (2010) used a high-range water reducing admixture to maintain a constant workability of the concrete since, the concretes containing RHA required higher water content than those containing only Portland cement. This is due to the high specific surface area and high carbon content of RHA. Therefore, the superplasticizer content of RHA concrete mixtures is higher than that of the control mixture. The superplasticizer content increases along with the RHA percentage. Rodriguez de Sensale (2010) has investigated the durability aspects of concrete containing two different RHAs; amorphous RHA produced by controlled combustion (CRHA) from USA and partially crystalline RHA optimized by dry milling not produced by controlled burning (RRHA) from Uruguay. The test results showed that CRHA concrete requires more superplasticizer that RRHA concrete; this is because CRHA presents greater loss on ignition that RRHA and therefore higher un-burnt carbon content. Un-burnt carbon has very large surface area, and water demand is higher, so CRHA needs higher superplasticizer dosage for a given level of workability.

IV. Compressive Strength

The experimental investigations in previous studies showed that incorporating RHA as partial replacement of cement improves the compressive strength of concrete. The replacement percentages varied from 5% to 30% by weight of cement. However, the optimum replacement level of cement by RHA to give maximum strength varied in different studies. H. Thanh Le et al. (2014) reported that addition of RHA has increased the compressive strength regardless of ages. The optimum replacement percentage for maximum compressive strength was 10%. They suggested that the positive effect of RHA on compressive strength will be due to the high pozzolanity of RHA resulting from the large SSA and the high silica content. RHA reacts intensively with the water and the calcium hydroxide generated from the hydration of cement to produce additional C–S–H. The additional C–S–H itself is the main strength-contributing compound, and also fills in the capillary pores to improve the microstructure of the paste matrix and transition zone in concrete resulting in enhancement of compressive strength. RHA is however assumed to improve compressive strength due to the internal water curing and the lower effective w/b ratio of concrete. The experimental study carried by A. Muthadhi et al. (2013) showed that the maximum compressive strength is found at 20% RHA level for all investigated mixtures. RHA improves compressive strength development in two ways apart from its pozzolanic activity; it accelerates the hydration process in the wet phase by providing more nucleation sites for the process to occur, while its pore-filling effect improves the packing characteristics of solid particles within the concrete matrix during later ages. Ganesan et al. (2007) concluded that concrete containing 20% of RHA showed maximum compressive strength. The principle reasons for the excellent pozzolanic activity and increase in compressive strength are amorphous silica and the fine particle size of RHA. Rodriguez de Sensale (2006) reported that the RHA concrete had higher compressive strength at 91 days in comparison with that of the concrete without RHA. The increase in compressive strength of RHA concretes were mainly due to the filler effect (physical) and by the pozzolanic effect (chemical/physical). H. Chao-Lung et al. (2011) also reported increase in compressive strength for 10% replacement of cement by RHA.

V. Chloride Permeability

The resistance to chloride penetration in concrete is an important aspect in terms of durability of concrete. For concrete exposed in marine atmosphere the ingress and build up of chlorides in the vicinity of the reinforcing bar in concrete could initiate and accelerate the corrosion process. It is generally accepted that incorporation of a pozzolan improves the resistance to chloride penetration and reduces chloride induced corrosion initiation period of steel reinforcement (R. Madandoust et al. 2011). H. Thanh Le et al.(2014) concluded that increasing RHA replacement percentage decreases charge passed. The lowest value of charge passed in his study was obtained for 20 % RHA sample as 261 coulombs. The authors stated that RHA incorporation refines the cement matrix and reduces the amount of large calcium hydroxide due to additional C–S–H phases generated from the pozzolanic reaction reducing the permeability of concrete. Rodriguez de Sensale (2010) has investigated the durability aspects of concrete containing two different RHAs and has reported that the Cl^- depth of penetration and the diffusion coefficient in concretes with water/cementitious materials ratio of 0.50 decreases with both RHAs. In his study the best resistance to chloride ion penetration is obtained with 15% substitution of Portland cement by RHA, mainly due to the pore-refining capacity of RHA in concrete. Also, A. Muthadi et al. (2013) showed that the addition of RHA reduced the chloride permeability of concrete due to pore refining effect. R. Madandoust et al. (2011) concluded that that blending of Portland cement with RHA is beneficial from the standpoint of the prevention of diffusion of Cl^-. This blending leads to lower porosity and finer pore structures, thereby inhibiting penetration of chlorides. Cook (1986) has reported that highly reactive pozzolana, such as rice husk ash is able to reduce the size of voids in hydrated cement pastes, thus, making them almost impermeable even at early age (7–28 days). K. Ganesan et al (2008) showed from his experimental study that the total coulombs charge passing through RHA blended concrete specimens continuously decreases with increase in RHA content up to 30%. The pore-refining capacity of RHA in concrete has been assumed to improve resistance to chloride penetration.

VI. Conclusion

To produce environment friendly and durable concrete products incorporation of RHA as partial replacement of cement in concrete has gained importance. In the previous studies tests were carried on RHA concrete containing RHA as partial replacement in comparison with control concrete by varying replacement percentage. From the literature review it can be concluded that the workability of the fresh concrete mix decreases as the RHA replacement percentage in concrete increases. The required workability can be attained by good superplasticizer and proper mix design. The partial replacement of cement by RHA improves the compressive strength of hardened concrete whereas; the optimum replacement percentage varies in the studies. The chloride ion penetration of the concrete decreases as RHA percentage increases mainly due to pore refining capacity of RHA. From the above literatures the optimal replacement percentage was found to be ranging from 10% to 20%.

The literature review shows that RHA has the potential to be used as a supplementary cementitious material in concrete production however further research can be carried out on ultrafine RHA. The use of RHA will help in reducing the CO_2 emission and also reduce the problem of disposal of this agro-waste

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