ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Effective Utilization of agricultural waste-RHA; as pozzolanic admixture in cement.

Vijayalakshmi R*.

Department Of Civil Engineering, Siva Subramania Nadar College Of Engineering, Kalavakkam, Chennai-603110

ABSTRACT

This paper presents an overview of some of the published results on the successful utilization of rice husk ash (RHA) as a supplementary cementitious material and the properties of such concrete at fresh and hardened stages. Studies indicate that there is a promising future for the use of rice husk ash in normal, high strength and self compacting concrete as it shows high strength, low shrinkage and permeability, high resistance to carbonation, chloride, sulphate and acidic environments. Rice husk ash is one of the promising pozzolanic materials that can be blended with Portland cement for the production of durable concrete and at the same time it is a value added product. Addition of rice husk ash to Portland cement not only improves the early strength of concrete, but also forms a calcium silicate hydrate (CSH) gel around the cement particles which is highly dense and less porous. The summery and discussions provided in this paper provides new information and knowledge on the applications of greener and sustainable rice husk ash concrete.

Keywords: RHA, pozzolanic admixture, cement, ash.

Corresponding author

INTRODUCTION

Rice husk is one of the main agricultural residues obtained from the outer covering of rice grains during the milling process. It constitutes 20% of the 500 million tons of paddy produced in the world [1]. Rice husk is an agricultural waste, whose natural degradation is restricted due to the irregular abrasive surface and high siliceous composition. It is not appropriate to be used as a feed for animals due to the low nutritional values. If dumped as landfill, they can take a lot of area and become a major challenge to the environment. If they are disposed by burning, the ashes can spread to the surrounding areas, create pollution and destroy the natural beauty. One of the possible solutions for the disposal of rice husk is to convert them into rice husk ash and incorporate them into cement based materials. The partial inclusion of rice husk ash (RHA) for cement is found to be durable, environmental friendly and economically viable [2]. The rice husk ash had no useful application and had usually been dumped into water streams and caused pollution and contamination of springs until it was known to be a useful mineral admixture for concrete [3, 4]. Generally, mineral admixtures have a favourable influence on the strength and durability of concrete [5].

It is also reported that the microstructure of the cement paste can be significantly improved by adding pozzolanic materials such as, fly ash, silica fume, metakaolin and rice husk ash (RHA). Rice husk ash is a highly reactive pozzolanic material produced by controlling burning of rice husk ash. The utilization of rice husk ash as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits related to the disposal of waste materials and to reduced carbon di oxide emissions. Reactivity of RHA is attributed to its high content of amorphous silica, and to its very large surface area governed by the porous structure of the particles [6-9]. Generally, reactivity is also favoured by increasing fineness of the pozzolanic material [10-12]. However, Mehta [13] has reported that grinding of RHA to a high degree of fineness should be avoided, since it derives its pozzolanic activity mainly from the internal surface area of the particles. By blending rice husk ash with courser cement, higher packing can be expected, leading to improved behaviour of blended systems [14, 15].

Rice husk ash as supplementary cementious material

It is also reported that the microstructure of the cement paste can be significantly improved by adding pozzolanic materials such as, fly ash, silica fume, metakaolin and rice husk ash (RHA) [16]. Rice husk ash is a highly reactive pozzolanic material produced by controlling burning of rice husk ash. The utilization of rice husk ash as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties, reduced materials cost due to cement savings and environmental benefits related to the disposal of waste materials and to reduced carbon di oxide emissions. Reactivity of RHA is attributed to its high content of amorphous silica, and to its very large surface area governed by the porous structure of the particles [17–20].

Physical and chemical Properties of RHA

The physical and chemical properties of RHA and OPC have been presented in Table 1. RHA have lesser specific gravity than OPC. Therefore, more volume is expected when RHA replaces OPC by mass. Generally reduction in fine aggregate contents is necessary to overcome the volume increase [8]. The most important constituents for any mineral admixture are silica and alumina oxides. In comparison with OPC, the mineral admixtures namely RHA have higher quantity of silica oxide in its constituent. The maximum content of silica oxide is in *RHA* showing the reaction capability with the primary hydrate of cement to produce calcium silicate hydrate (CSH) which is strengthening gel in concrete. The particle size and surface area are the utmost important for mineral admixtures. As reported in the literature, smaller particle size with greater surface area is favourable within concrete to be more reactive with the alkaline environment [21]. *RHA* have the smaller particle size and greater surface area showing their capability to react more effectively with Ca (OH) ^{2} in the concrete [2]. The microstructure *RHA* through field emission scanning electron microscope (FESEM) is shown in Figure 1.

ISSN: 0975-8585

Table 1: Comparison of physical and chemical properties of OPC and RHA [29]

	OPC	RHA
Specific gravity	3.05	2.11
SiO2 %	20.44	88.32
Al_2O_3 %	2.84	0.46
Fe_2O_3 %	4.64	0.67
CaO %	67.73	0.67
MgO %	1.43	0.44
SO_3 %	2.20	-
Na_2O %	0.02	0.12
K_2O %	0.26	2.91
MnO %	0.16	-
TiO_2 %	0.17	-
Particle size µm	10-40	11.5-31.3
Specific surface m^2/g	1.75 BET surface area	30.4 – 27.4 BET surface area
Loss on ignition %	1.8	5.81
Pozzolan reactivity	-	-

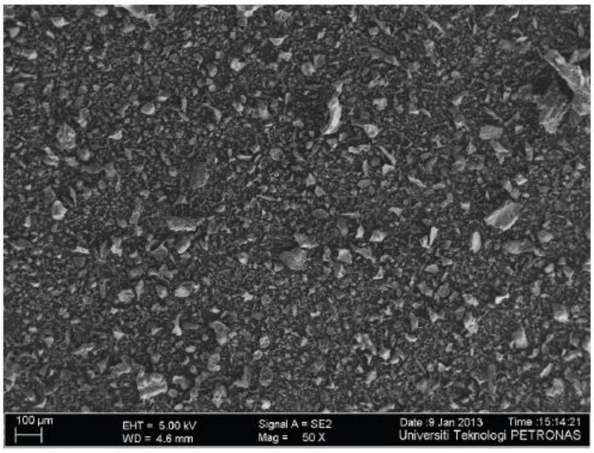

Figure 1: Micro structure of RHA through field emission scanning electron microscope showing particle size distribution [2]

Fresh properties of concrete replaced with RHA

The most essential asset of HA that that identities pozzolanic activity is the amorphous phase substance. The production of RHA can lead to the formation of approximately 85% to 95 % by weight of amorphous silica [22]. RHA is an extremely reactive pozzolanic substance appropriate for use in lime pozzolanic mixes and for Portland cement substitution [23]. Cement replaced by RHA accelerates the early hydration of tri calcium silicate [24]. The fresh properties of RHA partially replaced concrete namely workability and setting time is discussed below.

Workability

Typical concrete mixtures do not have an optimum particle size distribution and this account for the high water requirement to attain certain workability. Studies indicate that a high volume RHA concrete mixture reduces the water requirement by 20%. Studies were carried out to study the rheological behavior of high performance concrete. RHA was used to replace cement on mass basis at the rate of 5%, 10%, 15% and 20%. From the study it was conclude that the plastic viscosity increases tremendously with the increase in replacement level of RHA [25]. RHA fill into the spaces made by larger cement particle, decreases the frictional forces of RHA and OPC system and improve packing ability and reduces yield stress. The fineness and shape of RHA has a critical impact in the increase in plastic viscosity. The more the fineness the more is the number of contacts among the particles and hence the more is the resistance to flow [26].

Initial and final setting time

Initial and final setting time shows different results on cement paste having different RHA percentage. Rice husk ash increases the setting time of cement paste. The reactivity of RHA cement depends very much on the specific surface area or particle size [27]. The RHA cement with finer particles exhibits superior setting time. The increase in initial setting time can be achieved by increasing the percentage of RHA in cement. This may be due to the slower pace of heat induced evaporation of water from the cement –RHA [28]. The variation in the initial setting time and final setting time of cement replaced with different level of RHA is shown in Figure 2.

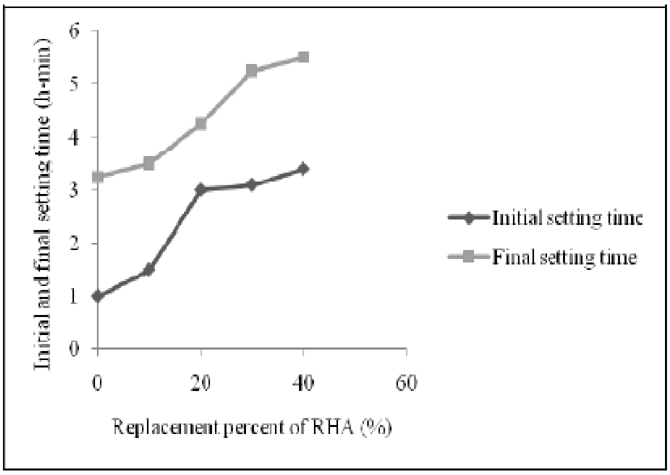

Figure 2: Initial and final setting time of RHA with different replacement percentage [23]

Hardened properties of concrete replaced with RHA

Rice husk ash (RHA) has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in high-performance concrete. Mechanical experiments of RHA blended Portland cement concretes revealed that in addition to the pozzolanic reactivity of RHA (chemical aspect), the particle grading (physical aspect) of cement and RHA mixtures also exerted significant influences on the blending efficiency. The relative Strength increases (relative to the concrete made with plain cement, expressed in %) is higher for coarser cement.

Compressive strength

Concrete samples made with the ultra fine RHA particles (U series) showed considerably higher strength than those made with the coarser RHA (M series) for all cement replacement ratios. The compressive strengths of the U series mixtures are higher than that of the control concrete at all ages. The compressive strengths development with age for Mortar and concrete series at 10% (optimal) level of cement replacement by RHA in comparison to control series are shown in Figure 3. The highest enhancement in compressive strength of the concrete series was obtained similar to Mortar series for RHA content of 10% at 90 days age. The favourable results of ultra fine RHA-blended concrete are due to the rapid consuming of Ca (OH) ^{2} which was formed during hydration of Portland cement at early ages that is related to the high pozzolanic reactivity of ultra fine RHA [29]. As a consequence, the hydration of cement is accelerated and larger volumes of reaction products are formed. The fine RHA particles recover the particle packing density of the blended cement, directing to a reduced volume of larger pores in the cement paste [30].

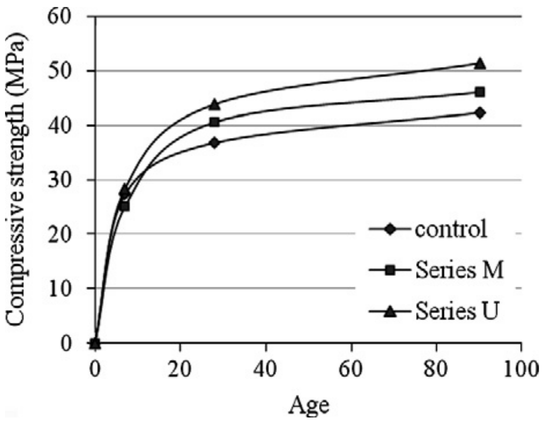

Figure 3: Compressive strength developments for coarse and ultra fine RHA at 10% level of Cement replacement comparison to control sample at the first 90 days [29]

Table 2 shows the compressive strength of rice husk ash replaced concrete after 7, 14 and 28 days of curing with replacement level from 5-30 %. it is found that the compressive strength increases with blending percentage and with age (Table 2). This value is pronounced for all replacement levels. Higher concentration of RHA also can be used without strength loss [31].

Table 2: Compressive strength of RHA replaced concrete after 7, 14 and 28 days [31]

% of replacement	Average compressive strength (N/mm^2)		
	7 days	14 days	28 days
0 (OPC)	27.22	33.29	36.45
5	31.32	35.62	36.49
10	30.45	35.97	37.43
15	31.52	35.04	37.38
20	31.64	36.17	37.71
25	33.09	35.27	39.55
30	33.53	35.44	37.80

Table 3: Split tensile strength and coefficient of water absorption of RHA replaced concrete [31]

% of replacement	Split tensile strength (N/mm^2)	Coefficient of water absorption (m^2/s)
OPC	4.49	$3.5571 x10^{-10}$
5	4.57	6.7587×10^{-11}
10	4.65	1.0320×10^{-11}
1	4.92	1.0644×10^{-10}
20	4.60	1.2122×10^{-10}
25	4.58	1.4548×10^{-10}
30	3.67	1.3030×10^{-10}

Split tensile strength

The split tensile strength of rice husk ash blended concrete up to 30% replacement levels after 28 days curing are shown in Table 3. Up to 25% replacement of rice husk ash the split tensile strength has not been affected. After 25% replacement level, a slight decrease in split tensile strength is observed [31]. The effects of concrete incorporating 20 % RHA as partial replacement of cement at three different particle sizes were studied [32]. It was reported that the tensile strength of concrete increases systematically with the increasing RHA replacement [32].

Rapid Chloride penetration test

As the replacement level of RHA increases the charge passed decreases. Replacement of rice husk ash drastically reduced the Coulomb values. As the replacement level increases, the chloride penetration decreases [31]. As per ASTM C1202, RHA reduced the rapid chloride penetrability of concrete from a low to very low ratings from higher to lower replacement levels. The same trend was reported by Nehdi et al. [33] in RHA replaced concrete. Salas et al [34] reported that the reduction in the average pore diameter of cement paste caused by the incorporation of RHA in the mix effectively reduces the pore size, permeability and diffusivity of chloride ions in concrete.

Co efficient of water absorption

Significant reductions in the coefficient of water absorption can be observed with increase in RHA content up to 10% for ultra fine RHA at 7 days of curing. At 15% and 20% of ultra fine RHA, an increase in values of coefficient of water absorption was observed. However, those values were lower than that of control concrete samples. For M coarser RHA, the values of coefficient of water absorption are higher than those of the control concrete at all cement replacement contents. But at 90 days of curing, the coefficient of water absorption values up to 20% are quite lower than those of the control concrete for both series confirming that cement replacement by RHA with prolonged curing leads to a reduction of pore spaces and permeable voids in the concrete[29]. The coefficient of water absorption for rice husk ash replaced concrete at all replacement levels namely 0-30 % is found to be less when compared to control concrete[31]. The value of coefficient of water absorption for rice husk ash replaced concrete at all replacement levels is given in Table 3.

Durability properties of RHA replaced concrete

Alkali silica reaction

Pozzolanic materials are used to prevent or minimize cracking in concrete due to the expansive gel formed by the alkali- silica reaction. RHA is an highly active pozzolans. Based on the studies carried out on mortar bars made with different levels of cement replacement with RHA and reported that replacement level upto 12 % to 15 % may be sufficient to control deleterious expansion due to alkali silica reaction in concrete [35].

Corrosion resistance and drying shrinkage

Corrosion performance of concrete made with different level of replacement of RHA was studied [31]and the open circuit potential measurement with reference to saturated calomel electrode were monitored. The time of cracking was 42, 72 and 74 hours for concrete with 0, 5 and 10 % RHA. However no cracking was observed for concrete with 15, 20, 25 and 30 % RHA even after 144 hrs of exposure. In contrast OPC cement concrete the specimens were cracking after 42 hrs of exposure in 5 % NaCl solution. The replacement of RHA refines the pores and thereby reducing the permeability [31]. Habeeb et al [32] studied the effect of RHA on shrinkage of concrete mixtures containing 20 % of RHA at three different average particle sizes. The drying shrinkage was significantly affected by RHA fineness. The addition of micro fine particle of RHA would increase the drying shrinkage, while coarser particles of RHA exhibited lower values than the plain cement based concrete.

CONCLUSION

The employment of RHA in cement and concrete has gained importance because of the requirement of environmental safety and durable construction in future. Based on the literature review carried out it can be concluded that RHA is an effective pozzolanic material and can contribute to the mechanical properties of concrete. RHA blended concrete can decrease the temperature effect that occur during the hydration process. RHA blended concrete can improve the workability of concrete compared to OPC. The initial and final setting time is increased by the partial replacement of RHA. Additionally RHA blended concrete can decrease the porosity of concrete and modifies the pores structure of cement. RHA concrete improves the compressive strength, split tensile and flexural strength of concrete. RHA replacement also reduces the water permeability by capillary action. Is also increases the resistance of concrete to sulphate attack. Incorporation of RHA between 12 -15 % is sufficient to control deleterious expansion due to alkali- silica reaction in concrete.

REFERENCES

[1] Bhanumathidas N., Mehta P.K. 2004. Concrete mixtures made with ternary blended cements containing fly ash and rice husk ash. International conference proceeding seventh CANMET-Chennai, India. vol. 1. SP 199-22: 379–91.
[2] Sadaqat Ullah Khan., Muhammad F. N., Tehmina A., Nasir Shafiq. 2014. Effects of Different Mineral Admixtures on the Properties of Fresh Concrete. Scientific World Journal. 3: 245-50.
[3] Rodriguez G.S. 2006. Strength development of concrete with rice husk ash. Cem Concr Compos .28(2):158–60.
[4] Rodriguez G.S., Ribeiro A.B., Gonçalves A. 2008. Effects of RHA on autogenous shrinkage of Portland cement pastes. Cem Concr Compos. 30 (10):892–897.
[5] Ferraris C.F., Oblab K.H., Hill R.2001. he influence of mineral admixtures on the rheology of cement paste and concrete. Cem Concr Res .31(2):245–55.
[6] Mehta P.K. 1978. Siliceous ashes and hydraulic cements prepared there from, US Patent 4105459.
[7] Mehta P.K. 1994. Rice husk ash – a unique supplementary cementing material. Advances in concrete technology. Ottawa: Centre for Mineral and Energy Technology. 419–44.
[8] Cook D.J. 1984. Development of microstructure and other properties in rice husk ash – OPC systems. In: Proceedings the 9th Australasian Conference on the Mechanics of Structures and Materials. Sydney: University of Sydney. 355–60.
[9] James J., Rao M.S. 1986. Characterization of silica in rice husk ash. Am Ceram Soc Bull. 65(8):1177–80.
[10] Kraiwood K., Chai J., Smith S., 2001. Seksun C. A study of ground coarse fly ashes with different finenesses from various sources as pozzolanic materials. Cement Concrete Comp. 23: 335–43.
[11] Paya J., Monzo J., Peris-Mora E., Borrachero M.V., Tercero R., Pinillos C. 1995. Early-strength development of Portland cement mortars containing air classified fly ashes. Cement Concrete Res. 25(2): 449–56.
[12] Paya J., Monzo J., Borrachero M.V, Peris E., Gonzalez-Lopez E. 1997. Mechanical treatment of fly ashes. Part III: studies on strength development on ground fly ash cement mortars. Cement Concrete Res. 27(9):1365–77.
[13] Mehta P.K. 1979. The chemistry and technology of cement made from rice husk ash. In: Proceedings UNIDO/ESCAP/RCTT Workshop on Rice Husk Ash Cements, Peshawar, Pakistan. 113–22.
[14] Bui D.D. 2001. Rice husk ash as a mineral admixture for high performance concrete, PhD thesis. Delft University Press, Delft.
[15] Stroeven P., Stroeven M., Bui D.D. 2002. Design principles of particle packing; application to supplementary cementing materials. Proceedings ACI 5th International Conference on Innovation in Design with Emphasis on Seismic, Wind and Environmental Loading, Quality Control and Innovation in Material/Hot-weather Concreting. Farmington Hills: ACI. 43–60.
[16] Gonsi S., Lorenzo M.P., Sagrera J.L. 1994. Durability of hydrated Portland cement with copper slag addition in NaCl + Na2SO4 medium. Cem Concr Res. 1403–12.
[17] Mehta P.K. 1978. Siliceous ashes and hydraulic cements prepared there from, US Patent 4105459.
[18] Mehta P.K. 1994. Rice husk ash – a unique supplementary cementing material. Advances in concrete technology. Ottawa: Centre for Mineral and Energy Technology. 419–44.
[19] Cook D.J. 1984. Development of microstructure and other properties in rice husk ash – OPC systems. In: Proceedings the 9th Australasian Conference on the Mechanics of Structures and Materials. Sydney.355–60.
[20] James J., Rao M.S. 1986. Characterization of silica in rice husk ash. Am Ceram Soc Bull. 65(8): 1177–80.
[21] Thomas M., Hotoon R.D., Fournier B. 2012. 50 years and still going strong. Concrete international. 34: 35.
[22] Della V. P., Kuhn I., Hotza D. 2002. Rice husk ash as an alternate source for active silica production. Materials letters. 57 (4):818-21.
[23] Dakroury A. E., gasser M. S. 2008. Rice husk ash as cement admixture for immobilization of liquid radioactive waste at different temperature. Journal of nuclear materials. 381 (3): 271-77.

[24] Feng Q., Yamamichi H., Shoya M., Sugita S. 2006. Study on the pozzolanic properties of rice husk ash by hydrochloric acid pre-treatment. Cement and concrete research. 34(3):521-26.

[25] Mehta P K., high performance, high volume fly ash concrete for sustainable development. Proceedings of the international workshop on sustainable development and concrete technology, university of California, Berkeley, USA.

[26] Nedhi M., Mindess S., Aitcin P.C., 1998. Rheology of high performance concrete: effect of ultra fine particles. Cement and concrete research. 28(5): 687-97.

[27] Cook J. D. 1986. Rice husk Ash, concrete technology and design. Cement replacement materials. 3: 171-95.

[28] Ganesan K., Rajagopal K., Thangavel K. 2008. Rice husk ash blended cement : assessment of optimal level of replacement for strength and permeability properties of concrete. Construction and building materials. 22(8): 1675-1683.

[29] Alireza N.G., Surya A.R., Farah N.A., Mohamad A. M. 2010. Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete. Construction and building materials. 24: 2145-50.

[30] Bui D.D., Hu J., Stroeven P. 2005. Particle size effect on the strength of rice husk ash blended gap-graded Portland cement concrete. Cem Concr Compos. 27(3):357–66.

[31] Saraswathy V., Ha Won S. 2007. Corrosion performance of rice husk ash blended concrete. construction and building materials. 21: 1779-84.

[32] Habeeb G. A., Fayyadh M. 2009. Rice husk ask concrete: the effect of RHA average particle size on mechanical properties and drying shrinkage. Australian journal of basic and applied sciences. 3(3):1616-22.

[33] Nehdi M., duquette J., Damatty A.E. 2003. Performance of rice husk ash produced using a new technology as a mineral admixture in concrete. Cement Concrete Res. 33(8):1203–10.

[34] Salas A., Delvasto S., Gutierrez R. M., Lange D. 2009. Comparison of two processes for treating rice husk ash for use in high performance concrete. Cement and concrete research. 39(9): 773-78.

[35] Laskar A.I., Talukdar S. 2008. Rheological behavior of high performance concrete with mineral admixtures and their blending. Construct Build Mater. 22(12):2345–54.