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Effect of Uncontrolled Burning Rice Husk Ash in Foamed Concrete

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Abstract. Recently, foamed concrete has become a popular construction material that can be used in wide range of constructions application. Whilst the Rice Husk Ash (RHA) as agro-waste is contain high amount of silicon dioxide. RHA is produced in significant amount every year from agriculture countries. RHA has potential as a material to produce foamed concrete. In this research RHA has been used as a replacement for fine aggregate which used in construction as ordinary concrete material. In this study, foamed concrete with target density 1400, 1600 and 1800 kg/m^3 has been produced. The compressive strength of foamed concrete with RHA has been tested. Concrete with Ratio 1:3 of RHA/Sand has higher compressive strength than ratios 3:1 and 2:2 of RHA/sand for every density. XRD and XRF test has been used to determinate chemical composition and crystalline structure of RHA. The result showed that RHA is an amorphous material, which amorphous is important thing to pozzolanic process when hydration of cement paste. SEM and EDS test has been conducted to determine microstructure and chemical composition on microstructure of RHA foamed concrete. Amorphous RHA incorporating cement paste produces pozzolanic reaction. It is reduces the porosity and width of interfacial zone in such a way the density is increase.

1. Introduction

Many reason that the people chose the foamed concrete, besides lightweight and cheap the foamed concrete exhibit excellent characteristics including high strength, energy saving, waste utilizing, heat preservation and noise insulation [1], which can be used in wide range construction applications such as infrastructure facilities for high-grade highway and subways [2], Basically the material constituent of foamed concrete is same with normal concrete that used Portland Cement, aggregate and water. However only fine sands and with extremely lightweight foamed material that containing only cement, water and foam to develop the product more accurately to describe as foamed concrete [1].

Recently, most investigations have been confined cement paste with replacement admixture of cement-sand mixes partially to something a specific purpose such as to increase density and strength. Foamed concrete can be made high density which ranging from 1000 to 1500 kg/m^3 [3]. Nambiar and Ramamurthy [4] reported that replacement of sand with fly ash resulted in higher strength which finer filler resulted in higher ratio of strength to density. The finer the filler caused an increasing strength of foamed concrete.

Rice Husk Ash (denoted RHA) is a product of agriculture industry as agro-waste constituent one-fifth by weight when the rice harvested. This is a significant amount every year which that over 100 million tons of rice husk and 90% from developing countries [5]. It can be used as filler or binder of sustainable material base on cement i.e. concrete [6].

The characteristic of RHA as pozollan material has high pozzolanic activity index and it influence on improvement strength of conventional concrete [7]. Control burning of RHA produce rice husk ashes with expectable high pozzolanic activity index. Furthermore the RHA manufacture produces un-control burning below 700ºC precisely that obtain expecting high pozzolanic activity index [7]. In this research, foamed concrete will produce with uncontrolled burnt RHA served as sand partial replacement.

2. Materials and Methodology

2.1. Materials and Mix Proportions

Strength characteristic of foamed concrete influenced by many factors such as curing condition, particle size of constituent materials, filler and ratio of concrete materials i.e. sand to cement ratio, water-cement ratio, cement-sand-filler-water ratio.

In this experiment pre-foaming method was applied. First step was to produce base mix of concrete contained OPC, Sand and water, whilst stable preformed aqueous foam made separately. Then thoroughly blending foam into the base mix until reach target density. Plain foamed concrete samples were combination of the following constituent materials i.e. Portland cement [8], natural sand as fine aggregate with particles mainly passes on a 5.0 mm [9]. Base on chemical composition RHA and original fly ash is similar with each other [10]. So that the investigation of RHA was treated as originally fly ash [11]. The RHA obtained from rice manufacturer at Muar-Johor Malaysia which uncontrolled burning under 700ºC during ± 6 hours.

The density of foam 50 kg/m^3 that prepared aqueous surfactant solution was diluted by water 1:5 in a dry system generator which ordinary used by industry. Density of foam is agree with Jones and McCarthy that stability of test mixes can be assessed by comparing calculation of actual quantities within 50 kg/m^3 of design volume or calculating actual w/c ratio [12, 13]. The target densities of all foamed concrete specimens are 1400, 1600 and 1800 kg/m^3. For all specimens water-cement ratio is 0.60 and cement-sand ratio is 0.25. The Ratio of Cement-Sand-RHA in foamed concrete with added RHA as fine substitute is showed in table 1 and ratio of RHA-water is 1.25.

Table 1 Ratio Foamed concrete with RHA for each target density.

Target Density kg/m^3	CODE	Ratio PC/Sand/RHA
1400 (CR1)	C1R1	1:1:3
	C1R2	1:2:2
	C1R3	1:3:1
1600 (CR2)	C2R1	1:1:3
	C2R2	1:2:2
	C2R3	1:3:1
1800 (CR3)	C3R1	1:1:3
	C3R2	1:2:2
	C3R3	1:3:1

2.2. Experimental and Test Procedures

The compressive strength is an important mechanical characteristic of concrete. The uni-axial load was applied on the specimens to carry out compressive strength test of specimens with size 100 mm x 100 mm x 100 mm cube [14]. The specimens were moulded from each mix and maintained at temperature 23 ± 2°C for 24 hours. After casting, the specimens were remove from the mould and stored in water at temperature 23 ± 2°C. 9 samples were made for every ratio as illustrated in table 1 and every various densities is limited for 28 days curing with non exception of the control specimens.

XRF test was conducted to examine the chemical content of RHA whether XRD test to investigate its crystalline structure. Also SEM and EDS was applied to determine the microstructure and composition of foamed concrete containing RHA.

3. Result and Discussion

3.1. XRF and XRD of RHA

Most investigation produces ashes by control burning. The burning temperature influences the ultimate quality of ash [15]. However the manufacturers are produces the ashes with uncontrolled combustion which can be difficult for controlling expecting result. The sample of RHA is uncontrolled burning which burnt under 700ºC during ± 6 hours. The composition of RHA as shown in table 2, that the XRF result depict that composition of RHA appropriate with Ramezanianpour et, al. [7].

Table 2 Chemical composition un-control burning of RHA.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	MgO	Na_2O	K_2O	P_2O_5	SO_3	CO_2	LOI
RHA	89.90	0.46	0.47	1.01	-	0.79	-	4.50	2.45	-	0.1	0.32

Figure 1 shown, the result of XRD test on RHA that used as a filler. Base on International Centre for Diffraction Data (ICDD), the crystalline phase has sharp pointing peak in their pattern which describe original pattern of their phase. On the contrary, XRD result showed the phase of substances of RHA has smooth broad peak and does not have significant sharp pointing peak in their pattern which indicated the amorphous phase of RHA.

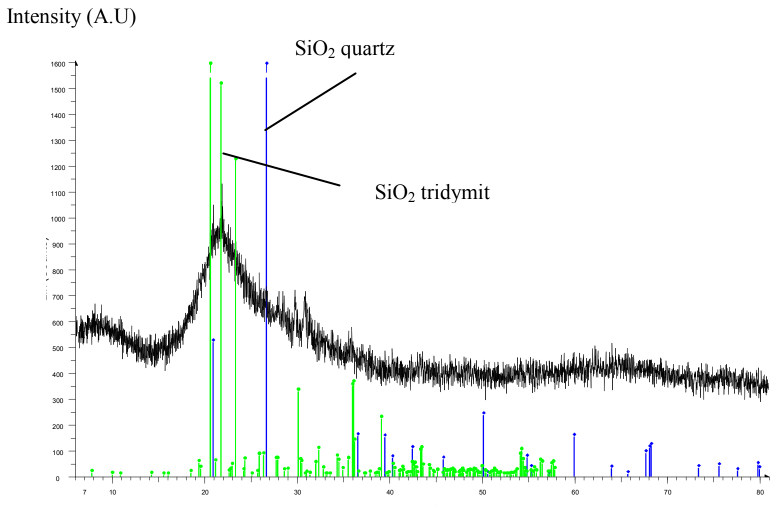

Fig. 1 XRD amorphous of RHA uncontrolled burning 700ºC, 6 hours RHA

The reactivity of RHA depend on silica in amorphous form of RHA when it burning. Furthermore RHA gives contribution on strength of concrete when form of RHA is amorphous [16, 17]. So it is performed in rice husk in low burning in range 400°C to 700°C [7, 16]. Previous research has been confirmed that RHA in amorphous form has the best pozzolanic reaction, and most of the investigation utilizes RHA as a cement partial substitution [16]. However in this study, RHA has been used as a partial sand replacement, and the result showed that the reaction occurred same with the RHA as a cement partial substitution.

3.2. Compressive Strength of Foamed Concrete containing RHA

Figure 2 shows the result of compressive strength with various densities 1400 kg/m^3, 1600 kg/m^3 and 1800 kg/m^3. Ratio C1R1 and C2R1 quite comparable since both have lowest density, even to control of foamed concrete. However ratio with density CR3 higher compressive strength then control of foamed concrete. Each ratio with densities CR2 and CR3 has significant high compressive strength compare to all ratio especially to control of foamed concrete

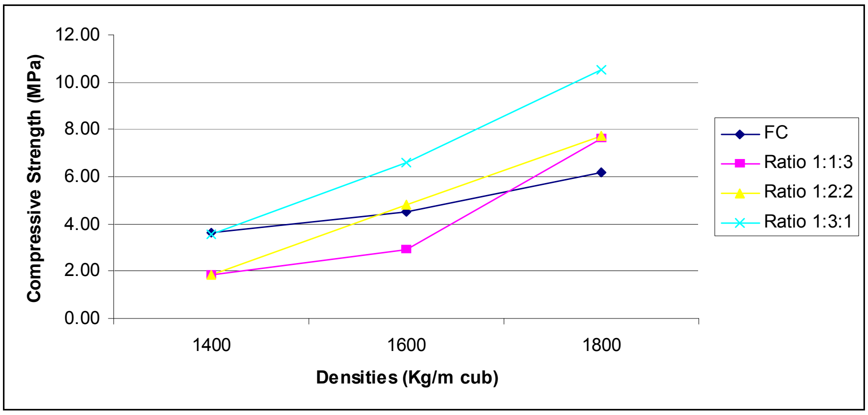

Fig. 2 Compressive strength of foamed concrete with RHA as sand replacement and FC control in various density: 1400 kg/m^3, 1600 kg/m3 and 1800 kg/m^3.

Presence of RHA overabundance into matrix not at all hydration process occurs. The compressive strength for all ratio may increase when reduces the amount of RHA. It is obvious in the densities of 1600 kg/m^3 (CR2) and 1800 kg/m^3 (CR3). At the last is C3R3 that highest compressive strength with proper ratio of PC/sand/RHA. This is agree with Ismail and Waliudin [16], reported that strength of concrete which any replacement of cement by RHA more strength than contain RHA. Also Al-khalaf and Yousif [6], reported with the same condition that 40% cement replaced by RHA can be made no significant in compressive strength.

The compressive strength of foamed concrete is accordance with causal of incorporation between cement and silica. The presence of RHA gives contribution on compressive strength, which its reactivity is additive for cement in concrete. It is called pozzolanic reactivity. During process of the cement hydration is liberating the pozzolanic reaction between silica and calcium hydroxide, that the RHA is which contain high amount of silicon dioxide (SiO_2). Further, calcium silicate hydrate that produce during reaction make into microstructure of concrete denser than foamed concrete without RHA [7].

3.3. Microstructure of Foamed Concrete with RHA as Sand Replacement

Utilizing scanning electron microscope, foamed concrete with RHA was observed with 55 times magnification. Figure 3 shows RHA that has not all burnt (SO1), partially fusible into solid part (SO2). Figure 4 shows the EDS result test detect amount of carbon as RHA which has not all burnt. The carbon can be filled the porosity of foamed concrete.

Cement hydration reaction

$$2Ca_3SiO_5 + 7H_2O \rightarrow 3C_{aO}.2SiO_2.4H_2O + 3Ca(OH)_2 \quad (1)$$

Pozzolanic reaction

$$3Ca(OH)_2 + 2SiO_2 + H_2O \rightarrow 3CaO.\ 2SiO_2.4H_2O \quad (2)$$

Calcium hydroxide that was produced from cement hydration reaction is used in the pozzolanic reaction when mixed with RHA.

According to Figure 5, EDS detect amount of Ca which is showed hydration process of cement is occured. And react with Si from RHA to create pozzolanic reaction.

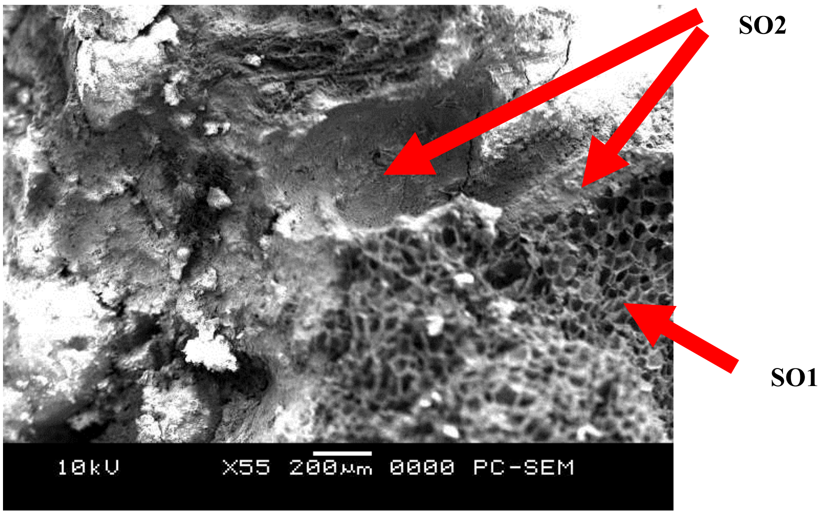

Fig. 3 Microstructure of cross section foamed concrete with RHA as sand replacement.

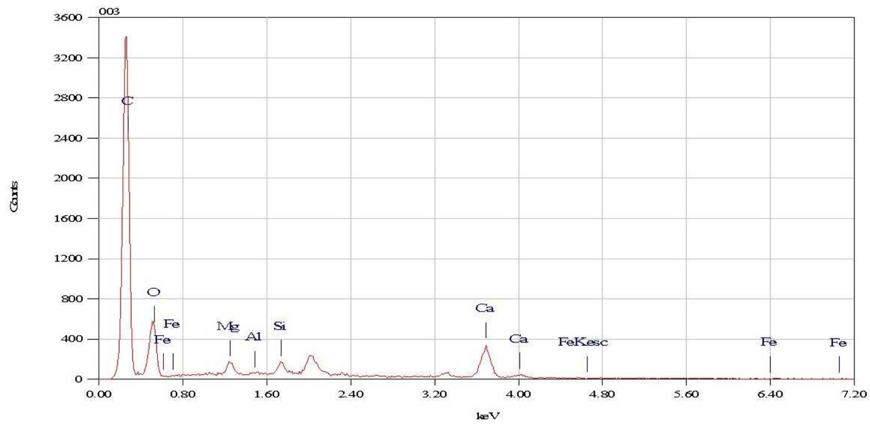

Fig. 4 EDS result test for chemical composition of S01

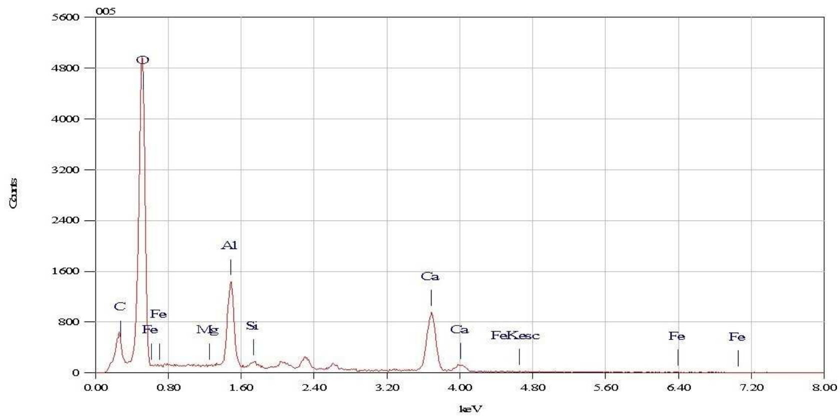

Fig. 5 EDS result test for chemical composition of S02

Calcium hydroxide and silicate hydrate that the major product of hydration and reaction process of RHA. It is found in cement paste, and indicates that the pozzolanic reaction. The presence of RHA in foamed concrete reduces its porosity and amount of calcium hydroxide in the interfacial zone. This is agree with Zang, et, al.[17], were reported that The cement paste incorporating with RHA had a lower Ca (OH) content than the control Portland cement paste without RHA. Further the pozzolanic reaction reduces width amount of interfacial zone between aggregate (sand) and cement paste. Increasing compressive strength of foamed concrete due to reduce porosity of foamed concrete and liberated calcium hydroxide in RHA pozzolanic process also reduce amount of interfacial zone between the sand and cement paste and density of the zone is increased.

4. Conclusion

Lightweight of foamed concrete is the important factor which was gained from the distribution of air bubbles throughout the mass of concrete without coarse aggregate incorporated. Usage RHA as sand replacement in this investigation was from uncontrolled burning process which obtained from rice milling kiln that used rice husk as fuel in its boiler generator. However the XRF result indicates that expected chemical composition that is contained in RHA. Especially silicone dioxide that used in pozzolanic process when cement hydration liberating the Calcium Hydroxide. Pozzolanic reaction contributes to the foamed concrete strength. The compressive strength increases along with the RHA addition.

The result showed foamed concrete with addition of RHA with ratio cement-sand-RHA 1:3:1 has better compressive strength than normal foamed concrete. The presence of RHA especially the un-burning partially and contains the Carbon can be filled the porous in foamed concrete. Nonetheless the nature of RHA that was porous adding to the lightweight property of the concrete.

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References

[1] Aldridge, D. *Introduction To Foamed Concrete : What, Why, How?* in *Used of Foamed Concrete in Construction*. 2005. International Confrence of University of Dundee, Scotland UK: Thomas Telford.

[2] Jones, M.R. and A. McCarthy. *Behviour and assesment of Foamed Concrete for Concrtuction Applications*. in *Use of Foam Concrete in Construction*. 2005. International Concference of University of Dundee, Scotland, UK.: Thomas Telford.

[3] Kearsley, E.P. and P.J. Wainwright, *The effect of high fly ash content on the compressive strength of foamed concrete.* Cement and Concrete Research, 2001. **31**(1): p. 105-112.

[4] Nambiar, E.K.K. and K. Ramamurthy, *Influence of filler type on the properties of foam concrete.* Cement and Concrete Composites, 2006. **28**(5): p. 475-480.

[5] Lee, Y.L. and Y.T. Hung. *Exploitation of Solid Wastes in Foamed Concrete Challenges Ahead*. in *Use of Foamed Concrete in Construction*. 2005. International Confrence of University of Dundee, Scotland, UK Thomas Relford.

[6] AI-Khalaf, M.N. and H.A. Yousif, *Use of Rice Husk Ash in Concrete.* The International Journal of Cement Composites and Lightweight Concrete, 1984. **6**.

[7] Ramezaniapour, A.A., M. Mahdi Khani, and G. Ahmadibeni, *The effect of Rice Husk Ash on Mechanical Properties and Durability of Suistainable Concretes.* International Journal of Civil Engineering, 2009. **7**: p. 83-91.

[8] BSEN-197-1, *Cement —Part 1: Composition, specifications and conformity criteria for common cements.* 2000.

[9] BSEN-882, *Specification for aggregates from natural sources for concrete.* 1992.

[10] Chareerat, T., et al. *Composition and Microstructure of Fly Ash Geopolymer Containing Rice Husk Ash*. in *Technology and Innovation for Sustainable Development Conference (TISD2008)*. 2008. Faculty of Engineering, Khon Kaen University, Thailand.

[11] BSEN-450-1, *Fly ash for concrete — Part 1: Definition, specifications and conformity criteria.* 2005.

[12] Jones, M.R. and A. McCarthy, *Utilising unprocessed low-lime coal fly ash in foamed concrete.* Fuel, 2005. **84**(11): p. 1398-1409.

[13] Jones, M.R. and A. McCarthy, *Heat of hydration in foamed concrete: Effect of mix constituents and plastic density.* Cement and Concrete Research, 2006. **36**(6): p. 1032-1041.

[14] BS1881, *BSI, Part 116-Method for determination of compressive strength.* 1983.

[15] Odler, I., *Special Inorganic Cement*. Modern Concrete Technology Series, ed. A. Bentur and S. Mindess. Vol. 8. 2000, New York: E & FN Spon. 162-163.

[16] Ismail, M.S. and A.M. Waliuddin, *Effect of Rice Husk on High Strength Concrete.* Construction and Building Materials, 1996. **10**(7): p. 521-526.

[17] Zhang, M.H., R. Lastra, and V.M. Malhotra, *Rice-husk ash paste and concrete: Some aspects of hydration and the microstructure of the interfacial zone between the aggregate and paste.* Cement and Concrete Research, 1996. **26**(6): p. 963-977.