



AENSI Journals

**Australian Journal of Basic and Applied Sciences**

ISSN:1991-8178

Journal home page: [www.ajbasweb.com](http://www.ajbasweb.com)

## An Overview on Manufacturing of Rice Husk Ash as Supplementary Cementitious Material

M.N.N. Khan, M. Jamil, A.B.M.A. Kaish, M.F.M. Zain

*Sustainable Construction Materials and Building Systems (SUCOMBS) Research Group, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia.*

### ARTICLE INFO

#### Article history:

Received 15 April 2014

Received in revised form 22 May 2014

Accepted 25 October 2014

Available online 10 November 2014

#### Keywords:

Rice husk ash; Pozzolan; Furnace;  
Combustion; Compressive strength;  
Cement replacement.

### ABSTRACT

Rice husk is an agro-industrial by-product with high silica content. With proper incineration and controlled burning, this husk becomes a pozzolanic material that can be used for replacement of cement at various percentages of dosage. Proper techniques of combustion and grinding are two main factors for producing reactive rice husk ash (RHA). The nature of producing ash could be measured by X-ray diffraction (XRD) analysis. Incorporating RHA with concrete and mortar mix showed higher compressive strength. It is due to both the filler and the pozzolanic effect of RHA in concrete and mortar mix. It is possible to maintain high strength in concrete and mortar with RHA up to 30% replacement of cement.

© 2014 AENSI Publisher All rights reserved.

**To Cite This Article:** M.N.N. Khan, M. Jamil, A.B.M.A. Kaish, M.F.M. Zain., An Overview on Manufacturing of Rice Husk Ash as Supplementary Cementitious Material. *Aust. J. Basic & Appl. Sci.*, 8(19): 176-181, 2014

## INTRODUCTION

Rice milling industry generates huge amount of rice husk during milling of paddy which comes from the agricultural fields. During the milling process of paddy about 78% of weight representing rice, broken rice and bran and 22% of weight representing husk. Generally this husk is used as fuel in the rice mills to produce steam in the parboiling process. A rice plant is one of the plants that soaks silica from the soil and also assimilates it into its structure during the growth (Smith, R.G. and G.A. Kamwanja, 1986). An amount of 25% of the weight of husk is converted into ash during incineration process, known as rice husk ash (RHA) and the remaining major of 75% are organic volatile matter (Koteswara Rao, D., 2012). More than 80-85% of silica contains in rice husk ash (Siddique, R., 2008). The silica presents in two forms, one is amorphous silica which is reactive as pozzolan to replace part of Portland cement. This form of silica present in RHA depends on the temperature and duration of burning (Chindaprasirt, P., 2007). Only properly burnt and ground rice husk ash is favorable for use as a pozzolanic material (Rukzon, S. and P. Chindaprasirt, 2008). Grinding has great impact on properties of rice husk ash. A satisfactory results obtained by using both rod and iron ball for grinding of burnt RHA in Los Angeles machine at 30 minutes (Jamil, M., 2013). To get highly reactive RHA, proper burning and grinding is the most important factors. Rice husk combustion process has developed a few decades ago in the early 1970s (Zain, M.F.M., 2011). Different researchers follow different production methods of RHA and develop their own furnace or incinerator.

Replacement of cement in concrete with RHA at various percentages (like 5%, 10%, 20% and 10%, 20%, 30% etc.) shows higher strength compared with control specimen. Due to both the filler and pozzolanic effects, RHA is an excellent supplementary cementitious material. Amorphous RHA is dominating the chemical or pozzolanic effect and physical or filler effect is dominating due to the crystalline form of RHA (Jamil, M., 2013). Many developing countries produce large quantities of agro waste which cause severe pollution to the environment. Using RHA in cement improves the strength and durability of concrete and mortar (Sensale, G.R., 2006). Cement can be replaced with RHA up to 30% without reducing strength even improves its strength. Use of RHA not only increase the strength or durability of concrete but also reduce environmental pollution related to the disposal of waste materials (Jamil, M., 2013).

This paper illustrates a short discussion on production process of RHA, favorable conditions for producing active RHA and also its effects on the strength of concrete and mortar.

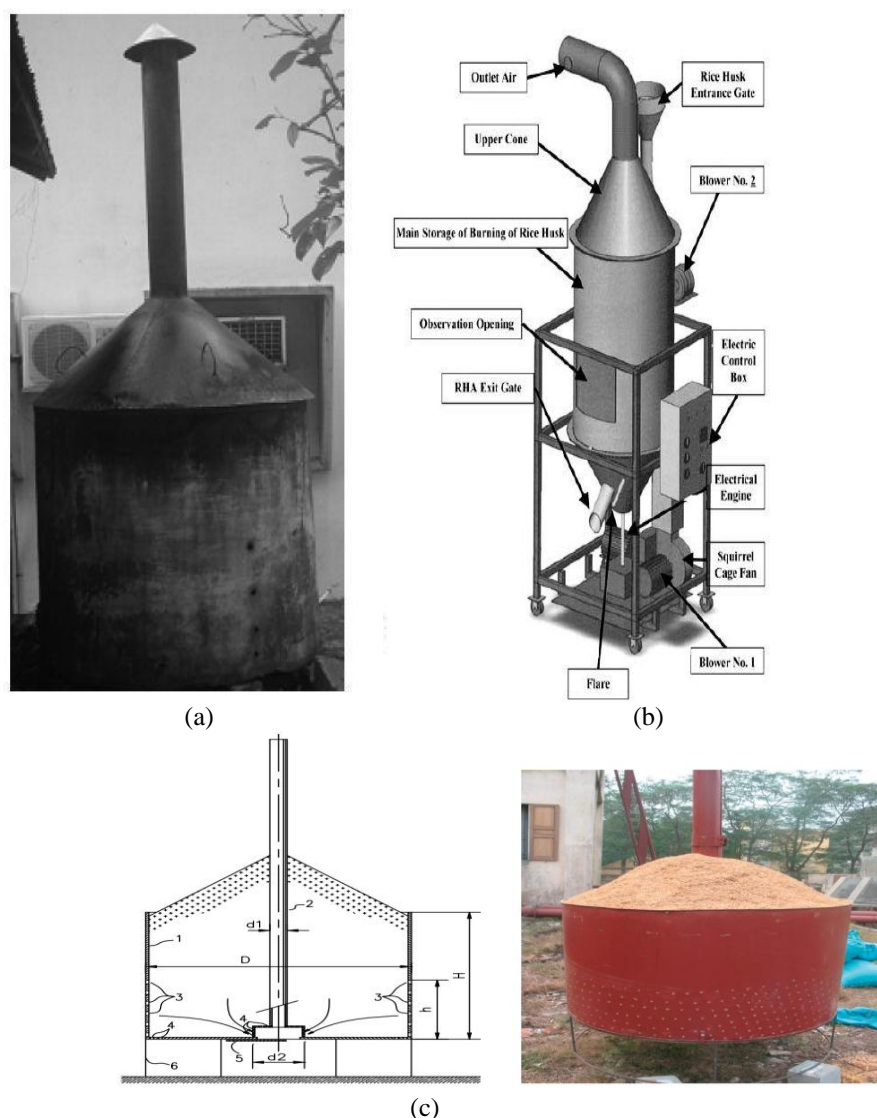
**Corresponding Author:** M.N.N. Khan, Sustainable Construction Materials and Building Systems (SUCOMBS) Research Group, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia.  
Ph: +60169714389; E-mail: [nahid.cuet07@gail.com](mailto:nahid.cuet07@gail.com)

### **Production of Rice Husk ASH (RHA): Incineration Furnace:**

There are various incineration process reported in the published literature to produce the RHA. This paper discusses three of those incineration processes.

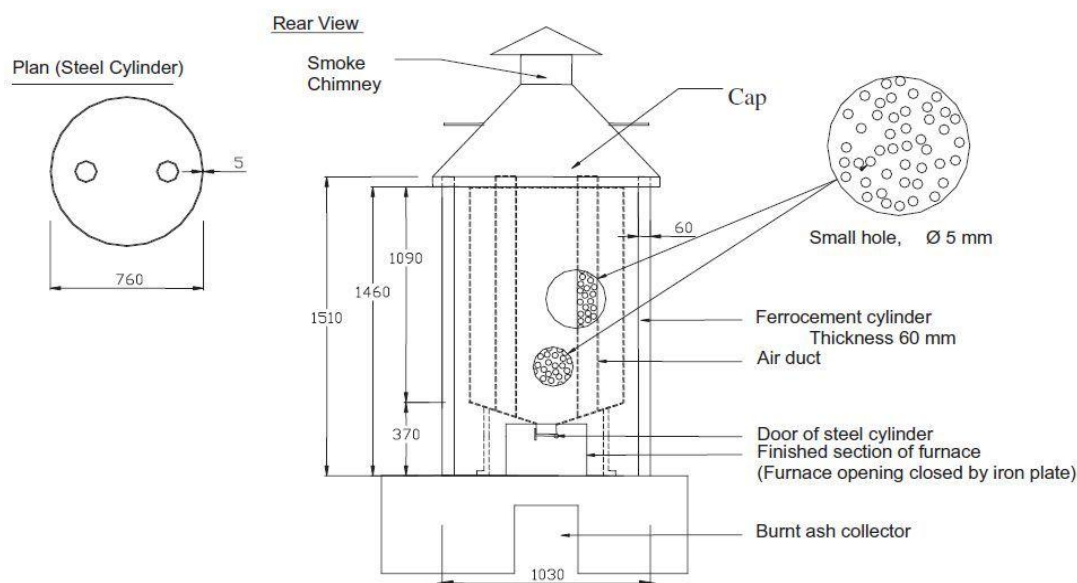
To produce RHA, a ferrocement furnace was designed according to Loo *et al.* (1984). Raw rice husk was kept in the incineration furnace for burning in controlled temperature and time. After incineration then it was allowed to cool for 24 hours and the cool incinerated ash was continuously ground in a Los Angeles machine incorporates forty mild steel rods of 10 mm diameter and 500 mm in length placed in the rotating drum, instead of the conventional ball mills (Raman, S.N., 2011). Identical grinding procedures have also been applied by Zain (2011). The furnace designed by Habeeb *et al.* (2010) has a capacity of 60 kg of raw rice husks & it has three small openings for ventilation as shown in Figure 1(a). Fire source was provided below the furnace and the husks slowly burned for more than one day. The ash was left inside the furnace to cool down before collected.

Another type of special furnace was designed in Amir Kabir University of Technology in order to produce RHA (Ramezaniapour, A.A., 2009). A schematic diagram of the furnace is shown Figure 1(b). This furnace was manufactured and designed in the shape of pilot size in order to control temperature and rate of burning. The furnace can be used to produce rice husk ashes with different un-burnt carbon contents. Natural gas was used as fuel for the combustion. There are two ways for providing the required air for combustion. The combustion procedure is directly controlled by the air blowers. By using thermocouples, temperature can be measured at the fire zone for both air inlet and outlet zones. Measured temperature could be confirmed by an electrical controller. The main advantage of the temperature controller is controlling required temperature during the burning process. Furthermore, the blowers can be switched on or off easily (Ramezaniapour, A.A., 2009).



**Fig. 1:** Photograph and schematic shape of RHA furnace: (a) Habeeb *et al.* (2010); (b) Ramezaniapour *et al.* (2009) and (c) (Viet-Thien-An Van *et al.* 2013).

Figure 1(c) represents a modified incinerator developed from sugita's batch method (Viet-Thien-An Van *et al.*, 2013). A simple ferrocement furnace was designed in Universiti Kebangsaan Malaysia as shown in Figure 2 (Zain, M.F.M., 2011). It has two parts which are one is ferrocement cylinder and another one is steel cylinder. The dimensions of the ferrocement cylinder are 1030 mm diameter, 1510 mm height and wall thickness is 60 mm. The combustion heat is trapped by the ferrocement cylinder within the furnace and preventing it from escaping into the air. The steel cylinder has dimensions of 760 mm diameter, 1090 mm height and thickness is 5 mm. The steel cylinder plays as a container for burning rice husk. It consists of two units of air ducts, inside the steel cylinder, each duct with a dimension of 100mm diameter, 200 mm height, and 100 mm thickness respectively. Air ducts are used for supplying air to husk during combustion process as well as providing passages for fire. Combustion process takes place at same period for both the lower and upper levels of the furnace in order to burn the husk faster. Air ducts are also effective in controlling combustion temperature. The combustion temperature is controlled by providing air through air ducts using electric fans. The surfaces of the steel cylinder and air ducts are porous with small holes of 5 mm diameter. Both ferrocement and steel cylinders are covered at the top with steel cap equipped with smoke chimney.



**Fig. 2:** Furnace for burning rice husk (Zain, M.F.M., 2011).

#### **Incineration Temperature:**

Temperature control is the most important phenomenon during combustion. Different researcher suggested different temperature ranges for burning rice husk depending on their types of furnace, type of husk etc. In RHA, silica is found in two states one is amorphous silica and another is crystalline silica. Burning of rice husk below 700°C temperature, amorphous silica was obtained (Della, V.P., 2002). Proper burning and grinding rice husk ash are suitable for reactive amorphous silica (Metha, P.K., 1979). Higher burning temperature may produce some crystalline formation of silica [8]. Combustion of rice husk took place at four steps. At temperature of 350°C water became vapor and loss of weight continued. Finally in a temperature range of 400–500°C, carbon became oxidized and rice husk lost its major part of the weight. The burnt rice husk is black in color at this stage. Silica in the husk was found in amorphous state (Zain, M.F.M., 2011). In a temperature ranges between 550°C and 700°C for 1 hour controlled burning, the silica content of the rice husk ash transformed into amorphous silica and this form of silica is excellent for use as pozzolan (Madandoust, R., 2011).

#### **Properties of RHA:**

X-ray Diffraction (XRD) analysis was performed to determine the total amorphous nature of SiO<sub>2</sub> present in the produced RHA powder samples (Deshmukh, P., 2011). According to Zain *et al.* (2011), size of RHA was verified using Scanning Electron Microscopy (SEM) (Zain, M.F.M., 2011). Effect of grinding on the specific surface area of RHA was done with the nitrogen absorption test. The chemical analysis of the RHA was determined using the X-ray fluorescence spectrometry (XRF) (Habeb, G.A. and H.B. Mahmud, 2010). Physical and chemical properties of RHA by different researchers were given in Table 1.

**Table 1:** Chemical and Physical properties of RHA.

Chemical properties of RHA								
Constituent	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	LOI
Habeeb <i>et al.</i> (2010)	88.32	0.46	0.67	0.67	0.44	----	2.91	5.81
Islam <i>et al.</i> (2012)	86.49	0.01	0.91	0.50	0.13	0.05	2.7	8.83
Saraswathy <i>et al.</i> (2007)	92.95	0.31	0.26	0.53	0.55	0.08	2.06	1.97
Ganesan <i>et al.</i> (2008)	87.32	0.22	0.28	0.48	0.28	1.02	3.14	2.10
Physical Properties of RHA								
	Specific gravity	Specific surface area (m <sup>2</sup> /Kg)		Fineness passing 45μ sieve		Mean grain size (μm)		
Habeeb <i>et al.</i> (2010)	2.11	-		-		-		
Islam <i>et al.</i> (2012)	2.00	183.3		-		-		
Ganesan <i>et al.</i> (2008)	2.06	-		99		3.80		

**Effect of RHA in Strength of Mortar and Concrete:**

The use of RHA as partial replacement of cement produced different behavior of compressive strength development. The maximum compressive strength was obtained for ultra-high performance concrete (UHPC) by using 10% RHA at 3 and 7 days whereas, at 20% replacement by RHA 28 to 91 days curing is required to get maximum strength according to Tuan *et al.* (2011). At early ages with low w/b ratio showed significant strength is shown in Table 2. It shows that compressive strength is proportional to the age of concrete. Using 15% rice husk ash at 28 days water curing showed higher compressive strength compared to ordinary concrete (Ramadhansyah, P.J., 2011). Use of 20% ground RHA at 56 and 91 days curing showed equivalent compressive strength to control concrete specimens (Hwang, C.L., 2011). However, Saraswathy *et al.* (2007) found that there is no decrease in compressive strength compared to control concrete if the replacement level of RHA increased up to 30%. Therefore, the satisfactory limit for replacement of cement with RHA is considered up to 30%. Compressive strength developments of RHA concrete reported by Hwang *et al.* (2011) is shown in Table 2.

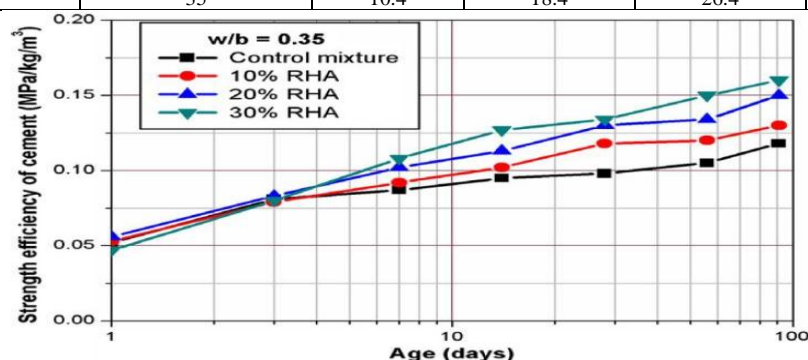
**Table 2:** Strength development of RHA concrete (Hwang *et al.* 2011).

Mix	w/b ratio	RHA content (%)	Compressive Strength (MPa)						
			1 day	3 days	7 days	14 days	28 days	56 days	91 days
A23-10	0.23	10	41	59	62	63	66	69	74
A35-00	0.35	0	30	46	50	54	56	60	67
A35-10	0.35	10	27	41	47	52	61	62	67
A35-20	0.35	20	26	38	47	52	60	61	69
A35-30	0.35	30	19	32	43	51	54	60	64
A47-10	0.47	10	16	26	37	40	47	51	56

The compressive strengths of RHA blended cement mortars are shown in Table 3 (Ganesan, K., 2008). The compressive strength increased for up to 15% replacement of RHA blended cement mortars at various curing times. However strength reduced for replacement of RHA more than 15%. The strength efficiency of cement versus the age of curing is shown in Figure 3 shows that higher amount of ground RHA attained higher strength efficiency of cement.

**Table 3:** Mix proportion and compressive strength of RHA blended cement mortars (Binder to sand ratio of 1:3) (Ganesan, K., 2008).

Mix design	RHA (%)	Compressive strength (MPa)			
		1 day	3 days	7 days	28 days
M <sub>0</sub> (control)	0	11.6	20.9	27.2	37.0
M1	5	12.0	22.1	27.4	38.9
M2	10	12.8	24.4	27.8	42.8
M3	15	13.8	28.9	29.3	46.7
M4	20	12.2	24.8	28.3	39.8
M5	25	11.7	23.6	27.6	38.3
M6	30	11.1	20.7	27.4	37.0
M7	35	10.4	18.4	26.4	36.0

**Fig. 3:** Effect of RHA content on strength efficiency of cement (Hwang, C.L., 2011).

### Conclusion:

This paper deals with the production procedure of RHA as well as its effect on concrete and mortar. It is noticed that in order to get desired properties RHA, control of burning temperature and well grinding are essential. It is difficult to get all ash in amorphous form since some of ash converted to crystalline form. Incorporating incinerated rice husk ash has a significant effect on the properties of concrete or mortar. Compressive strength of mortar and concrete increased when cement is partially replaced by RHA. This is due to active amorphous silica content present in RHA. This active silica reacts with hydration product of cement and produced secondary C-S-H gel.

### ACKNOWLEDGEMENT

The authors acknowledge the Ministry of Higher Education of Malaysia for providing the necessary funding required for the research through ERGS Grant scheme (ERGS/1/2011/TK/UKM/02/10).

### REFERENCES

- Chindaprasirt, P., P. Kanchanda, A. Sathonsaowaphak and H.T. Cao, 2007. Sulfate Resistance of Blended Cements Containing Fly Ash and Rice Husk Ash. *Construction and Building Materials*, 21: 1356-1361.
- Della, V.P., L. Kuhn and D. Hotza, 2002. Rice Husk Ash as an Alternative Source for Active Silica Production. *Mater Lett.*, 57: 818-21.
- Deshmukh, P., J. Bhatt, D. Peshwe and S. Pathak, 2011. Determination of Silica Activity Index and XRD, SEM and EDS Studies of Amorphous SiO<sub>2</sub> Extracted from Rice Husk Ash. *Trans Indian Inst Met*, 10.1007/s12666-011-0071-z.
- Ganesan, K., K. Rajagopal and K. Thangavel, 2008. Rice Husk Ash Blended Cement: Assessment of Optimal Level of Replacement for Strength and Permeability Properties of Concrete. *Construction and Building Materials*, 1675-1683.
- Habeeb, G.A. and H.B. Mahmud, 2010. Study on Properties of Rice Husk Ash and Its Use as Cement Replacement Material. *Materials Research*, 13(2): 185-190.
- Hwang, C.L., A.T. Bui Le and C.T. Chen, 2011. Effect of Rice Husk Ash on the Strength and Durability Characteristics of Concrete. *Construction and Building Materials*, 25: 3768-3772.
- Islam M.N., M.F.M. Zain and M. Jamil, 2012. Prediction of strength and slump of Rice Husk Ash Incorporated High-Performance Concrete. *Journal of Civil Engineering and Management*, 18(3): 310-317.
- Ismail, M.S. and A.M. Waliuddin, 1996. Effect of Rice Husk Ash on High Strength Concrete. *Construction and Build Materials*, 10: 521-6.
- Jamil, M., A.B.M.A. Kaish, S.N. Raman and M.F.M. Zain, 2013. Pozzolanic Contribution of Rice Husk Ash in Cementitious System. *Construction and Building Materials*, 47: 588-593.
- Kartini, K., 2009. Mechanical, Time dependent and durability properties of grade 30 rice husk ash concrete, PhD thesis, University Malaya, Malaysia.
- Koteswara Rao, D., P.R.T. Pranav and M. Anusha, 2012. Stabilization of Expansive Soil with Rice Husk Ash, Lime and Gypsum—An Experimental Study. *International Journal of Engineering Science and Technology*, 3: 8076-8085.
- Loo, Y.C., P. Nimityongskul and P. Karasudhi, 1984. Economical Rice Husk Ash Concrete. *Building, Research and Practice*, 12(4): 233-238.
- Madandoust, R., M.M. Ranjbar, H.A. Moghadam and S.Y. Mousavi, 2011. Mechanical Properties and Durability Assessment of Rice Husk Ash Concrete. *Biosystems Engineering*, 110: 144-152.
- Metha, P.K., 1979. The Chemistry and Technology of Cement Made from Rice Ash. In the Proceeding of UNIDO/ESCAP/RCTT Workshop on Rice Husk Ash Cement, pp: 113-22.
- Ramadhansyah, P.J., B.H.A. Bakar, M.A.M. Johari and M.H.W. Ibrahim M.H.W, 2011. Strength and Permeability Properties of Concrete Containing Rice Husk Ash with Different Grinding Time. *Cent. Eur. J. Eng.*, 1(1): 103-11.
- Raman, S.N., T. Ngo, P. Mendis and H.B. Mahmud, 2011. High-Strength Rice Husk Ash Concrete Incorporating Quarry Dust as a Partial Substitute for Sand. *Construction and Building Materials*, 25: 3123-3130.
- Ramezaniapour, A.A., K.M. Mahdi, and G. Ahmadi Beni, 2009. The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes. *International Journal of Civil Engineering*, 7(2): 83-91.
- Rukzon, S. and P. Chindaprasirt, 2008. Use of Waste Ash from Various By-Product Materials in Increasing the Durability of Mortar. *Songklanakarin J. Sci. Technol.*, 30(3): 485-489.
- Saraswathy, V. and H.W. Song, 2007. Corrosion Performance of Rice Husk Ash Blended Concrete. *Construction and Building Materials*, 21: 1779-1784.
- Sensale, G.R., 2006. Strength Development of Concrete with Rice Husk Ash. *Cement & Concrete Composites*, 28: 158-160.

Siddique, R., 2008. Waste Materials and By-Products in Concrete with 174 Tables. Springer Press.

Smith, R.G. and G.A. Kamwanja, 1986. The Use of Rice Husk for Making a Cementitious Material. In the Proceeding of Joint Symposium on Use of Vegetable Plants and their Fibers as Building Material, pp: 85-94.

Tuan, N.V, Y. Guang, K.V. Breugel, A.L.A. Fraaij and B.D. Dai, 2011. The Study of Using Rice Husk Ash to Produce Ultra High Performance Concrete. Construction and Building Materials, 25: 2030-2035.

Zain, M.F.M., M.N. Islam, F. Mahmud and M. Jamil, 2011. Production of Rice Husk Ash for Use in Concrete as a Supplementary Cementitious Material. Construction and Building Materials, 25(2): 798-805.