Construction and Building Materials 25 (2011) 798–805

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Production of rice husk ash for use in concrete as a supplementary cementitious material

M.F.M. Zain, M.N. Islam *, F. Mahmud, M. Jamil

Faculty of Engineering and Built Environment, National University of Malaysia (UKM), 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia

ARTICLE INFO

Article history:
Received 11 March 2009
Received in revised form 1 July 2010
Accepted 18 July 2010
Available online 14 August 2010

Keywords:
Rice husk ash (RHA)
By-product
Concrete
Waste
Combustion
Grinding
Pozzolan
Supplementary cementitious material
X-ray diffraction
Scanning electron microscopy

ABSTRACT

Rice husk ash (RHA), rich in silica content, can be produced from rice husk using appropriate combustion technique for use in concrete as a supplementary cementitious material. This paper discusses production process of RHA from rice husk and the quality of RHA produced using rudimentary furnace of the National University of Malaysia (UKM). Three combustion methods and two grinding methods were used to investigate physical characteristics and chemical aspects of RHA produced. Combustion temperature distribution of the furnace, ash particle size, silica crystallization phase and chemical content of the produced RHA were studied using X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM). From the investigation, it was found that combustion period, chilling duration, and grinding process and duration are important in obtaining RHA of standard fineness and quality. In addition, air ducts in the furnace are very useful in order to supply air for proper burning of rice husk.

1. Introduction

Rice husk can be burnt into ash that fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon. RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature [1]. Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash.

Rice husk combustion technology has developed from open air burning in the field (around 1970s) to combustion using liquidized layers method (around 1990s). Temperature and combustion period can be controlled in liquidized layers combustion method [2]. Only moderate temperature and short period are required in this method. However, researchers who study RHA usually build their own incinerator/furnace or collect ash from rice mill. Although the studies on pozzolanic activity of RHA, its use as a supplementary cementitious material, and its environmental and economical benefits are available in many literatures [3–54], very few of them deal with rice husk combustion and grinding methods.

In this study, rice husk combustion was performed using a simple furnace designed and built at the National University of Malaysia (UKM), Malaysia. The design concept of this furnace was based on those reported by Loo et al. [28] and Ramli [44]. In this research, three methods of rice husk combustion were used based on combustion fire, air supply, and cooling durations. The produced ash was ground to ensure that it meets the requirements of BS 3892 standard [55]. In this study, two grinding methods were tried for grinding burnt ash. After grinding, physical characteristics and chemical composition of the rice husk ash were determined using X-ray diffraction (XRD), scanning electron microscopy (SEM), and chemical analysis.

2. Experimental program

2.1. Furnace details

A simple furnace shown in Fig. 1 was designed and built after reviewing furnaces reported by Loo et al. [28] and Ramli [44]. It has two sections: a ferrocement cylinder and a steel cylinder. Diameter of the ferrocement cylinder is 1030 mm, height is 1510 mm and wall thickness is 60 mm. The function of ferrocement cylinder is to trap combustion heat within the furnace and preventing it from escaping into air. Diameter of the steel cylinder is 760 mm, height is 1090 mm and thickness is 5 mm. The steel cylinder acts as a container for burning rice husk.

* Corresponding author. Tel.: +880 1716539548.
E-mail addresses: nazrul@eng.ukm.my, nazrul2100@yahoo.com (M.N. Islam).

0950-0618/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2010.07.003

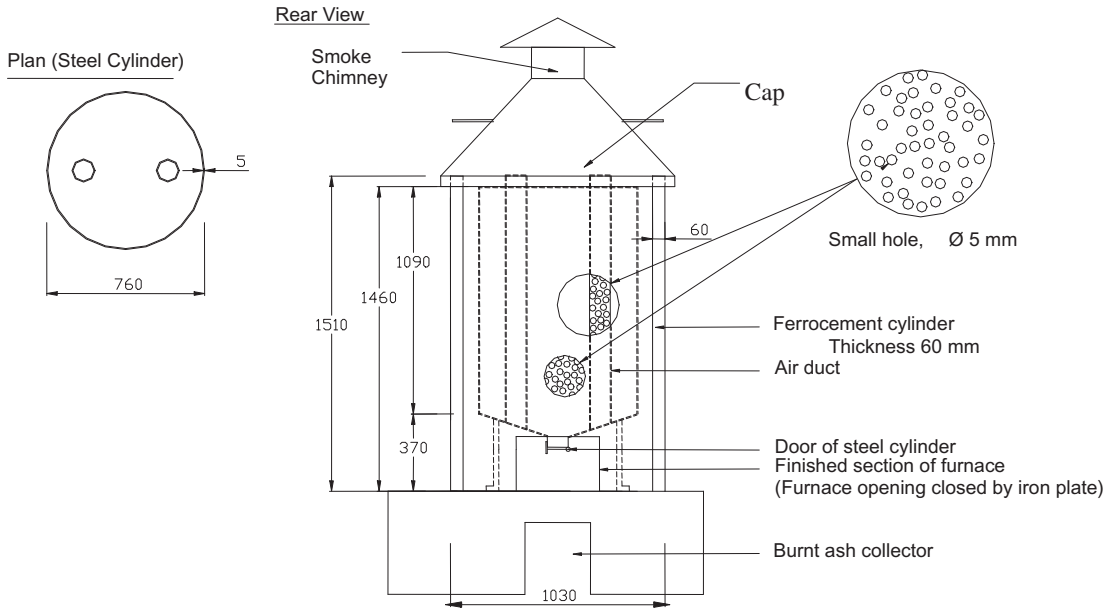

Fig. 1. Furnace at UKM for burning rice husk.

Inside the steel cylinder, two units of steel air ducts are located. Diameter, height and thickness of each duct are 100 mm, 200 mm, and 5 mm, respectively. Air ducts play two roles: supply air to husk during combustion process and act as passages for fire. Combustion at the lower and upper levels of the furnace takes place at the same time, causing the husk to burn faster. Air ducts are also useful in controlling combustion temperature. Combustion temperature is controlled by supplying air through air ducts using electric fan. Surfaces of the steel cylinder and air ducts are perforated with small holes of 5 mm diameter. Both ferrocement and steel cylinders are covered at the top with steel cap equipped with smoke chimney as shown in Fig. 1.

2.2. Combustion of rice husk

Rice husk was put into the furnace through opening at the top. Gasoline burners were placed inside the furnace under the air ducts (Fig. 2a). Combustion was continued for a preset duration. After that duration, gasoline burners were taken out. Electric fan was then switched on and placed near the door of the furnace. It supplied air and maintained embers of the burning husk. Air was supplied for a few minutes and then ash was allowed to chill. When the ash was cold, outlet at the bottom of the cylinder was opened and the ash was allowed to fall into a container (Fig. 2b). In this study, three combustion methods, labelled as A, B, and C were tried as shown in Table 1. The main differences among A, B, and C were durations of combustion, air supply, and chilling of ash. During combustion process, temperature was recorded using thermometers located along the height of the furnace (200, 400 and 600 mm above the base of the steel cylinder) as shown in Fig. 3. The thermometers were set into the furnace through holes of the ferrocement cylinder (thermometer 1 at layer 1 and so on).

Table 1
Comparison of rice husk combustion methods A, B, and C.

Serial no.	Combustion stage duration	Combustion method		
		A	B	C
1	Fire duration (min)	30	60	30
2	Air supply duration (min)	90	105	60
3	Chilling duration (day)	1	1	2

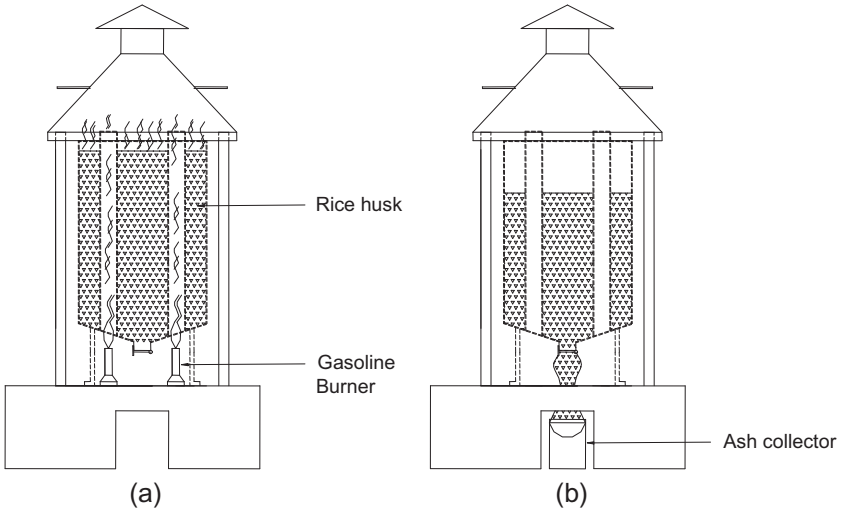

Fig. 2. Rice husk combustion process: (a) combustion using gasoline burner and (b) taking out the burnt rice husk.