Journal of Building Engineering 14 (2017) 7–14

Contents lists available at ScienceDirect

Journal of Building Engineering

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

Production of sustainable clay bricks using waste fly ash: Mechanical and durability properties

Safeer Abbas[a,1], Muhammad A. Saleem[a], Syed M.S. Kazmi[b,c], Muhammad J. Munir[b,c,*,1]

[a] Department of Civil Engineering, University of Engineering and Technology, Lahore 54000, Punjab, Pakistan
[b] School of Engineering, RMIT University, 376-392 Swanston Street, Melbourne, Victoria 3001, Australia
[c] Department of Civil Engineering, Mirpur University of Science and Technology (MUST), Mirpur 10250, AJK, Pakistan

ARTICLE INFO

Keywords:
Brick
Clay
Fly ash
Mechanical properties
Durability

ABSTRACT

Burnt clay brick is one of the ancient building material. The use of waste materials in bricks can lessen the consumption of clay material and reduce the environmental burden due to accumulation of waste materials. Furthermore, addition of recycled materials can decrease the high carbon footprint. In the current study, bricks were manufactured using fly ash (by-product of coal) and conventional earthen materials. Fly ash was acquired from the coal power plant. Manufacturing of brick specimens was done in a local brick industry. The main variable in this study was the percentage of fly ash (i.e. 0–25% of clay). Results indicate that the compressive strength of bricks incorporating fly ash was lower as compared to that of clay bricks without fly ash. However, compressive strength of bricks incorporating up to 20% of fly ash satisfied the minimum requirements of the Pakistan Building Code. Reduction in weight was also observed in the fly ash bricks which would lead to overall weight reduction of the structures. Furthermore, less efflorescence was observed in bricks incorporating fly ash. Therefore, it can be concluded that clay bricks incorporating fly ash can be helpful in producing more sustainable bricks leading to economical solution.

1. Introduction

Brick manufacturing is one of the oldest industry having traces since 8000 BCE [1]. Brick is a burnt block obtained after burning of clay in a kiln. Earth bricks used in the construction of shelters accommodate 30% of world population, which is living in earthen structures [2]. Burnt clay bricks are made after subjecting clay mixture through molding, sun drying and burning processes. The properties of burnt clay bricks depend upon the nature of material and manufacturing process [3]. Temperature also plays a key role in development of brick properties [4]. Temperature melts the naturally occurring oxides of silica in clay. After cooling, bond develops between the clay particles.

In many parts of the world, burnt clay bricks are still commonly utilized as a building material. China is the largest brick producing country [5]. India is the second largest country in brick production having an annual consumption of 180 billion tons of bricks [6]. Fertile soil is being rapidly consumed for brick manufacturing. In India, 300 million tons of fertile soil is consumed per day for brick manufacturing [7]. In Ontario (Canada), production of clay bricks is approximately 700 million per year [8]. It is also considerable that clay deposits are under depletion in many parts of the world. Therefore, to overcome this problem, some countries like China are now limiting the use of clay for brick production [9,10].

Burnt clay bricks usually have higher strength than sun dried bricks. However, in terms of strength and durability, these bricks are observed weaker than cement blocks [5]. To overcome these deficiencies, different pozzolanic materials are added in clay bricks as admixtures. These materials not only increase the bond between particles but also help in lowering the melting temperature by acting as a flux [4]. As a result, strength of the clay brick increases [11].

Various researchers have explored the use of different waste materials in burnt clay bricks. Waste glass can be used as an additive in burnt clay bricks. By using waste glass, bricks with improved compressive strength and water absorption can be produced [12]. Agro-wastes like sugarcane bagasse ash and rice husk ash can also be utilized in clay bricks [3,13,14]. Although, these wastes reduce the strength and increase the water absorption of clay bricks; however, they result in lighter and energy efficient structures by improving insulation properties of bricks [3,5]. Lighter bricks are also preferred in earth quake affected areas [15,16].

Fly ash (FA) is a fine waste material of power generation plant. It is obtained after coal combustion. The FA usually possesses pozzolanic

* Corresponding author at: School of Engineering, RMIT University, 376-392 Swanston Street, Melbourne, Victoria 3001, Australia.
E-mail address: junaidmunir17@gmail.com (M.J. Munir).
[1] Joint first author.

http://dx.doi.org/10.1016/j.jobe.2017.09.008
Received 29 November 2016; Received in revised form 7 June 2017; Accepted 15 September 2017
Available online 19 September 2017
2352-7102/

properties and helps in improving the strength of concrete [17,18]. Different researchers [19,20] have studied the utilization of fly ash in burnt clay bricks. Fly ash can be utilized in production of 10% lighter bricks as compared to clay bricks [6]. Fly ash also increases the strength and reduces water absorption [19]. Leiva et al. [21], observed the increase in compressive strength of fly ash bricks at firing temperature of 1000 °C. However, clay bricks showed decrease in compressive strength with increasing fly ash content at firing temperature lower than 1000 °C. Çiçek and Çinçin reported the superior thermal conductivity of fly ash bricks as compared to conventional clay bricks [22] Fly ash bricks usually have smooth edges than burnt clay bricks [6]. The utilization of fly ash is less as compared to its production. It is estimated that approximately 0.16 billion tons of fly ash is produced every year [5]. In many parts of the world, fly ash is used to replace cement [23]. Environmental problems exist with respect to coal in countries where coal is the main source of power generation [7]. Moreover, the cost of production of fly ash bricks is 2% less as compared to burnt clay bricks [20].

In this study, the use of FA was focused for brick manufacturing. Utilization of FA not only improved the brick performance but also reduced the environmental pollution and landfill burden. FA was used in different dosages (5%, 10%, 15%, 20%, 25% by clay weight) in clay bricks to explore its effect on different mechanical as well as durability properties. Although, many studies exist regarding the utilization of fly ash in clay bricks; however, in all the studies, bricks with fly ash were prepared in laboratory under controlled conditions. This study was focused on the production of fly ash burnt clay bricks on large scale in the industrial kiln.

2. Research significance and objectives

Disposal of waste materials is one of the major environmental problems in the world. In many parts of world, dumping landfill sites are limited. Therefore, dumped waste material is not only polluting the environment but also a burden on the earth. Furthermore, in some parts of the world, the waste material is discharged into the rivers, which causes spread of various deceases. For instance, in Egypt wastes are discharged in River Nile [24] and as a result, aluminium concentration in the water increases, causing the major diseases like, Alzheimer and mental retardation [25]. In Asia, 4.4 billion tons of solid waste is produced annually [26]. Therefore, due to environmental concerns, there is an urgent need to utilize these wastes, especially due to the accumulation of these pollutants. Moreover, natural resources of clay are also under depletion due to the continuous extraction.

In this research, the consumption of fly ash in burnt clay bricks was investigated for the manufacturing of sustainable bricks. The primary focus of this research was to experimentally investigate the effect of ash on the mechanical and durability properties of burnt clay bricks. Utilization of such wastes is not only helpful to address problems related to pollution but would also reduce the number of landfill site. Utilization of these wastes will reduce the depletion of natural resources. It will also help in the production of innovative construction material.

3. Experimental program

3.1. Materials and mixing of raw materials

The materials used for the manufacturing of bricks were clay, fly ash and water. Clay used in the present study was taken from Pak Bricks Company, Multan, Pakistan. The used fly ash was obtained from a local coal power plant. Raw materials (clay and fly ash) were used without any processing during the study. The sieve analysis, chemical analysis and x-ray diffraction (XRD) of clay and fly ash was performed in order to identify the chemical and mineralogical characterization.

A total of 150 brick specimens of size 225 × 112 × 75 mm were prepared at brick kiln site (Fig. 1) by varying the fly ash proportions (Table 1). General hand mixing and molding technique was adopted for brick manufacturing. Materials were weighed according to desired proportions and manually mixed (Fig. 2**(a)**). Afterwards, plasticity water (20.8–18.7%) was added into the dry mix and manual mixing continued until a homogenous mixture achieved (Fig. 2**(b)**).

Fig. 1. Brick manufacturing industry.

Table 1
Test matrix for brick specimens.

Mixture	Fly ash (%)	Clay (%)	No. of specimens
1	0	100	25
2	5	95	25
3	10	90	25
4	15	85	25
5	20	80	25
6	25	75	25

3.2. Brick manufacturing

For the molding of bricks, balls of clay (Fig. 2**(c)**) were made on a dry area and bricks were molded using these balls of clay. Brick mould was oiled from inside before putting clay ball in it. Moreover, a dry sand coating of clay ball was done to prevent sticking of clay with the mould. Brick specimens were marked with numbers according to the quantity of fly ash added. General industry practice followed in Pakistan to prepare bricks was adopted during the study. Freshly prepared wet bricks were allowed to dry for 4–5 days in open air (Fig. 3**(a)**) in sunlight to harden enough to transport to the kiln undamaged. Afterwards, bricks were placed in kiln and subjected to fire for three days. The temperature in the kiln was around 800 °C. After 20 days, burnt clay bricks were removed from the kiln (Fig. 3**(b)**).

4. Experimental methodology

4.1. Mechanical properties

The mechanical properties of brick specimens were determined as per ASTM C67 (Standard test methods for sampling and testing brick and structural clay tile). Five specimens were tested for each mix proportion. Firstly, the unit weight of brick specimens was determined. For 24 h, brick specimens were oven dried at 100 °C and then cooled for 5 h at room temperature (25 °C). Afterwards, weight of brick specimens was determined using weighing balance of 0.50 g least count (Fig. 4).

The compressive strength was determined by capping the brick specimens using plaster of paris for uniform application of load. The