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Manufacturing of sustainable clay bricks: Utilization of waste sugarcane bagasse and rice husk ashes

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HIGHLIGHTS

- Incorporation of waste materials in manufacturing of clay bricks was investigated.
- Mechanical and durability properties of bricks incorporating RHA and SBA was studied.
- Addition of RHA and SBA in brick manufacturing can lead towards sustainable and economical construction.

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ABSTRACT

Burnt clay brick is one of the major and widely used building unit in masonry construction around the globe. The manufacturing of burnt clay bricks using waste materials can minimize the environmental overburden caused by waste deposition on open landfills and would also improve the brick performance at low production cost leading to more sustainable construction. This study aims to evaluate the effect of the waste addition produced from two major crops: sugarcane and rice in clay bricks manufacturing. In this study, sugarcane bagasse ash (SBA) and rice husk ash (RHA) were collected locally from a sugar mill and bull's trench kiln, respectively. Brick specimens were manufactured at an industrial brick kiln plant using various dosages (5%, 10% and 15% by clay weight) of SBA and RHA. Mechanical and durability properties of these bricks were studied. It was observed that clay bricks incorporating SBA and RHA exhibited lower compressive strength compared to that of clay bricks without SBA and RHA. However, compressive strength of bricks with 5% of SBA and RHA satisfied the Pakistan Building Code requirements (i.e. >5 MPa). Scanning electron microscopy (SEM) analysis confirms the porous microstructure of the brick specimens incorporating SBA and RHA, which resulted into lesser unit weight leading to lighter and economical structures. Furthermore, resistance against efflorescence was improved in all the tested bricks incorporating SBA and RHA. Based on this study, it can be concluded that the brick specimens incorporating lower dosage of SBA and RHA (i.e. 5% by clay weight) will not only relieve the environmental burden but also result into a more sustainable and economical construction.

1. Introduction

Fired clay bricks are one of the oldest construction material used in the construction of partition and load carrying walls in the buildings. The extensive use of natural clay deposits for brick production has caused an alarming deficit level of this natural material [1–3]. This situation has forced the researchers to shift their focus towards the development of new materials or recycle waste materials produced from various industries. In the same context, various wastes including rice husk ash and sugarcane bagasse ash can be used in the production of bricks. In this study, the use of these two wastes for brick production has been attempted.

Rice husk is the outer cover of rice kernel, which have two interlocking halves. Approximately, husk is obtained 20% of rice paddy and Pakistan is capable of producing one million tons of husk every year [4,5]. Major disposal of rice husk is either in brick industry where it is used in kilns as a fuel source or in the paper industry. After combustion of rice husk, ash is produced. Different percentage of ash obtained have been reported by various researchers. Normally, it is obtained 15–25% of rice husk [6,7]. The disposal of this ash is a great challenge. Rice husk ash (RHA) obtained from brick kilns has great potential to be used for brick manufacturing.

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This can lead to environmental friendly, sustainable and economical construction.

Moreover, after extraction of juice from sugarcane in the sugar mills, the bagasse is left as a residue. Approximately, 1 kg of sugarcane generates 25% of bagasse and 0.6% of bagasse ash [8]. Sugar cane is produced around 50 million tons annually in Pakistan and consumed mostly in sugar production [9,10]. As a result, bagasse is obtained in a range of 24–30% and used as a source of fuel in the sugar industry [11]. The residue left after burning is called as sugarcane bagasse ash (SBA) having two main constituents: oxides of silicon and aluminum. Approximately, sugarcane is consumed 81% in sugar industry [12]. In Pakistan, 0.26 million tons of bagasse ash is produced annually, after combustion of approximately 11 million tons of bagasse [13], which can be potentially used in brick production.

2. Literature review

Brick properties depend on the composition of raw materials and method of production. Furthermore, temperature of burning significantly influence the brick performance because it plays an important role in bond development between the clay particles. High temperature softens the naturally occurring silica (SiO_2) in clay and on cooling it develops bond between adjacent clay particles. To achieve good bond between particles, generally additives are used in bricks, which act as flux to lower the melting temperature and help in bond development. Now-a-days, researchers are focusing on the waste materials that can be used as an additive in bricks to improve the strength and durability characteristics of bricks [1,14–16]. Glass is one of the waste materials which can be used as an additive. Use of waste glass as an additive produces bricks with higher compressive strength and lower initial rate of absorption, pore volume and porosity. However, increase in shrinkage for brick specimens incorporating glass waste has been reported in previous studies [17,18].

Sawdust and marble residues have been used in bricks manufacturing (ceramic bricks). These additives resulted in an increased apparent porosity and water absorption; however, decreased porosity at high temperature (sintering) with higher compressive strength was also observed [19]. The use of 15–20% of marble powder can be considered as an optimum dosage for improved brick performance. However, the water absorption was higher for civil construction purposes [20]. Fly ash can also increase the strength of clay bricks and reduces the water absorption [21–23]. Furthermore, fly ash bricks are environment friendly, leading to a greener building material [24].

Similarly, nano clay can also be used in brick manufacturing. It can increase the compressive strength up to four times; however, durability characteristics are still under investigation [25]. Special techniques are required for obtaining nano clay; therefore, use of nano clay may not be an economical option.

In the previous researches [26], an increased compressive strength with small quantity of rice husk ash was observed. However, increased water absorption [26,27] with decreased shrinkage and thermal conductivity was reported for clay mixture incorporating rice husk ash. On the other hand, bricks incorporating sugarcane bagasse ash showed lower unit weight leading to lighter bricks with improved behavior in earthquake prone areas [28]. Use of sugarcane bagasse ash (SBA) in bricks is highly encouraging in terms of waste disposal. However, the use of higher concentrations (i.e. 10%) of SBA in clay bricks tend to decrease the compressive strength [29,30]. Bricks are normally manufactured in industrial kilns on large scale; whereas, in all the previous researches [17,20], electrical furnace had been used in the laboratory to burn the bricks. Moreover, research on durability properties (freeze-thaw, efflorescence, sulfate attack and porosity) of clay bricks incorporating rice husk and sugarcane bagasse ashes is very scant in the open literature.

In this research program, waste materials (rice husk ash and sugarcane bagasse ash) have been used for brick manufacturing. The use of these waste materials not only improves the brick performance but also attractive with respect to environment, sustainability and economy. RHA and SBA were used in three different replacement ratios (5%, 10%, 15% by weight of clay) in bricks to investigate their effect on mechanical and durability properties. Unlike the previous researches, all the bricks were manufactured in an industrial brick kiln.

3. Research significance and objectives

Engineers and researchers have been compelled to find new alternative materials for brick manufacturing due to excessive consumption of the natural resources. The natural resources, such as clay (top soil), is getting depleted due to over utilization in brick manufacturing, which demands for its conservation. Moreover, various landfill scarcity and environmental problems are the other factors owing to the inefficient management of wastes produced from various industries. This situation demands the construction industry stakeholders to investigate new alternative materials and develop novel methodologies for effective use of wastes produced from industry.

This research investigates two cheaply available waste materials: sugarcane bagasse ash (SBA) and rice husk ash (RHA) which were probed for brick manufacturing on large scale. Reuse of such wastes in brick production can lead to a sustainable construction material that addresses the environmental pollution issue and landfilling problem at low cost. The main objective of this study is to experimentally explore the effect of RHA and SBA on mechanical and durability properties of burnt clay bricks.

Additionally, being an agricultural country, Pakistan produces huge amount of sugarcane and rice annually. Therefore huge quantity of wastes are also produced by these crops. Scientific application of these wastes in different construction projects will not only help to reduce pressure on the natural resources but will also lead a way to produce improved construction material with refined properties.

4. Materials and methodology

4.1. Raw materials

Common clay (soil), dry sugarcane bagasse and rice husk ashes were used as raw materials for brick manufacturing. Clay was acquired from the kiln located in Mirpur Azad Kashmir, Pakistan. Sugarcane bagasse ash was obtained from Khazana sugar mill, Peshawar; while, rice husk ash used in this research was acquired from an industrial brick kiln near Wazirabad, Pakistan. Brick specimens were prepared in an industrial brick kiln plant (Fig. 1).

4.2. Preparation of brick specimens

Firstly, SBA and RHA were manually mixed in desired proportions with clay in dry state (Fig. 2 (a)). The proportions of the SBA and RHA used in this study are listed in Table 1. Afterwards, water was added into the dry mixture (Fig. 2(b)). The mixture was then left for 2–3 h allowing the water to fill in the voids for achieving the maximum homogeneity. Lumps of the mixture required for preparing bricks (Fig. 2(c)) were then prepared and coated with dry sand to avoid sticking with the mold. The clay lumps were placed in the brick molds of size 228 × 114 × 76 mm. In contrast to the normal period of 1–2 days, bricks were dried for 10 days, as they were casted in covered shed in order to provide rain protection (Fig. 3(a)). After drying, bricks were transported to brick kiln. A total of 400 bricks were placed in kiln for 45 days. Brick specimens were fired at approximately 800 °C for 36 h. After 45 days, brick specimens were removed from the kiln (Fig. 3(b)).