Reducing Carbon footprint of clayey bricks by using demolished ceramics and brick as a fractional substitute of clay

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Abstract. Present research comprises of reprocessing discarded brick and ceramic powders as a fractional substitute of clay in making clayey bricks. The extensive use of clay during the development of bricks is the cause of loss of fertile land, which is affecting the climate. The substitution rates of 5, 10, 15% for brick and 4, 8, 12% for ceramic are explored. The brick samples were evaluated based on their physical, mechanical and durability properties. The comparison of control and modified bricks depicted approximately the same unit weight, decreased mechanical strength, and good improvement against water absorption.

Keywords: Clayey bricks, brick powder, ceramic powder.

1 Introduction

Bricks are extensively used in the construction industry. According to an estimate, 27 million bricks are produced in Mirpur city of Azad Jammu & Kashmir [1]. This is adversely affecting the environment. There is a need to mitigate the environmental impact by exploring novel materials, which are eco-friendly and can replace clay. Several authors have explored different materials as a fractional substitute of clay in making brickmaking. Some important research is documented here.

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Kazmi et al. utilized Sugarcane Bagasse Ash (SBA) and Rice Husk Ash (RHA) as a partial replacement of clay in making clayey brick [2, 3]. The study showed that the substitution reduced the mechanical strength; however, the replacement also reduced the density and the efflorescence effects. The porous bricks offer more resistance against temperature effect. Riaz et al. recycled pulverized waste brick as a fractional substitute for clay in manufacturing clayey bricks [4]. The study documented that 25% replacement marginally reduced the strength and enhanced the resistance against efflorescence and heat transfer. The substitution also reduced the density by enhancing the pore volume. Riaz et al. recycled waste ceramic powder as a fraction of clay[5]. The research revealed that the alternate material raised the mechanical strength, density, and durability of the bricks. Munir et al. employed waste marble powder in place of clay in bricks[6]. The authors depicted that the replacement reduced the strength, and density and enhanced resistance to efflorescence and sulphate attack. Khitab et al. employed a mixture of ceramic powder and brick powder as fractional alternate of clay in bricks[7]. The findings suggested that a substitution of 9% (5% brick powder and 4% ceramic powder) enhanced the mechanical strength. The researchers have further reported that the substitution also enhanced the resistance against freeze and thaw, sulphate attack and efflorescence.

The present study is an extension of the previous work conducted in our lab. In past research, a mixture of fine powders of brick and ceramic waste was employed as a fractional substitute of clay. It has been asserted that the combination reduced the strength of the bricks after 9% combined replacement. Another two past studies suggested that the fine brick powder reduced, while the course ceramic powder enhanced the mechanical strength [4, 5]. Consequently, this study was designed to recycle a blend of fine brick powder and course ceramic powder as a fractional substitute of clay in making climate-friendly bricks. The substitution levels were decided as 9% (5% brick + 4% ceramic), 18% (10% brick + 8% ceramic), and 27% (15% brick + 12% ceramic). The brick samples were assessed through mechanical strength, physical and durability characteristics.

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2 Materials and methods

Fertile Clay (C), Waste Brick Powder (WBP), and Ceramic Powder (CP) were employed as the primary materials utilized for brickmaking. The materials are shown in

Fig. 1.

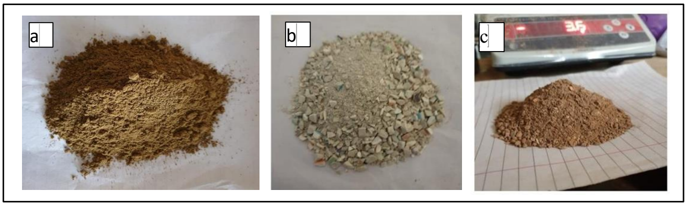

Fig. 1 Primary materials for making bricks (a) clay, (b) ceramic powder, (c) brick powder.

Table 1 Chemical composition of raw ingredients

Oxides	Clay (%)	WBP (%)	CP (%)
SiO_2	59.2	46.4	71.0
Al_2O_3	16.6	29.7	21.9
CaO	13.1	4.9	3.7
Fe_2O_3	6.9	7.8	1.2
ZrO_2	2.9	4.9	1.1
K_2O	0.9	3.9	0.4
CeO_2	0.1	5.2	0.3
MnO	0.04	0.05	0.11
CuO	0.02	0.01	0.02

The composition revealed that all the ingredients contained the same basic compounds as are required in clay suited for brick making. Nevertheless, the proportions are different. The XRD study is mentioned in Fig. 2. The analysis suggested that the clay mainly contained Alumina, lime, and Quartz; the WBP mainly consisted of Alumina, lime, Iron oxide and Quartz; and the CP was mainly comprised of Quartz. Thus, the XRF and XRD studies are closely inter-connected.

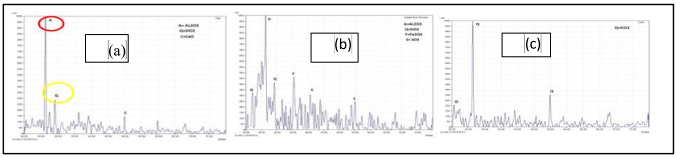

Fig. 2 X-ray diffraction images of (a) Clay, (b) WBP, and (c) CP

The material configuration of brick specimens is presented in **Table 2**. Forty brick specimens were made in each category. Also in each case, the same amount of water, i.e. 52 liters, was used.

Table 2 Composition of brick specimens

ID	Composition	Clay (kg)	WBP (Kg)	CP (Kg)
C0	Control	140	0	0
C4	4% CP & 5% WBP	127.4	7	5.6
C8	8% CP & 10% WBP	114.8	14	11.2

C12	12% CP & 15% WBP	102.2	21	16.81

The mixing and manufacturing of bricks is shown in **Fig. 3**. The bricks were manufactured in a local Bull's Trench Kiln [8].

Fig. 3 Manufacturing of clayey bricks

The specimens were tested from the perspective of density, compressive strength, and initial water absorption in accordance with the ASTM standards. All these attributes were measured in compliance with ASTM C67 standards [9].

2.1 Density

The bricks were dehydrated in the oven at 110°C for one day. When cooled, the weight was recorded using five readings. To find out the specific weight, the mass of a unit was divided by its surface area as shown in the equation (1):

$$\text{Specific mass} = \frac{w}{a} \tag{1}$$

Here *w* represents the weight in Kg and *a* indicates the area in m^2. The density of bricks was calculated by using the equation (2) as below:

$$\text{Density} = \frac{w}{v} \tag{2}$$

Here *w* denotes the weight in g and *v* indicates the volume in cm^3.The density was determined in accordance with ASTM C67-17.

2.2 Compressive strength

The Compressive strength was determined by using the equipment Controls AUTOMAX PRO-M. Bricks were dried-out in an oven under a temperature of 110 °C for 24 hours. Load was applied depth-wise. The loading rate was adjusted to 3500 (N/Sec). Compressive strength was computed by equation (3):

$$f_c' = \frac{w}{a_c} \tag{3}$$

Where f_c' is the compressive strength (MPa), *w* indicates the weight of the brick (N) and a_c denotes cross-sectional area of the brick (mm^2).

3 RESULTS AND DISCUSSION

The results and their analysis are presented in the following paragraphs.

3.1 Density

The variation of weight per unit area is mentioned in **Fig. 4**, whereas that of density with partial substitution is shown **Fig. 5**. The outcomes show that both the parameters increase with increase in the substitution.

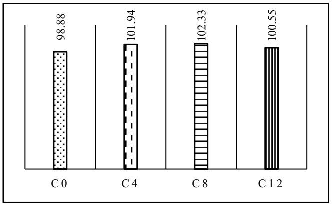

Fig. 4 Variation of specific mass with waste

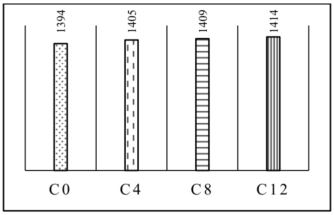

Fig. 5 Variation of density with waste

The increase in weight per unit area and density is associated with the higher density of the particles. The clay, WBP and CP have densities of 1.3 gm/cm^3, 1.25 gm/cm^3. and 1.63 gm/cm^3 [5, 10]. The rise in the density of the ingredients is the cause of the increase in the weight per unit area and density of the bricks.

3.2 Compressive strength

The fluctuation in compressive strength with the substitution is shown in Fig. 6. The findings showed that C4 is the optimum combination. Beyond that, the strength decreases. The quality of the brick is normally expressed in compressive strength and water absorption. A good quality brick has a high strength and low water absorption [11]. For exploring the reasons for high strength, the initial water absorption was determined in compliance with ASTM C67-17. The outcomes are mentioned in Fig. 7, which indicated that C4 specimens offered the densest combination owing to the lowest water absorption.

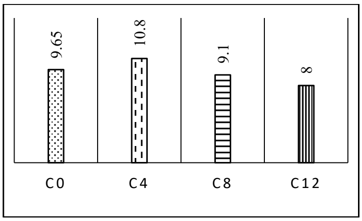

Fig. 6 Change in compressive strength (MPa) using waste

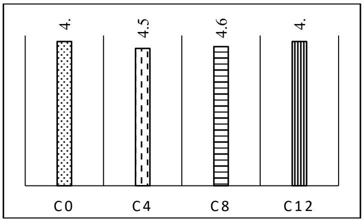

Fig. 7 Variation of Initial water absorption with waste

4 Conclusions

1. The combined mixture of brick and ceramic powders enhanced the density and specific weight of the bricks.
2. The optimum mechanical strength is obtained with 4% ceramic and 5% brick powders as a fractional substitute of clay.
3. The optimum initial water absorption is also obtained with 4% ceramic and 5% brick powders as a fractional substitute of clay.

The bricks up to 27% (15% brick + 12% ceramic) partial replacement can be manufactured with marginal compromise over density and strength. This shall lessen the burdens on fertile clay and add to climate conservation efforts.

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