Clay Bricks

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Clay bricks are extensively used as building material worldwide. Natural soil deposits are in constant reduction due to the frequent use of clay to manufacture bricks. About 1600 billion bricks are produced annually by the consumption of millions of tons of natural resources.

bricks clay recycling waste brick powder waste ceramic powder sustainable development

1. Introduction

The construction industry plays a vital role in the socio-economic development of any country [1]. Nevertheless, it is also a significant source of greenhouse gas emissions and depletion of natural resources. A shift in the construction approach towards sustainable development is the critical need of the day. In construction projects, bricks are extensively used as they possess beneficial properties like the ease of handling, high durability, and low cost [2]. They are used in almost every type of civil engineering project, including commercial, industrial, and residential. The primary raw material used for the manufacturing of bricks is clay. Every year almost 340 billion tons of clay are consumed worldwide to manufacture bricks, and in Pakistan, about 59 billion bricks are produced in 1200 brick kilns [3]. Brick manufacturing involves collecting, mixing, molding, drying, and burning raw materials in brick kilns. Bricks are usually composed of various types of clays and other ingredients like sand. Clays suitable for brick manufacturing usually comprise 20–30% alumina, 50–60% silica, 1–5% lime, and 5–6% iron oxide, along with various other carbonates and oxides in minor quantities [4]. The mineralogical composition of the clay is important for the quality of the end product. Carbonates lead to the formation of pores when bricks are manufactured at a temperature of 800–1000 °C [5], alkalis (Na and K salts) absorb moisture from the atmosphere and lead to dampness and efflorescence [6], quartz mainly acts as a filler and maintains the shape of the bricks and improves the mechanical properties [7], and iron oxide (hematite or magnetite) is responsible for the color and strength of the bricks [8]. It is imperative to have a clear understanding of different types of waste that can be used in brick manufacturing to partially replace clay.

The properties of bricks are greatly affected by the following factors:

(a) Properties of raw material usedMany researchers have forecasted that natural soil deposits are on a constant
(b) Manufacturing techniquesdecline because of the large quantity of production of clayey bricks and ceramic tiles
(c) Temperatureworldwide. Countries like Pakistan are also facing the issue of disturbance in the natural balance of

fertile soil due to the manufacturing of large quantities of bricks throughout the year. This issue sometimes becomes more critical due to the lack of an efficient solid waste management system. Developing countries with struggling economies are adversely affected by the hazardous impacts of unmanaged solid waste generated from domestic and commercial activities. This waste is a potential threat to environmental sustainability and human health. Recycling wastes addresses environmental concerns and is also an economically viable approach towards environmentally friendly construction. Many researchers in the past have used many other waste materials. In the following paragraph, a brief introduction is presented.

Andreola et al. studied clay recycling via rice husk ash (RHA) [9]. Their study revealed that RHA produces lightweight bricks with low strength. A 5% replacement as the optimum percentage for load-bearing purposes was reported. Kazmi et al. replaced clay with sugarcane bagasse ash [10] and showed that the replacement leads to lighter bricks with lower compressive and flexural strengths. Ibrahim et al. used sawdust to partially replace clay (0–10%) [11]. It was concluded that the replacement leads to lighter bricks but with a drastic reduction in compressive strength from 14.5 to 6.7 MPa at a 10% substitution level. Ahmed et al. studied the effect of coal and wheat husk additives on the properties of clayey bricks [12]. It was demonstrated that both the additives induce porosity and reduce strength. Munir et al. used waste marble powder (WMP) as a partial replacement of clay in bricks [13] and confirmed a subsequent strength reduction and increased porosity. Mandal et al. used iron slime as an additive in making bottom ash bricks [14]. The addition enhanced both strength and density.

Riaz et al. added WBP to partially replace clay to manufacture eco-friendly bricks [15]. The addition led to lightweight porous bricks with reduced strength. Riaz et al. incorporated WCP as a partial replacement of clay in making clayey bricks [4]. The incorporation resulted in bricks with enhanced strength as well as weight. Hasan et al. investigated the effect of the partial replacement of clay by waste glass [15]. Their findings revealed that the replacement increases compressive strength and density. All the above research indicates that the partial replacement of clay by any one material reduces strength and weight or increases both. Keeping that in mind, it would be logical to use binary or ternary mixes instead of unary ones. For example, Li et al. used iron ore tailing (IOT) to prepare bricks [16]. The addition increased not only the strength but also the weight due to the heavier density of iron. In order to induce different porosity and reduce weight, they used foam gel casting technology. In the same way, Quero et al. used a binary mixture (screened clay + fly ash (FA)) as a partial replacement of clay in brick manufacturing and reported products with enhanced porosity and compressive strength [17].

Besides the bricks, recycling waste materials has been investigated in ceramic tiles and traditional ceramics. In this regard, significant work has been carried out by Jordan et al. [18] and Montero et al. [19][20]. Sludge rich in calcium carbonate was successfully utilized in traditional ceramics as a secondary raw material, resulting in significant cost savings [20]. The beneficial use of sewage sludge and marble residues in ceramic tile was also corroborated [19], wherein the reactivity of added residues (sewage sludge and marble sludge) with the clay minerals and quartz was shown.

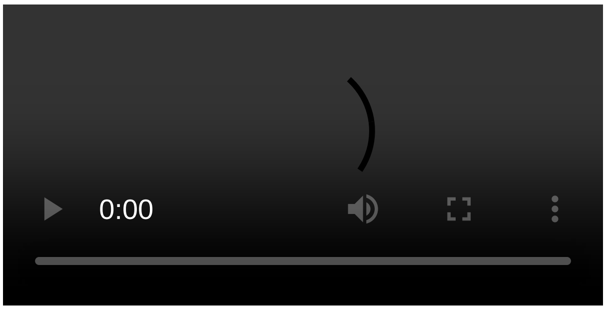
2. Manufacturing of Clay Bricks by Synergistic Use of Waste Brick and Ceramic Powders as Partial Replacement of Clay

We focus on introducing environmentally friendly bricks that are durable and sustainable and help preserve the natural environment. Existing research findings on waste utilization in brick manufacturing were carefully reviewed to develop a base for the study. An effort has been made to devise new ways to preserve natural clay by replacing it with waste ceramic powder (WCP) and waste brick powder (WBP) in the manufacturing of bricks. It is based on some previous work conducted in our research group. In one study, clay was partially replaced by WBP in the range of 5–15%—the resulting bricks were lightweight but had lower mechanical strength than the control specimens [21]. In the other study, the clay was replaced by WCP in the range of 4–12%—the modified bricks exhibited high density with higher mechanical strength. In this study, a composite replacement of WCP and WBP, i.e., 4 + 5%, 8 + 10%, and 12 + 15% (WCP + WBP), respectively, is proposed. The goal is to produce bricks with acceptable density, durability, and mechanical strength (comparative to those of the control products) by using the composite advantage of the proposed binary mix. This would also ensure the efficient utilization of wastes generated from two different resources.

Hazardous impacts of construction activities have forced researchers to innovate new ways to ensure the sustainable development of future generations. As the conservation of natural resources is a significant part of sustainability, recycling waste is a rational, logical, and economical step towards conserving these resources. The results indicated that brick and ceramic wastes are suitable for being used as clay replacements in manufacturing bricks. The following conclusions have been drawn from the study:

- Bricks containing waste ceramic and brick powder were free of efflorescence and had equal resistance against chemical attack, as observed in the ASTM C67 standard test.
- Bricks containing 27% (15% WBP + 12% WCP) waste materials possessed the same density, porosity, and water absorption capacity as those containing 100% clay.
- Bricks containing 27% (15% WBP + 12% WCP) waste materials possessed a 27% decreased initial water absorption rate compared to the control specimens.
- Bricks with 9% (5% WBP + 4% WCP) waste materials had a compressive strength of 11 MPa, more than the control specimens with 9.8 MPa strength. However, bricks with 27% waste materials had a strength of 8.1 MPa.
- Bricks with 9% (5% WBP + 4% WCP) waste materials had a modulus of rupture of 3.32 MPa, more than that of the control specimens with 3.26 MPa strength. However, bricks with 27% waste materials had a strength of 1.84 MPa.
- The combination of waste brick and ceramic powder was effective against sulfate attack, and the resistance increased with an increase in the replacement level.
- Bricks with 9% (5% WBP + 4% WCP) waste materials showed the highest resistance against freeze and thaw (only 0.87% weight loss). Nevertheless, the weight loss in all the specimens was found to be less than 1%.

It is concluded that 27% mass of clay can be successfully replaced with 12% waste ceramic powder and 15% waste brick powder. The resulting end products show characteristics similar to the control specimens and overcome the deficiencies arising from using unary replacement either by waste brick powder or waste ceramic powder.



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