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Review

Production of bricks from waste materials – A review

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HIGHLIGHTS

- A wide variety of waste materials have been researched for production of bricks, including mainly fly ash and slags.
- Methods for producing bricks from waste materials can be divided into 3 categories: firing, cementing and geopolymerization.
- Commercial production of bricks from waste materials is still very limited due to different reasons.
- Further research and development is needed to promote wide production and application of bricks from waste materials.

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ABSTRACT

Bricks are a widely used construction and building material around the world. Conventional bricks are produced from clay with high temperature kiln firing or from ordinary Portland cement (OPC) concrete, and thus contain high embodied energy and have large carbon footprint. In many areas of the world, there is already a shortage of natural source material for production of the conventional bricks. For environmental protection and sustainable development, extensive research has been conducted on production of bricks from waste materials. This paper presents a state-of-the-art review of research on utilization of waste materials to produce bricks. A wide variety of waste materials have been studied to produce bricks with different methods. The research can be divided into three general categories based on the methods for producing bricks from waste materials: firing, cementing and geopolymerization. Although much research has been conducted, the commercial production of bricks from waste materials is still very limited. The possible reasons are related to the methods for producing bricks from waste materials, the potential contamination from the waste materials used, the absence of relevant standards, and the slow acceptance of waste materials-based bricks by industry and public. For wide production and application of bricks from waste materials, further research and development is needed, not only on the technical, economic and environmental aspects but also on standardization, government policy and public education related to waste recycling and sustainable development.

Contents

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1. Introduction

Bricks have been a major construction and building material for a long time. The dried-clay bricks were used for the first time in 8000 BC and the fired-clay bricks were used as early as 4500 BC [1,2]. The worldwide annual production of bricks is currently about 1391 billion units and the demand for bricks is expected to be continuously rising [3,4]. Conventional bricks are produced from clay with high temperature kiln firing or from ordinary Portland cement (OPC) concrete. Quarrying operations for obtaining the clay are energy intensive, adversely affect the landscape, and generate high level of wastes. The high temperature kiln firing not only consumes significant amount of energy, but releases large quantity of greenhouse gases. Clay bricks, on average, have an embodied energy of approximately 2.0 kWh and release about 0.41 kg of carbon dioxide (CO_2) per brick [5,6]. It is also noted that there is a shortage of clay in many parts of the world. To protect the clay resource and the environment, some countries such as China have started to limit the use of bricks made from clay [7–9].

The OPC concrete bricks are produced from OPC and aggregates. It is well known that the production of OPC is highly energy intensive and releases significant amount of greenhouse gases. Production of 1 kg of OPC consumes approximately 1.5 kWh of energy and releases about 1 kg of CO_2 to the atmosphere. Worldwide, production of OPC is responsible for about 7% of all CO_2 generated [5,10–12]. So the production of OPC concrete bricks also consumes large amount of energy and releases substantial quantity of CO_2. In addition, the aggregates are produced from quarrying and thus have the same problems as described above for clay.

For environmental protection and sustainable development, many researchers have studied the utilization of waste materials to produce bricks [8,9,13–15,17–66,80–85]. A wide variety of waste materials have been studied, including fly ash, mine tailings, slags, construction and demolition (C&D) waste, wood sawdust, cotton waste, limestone powder, paper production residue, petroleum effluent treatment plant sludge, kraft pulp production residue, cigarette butts, waste tea, rice husk ash, crumb rubber, and cement kiln dust. Different methods have been used to produce bricks from waste materials.

This paper presents a state-of-the-art review of the research on utilization of different types of waste materials to produce bricks. The advantages and disadvantages of different methods for utilizing waste materials to produce bricks are described. The concerns related to production of bricks from waste materials are also discussed.

2. Review of research on utilization of waste materials to produce bricks

The extensive research on utilization of waste materials to produce bricks can be divided into three general categories based on the production methods: firing, cementing and geopolymerization, as detailed below.

2.1. Production of bricks from waste materials through firing

This method uses waste material(s) to substitute a portion or entire amount of clay and follows the traditional way to kiln fire the material(s) to produce bricks. Many researchers have studied the production of bricks from waste materials based on firing (see Table 1).

Chen et al. [8] studied the feasibility of utilizing hematite tailings and class F fly ash together with clay to produce bricks. Brick samples were prepared by using 77–100% tailings, 0–8% fly ash and 0–15% clay. Tests were performed to determine the compressive strength, water absorption and bulk density of brick samples prepared at different conditions. Based on the results, they recommended a tailings:fly ash:clay ratio of 84:6:10, a forming water content of 12.5–15%, a forming pressure of 20–25 MPa, and a firing temperature of 980–1030 °C for 2 h, to produce good quality bricks.

Lingling et al. [9] investigated the production of fired bricks by using class F fly ash to replace clay at high volume ratios. Brick samples were prepared by mixing fly ash and clay at designed proportion, casting the mixture into bricks, drying the bricks at ambient condition for 2 days, at 60 °C for 4 h and at 100 °C for 6 h, and firing the dried bricks in an electric furnace at 100 °C/h below 500 °C, 50 °C/h from 500 °C to highest temperature (1000, 1050, or 1100 °C), and at the highest temperature for 8 h. Tests were conducted on the fired bricks to evaluate their compressive strength, water absorption, bulk density, apparent porosity, cracking due to lime, frost and frost-melting. The results showed that when high percentages of fly ash were used, a firing temperature about 1050 °C should be adopted. The fired bricks with high percentages of fly ash had high compressive strength, low water absorption, no cracking due to lime, and high resistance to frost-melting. The study also indicated that the properties of fired bricks were improved by using pulverized fly ash (i.e., by decreasing the particle size of the fly ash).

Kute and Deodhar [13] studied the bricks manufactured in laboratory using class F fly ash and clay. The brick samples were prepared by mixing different amount of fly ash with clay and sufficient quantity of water, and then compressing the mixture in a mold. The molded bricks were dried in air for 2 days and then fired in a laboratory furnace respectively at 850 and 1000 °C for 24 h. Laboratory tests were conducted to evaluate the compressive strength and water absorption of the produced bricks. The results indicated that the inclusion of fly ash in general increased the compressive strength and decreased the water absorption of bricks. The highest compressive strength of 12.4 MPa (an average of eight samples) was obtained at 40% fly ash content, with the corresponding water absorption being 13.8%.

Chou et al. [14,15] conducted systematic study on utilization of class F fly ash to replace part of the clay and shale in production of bricks using the conventional kiln firing procedure. Paving bricks with up to 20 vol.% of fly ash and building bricks with up to 40 vol.% of fly ash were successfully produced in commercial-scale production test runs, with the properties exceeding the ASTM commercial specifications. They also conducted leaching study on the fired bricks from commercial-scale production following US EPA Method 1320 [16]. The results indicated that the amounts of leached metals were well below the US EPA's regulatory thresholds.

Kayali [17] studied the performance of FlashBricks, bricks produced from fly ash. The bricks were produced by mixing fly ash with water and a small amount of commercially protected additive, molding the mixture, drying the formed units for 3 days, and then firing them for hours. The FlashBricks were about 28% lighter than clay bricks and had a compressive strength greater than 40 MPa. Other important performance parameters such as water absorption, modulus of rupture, bond strength and durability also exceeded those pertaining to clay bricks.

Menezes et al. [18] evaluated the possibilities of using granite sawing wastes as alternative raw materials in the production of ceramic bricks and tiles. The results showed that the granite sawing wastes had physical and mineralogical characteristics that were similar to those of conventional raw materials for ceramic bricks and tiles and could be used to partially replace the conventional raw materials to produce ceramic bricks and tiles meeting the Brazilian standardizations.

Lin [19] studied the utilization of municipal solid waste incinerator (MSWI) slag to partially replace clay for the production of fired