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Properties and environmental impact of the mosaic sludge incorporated into fired clay bricks

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HIGHLIGHTS

- Comparison between clay brick and mosaic brick were made at different ratio waste.
- The effects of physical and mechanical properties were examined.
- We analyzed the environmental leaching effects from manufactured brick.
- Gases emit from manufactured brick were identified through indoor air quality test.
- Indoor air quality test was done with controlled temperature and relative humidity.

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ABSTRACT

This paper presents fundamental information on the utlization of mosaic sludge waste from industrial mosaic activities into building materials. The study greatly benefits solid waste management and industries that produce waste with high heavy metal concentration by providing insights on ways to dispose waste by minimizing heavy metal leaching potential whilst providing a new formulation of low-cost and environmentally friendly building materials. Therefore, an alternative disposal method is to incorporate mosaic waste such as bodymill sludge (BS) and polishing sludge (PS) into fired clay brick. The bricks were incorporated with different percentages (0%, 1%, 5%, 10%, 20% and 30% by weight) of sludge waste and fired at 1050 °C (0.7 °C/min heating rates). The optimization results showed that the incorporation of up to 30% of mosaic sludge into fired clay bricks is capable of improving its physical and mechanical properties. Moreover, the incorporation of mosaic sludge waste into clay bricks has a positive effect on firing shrinkage, density and compressive strength. However, a decreased performance was reported for certain aspects. Hence, this study demonstrated that BS and PS can be alternative low-cost and environmentally friendly which can be used to improve the physical and mechanical properties of fired clay bricks.

1. Introduction

Mosaic is known as small coloured pieces made of hard materials such as stones or glass. It is made to provide a durable form of decoration for walls and pavements. Today, mosaics are usually made of clay, sand, feldspar, quartz and water [1]. The raw material is mixed with water before transforming into a slurry mixture. The slurry is transferred to a storage tank fitted with an atomizer which turns into atomized powder after being blown by hot air. The powder slurry is then moved to a tray and pressed by a hydraulic press which eventually transforms powder into a solid mass. After a while, the drying process is performed to remove the remaining moisture. Glaze and screening applications are important stages because they will provide aesthetic beauty, water repellency, durability and hygienic properties of mosaic. Once the glaze has been applied, the mosaic was fired in a kiln at a temperature of 1050 °C to 1300 °C [2].

During the fabrication process of mosaic, various types of wastes including sludge, dust and solid waste are generated. However, only mosaic sludge, namely bodymill sludge and polishing sludge was used in this study. Bodymill sludge comes from the body milling process during tiles manufacturing. The process involves crushing hard materials and dry mill. Throughout the process, the mill continues to be stored in an underground tank. The tile-colouring process also occurs during this stage. Waste water produced during the milling process is handled into a recovery tank and wastewater treatment plant for treatment. The

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residue that remains is called bodymill sludge. Concurrently, polishing sludge is produced during the polishing process. During this stage, a few procedures such as glazing and printing take place. Finishing tiles are subjected to glaze in order to give texture to the colours in ceramic tiles. Therefore, a large amount of water is used to complete the process. Excess water from this process is transferred to a recovery tank and treated at a wastewater treatment plant. The residue on this process is called polishing sludge.

Globally, 119 thousand tons of industrial sludge (in dry substances) is generated annually from industrial activities. These include mineral sludge, heavy metal sludge, dross, slag, clinical waste, clinker, ash, gypsum, oil and hydrocarbon [3]. It is expected that the amount of sludge produced is quite high compared to other types of waste. Due to the huge amounts of industrial sludge generated, an alternative disposal method is essential as landfills are no longer an ideal disposal method for this type of waste [4]. In addition, landfills have also been regarded as one of the contributors to the negative impact on the environment [5]. Therefore, an alternative disposal method for sewage sludge is highly required because most landfills are no longer effective for the disposal of this hazardous waste. Another concern is that industrial sludge could be in either organic or inorganic form [6,7]. Inorganic content is always threat because harmful heavy metals which require special treatment to avoid environmental pollution [8]. Additionally, mosaic sludge usually contains chemical pollutants from mosaic colouring substances which will lead to environmental pollution if it is not managed in a proper manner.

Due to high demand, the flexibility and success of sludge waste incorporation into fired clay bricks, more and more researchers are driven to further investigate the potential of different types of sludge to be incorporated into bricks. Recycling and reusing sludge by incorporating them into fired clay brick could improve brick properties and offer environmentally-friendly disposal alternative. Examples of sludge include marble sludge and stone sludge [9], water treatment sludge [10,11], sewage sludge [12,13] and textile sludge [14]. Researchers have found that the incorporation of sludge waste into fired clay a brick helps reduce transportation and handling costs. Moreover, this method is also able to reduce clay content in fired clay bricks which results in lower manufacturing cost [15]. Nevertheless, most researchers only focus on the physical and mechanical properties of bricks. There is a lack of investigation so far on the use of mosaic sludge waste as an alternative material in brick production especially from the environmental aspect. Consequently, this study attempts to investigate the utilization of mosaic sludge for low-cost brick production in terms of physical, mechanical and environmental impacts on indoor air quality.

2. Materials and methods

2.1. Raw materials and their preparation

Mosaic sludge waste was obtained from the mosaic industry located in Johor, Malaysia. The mosaic sludge was collected in a semi-solid condition (Fig. 1). Meanwhile, clay soil was supplied by a brick company located in Johor, Malaysia. The mosaic sludge and clay soil were kept properly in a closed container before being used. Upon delivery, the clay soil and mosaic sludge were oven dried at 105 °C for 24 h. Both were grounded and crushed manually and sieved with sieve sizes from 3 mm to 5 mm to yield a homogeneous size distribution.

Fig. 1. Mosaic sludge.

2.2. Chemical and geotechnical properties

The chemical composition of raw materials was tested using the X-ray fluorescence method (XRF, Philips, PW1840). Geotechnical tests, which include the Atterberg Limit test, specific gravity test, standard proctor test and loss of ignition are carried out to determine the general characteristics of raw materials used in this study. The Atterberg limit and specific gravity were determined according to BS 1377-2 [16] while a standard proctor test was performed to determine the optimum moisture content (OMC) of control bricks and clay-sludge bricks in accordance with BS 1377-4 [17]. The loss of ignition was determined by igniting raw materials at 1000 °C in a laboratory furnace for 4 h in accordance with BS 1377-3 [18].

2.3. Methods for the preparation of brick samples

Two types of bricks were manufactured, namely control bricks and clay-mosaic sludge bricks. The control brick was designed without sludge material (0%) while the clay-mosaic sludge brick was formulated with different sludge content (1%, 5%, 10%, 20% and 30% by weight) as tabulated in Table 1. The bricks were manufactured by mixing clay soil with different mosaic sludge content with a predetermined amount of water in a 10 L mechanical mixer. After the mixture was satisfactorily homogenized, it was compressed into mould with the following size; 215 mm × 102.5 mm × 65 mm and compressed at 3000 psi. The bricks were then dried at room temperature for 24 h to reduce its initial moisture content then dried for another 24 h in a ventilated oven at 105 °C. Proper drying is compulsory as it allows a slow loss of moisture from the bricks without disintegration. After that, the bricks were fired in the furnace and gradually heated at

Table 1
Mixture identification of mosaic sludge brick.

Mixture	Clay (g)	Sludge (g)	Water (mL)
CB-0%	3000	0	450
BS/PS-1%	2970	30	480
BS/PS-5%	2850	150	520
BS/PS-10%	2700	300	540
BS/PS-20%	2400	600	570
BS/PS-30%	2100	900	600