Potential of Pressmud Waste from Sugar Industry in Brick Manufacturing for Green Business and Sustainability

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ABSTRACT

The construction industry in Malaysia is currently witnessing sustained expansion, as seen by the rising demand for residential properties, commercial structures, and other infrastructures throughout our country. Therefore, the present study seeks to identify suitable materials and proportions for manufacturing lightweight bricks utilizing industrial waste materials. This study investigates the feasibility of using pressmud, a sugarcane refinery waste, as a fine bio-aggregate for the production of construction materials. Binary blended cement-pressmud bricks were formed by mixing Ordinary Portland cement with pressmud at various weights percentages (50%, 40%, 30%, 20%, and 10%). Various experiments were undertaken to investigate and compare the characteristics of pressmud bricks and commercial sand bricks. The experiments focused on density determination and compression tests (standard brick). The compression tests demonstrated that cement-pressmud bricks with a weight ratio of up to 20% exhibited a compatible strength to standard brick, with values ranging from 17.16 MPa to 23.01 MPa. The pressmud bricks exhibited reduced weight, with 10% and 20% variants weighing 17-23% less than the standard brick. Thus, it can be concluded that pressmud possesses significant potential as a bio-aggregate for producing lightweight and cost-effective construction materials when used in appropriate proportions.

KEYWORDS: Pressmud; Bricks; Bio-aggregate; Cement

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1. INTRODUCTION

The production of construction materials leads to the depletion of natural resources that are exploited during the process. In contrast, due to the pollution potential of industrial waste, preparing construction materials from it is a sustainable approach to its management. Cement is the most widely used construction material, followed by bricks. However, cement production contributes significantly to greenhouse gases, engendering an adverse environmental impact. Manufacturing cement and bricks require significant energy (Mo et al., 2016). Consequently, environmentally friendly building materials can be produced sustainably by substituting industrial waste for energy-intensive and pollutant raw materials (Jothilingam et al., 2023).

However, information regarding the impact of organic aggregates on the properties of composite concrete is scarce, and the effect of pressmud in concrete still needs to be documented. Pressmud waste is categorized as non-hazardous waste due to the absence of hazardous substances and its nearly neutral pH value, enabling its direct utilization without pretreatment (Mohamad, 2018). Thus, this research examines the impact of varying proportions of partial cement replacement with pressmud, a byproduct of sugar manufacturing, on binary blended concrete's workability, strength, and physicochemical properties.

In addition, an evaluation is conducted on the leaching mechanism of organic and inorganic substances from pressmud fine bio-aggregate-enhanced concrete to ascertain the potential quantity of contaminants that may permeate the surrounding environment (Pawar & Khadake, 2020). Optimistically, this study will eliminate the possibility of a justification for immobilizing organic refuse into bricks, which is particularly beneficial for the construction industry's sustainable development.

Bricks have been utilized as a building material for several centuries. The current study involves an,

experimental approach to combine hypo sludge and sugarcane pressmud with several other components. Hypo sludge has the potential to function as a compatible substance with cement, so it serves as a viable construction material. When cement is combined with this substance, it effectively enhances the strength of the cement. Significant research endeavours have been undertaken to assess the robustness. It has been determined that adding it can effectively enhance the compressive strength of cement. Hypo sludge, a substantial byproduct of the paper industry, is commonly used to manufacture concrete as a means of partially substituting cement. The substance has a low calcium content and a minimal quantity of silica, which may be attributed to the presence of silica and magnesium properties. It is these features that contribute to its cement-like behavior. of the utilization of hypo sludge in concrete presents a potential solution for reducing disposal expenses within the paper industry while yielding a sustainable construction material- the potential impact of odour-related issues on the surrounding environment. Sludge, fly ash, and pressmud are waste materials that have the potential to be transformed into valuable construction materials with minimal investment.

This initiative facilitates the provision of affordable housing options. Sugar production in sugar mills involves a series of operations that generate significant quantities of solid waste. Molasses and pressmud are the primary byproducts derived from the sugar industry. Pressmud is a residual substance derived from the process of clarifying sugarcane juice, wherein non-sugar impurities are eliminated by using a chemical mixture of sulfur and lime. After the crushing process of sugarcane, it is observed that around 3.3 tons of pressmud are produced as a residual byproduct per every 100 tons of crushed sugarcane. Calcium oxide (CaO) is the primary chemical constituent found in pressmud. According to Bharathi et al. (2018), it has been suggested that sugarcane pressmud has the potential to serve as a filler material in the production of bricks.

According to Saini et al. (2022), the addition of pressmud increased the optimal moisture content and reduced the maximal dry density. The unconfined compressive strength and California bearing ratio values increased by 5% of pressmud before declining. Experimental investigations were conducted by James (2019) to examine the impact of pressmud on the strength properties of expansive soil. According to this study, the strength of soil was found to increase with the addition of pressmud. After extensive research, Biffi and Janani (2018) reported that the unconfined compressive strength of the treated soil increased with the curing period and was enhanced by adding pressmud (Kuriakose et al., 2021). Radwan et al. (2021) investigated the innovative application of solid waste products derived from the sugar industry, specifically waste glass powder (GP) and pressmud, as substitutes for cement in ternary blended cement. 20% GP is incorporated into the ternary blended cement, and the effect of pressmud replacement at cement replacement levels ranging from 5% to 20% was studied. An evaluation was conducted on the freshness, strength, sorption, morphological, and thermogravimetric properties of the ternary blended cement. The findings indicated that including pressmud at 10% and 15% concentrations in the GP binary cement mortar enhanced its consistency, early and later age strengths, flexural strength, and reduced sorptivity. Additionally, it was noted that the morphologies underwent enhancement through the reduction of cavities, facilitation of GP particle reaction, and addition of hydration products. The findings of the thermogravimetric analysis corroborated this, as ternary cement pastes composed of cement-GP-pressmud exhibited a greater abundance of hydration products. Incorporating pressmud into ternary blended cement containing GP could reduce cement consumption while improving its properties (Radwan et al., 2021). According to research conducted by Surya Bharathi et al. (2018), the production of clay bricks results in more significant CO_2 emissions due to the combustion process and the depleting nature of the clay. Hypo-sludge and sugarcane pressmud are examples of environmentally hazardous waste materials. Considerable effort has been devoted to surmounting these challenges. Consequently, industrial byproducts and waste materials are utilized to produce bricks. This investigation combined hypo-sludge and sugarcane pressmud with fly ash, lime, and quarry dust to increase the binding and compressive strengths. By preventing the burning of the masonry, CO_2 emissions are reduced. The endeavour undertaken will be a more effective resolution to this issue. Various proportions of sugarcane pressmud and hypo sludge are incorporated, including 4, 8, and 12. The experiments are carried out, and the optimal percentage is acquired. A study revealed that the bricks exhibited water absorption values below 4%, indicating that a negligible quantity of water was necessary for the curing process. It has been observed that the compressive strength of 4% silt is greatest during compression tests. The inclusion of sludge will decrease the price of bricks, according to the cost analysis results. The environmental impacts associated with waste and disposal issues can be mitigated or regulated with the aid of this research. The environment is safeguarded against the release of CO_2. An improved metric for an innovative building material is developed as a result of this research.

2. METHODOLOGY

2.1 Sample Preparation

The fine bio-aggregate used in this study was a fresh

pressmud acquired from Malaysia Sugar Manufacturing (MSM) Prai Berhad, Pulau Pinang. The pressmud were transported to the laboratory in a semi-solid and subjected to a one-week drying process under sunlight. The drying process aimed to eliminate excess moisture and coarse pebbles present in the samples. The laboratory used readily available wood from a hardware shop to create simple wooden molds, as shown in **Figure 1**. The dimensions of the constructed mould are 215 mm x 100 mm x 65 mm, which aligns with the standard commercial brick size, as recommended by Ling and Teo (2013).

Figure 1: *Mould of Brick*

The concrete binder utilized in this study was Ordinary Portland cement (CASTLE®, CEM II / B-L 32.5N). Next, the dried pressmud was ground using a laboratory grinder, and a 500-µm sieve in the laboratory to remove unwanted substances and coarse pebbles. The combination of cement (C) and pressmud (P) percentages was carried out at five distinct weight ratios, which are 50C:50P, 60C:40P, 70C:30P, 80C:20P, and 90C:10P. In contrast, a standard sand brick (S) was obtained from a commercial market. These materials were utilized as control materials in this study. In order to facilitate the hydration process of cement, it is common practice to utilize a water-cement ratio that ranges between 60% and 80%, which is adjusted based on the initial weight of the combination, according to Acda (2010). The homogeneously blended concrete was introduced into the constructed mould and evenly dispersed to eliminate empty areas. The concrete specimens are allowed to undergo a curing process for a week within an enclosed room, wherein sunlight is present, and the temperature is maintained at 33°C±1. Once the curing process was completed, the mould was opened, producing pressmud bricks that are now prepared for density and compressive testing.

2.1.1 Compressive Strength Test

Compressive tests were performed on the bricks following the guidelines outlined in to IS 3495 to achieve the samples' optimal strength. The test compression machine, specifically the ADR-Auto, was employed to compress the sample until it reached its maximum load value. The bricks samples were compressed until it crushed with compression pace rate applied at 14.80 N/mm^2 per minute, as in **Figure 2**.

Figure 2: *Condition of Bricks Sample after Compressive Test*

3. RESULTS AND DISCUSSION

Pressmud is a superior alternative to sand as a fine aggregate for the production of lightweight construction materials. Simultaneously, the incorporation of pressmud induces alterations in the physical characteristics of a brick, contingent upon the specific ratio employed. The presence of pressmud resulted in an increased number of pores in binary blended cement-pressmud bricks. **Figure 3** illustrates the composition of pressmud bricks. The process of curing concrete paste in the absence of external components results in a strong bond between the constituent materials.

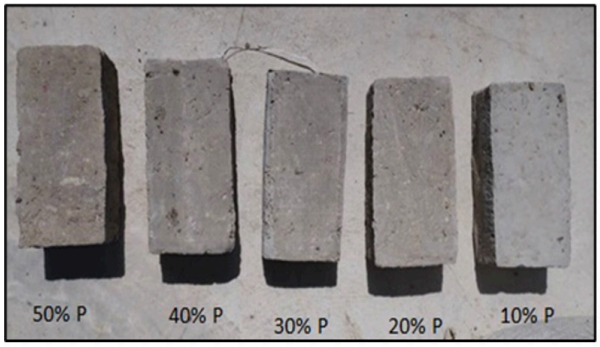

Figure 3: *Types of Bricks Tested*

The porosity of a 50% sample is undoubtedly higher because of the presence of pressmud, which constitutes half of its composition. The presence of pressmud in the 50% sample has increased its porosity and altered the physical characteristics of the brick. The visualization in **Figure 3** provides an evident depiction of numerous holes and cracks observed on the surface of the 50% bricks. This observed phenomenon can be attributed to the disparity in bulk density and specific surface area between cement and pressmud. Cement exhibits a lower bulk density and a higher specific surface area, with reported values of 94.82 m^2/g and 17.80 m^2/g, respectively (Thomas et. al., 1998; Mohamad, 2018). The correlation between a greater surface area, increased contact area, and bonding is well-established. Therefore,

an increase in cement consumption undoubtedly leads to improved bonding. In addition, it has been shown that the excessive use of water during the process of cement mixing can impact the porosity of the resulting material (Rougelot et al., 2009). The cement-to-water ratio was consistently maintained within 60-80% range. The weight and density of each sample are presented in **Table 1**. The control specimen, standard brick, exhibits the most significant weight value of 2.77 kg. The pressmud bricks exhibited a lower weight than the standard bricks produced by the industrial sector. As the quantity of waste employed as a fine bio-aggregate increased, there was a corresponding decrease in the weight of the bricks. The weight of Specimen 10% is 2.35 kg, followed by Specimen 20% weighing 2.19 kg, Specimen 30% weighing 1.71 kg, Specimen 40% weighing 1.30 kg, and finally Specimen 50% weighing 1.27 kg. This trend elucidates the employment of pressmud in creating construction materials, which shows promise in creating lightweight construction materials. Lightweight bricks offer significant advantages in the building industry, as they enable enterprises and workers to conserve energy and reduce costs when handling and transporting construction materials. The total volume of brick samples was 0.0014 m3. Despite the use of fixed-size moulds, the non-uniform volume observed in each of these samples can be attributed to the shrinkage of the cement paste material throughout the curing process. The concrete dimensions were influenced by water absorption and desorption throughout the drying process (Rougelot et al., 2009). Notwithstanding this, the density of each sample brick varies from one another. The standard brick exhibits a reported density of 1978.57 kg/m^3, the highest on record. The compressive test is often conducted to ascertain the ultimate load capacity of bricks. The calculation of the compressive strength of the specimen was performed using the equations (Equation 1) provided by Mohammed (2012). Where

$$C = \frac{W}{A} \qquad (1)$$

Where
C = stress, Megapascal (MPa) or N/m^2
W = maximum load applied, Newton (N)
A = surface area, meter square (m^2)

The compressive test results for all the bricks are depicted in **Figure 4**. The brick, which contained 10% pressmud, exhibited a compressive strength of 23.01 MPa. The observed value exceeds the compressive strength of the control specimen standard brick (19.01 MPa) by 4 MPa. As for 20% of the compressive strength, it measures 17.16 MPa, which is close to the standard brick strength. The findings indicate that the combination of 10% and 20% mixtures is the most optimal for producing brick with a strength comparable to the standard brick.

However, the compressive test results indicated that the values obtained for specimens containing 30%, 40%, and 50% were lower. The compressive strength results for the 30% and 40% specimens are recorded as 2.91 MPa and 2.96 MPa, respectively. These values indicate a reduction of 16.0 MPa compared to the standard control specimen. Additionally, the specimen with 50% exhibits a decrease of 11.0 MPa in the compressive strength. The observed outcome can be attributed to the pores inside the examined samples. As previously mentioned, the presence of pores increases proportionally with the higher ratio of pressmud.

Consequently, in this scenario, the three samples exhibit a more significant number of pores than those with 20% and 10% pressmud. The current presence of pores is exerting an influence on the strength of the pressmud bricks. The presence of empty voids within the specimens renders the bricks susceptible to brittleness. For example, when comparing the compression strength of a solid iron ball to that of an empty solid ball, it is evident that it exhibits superior compression strength. The solid iron ball exhibits rigidity and compactness, enhancing its strength and stability. The present scenario involves the application of a comparable concept, wherein the materials with compositions of 30%, 40%, and 50% exhibit a void structure that renders them susceptible to brittleness and prone to fracture under the influence of external forces. This assertion can be substantiated by the research conducted by Frybort et al. (2008) on cement-bonded compositions. Their findings indicate that an increase in porosity leads to a decrease in the elasticity and strength of bricks. However, it is essential to note that this relationship varied when comparing bricks with porosities of 10%, 20%, and pure cement bricks. These samples exhibit reduced porosity, resulting in enhanced compressive strength. The tension exhibited by pure cement samples is 13.7 MPa greater than that of standard bricks.

Table 1: *Density of Bricks*

Sample	Weight (kg)	Volume (m^3)	Density, ρ (kg/m^3)
Standard brick	2.77	0.0014	1978.57
50C:50P	1.27	0.0014	907.14
60C:40P	1.30	0.0014	928.57
70C:30P	1.71	0.0014	1221.43
80C:20P	2.19	0.0014	1564.29
90C:10P	2.35	0.0014	1678.57

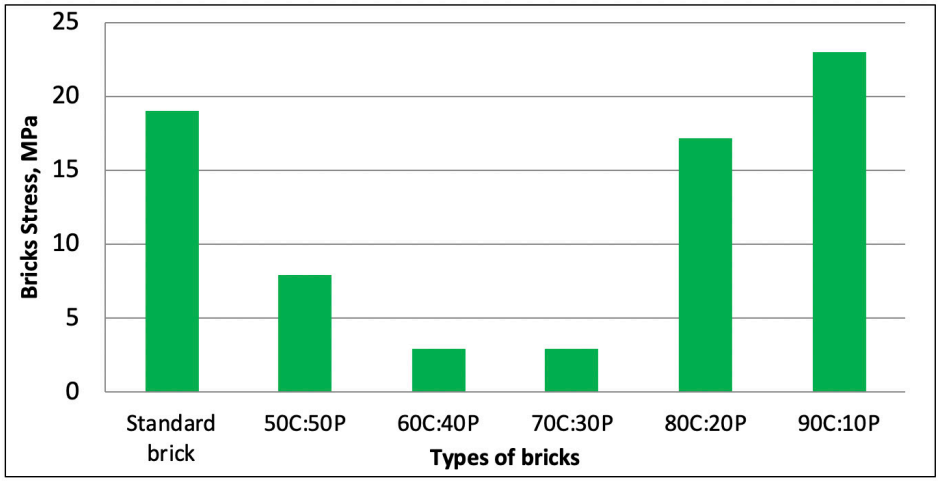

Figure 4: *Compressive Strength of Bricks*

4. CONCLUSION

This study demonstrates that pressmud exhibits significant potential as a bio-aggregate for producing environmentally friendly construction materials that are both strong and lightweight when used in appropriate ratios. The pressmud bricks exhibited reduced weight, with the 10% and 20% bricks weighing 17-23% less than the standard brick. The compression test results demonstrated that cement-pressmud bricks with a weight ratio up to 20% exhibited comparable strength to standard brick, with values ranging from 17.16 MPa to 23.01 MPa. The experimental results suggest that the inclusion of pressmud in bricks has the potential to improve the engineering properties of bricks. Additionally, it is advisable to undertake a further investigation into the behavioral characteristics of structural components (i.e., wall panels), that are constructed using pressmud bricks. This study would validate masonry construction's enhanced durability and cost-effectiveness with such materials. Therefore, the use of pressmud as bio-aggregates holds significant promise in developing environmentally friendly products, particularly in producing strong and lightweight construction material when used in appropriate ratios. The construction industry possesses the capacity to achieve cost and energy savings through efficient management and transportation of pressmud bricks.

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