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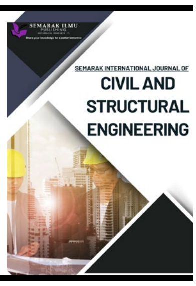

Sustainable Use of Spent Bleaching Earth as Partial Cement Substitute in Cement Sand Brick

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ABSTRACT

This study investigates a use of spent bleaching earth pozzolanic, byproduct of biodiesel production, as sustainable substitute in the cement mortar. As a waste material, spent bleaching earth pozzolanic present viable solution for enhances construction materials while reducing environmental impact. The study aims to assess spent bleaching earth pozzolanic effectiveness as a partial cement replacement in a cement mortar, focusing on its effect on material properties and structural performance at varying replacement levels of 10%, 20%, 30%, 40%, and 50%. Tests conducted include the sieving analysis, water absorption, and compressive strength. The results indicate Portland limestone cement in 75 µm pan sieve weighed for 69 g, and a spent bleaching earth pozzolanic weighed for 77 g, with respective indicating a potential for improved particle packing. By increasing the spent bleaching earth pozzolanic in Portland limestone cement with river sand for cement sand brick, reduce the water absorption values of 0%, 10%, 20%, 30%, 40%, and 50% spent bleaching earth pozzolanic for 9.8%, 9.6%, 9.4%, 9.2%, 9.1%, and 9% at 28 days. The packing packed of Portland limestone cement, spent bleaching earth pozzolanic, and river sand showed as spent bleaching earth pozzolanic increased, the water demand slightly decreased, resulting in compressive strength values suitable for load-bearing application. Finding suggest spent bleaching earth pozzolanic effective as binder at 20% replacement, providing enhance performance without compromising cement sand brick strength, thus supporting the material's potential in the eco-friendly construction. This research contributes to the sustainable utilization of the industrial byproducts, proposing spent bleaching earth pozzolanic as viable ingredient in building materials that balances mechanical properties with environmental benefits.

1. Introduction

Bleaching earth, used in the palm oil refineries, undergoes degumming and bleaching to eliminate color, phospholipids, odors, and impurities from the crude palm oil, producing edible oil. This process generates the spent bleaching earth, which, when processed, yields spent bleaching earth pozzolanic, eco mineral, and spent bleaching earth oil. This research investigates a suitability of spent bleaching

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earth pozzolanic, replacing 10%, 20%, 30%, 40%, and 50% of Portland limestone cement in a cement sand brick production. Combining spent bleaching earth pozzolanic and Portland limestone cement with river sand aims to understand their properties and the sustainable application of biodiesel waste in construction materials, contributing to waste reduction and eco-friendly building practices. The main research problem centre on optimizing a spent bleaching earth pozzolanic utilization, improve performance, and overcome the industry adoption challenges. The spent bleaching earth pozzolanic significance lies in addressing performance issue in the construction materials. Specifically, this study evaluates the elemental composition and mechanical properties of spent bleaching earth pozzolanic in the combination with the Portland limestone cement and river sand, particularly examining spent bleaching earth pozzolanic performance as the void filler, enhancing compressive strength, and water absorption properties. Previous research, "such as Lin *et al*., [1]; Chong *et al*., [2]; Rahman *et al*., [3]; Kho [4]; Kusaimi *et al*., [5]; Othman *et al*., [6]", highlight silica-rich properties of spent bleaching earth pozzolanic and its potential for cement applications according to British and European Standards 197-1 (2011) for common cement.

This study contributes to this growing body of knowledge by assessing SBEP's elemental composition and mechanical properties in combination with PLC and river sand. Notably, SBEP is investigated as a void filler, improving brick performance in terms of compressive strength and water absorption, as per the requirements of British and European Standards BS EN 197-1 (2011) for common cement. By focusing on SBEP's performance, this research aims to advance the sustainable use of industrial byproducts in construction, addressing both environmental and material performance concerns. The growing global emphasis on sustainable practices has highlighted the need for innovative solutions to industrial waste management. In the palm oil refining industry, bleaching earth is widely used to remove color, odors, phospholipids, and other impurities from crude palm oil, rendering it suitable for consumption. However, this process generates significant amounts of spent bleaching earth (SBE), a byproduct often discarded in landfills, contributing to environmental pollution and waste management challenges. Recent research has revealed that SBE, when processed into spent bleaching earth pozzolanic (SBEP), offers significant potential for reuse, particularly in construction applications.

SBEP, characterized by its silica-rich composition, is a pozzolanic material that can enhance the properties of cement-based composites. This research investigates the feasibility of incorporating SBEP as a partial replacement for Portland limestone cement (PLC) in the production of cement-sand bricks. Replacement levels of 10%, 20%, 30%, 40%, and 50% SBEP are analyzed to understand their effect on mechanical properties, such as compressive strength and water absorption, in comparison to conventional cement bricks. By exploring these properties, the study aims to optimize the use of SBEP in construction materials, aligning with the broader goal of sustainable development and industrial waste valorization.

The potential of SBEP to address environmental and material performance concerns is supported by previous research. Studies by Lin *et al.,* [1] and *Chong et al.,* [2] emphasize SBEP's chemical composition and its suitability as a supplementary cementitious material (SCM). Similarly, Rahman *et al.,* [3] and Kho [4] demonstrate its effectiveness in enhancing the mechanical performance of concrete, particularly its compressive strength. Kusaimi *et al.,* [5] and Othman *et al.,* [6] further validate its potential to meet international standards for blended cements, such as BS EN 197-1 (2011). The environmental significance of this research cannot be overstated. Cement production is a major contributor to global CO_2 emissions, responsible for approximately 7-8% of total emissions worldwide. The integration of SBEP as a partial cement replacement not only reduces reliance on traditional cement but also provides a sustainable pathway for repurposing industrial byproducts. Additionally, the reuse of SBE mitigates the environmental hazards associated with its disposal, such as leaching of residual oil and other contaminants into the soil and water systems. This study contributes to the ongoing efforts to develop eco-friendly construction materials by focusing on the synergistic effects of combining SBEP with PLC and river sand. By addressing key challenges such as material compatibility, performance optimization, and industry adoption, the research offers practical insights into the application of industrial byproducts in the construction sector. Furthermore, the findings aim to advance the understanding of SBEP's role as a void filler, enhancing compressive strength, reducing water absorption, and contributing to the long-term durability of cement-sand bricks. Ultimately, this research supports the global shift towards sustainable construction practices by demonstrating the viability of SBEP as a valuable resource for reducing waste, lowering carbon emissions, and promoting environmental stewardship.

2. Methodology

This study assessed the mechanical properties of cement sand brick. Portland limestone cement, a "Gajah" brand product obtained from the local supplier, contains calcium oxide (CaO) and adheres to the British and European Standard 197-1 (2011) for the composition and specifications of common cement. The spent bleaching earth pozzolanic, a natural pozzolanic material rich in silica (SiO_2), was sourced from a biodiesel facility in the Lahad Datu, Sabah. River sand was collected from Sandakan. The mechanical tests included sieving analysis, water absorption, and compressive strength. All these tests aimed to quantify properties like the particle size distribution, porosity, and strength of cement sand brick, following various British and European standards. The fineness of these materials was determined by sieving through trays with mesh sizes of 2.36 mm down to 75 µm, per BS 410-1 (2000). Pozzolans, whether natural or artificial, react with the calcium hydroxide to form the cementitious compounds. In this study, spent bleaching earth pozzolanic proportions in the cement sand brick mix were tested at 0% (control), 10%, 20%, 30%, 40%, and 50%, with a fixed binder-to-sand ratio of 1:2.5 and a water ratio of 0.35. These proportions were based on the desired properties and requirements of cement sand brick. Pozzolan do not harden on their own when mixes with water unless combined with Portland limestone cement. In this research, Figure 1 shows the flowchart of cement sand brick section, that conducted for the testing. Following materials analysis, the mixing and molding process began. Portland limestone cement, spent bleaching earth pozzolanic, and river sand were mixed in specific proportions, then poured into iron molds (215 mm x 103 mm x 65 mm ±2), according to BS 6073-1 (1981) for precast masonry units. The mix was compressed using a 2-ton hydraulic jack at 30 MPa, monitored with a pressure gauge. This compression technique, coupled with the unfired brick fabrication, offers low-energy, less polluting production alternative. After 24 hours of stabilization, cement sand brick was cured in clean water for 28 days, in line with BS 3148 (1980) and BS 12390-2 (2000).

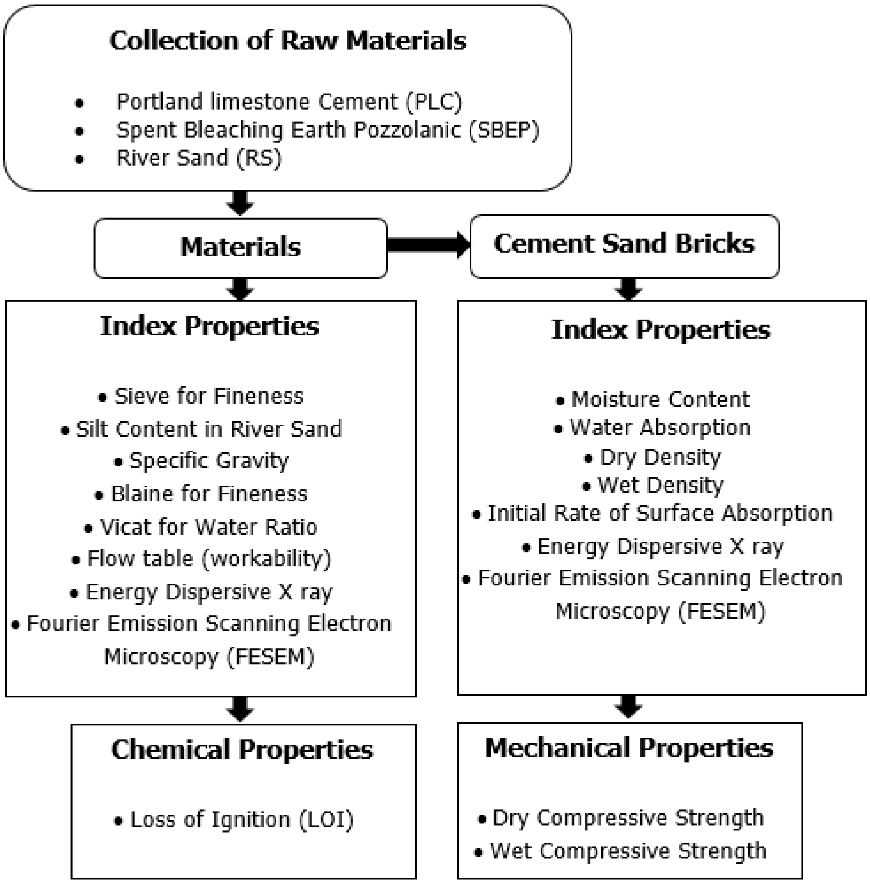


Fig. 1. Flowchart of the Materials and Cement Sand Bricks Testing

3. Results

3.1 Sieve Analysis

Gradation and particle size distribution analysis of Portland limestone cement, spent bleaching earth pozzolanic, and river sand. Figure 5 and Table 1 illustrate the properties of Portland limestone cement (CEM II/AL 32.5 R), spent bleaching earth pozzolanic, and river sand, with particular attention to the gradation and particle size distribution. Understanding the gradation of these raw materials is essential, as the arrangement of particles significantly influences void space within mixture, thereby impacting the water demand and workability of the final cement mortar then the cement sand brick. The gradation or particle size distribution, is assessed in terms of cumulative percentage of material passing through specific sieve sizes. This measurement helps evaluate the fineness of each material and its role in affecting the overall mix. Gradation profiles for each material were obtained through sieve analysis following British and European Standards: 410-1 (2000), which covers test sieves made of a metal wire cloth, and 1015-1 (1999), which defines the methods for the determining particle size distribution by sieve analysis. Additionally, the specification for the natural aggregate for concrete is referenced from British Standard 882 (1992).

Table 1
Particle Size Distributions of Fineness

BS 410 1 (2000) Sieve sizes	PLC (grams)	SBEP (grams)	RS (grams)
2.36 mm	–	–	–
1.18 mm	–	–	84.05
600 μm	–	0.4	80.1
425 μm	0.3	0.5	65
300 μm	25.4	23.1	51
150 μm	55.4	48	10
75 μm tray	99	100	1.8
75 μm pan	69	77	–

Portland limestone cement particle size distribution of Portland limestone cement is typical of cementitious materials, where a substantial proportion of particles pass through the finer sieve sizes. Due to its smaller particles, Portland limestone cement plays a crucial role in filling voids between larger particles, thereby contributing to the density and cohesiveness of the mix. In the 75 μm sieve, Portland limestone cement showed the retained weight of 69 grams, indicating its fine particulate nature, the key feature for achieving high early strength in cementitious materials. Spent bleaching earth pozzolanic particles are even finer than Portland limestone cement, with 77 grams retained at the 75 μm pan after sieving. This finer size is primarily due to factory grinding processes designed to increase reactivity when combined with Portland limestone cement. Particles exhibit an exponential growth in cumulative weight distribution between 600 μm and 75 μm ranges, followed by a plateau. This pattern indicates the substantial accumulation of fine particles in the lower micrometer range, enhancing the pozzolanic reactivity when blended with Portland limestone cement by filling micro voids and increasing density. River sand, commonly classified for uses in cement mortar and concrete, falls under different grading zones. For this study, river sand is categorized as grade M, appropriate for cement mortar applications. Further classification for concrete zones spans from Zone 1 (coarse) to Zone 4 (fine). Particle size distribution of a river sand differs from Portland limestone cement and spent bleaching earth pozzolanic. A distribution curve for river sand demonstrates a steady increase, transitioning to a sharper incline as particle size increases. This indicates river sand contains larger particles relative to cement and pozzolanic materials, contributing to a more open structure within the mix, which may necessitate a higher water demand to achieve workability.

Implication of particle distribution on mixture properties, this relative fineness of spent bleaching earth pozzolanic compared to Portland limestone cement and the larger particle size of river sand influence the overall mix properties in several ways: Void reduction – the finer particles in Portland limestone cement and spent bleaching earth pozzolanic help filling spaces between larger river sand particles, reducing voids and enhancing a compactness and density of mix. This reduction in voids consequently reduces water demand needed to achieve the desired workability. Water demand and workability – water demand is directly influenced by particle size and distribution of each material. Finer particles, such as those in spent bleaching earth pozzolanic and Portland limestone cement, have a higher surface area, leading to higher initial water demand. However, the presence of larger river sand particles balances this by creating more workable mix due to lower surface area of coarser particles.

Sieve analysis and classification details – the sieve analysis for each material, displayed in Figures 2, 3, and 4, follows the specified standards for evaluating material fineness. Key findings include the cumulative percentage passing – the cumulative percentage passing for each sieve size was plotted to create a gradation curve for each material. This analysis showed spent bleaching earth pozzolanic retained a higher cumulative percentage at the finer sieve levels, indicating its fine particle structure, which is optimal for filling voids and enhancing the pozzolanic reaction. Zone classification – the river sand gradation is designated as grade M, suitable for the cement mortar applications, with the steady gradation curve that supports a balanced distribution of particle sizes. This classification meets the requirements set by British Standard 882 (1992) for the natural aggregates in the concrete, ensuring suitability for use in cement mortar and then a cement sand brick production. Comparison of growth pattern in gradation curves – the particle size distribution curve of spent bleaching earth pozzolanic shows an exponential growth phase followed by the plateau. The initial exponential growth phase reflects the rapid increase in cumulative weight distribution across the sieve sizes, particularly in the range between 600 µm and 75 µm. This pattern stabilizes at a plateau, signifying that the majority of spent bleaching earth pozzolanic particles fall within this fine range, suitable for high reactivity when blended with Portland limestone cement. In contrast, river sand exhibits a gradual incline in a particle distribution curve, with an accelerated increase at larger sieve sizes, indicative of its relatively coarser particles. This sharper rise, as opposed to steady growth seen in cement and spent bleaching earth pozzolanic, underscores the distinction in the particle size and highlights the role of a river sand as a structural aggregate within the mix, requiring more water to maintain the desired workability and consistency in cement mortar (cement sand brick).

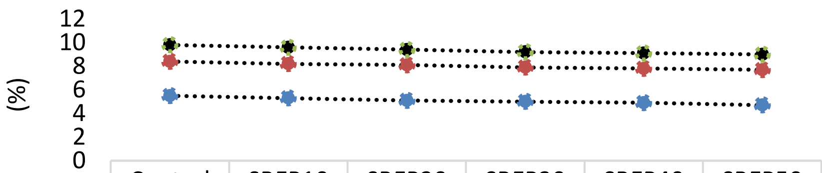
Fig. 2. Sieved Portland Limestone Cement

Fig. 3. Sieved Spent Bleaching Earth Pozzolan

Fig. 4. Sieved River Sand

3.2 Water Absorption

Figure 5 presents the properties of the control sample (Portland limestone cement and river sand) and spent bleaching earth pozzolan -modified samples, denoted as SBEP10, SBEP20, SBEP30, SBEP40, and SBEP50. The analysis shows the water absorption for 28 days, as the control having 9.8%. With increasing the spent bleaching earth pozzolan content, the water absorption decreases across all curing periods. Specifically, for 9.6%, 9.4%, 9.2%, 9.1%, and 9% respectively. All water absorption values remain well below 25% threshold specified in British Standard 3921 (1985) for clay bricks, indicating compliance and enhanced durability with spent bleaching earth pozzolan incorporation.



	Control	SBEP10	SBEP20	SBEP30	SBEP40	SBEP50
1 day	5.5	5.3	5.1	5	4.9	4.7
7 days	8.4	8.2	8.1	7.9	7.8	7.7
28 days	9.8	9.6	9.4	9.2	9.1	9

Design Mix

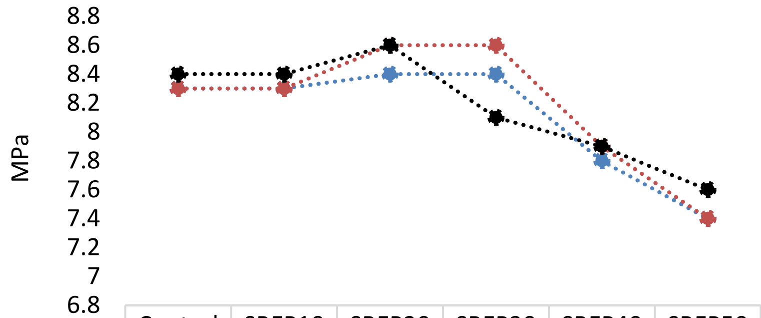
Fig. 5. Water Absorption

3.3 Compressive Strength

Figure 6 shows the results of 28 days dry compressive strength of SBEP10, increased to 8.4 MPa, for the SBEP20, further increased to 8.6 MPa, Moreover, SBEP30 reduce its compressive strength at 8.1 MPa. These SBEP40, and SBEP50, compressive strength decreased progressively to 7.9 MPa, and 7.6 MPa, respectively, when compared to the control. These results align with the BS EN 12390 (2000) for testing hardened concrete, with a reduction in compressive strength observed as the percentage of spent bleaching earth pozzolan increases beyond 20%. However, SBEP20 maintain dry compressive strength for making 20% of spent bleaching earth pozzolan having as the optimum. Figure 7 shows the results of 28 days wet compressive strength of SBEP10, increased to 7.0 MPa, for the SBEP20, further increased to 7.1 MPa, having the same compressive strength to SBEP30, while for the SBEP40, and SBEP50, compressive strength decreased progressively, for the values were 6.8 MPa, and 6.4

MPa. The wet compressive strength of SBEP20 and SBEP30 was found to be the highest, with the value of 7.1 MPa for all test intervals, indicating that 20% and 30% of spent bleaching earth pozzolan in the cement sand bricks mixes provides the optimal balance of strength.

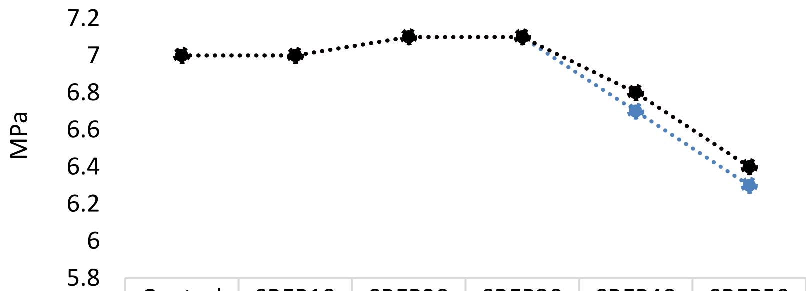
The decrease in compressive strength for SBEP30, SBEP40, and SBEP50 suggests spent bleaching earth pozzolan enhances pozzolanic reactions in the mix, higher proportions of spent bleaching earth pozzolan may disrupt the structural integrity of cement sand bricks. Spent bleaching earth pozzolan and Portland limestone cement are fine-grained materials with a high specific surface area, which enhances their reactivity with lime (calcium hydroxide) to form cementitious compounds, such as calcium silicate hydrate (C-S-H), when mix with water. The amorphous or non-crystalline structure of spent bleaching earth pozzolan, "as stated by Suhaimi and Mohamad [7], Sulaiman *et al.*, [8], and Sutarno and Mohamad [9]" contributes significantly to this reactivity. This amorphous nature allows the spent bleaching earth pozzolan to react readily with calcium hydroxide in the presence of water, making it potent pozzolan for improving the strength of cement sand bricks. However, the reactivity decreases if spent bleaching earth pozzolan percentage is too high, as observed in a reduced strength of the SBEP30, SBEP40, and SBEP50 samples.



	Control	SBEP10	SBEP20	SBEP30	SBEP40	SBEP50
1 day	8.3	8.3	8.4	8.4	7.8	7.4
7 days	8.3	8.3	8.6	8.6	7.9	7.4
28 days	8.4	8.4	8.6	8.1	7.9	7.6

Design Mix

Fig. 6. Dry Compressive Strength



	Control	SBEP10	SBEP20	SBEP30	SBEP40	SBEP50
1 day	7	7	7.1	7.1	6.7	6.3
7 days	7	7	7.1	7.1	6.8	6.4
28 days	7	7	7.1	7.1	6.8	6.4

Design Mix

Fig. 7. Wet Compressive Strength

4. Conclusions

The laboratory testing of material properties for the spent bleaching earth pozzolanic, Portland limestone cement and river sand, control mix (Portland limestone cement and river sand), and spent bleaching earth pozzolanic variations at 10%, 20%, 30%, 40%, and 50% substitution in control reveals several insights into their behaviors and potential applications in cement sand brick production. The data indicate that the presence of 40% and 50% of SBEP in a control mix significantly reduced water absorption, dry and wet compressive strength. However, 20% SBEP gained the optimum compressive strength. The result shows spent bleaching earth pozzolanic content in Portland limestone cement significantly contribute to formation of calcium silicate hydrate (C-S-H) gel, which fills voids in wet cement mortar and contributes to enhanced density and structural integrity. The data gathered suggests that spent bleaching earth pozzolanic is a promising component for cement sand brick production. Its void-filling properties and its role in C-S-H formation can lead to cement sand brick reduced permeability, enhanced durability, and increase compressive strength. Characteristics are valuable for a sustainable cement sand brick production, as the inclusion of spent bleaching earth pozzolanic can yield a product with lower water absorption, improved density, and greater resistance to the environmental wear.

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