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Study of the Effect of Bottom Ash and Palm Shell Kernel as Materials in Bricks

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Abstract

This study explores the incorporation of Bottom Ash (BA) and Palm Kernel Shell (PKS) as sustainable alternatives to traditional sand in cement brick manufacturing, aiming to address environmental concerns and resource depletion associated with fine aggregates. The research involved replacing varying proportions of sand with BA and PKS, ranging from 0% to 20%, and conducting laboratory tests based on standard codes to assess compressive strength and water absorption. The findings revealed that bricks with 10% BA and PKS each demonstrated optimal load-bearing properties, although water absorption rates exceeded the standard requirement for percentages above 10%. The study emphasizes the need for further investigation to identify an ideal proportion that meets water absorption standards. Mechanical properties assessment indicated that bricks with 10% BA and PKS exhibited the highest compressive strength, making them suitable for areas with severe weather conditions. Despite higher water absorption, the alternative cement bricks showed promise in weight reduction, contributing to transportation and construction efficiency. The study suggests that despite moisture susceptibility, these bricks are suitable for construction, particularly in applications with manageable loads, and their accessibility makes them beneficial in rural areas.

1. Introduction

The advancement of technology in construction in Malaysia, including the development of automated production processes, has made cement brick manufacturing more efficient and economical. This may have encouraged the adoption of concrete bricks as a preferred building material in Malaysia. cement brick is a popular construction material in Malaysia and is widely used for various types of building applications, including residential, commercial, and industrial buildings. It is known for its durability, strength, and affordability.

As a result, numerous studies involved in R&D department in developing a finished brick with alternative raw materials in brick manufacturing. The finished bricks should be suitable for withstanding the tropical climate of Malaysia. They also should be resistant to weather, moisture, and pests, making them a durable option for construction purposes.

In this research, the bottom ash (BA) and palm kernel shell (PKS) were added up to a few portions to replace the fine aggregate. The shell was dried under the sunlight for 1 day and sieved.

Then, the BA and the PKS are added into the mixture up to a few portions based on the ratio over aggregates ratio. Then the modified brick undergoes a curing process and a few tests were conducted to determine the effectiveness of the BA and PKS in replacing the fine aggregates in cement brick.

1.1 Objective and Scope of Work

The research objectives center on determining the optimal proportion for alternative bottom ash (BA) and palm kernel shell (PKS) in cement brick production, alongside investigating the physical and mechanical properties of the resulting bricks. The aim is to ensure that BA and PKS can offer comparable or enhanced performance compared to traditional raw materials. The study, based on materials sourced from Bukit Pasir, Muar, involves 48 samples of BA and PKS cement bricks adhering to the MS 76:1972 standard. Laboratory testing, in accordance with BS EN 12390-3:2002 for compressive strength and BS 1881-122:2011 for water absorption, is conducted on samples with varying proportions of BA and PKS replacement (0%, 10%, 15%, and 20%). The assessments take place at the FTK laboratory, UTHM Pagoh, contributing to a comprehensive understanding of the viability and performance of these alternative materials in cement brick manufacturing.

1.2 PKS Fine Aggregate

This research involves the production of Palm Oil Kernel Shell Fine Aggregate as a replacement material for fine aggregate on the brick mix. The percentages of PKS used in this experiment are 0%, 10%, 15%, and 20%. PKS that was used in this study is collected from a palm oil mill at Bukit Pasir, Muar, Johor. The figure below show that the PKS had been dried in the oven at 105°C for 24 hours. Because the PKS sample is already crushed at the palm oil mill, it still needs to be sieved by using BS Sieve 4.75 mm. The sample that is retained on the 4.75 mm sieve was used in the brick mix.

Fig. 1 *PKS after been dried in oven*

1.3 BA Fine Aggregate

Bottom ash was employed as a substitute for fine aggregate in a concrete mix in this experiment. Bottom ash percentages of 0%, 10%, 15%, and 20% are also used in this experiment. Bottom ash was collected from the boiler of palm kernel shell at the palm oil mill and sieved with a BS Sieve 4.75 mm. Only samples with a sieve size of no more than 5 mm was used in the concrete mix. The bottom ash is shown in Fig 2.

Fig. 2 *Bottom ash*

1.4 Methodology

As the main focus of this study is to find out the performance of cement brick with BA and PKS, the optimum mix proportion for materials also was discussed in this study. In addition, laboratory testing were also be conducted to achieve the objective of this study.

There was a total of 48 samples of alternative BA and PKS cement bricks that were produced in this study. The size of the bricks is 215 mm in length, 102,5 m in width, and 65 mm in height as per MS 76:1972.
Then, the proportion is decided with 0%, 10%, 15%, and 20% of BA and PKS replacement in the mixture. The finished product went through a curing process for 7 and 28 days and laboratory experiments were conducted after the samples had matured.

Mixing, casting, and testing were done in laboratories such as the Concrete Technology Laboratory, Furniture Technology Laboratory at Universiti Tun Hussein
Onn Malaysia, Pagoh Campus, and Building Services Laboratory at UTHM Parit Raja, Batu Pahat. Fig 3 illustrates the flowchart study.

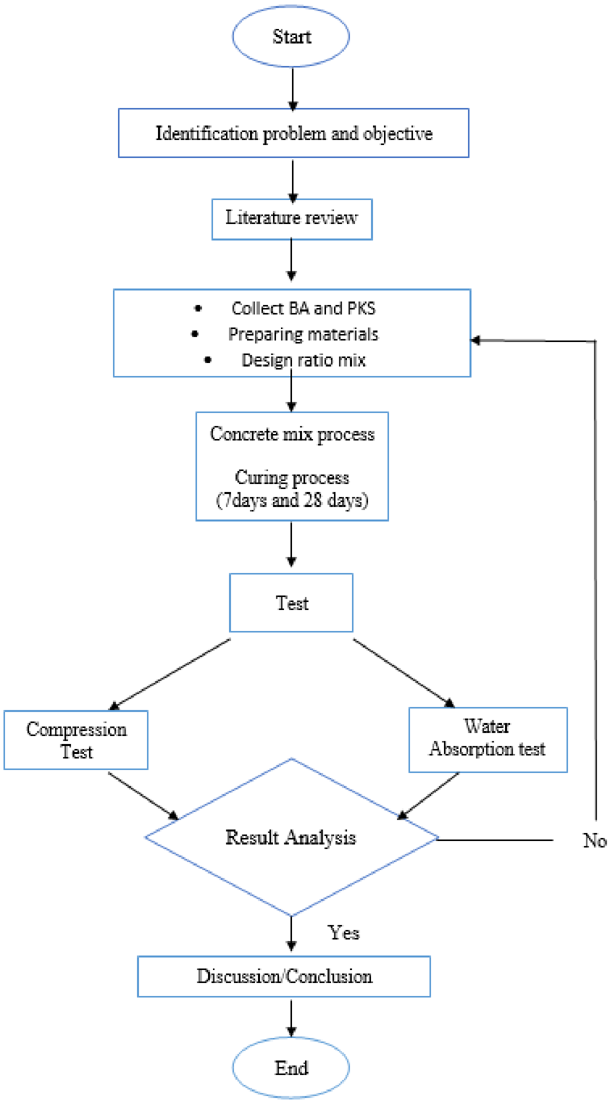

Fig. 3 *Flow Chart of Methodology*

1.5 Design (Mix Ratio)

The mixtures were designed according to the requirement of the British standard (BS-5628-3). In general, the ratio of cement: to sand in sand cement bricks is 1:6. The water-cement ratio used in the sand cement brick mix design is 0.6 (Azmi,2018). The mix design is calculated by the volume of the brick method. Table 1 shows the mix design for the mixture.

Table 1 *Design (Mix Ratio)*

Sample	Cement (kg)	Sand (kg)	PKS (kg)	BA (kg)	Water (L)
Control	4.8	35.4	0	0	2.88
10%	4.8	29.64	0.84	1.128	2.88
15%	4.8	24.84	1.32	1.68	2.88
20%	4.8	21.24	1.68	2.28	2.88

2. Laboratory Test Results

The laboratory results consist of the output of the experiments conducted for compressive strength and water absorption. The findings are presented through a relevant medium such as graphs and tables.

2.1 Compressive Strength Test

The compressive strength of a brick is significantly affected by the proportion of cement in the mixture, the type of raw material, and the amount of water present in a brick. In evaluating the load-bearing capacity of a brick, compressive strength is a crucial element that needs to be considered. The test was conducted at 7 and 28 days of curing. Table 2 and Fig 4 show the results of the testing.

Table 2 *Compressive strength*

Percentage of Palm Oil Kernel Shell Fine Aggregate and Bottom Ash Fine Aggregate	**Average Strength of Brick (N/mm^2)**	
	7 days	**28 days**
Control	20.5	23.7
10%	22.0	27.7
15%	20.9	23.2
20%	19.8	21.6

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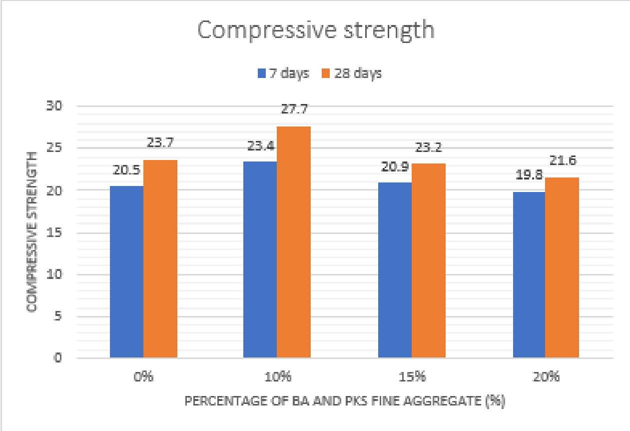

Fig. 4 *Graph of compressive strength test with different percentage of BA and PKS Fine Aggregate at the age 7 and 28 days*

The evaluation of compressive strength in brick load-bearing capacity reveals fluctuations influenced by the ratio of replacement materials, as depicted in Table 2 and Fig 4 for 7 and 28 days of curing. Notably, the study observes a peak in compressive strength at 10% replacement (23.4 MPa at 7 days, 27.7 MPa at 28 days), followed by a decline at 15% and 20% replacement. The presence of palm kernel shell (PKS) and bottom ash (BA) demonstrates a significant impact on compressive strength, attributed to their pozzolanic activity. The findings suggest that a 10% replacement with PKS and BA enhances brick strength, potentially due to effective gap filling and the synergistic properties of both materials. The compliance of brick samples with ASTM C62-17 [4] for exposure conditions and MS 1933-1 for load-bearing [1], as illustrated for various proportions, underscores their suitability for construction, meeting or exceeding the specified minimum strengths. Additionally, the study notes that the curing period plays a crucial role in the development of brick strength, with a positive correlation observed between strength and extended curing periods.

2.2 Water Absorption Test

The ability to absorb water is a major factor that influences the overall quality of bricks produced. The brick samples were initially oven-dried for 24 hours and then left to let it cool down before being submerged in the water tank for another 24 hours. To calculate the percentage of water absorption, the samples' weights were recorded both before and after the brick samples were submerged in the water tank. At the age of 7 and 28 days, this test was conducted according to BS 18881:122. The table shows the result for water absorption.

Table 3 *Water Absorption of brick*

Percentage of Palm Oil Kernel Shell Fine Aggregate and Bottom Ash Fine Aggregate	Average Percentage of Water Absorption (%)	
	7 days	28 days
Control	3.23	2.62
10%	5.09	4.63
15%	5.35	5.00
20%	5.53	5.17

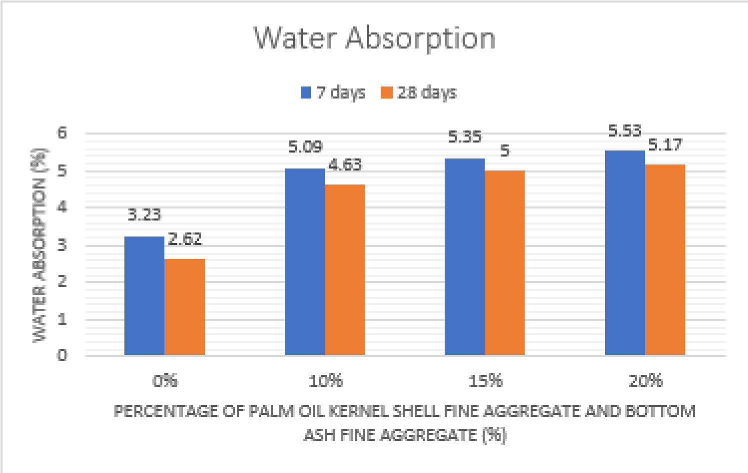

Fig. 5 *Graph of water absorption test with different percentage of BA and PKS Fine Aggregate at the age 7 and 28 days*

Fig 5 visually depicts the correlation between different proportions of Palm Kernel Shell (PKS) and Bottom Ash (BA) and the corresponding water absorption percentages in cement brick samples. The graph reveals an increasing trend in water absorption percentages, ranging from 3.23% to 5.53% after 7 days and 2.62% to 5.17% after 28 days of curing. Notably, bricks with 20% PKS and BA exhibit the highest absorption at 5.53%, while those with 5% PKS and BA show the lowest at 4.63%, excluding control samples at 0%. This pattern suggests a direct relationship between water absorption and higher percentages of PKS and BA. The study highlights a potential correlation between curing duration and absorption percentages, indicating that longer curing periods result in lower water absorption [6]. The increased absorption in 1:6 cement bricks, where sand is replaced with PKS and BA, is attributed to the porous nature of these materials, creating additional pathways for water ingress. This aligns with previous research and standards, emphasizing the importance of water absorption rates in ensuring proper hydration and bond establishment in cement bricks.

3. Conclusion

The primary objective of this study was to identify the optimal proportion for an alternative cement brick incorporating Bottom Ash (BA) and Palm Kernel Shell (PKS), replacing sand at varying percentages (0%, 10%, 15%, and 20%). Contrary to previous research, which found unsatisfactory results within the 5% to 30% range, this study utilized the volume method for precise mix design. Bricks with 10% BA and PKS exhibited optimal load-bearing properties; however, those with 10% to 20% did not meet the water absorption requirement of 4.5% or lower per BS EN 771-1, indicating the need for further investigation.

The second objective aimed to assess the mechanical properties of the alternative cement brick. Results revealed higher water absorption rates with increased BA and PKS percentages, but bricks with 10% each demonstrated the highest compressive strength, suitable for severe weather conditions according to ASTM C62-17 [4]. Despite BA and PKS's influence on mechanical properties, the study concludes that, when combined with cement, sand, and water, the mixture enhances the brick's performance, meeting standard requirements. The curing period significantly contributes to improved performance over time. While the alternative cement brick remains suitable for construction, particularly in manageable load applications like brick walls for fences, susceptibility to moisture damage suggests a need for regular maintenance. The accessibility of BA and PKS renders this alternative beneficial in rural areas.

4. Recommendation

Several key recommendations are proposed to guide future research and development endeavours focused on the alternative cement brick incorporating Bottom Ash (BA) and Palm Kernel Shell (PKS):

I. Optimization of Proportions:

The study suggests adjusting the proportions of BA and PKS in the mixture to achieve an optimal blend that delivers improved outcomes. Given the observed variations in compressive strength and water absorption at different replacement percentages, a more nuanced exploration of these ratios is warranted. Further investigations could involve additional replacement percentages or alternative combinations to identify a proportion that not only meets load-bearing requirements but also aligns with water absorption standards.

II. Extended Curing Period:

It is recommended to extend the curing period in future studies to explore the sustained development of the alternative cement brick. Extending the observation timeframe beyond the current 28-day period would provide insights into the long-term physical, chemical, and mechanical properties of the brick. This extended analysis could reveal potential trends or changes that might occur over time, contributing to a more comprehensive understanding of the material's behavior and performance.

III. Advanced Analytical Techniques:

Incorporating advanced analytical techniques, such as X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM), is proposed to delve deeper into the structural and chemical characteristics of the alternative cement brick. These techniques offer a detailed examination of the elemental composition and morphology, providing valuable insights into the microstructure and material interactions. Understanding these aspects can enhance our knowledge of how BA and PKS influence the overall properties of the brick, enabling a more informed and nuanced assessment of its suitability for construction applications.

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