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Study on Cement Brick Properties with Composition of Sago Fine Waste (SFW) As Filler

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Abstract

This paper presents the potential of sago fine waste (SFW) in brick production. Sago is well-recognized as a primary material in making local food. In Malaysia, Sarawak has the largest sago palm plantation areas and is currently one of the world's largest exporters of sago starch. However, due to the strong global demand for sago starch, the consumption of sago has increased, which in turn has raised the amount of waste generated. Typically, the waste from sago processing is discarded along riverbanks or in river streams. Therefore, utilizing sago waste in brick production aims to contribute to environmental quality and address the issue of improper waste disposal. In this study, SFW was used as a replacement for cement in the production of cement bricks. The objectives were to determine the performance of bricks with SFW replacing various percentages of cement through density tests, compressive strength tests, and water absorption tests. The cement-to-sand ratio and water-to-cement ratio were 1:3 and 0.5, respectively. The replacement volumes of cement with SFW were 0%, 1%, 3%, 5%, 7%, and 9%. Overall, the findings indicate that SFW has the potential to produce lightweight bricks. The optimal percentage of SFW for cement bricks was found to be 1%. The results showed that SFW at 1% (SFW1) exhibited a higher strength value of 16.16 MPa and a lower water absorption value of 11.72% compared to other percentages. Nevertheless, all samples with varying percentages of SFW met the standard requirements.

1. Introduction

In recent years, various studies have focused on producing bricks with comparable strength and durability using agricultural waste. As material waste increases due to a growing population and expanding urban areas, investigating the use of waste as construction material has become increasingly significant. In Malaysia, large quantities of agricultural by-products are generated, particularly from oil palm, banana, pineapple, paddy, and sugarcane [1]. This research specifically explores the use of sago husk, also known as sago fine waste (SFW), in brick production. Sago is well recognized as a basic material in making local food.

In Malaysia, Sarawak has the largest sago palm plantations, particularly in the Mukah division. It is currently one of the world's largest exporters of sago starch, shipping over 40,000 tons annually to various countries, including Peninsular Malaysia. This export volume is expected to increase each year in response to global demand, leading to a corresponding rise in waste generation [2]. Typically, sago processing waste is disposed of in landfills or left along riverbanks and sometimes in river streams. Improper disposal of Sago Fine Waste (SFW) can contribute to environmental issues over time. Therefore, utilizing this waste as a filler in cement bricks aims to conserve natural resources and promote environmental sustainability.

Bricks are fundamental construction materials in the industry. According to BS 5628-3:1985, bricks consist of a mixture of cement, fine aggregate, water, and admixture. Mahendran et al. [3]. noted that bricks can be classified based on specifications such as dimensions, visual appearance, compressive strength, density, and water absorption. To determine the quality of bricks, several tests are conducted, including compressive strength tests, density tests, water absorption tests, efflorescence tests, and visual appearance tests.

Brick density is a critical parameter for assessing the mechanical properties and classification of bricks. Ornam et al. [4]. reported that both high and low densities in bricks are influenced by factors such as void content, the fineness of composite materials, the mixing process, and the duration of drying and firing. This finding is supported by MS Farazela et al. [5], who observed that adding sawdust slightly reduces brick density due to increased void content. Additionally, a study has found that bricks made from sago waste are both lightweight and cost-effective [6].

Several factors influence the compressive strength of bricks. One factor is the low content of Portland cement in the mixture, which can reduce compressive strength due to insufficient calcium hydroxide produced during cement hydration [7]. Additionally, compressive strength increases with proper curing, which provides the necessary water for completing the hydration process without interruption [8]. Previous studies have shown that increased water absorption is related to the porosity of bricks, as water is absorbed by the pores [3]. Ornam et al. [4]. noted that water absorption properties increase with higher percentages of Sago Fine Waste (SFW) due to the rougher texture of SFW, which contributes to greater porosity in the bricks. This result suggests that utilizing sago waste can help address environmental issues by making full use of sustainable resources.

The global demand for construction materials is rising daily. To ensure durable building construction, this study aims to offer insights into alternative waste disposal methods by providing low-cost raw materials for brick manufacturing. The results of this study are significant for advancing green technology and contribute to the construction industry, innovation, and infrastructure, aligning with the Sustainable Development Goals (SDGs).

2. Materials and Methodology

2.1 Materials

This section details the raw and waste materials used in preparing the cement bricks for the study. The raw materials include cement, sand, and water. For the waste material, sago husk, referred to as Sago Fine Waste (SFW), was used as a replacement for cement material in the composite bricks.

2.1.1 Cement

Cement acts as a binder for material in composite brick. For this study, Ordinary Portland Cement (OPC), in accordance with MS 522: Part 1:2007, was used for casting all the samples. The cement was stored in an airtight steel drum prior to brick production to prevent exposure to moisture and avoid premature hardening.

2.1.2 Sand

The type of sand used as a fine aggregate in producing composite bricks was natural sand. The maximum particle size of the sand was less than 2.36 mm, as it passed through a 10 mm sieve, with a standard specific gravity of 2.68. The sand, which had undergone sieve analysis, was stored dry in a designated storage area until it was ready to use.

2.1.3 Water

Water is an important factor because it enhances the function of cement as a binder for sand and other materials. By reacting chemically with the cement, water facilitates the development of the desired properties in the brick. In this study, tap water provided by Syarikat Air Johor, Malaysia, was used for both the brick casting and curing processes.

2.1.4 Sago Fine Waste (SFW)

In the preparation of SFW, sago husk waste was collected from the River Link Sago Resources Sdn Bhd factory at Kg. Dalat, Mukah, Sarawak. The preparation process included drying, which is well-known for inhibiting bacterial and microbial growth in various industries, including the food sector. The fineness modulus of the SFW is 2.65, and its specific gravity is 0.75. Fig.1 shows the SFW after drying and grinding.

Fig. 1 *SFW after being dried and grinded*

2.2 Methodology

This section details the methods used in studying the properties of cement bricks with the addition of SFW. The main activities involved in the process included material testing, brick preparation, and laboratory testing.

2.2.1 Material Testing

2.2.1.1 Sieve Analysis Test

Sieve analysis is a process used to assess the quality of aggregates based on particle size, in accordance with the grading standard BS 410:1986. In this study, the materials subjected to sieve analysis were sand and SFW, with initial weights of 1000 g and 500 g, respectively. The materials were passed through a series of sieves with varying mesh sizes, and the mass retained in each sieve was measured and recorded.

2.2.1.2 Specific Gravity Test

Specific gravity (Gs) of a material is defined as the ratio of the mass of a unit volume of the aggregate at a specific temperature to the mass of an equal volume of water, in accordance with BS 812-2:1995. In this study, a specific gravity test was conducted to determine the density of 2000 g of sand and 2000 g of SFW at 100°C using a pycnometer. The specific gravity for the fine aggregate was calculated using Eq. (1) [9].

$$\text{Bulk Specific Gravity} = \frac{A}{(B + 500 - C)} \quad (1)$$

where A = mass of oven-dry sample in air (g), B = mass of pycnometer filled with water, (g), and C = mass of pycnometer with sample and water to calibration mark, (g).

2.2.1.3 Bulk Density Test

Bulk density is the weight per unit volume used to evaluate the porosity and void content of fine aggregates. In this study, the bulk density of cement, sand (fine aggregate), and SFW was assessed using the standard test methods outlined in BS 812: Part 2: 1995. The test procedure involved filling a container approximately one-third full of the fine aggregate, followed by 25 blows of tamping. The bulk density was then calculated using Eq. (2) [9].

$$\text{Bulk density} = \frac{\text{weight cylinder} + \text{fine aggregate} - \text{empty weight cylinder (kg)}}{\text{volume of cylinder } (\text{m}^3)} \quad (2)$$

2.2.2 Brick Preparation

In this study, cement, sand, water, and SFW were used in the production of composite bricks. According to the mix design, all materials were weighed before mixing. The mould for brick casting had dimensions of 215 mm in length, 102.5 mm in width, and 65 mm in depth. The mix ratios used were 1:3 for sand to cement and 0.5 for water to cement. The sand-cement ratio preparation followed the design method specified in BS 5628:2001. The volume of SFW used as a cement replacement material in producing composite bricks varied at 0%, 1%, 3%, 5%, 7%, and 9%. The samples were designated as SFW 1%, SFW 3%, SFW 5%, SFW 7%, and SFW 9%. A total of 72 samples were produced for this study.

2.2.3 Laboratory Testing

Laboratory tests, including density, compressive strength, and water absorption tests, were conducted for this study. The following subsections will provide detailed procedures and results for each of these tests.

2.2.3.1 Density Test

The relative density of bricks was conducted by measuring its weight and dividing the weight with the volume of the brick in accordance with BS EN 206-1:2000. In this study, a total of 36 samples from 6 mixes proportion were performed the density tests at 7 and 28 days of curing. Eq. (3)[9] was used to determine the density of brick.

$$\text{Bulk density} = \frac{\text{weight of sample (kg)}}{\text{volume of brick (m}^3)} \quad (3)$$

2.2.3.1 Compressive Strength Test

The compressive strength test assesses the behavior of a material under a specific load. In this study, the compressive strength test was conducted at 7 and 28 days of wet curing, in accordance with BS EN 772-1:2000. Before testing, any excess moisture on the surface of the samples was wiped off to ensure accurate results. The maximum load applied was recorded, and the strength of the samples was calculated using Eq. (4)[10].

$$\sigma = \frac{F}{A} \quad (4)$$

where σ = Compressive strength (kN/mm^2), F = Ultimate compressive load of concrete (kN), and A = Cube surface area (mm^2).

2.2.3.3 Water Absorption Test

Water absorption test measures the amount of water absorbed under specified conditions. In this study, the water absorption test was performed at 7 and 28 days of dry curing, in accordance with BS EN 772-11:2000. Initially, the brick samples were dried in an oven at 110°C for 24 hours. Subsequently, all samples were fully immersed in clean water for 24 hours. The weights of the samples before and after immersion were recorded, and the water absorption was calculated using Eq. (5) [11].

$$\text{Absorption, \%} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \text{x } 100 \quad (5)$$

3. Results and Discussion

This section provides a critical analysis and discussion of the experimental work. As previously mentioned, the experimental work involved material testing, including sieve analysis, specific gravity, and bulk density tests, as well as laboratory testing for density, compressive strength, and water absorption.

3.1 Material Testing

3.1.1 Sieve Analysis Test

A sieve analysis was conducted on natural fine aggregates (sand) and SFW to determine their particle size distribution. The sieve sizes used were 10 mm, 5 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, and 150 µm. The gradings of these materials were examined to ensure they conform to the overall grading standard of BS 410:1986.

As shown in Fig. 2, the sand particles were measured to be less than 2.36 mm, while the SFW particles were measured to be less than 600 µm as they passed through the sieves. The grading curve in the figure indicates that the fineness modulus of the sand is 2.82, and that of the SFW is 2.65.

3.1.2 Specific Gravity Test

This process is important for assessing the strength and quality of the materials used in composite bricks. Table 1 presents the specific gravity data for both sand and SFW.

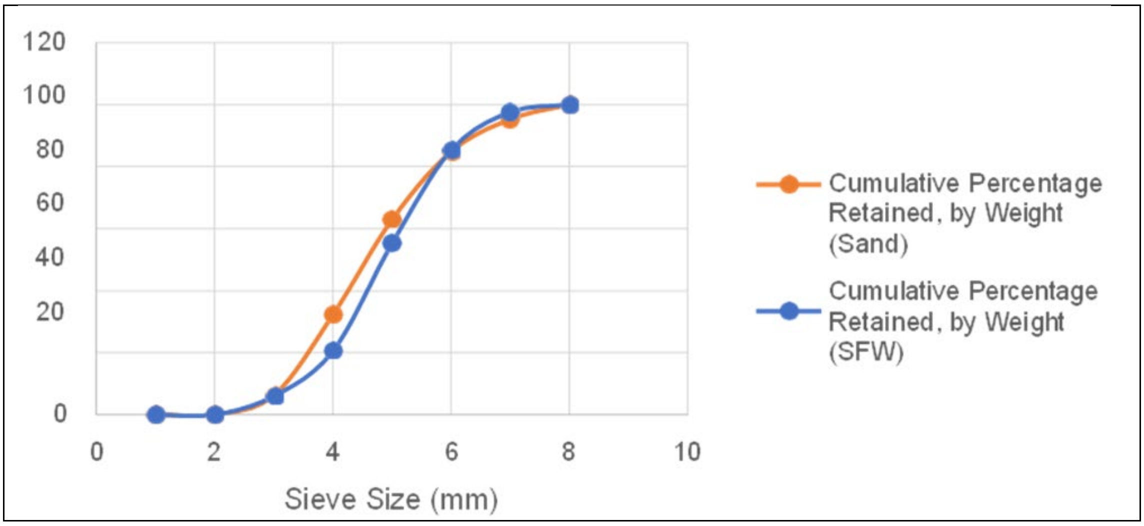

Fig. 2 *Grading curve of sand and SFW*

Table 1 *Specific gravity data of sand and SFW*

Material	Specific Gravity	Reference	Value
Sand	2.58	Albano et al. [6]	2.66
SFW	0.75	Hadi Izaan et al. [12]	0.45

3.1.3 Bulk Density Test

Bulk density is influenced by how densely the aggregate is packed, including factors such as particle size distribution and shape. As the particle size distribution decreases, the bulk density typically increases because the voids between the particles become filled. Based on the findings, the bulk densities for sand, SFW, and cement are 2237 kg/m^3, 1270 kg/m^3, and 31838 kg/m^3, respectively.

3.2 Brick Properties

3.2.1 Density Test

The density test was conducted after 7 and 28 days of dry curing in accordance with BS EN 206-1:2000 [13]. A total of 36 brick samples were tested by measuring their weight. The average density of the brick samples with a cement-to-sand ratio of 1:3 is shown in Fig. 3.

Fig. 3 indicates a decrease in density with an increasing percentage of SFW substitution in the cement bricks. Specifically, the density of bricks with 9% SFW substitution at 28 days is the lowest, at 1600.00 kg/m^3, which is 27.27% less compared to the control bricks. This reduction is likely due to the fine, lightweight nature of SFW and its high void content, which contribute to lower brick density [14].

In addition to material substitution, the age of the bricks also affects density. Longer curing periods allow bricks to develop better hardened properties through hydration. As shown in Fig. 3, the density of bricks at 28 days is generally lower than at 7 days. For example, the density of the SFW 1% brick decreases from 2050.00 kg/m^3 at 7 days to 2028.57 kg/m^3 at 28 days, representing a reduction of about 1.05%.

From the graph analysis, it can be summarized that partially replacing cement with SFW can produce lighter bricks. According to BS EN 206-1:2000, lightweight concrete is defined as having a dry density of less than 1850 kg/m^3. The results show that bricks with 5%, 7%, and 9% SFW replacement, at both 7 and 28 days, fall within the lightweight brick density range of 1600.00 kg/m^3 to 1807.14 kg/m^3. However, bricks with 1% and 3% SFW replacement did not meet the lightweight density standard but did satisfy the requirements for medium-weight density (1850 kg/m^3 - 2000 kg/m^3) and normal-weight density (≥ 2000 kg/m^3), respectively.

3.2.2 Compressive Strength Test

The compressive strength test was conducted after 7 and 28 days of curing in accordance with BS EN 772-1:2000 [10]. A total of 36 brick samples were tested to determine the maximum load they could withstand. The average compressive strength of the brick samples with a cement-to-sand ratio of 1:3 is shown in Fig. 4.

Fig. 4 illustrates a decrease in compressive strength with increasing percentages of SFW substitution in the cement bricks. For instance, the strength of bricks with 9% SFW substitution at 7 days is the lowest, at 1.86 MPa, which is 88.87% less compared to the control bricks. This reduction is likely due to the lower content of Portland cement in the mix, as SFW was used as a cement replacement. Ali et al. [14] also noted that the compressive strength of bricks is significantly influenced by the cement content in the mix. Lower cement content can reduce the binding component of calcium hydroxide, which is generated from cement hydration [7].

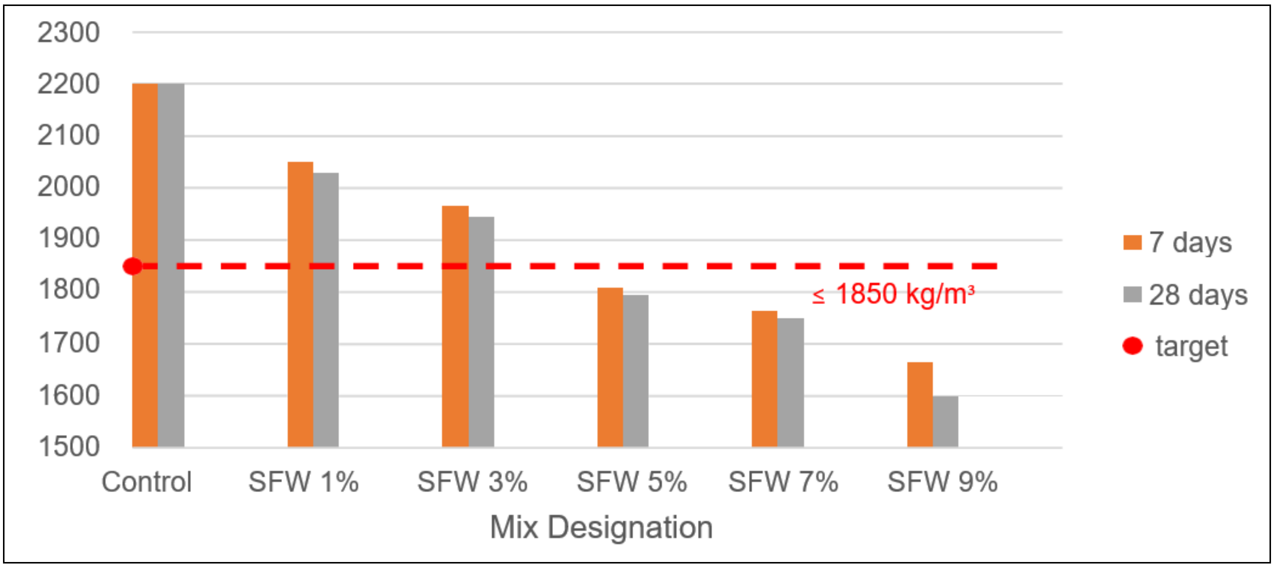

Fig. 3 *Density at 7 and 28 days*

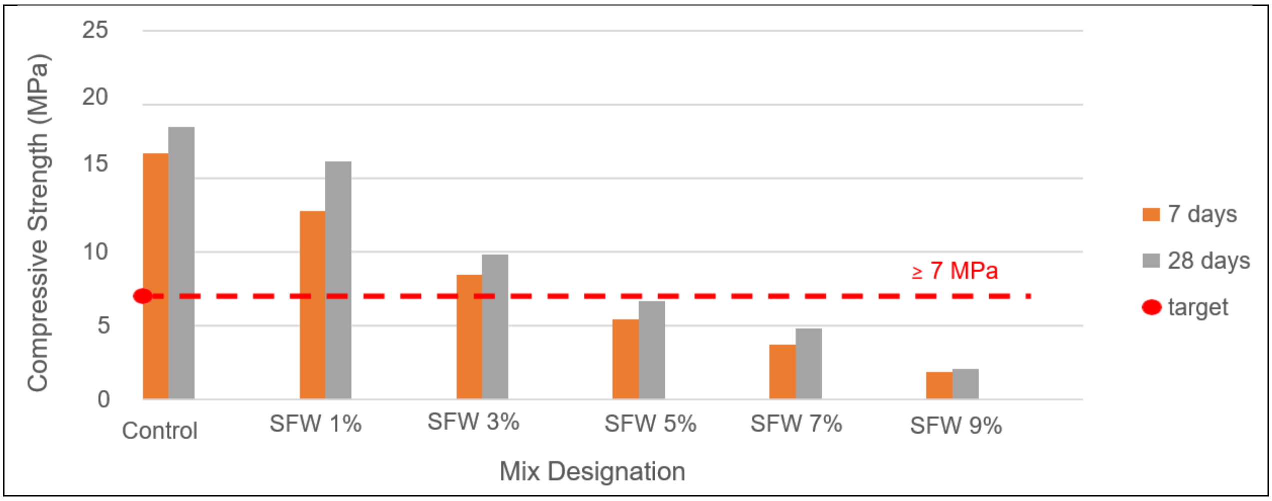

Fig. 4 *Compressive strength at 7 and 28 days*

Apart from cement content, the curing period is also a critical factor affecting brick compressive strength. Muthusamy et al. [8] support this, noting that compressive strength increases with curing age when sufficient water is provided to complete the hydration process without interruption. As shown in Fig. 4, the compressive strength of bricks at 28 days is slightly higher than at 7 days. For example, the strength of the SFW 3% brick increases from 8.47 MPa at 7 days to 9.82 MPa at 28 days, demonstrating a 13.75% increase.

From the graph analysis, it can be concluded that while the partial replacement of cement with SFW results in decreased compressive strength, the strength still meets the required standards. According to BS EN 772-1:2000 [10], the compressive strength of bricks should not be less than 7 MPa. The results show that bricks with 1% and 3% SFW replacement meet this standard, with strengths ranging from 12.79 MPa to 9.82 MPa at both 7 and 28 days. This indicates that the bricks produced in this study are suitable for use as load-bearing components.

3.2.3 Water Absorption Test

The water absorption test was conducted after 7 and 28 days of curing in accordance with BS EN 772-11:2000 [11]. A total of 36 brick samples were tested by measuring their dry and wet weights. The average water absorption of the brick samples with a cement-to-sand ratio of 1:3 is shown in Fig. 5.

Fig. 5 illustrates an increase in water absorption with a higher percentage of SFW substitution in the cement bricks. For instance, bricks with 9% SFW substitution at 28 days exhibit the highest water absorption value of

19.53%, which is 81.00% higher compared to the control bricks. This increase is likely due to the higher porosity of SFW particles, which leads to greater water absorption due to their rougher texture[4].

Additionally, the curing period also affects water absorption. A noticeable difference is observed between 7 days and 28 days of curing. For example, the water absorption of control bricks increases from 5.82% at 7 days to 10.79% at 28 days, representing a 46.06% increase. This increase in water absorption can be attributed to the hydrophilic characteristics of SFW, which allows the bricks to absorb more water over time [5]. Sago, being a hygroscopic material, readily absorbs water [4].

From the graph analysis, it can be concluded that the increased porosity of SFW leads to higher water absorption. According to the BS EN 772-11:2000 standard, acceptable water absorption for bricks is between 15% and 20%. Excessive water absorption can negatively impact the strength and durability of the bricks. The results from both 7 and 28 days indicate that the maximum water absorption does not exceed 20%, thus complying with the standard. Therefore, it is important for bricks to absorb a minimal amount of water, as excessive water penetration can affect the durability of the brick.

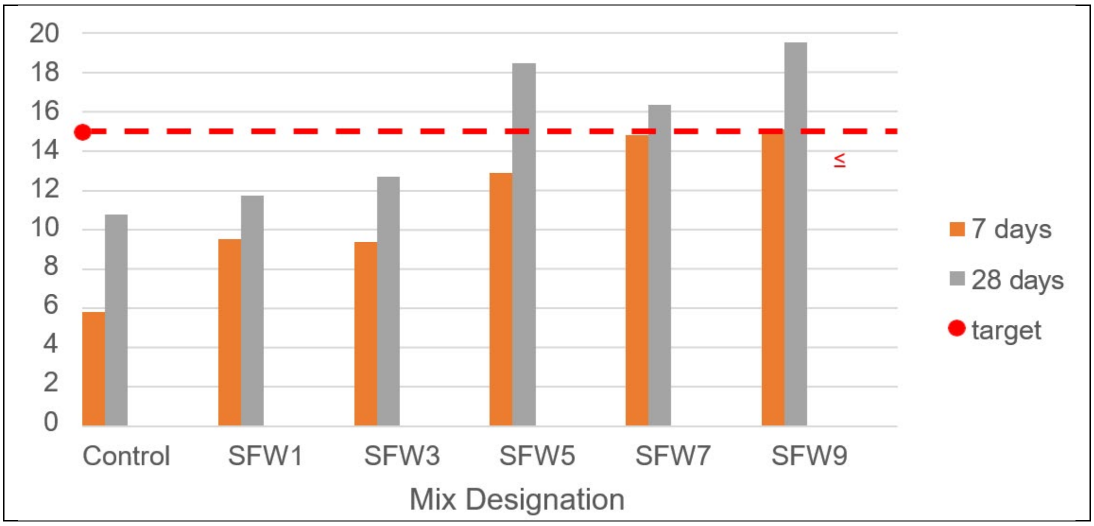

Fig. 5 *Water absorption at 7 and 28 days*

4 Conclusion

In this study, the performance of cement bricks with varying percentages of SFW (0%, 1%, 3%, 5%, and 9%) was evaluated through density, compressive strength, and water absorption tests. The key findings of this study are concluded as follows:

- Partial replacement of cement with SFW can produce lightweight bricks. Specifically, bricks with 5%, 7%, and 9% SFW substitution, at both 7 and 28 days, have densities ranging from 1600.00 kg/m^3 to 1807.14 kg/m^3. These densities fall within the lightweight brick standard, owing to the inherent lightweight properties of SFW.
- Substituting SFW for cement in the mixture significantly reduces compressive strength. For example, bricks with 9% SFW substitution at 7 days exhibit the lowest compressive strength, at 1.86 MPa. This reduction is attributed to the decreased amount of Portland cement in the mix.
- The increased porosity of SFW leads to higher water absorption. This is proved as bricks with 9% SFW substitution at 28 days exhibit the highest water absorption value of 19.53%. The rougher structure of SFW contributes to greater porosity in the bricks, resulting in increased water absorption.
- Overall, the tests indicate that the optimal percentage of SFW for composite cement bricks is 1%. This percentage indicates the optimum, with compressive strength ranging from 12.79 MPa to 16.16 MPa and water absorption rates between 9.54% and 11.72%. Although bricks with 1% SFW are classified as normal weight bricks (with densities between 2029 kg/m^3 and 2050 kg/m^3), they demonstrate superior performance compared to other SFW percentages.

Based on the conclusion, several recommendations could enhance the study. First, further research should investigate the use of SFW as a sand replacement in cement brick production. Additionally, extending the study to include other tests, such as Ultrasonic Pulse Velocity (UPV) and thermal tests, would improve understanding of SFW's effects on brick production. Finally, exploring new techniques to enhance SFW properties, such as removing loose particles and impurities, could also be beneficial.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *A. Suraya Hani, A. W. Norhayati, M. R. Siti Balqis;* ***data collection:*** *M. R. Siti Balqis, A. W. Norhayati;* ***analysis and interpretation of results:*** *A. Suraya Hani, A. W. Norhayati, MR Siti Balqis, O. Mohamad Hairi, W. A. Mohamad Nor Akasyah;* ***draft manuscript preparation:*** *A. Suraya Hani, A. W. Norhayati, M. R. Siti Balqis. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Aminudin, E., Khalid, N. H. A., Azman, N. A., Bakri, K., Din, M. F. M., Zakaria, R., & Zainuddin, N. A. (2017). Utilization of baggase waste-based materials as improvement for thermal insulation of cement brick. MATEC Web of Conferences, 103, 1-8. https://doi.org/10.1051/matecconf/201710301019

[2] Amin, N., Sabli, N., Izhar, S., & Yoshida, H. (2019). Sago wastes and its applications. Pertanika Journal of Science and Technology, 27(1), 1841-1862.

[3] Mahendran, K., Sivaram, T., Shahulhameed, M., & Logaraja, R., (2016). A comparative study on various building blocks as an alternative to conventional bricks. International Conference On Emerging Trends In Engineering and Management Research (ICETEMR-16), 1097-1109.

[4] Ornam, K., Kimsan, M., & Ngkoimani, L. O. (2017). Study on physical and mechanical properties with its environmental impact in Konawe-Indonesia upon utilization of sago husk as filler in modified structural fly ash-bricks. Procedia Computer Science, 111, 420-426. https://doi.org/10.1016/j.procs.2017.06.043

[5] Farazela, M. S., Arib, M. N., Azmi, M. M., Aniza, A. S., & Azhan, A. Z. (2021). Compressive strength performance of composite sand cement brick with power saw wood. Journal of Physics: Conference Series, 2051(1), 1-9. https://doi.org/10.1088/1742-6596%2F2051%2F1%2F012050

[6] Albano, C., Camacho, N., Hernandez, M., Matheus, A., & Gutierrez, A. (2009) Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios. Waste Management, 29, 2707–2716. https://doi.org/10.1016/j.wasman.2009.05.007

[7] Altwair, N. M., Johari, M. A. M., & Hashim, S. F. S. (2011). Strength activity index and microstructural characteristics of treated palm oil fuel ash. International Journal of Civil and Environmental Engineering, 11(5), 100-107.

[8] Muthusamy, K., Budiea, A. M. A., Mohsin, S. M. S., Zam, N. S. M., & Nadzri, N. E. A. (2021). Properties of fly ash cement brick containing palm oil clinker as fine aggregate replacement. Materials Today: Proceedings, 46, 1652-1656. https://doi.org/10.1016/j.matpr.2020.07.260

[9] BS 812: Part 2:1995 (1995). Methods of Determination of Density, Relative Density (Specific Gravity) and Absorption of Fine Aggregate. British Standard.

[10] BS EN 772-1. (2000). Methods of Test for Masonry Units. Part 1: Determination of Compressive Strength. British Standard

[11] BS EN 772-11 (2000). Method of Test for Masonry Units. Determination of Methods of Test for Masonry Units. Determination of Water Absorption of Aggregate Concrete, Manufactured Stone and Natural Stone Masonry Units due to Capillary Action and The Initial Rate of Water Absorption of Clay Masonry Units. British Standard

[12] Izaan, I. H., Hani, A. S., Norhayati, A. W., Hairi, O. M., Zalipah, J., Azlina, A. H., & Wimala, M. (2022). Preliminary study of sago fine waste as a sand replacement material for cement brick. IOP Conference Series: Earth and Environmental Science ,1022(1), 1-9. https://doi.org/10.1088/1755-1315%2F1022%2F1%2F012052

[13] BS EN 206-1 (2000). Concrete. Part 1: Specification, Performance, Production and Conformity. British Standard.

[14] Ali, N., Yusup, N. F. M., Khalid, F. S., Shahidan, S., & Abdullah, S. R. (2018). The effect of water cement ratio on cement brick containing high density polyethylene (HDPE) as sand replacement. MATEC Web of Conferences, 150, 1-5. https://doi.org/10.1051/MATECCONF%2F201815003010