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Strength and Water Absorption Properties of Cement Bricks Containing Sago Fine Waste

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ABSTRACT

The contamination created by the discharge of sago waste, a by-product of sago milling activities, must be addressed. Using sago waste, specifically sago fine waste (SFW), as a partial cement replacement can be environmentally responsible with a cost-effective choice. The effect of adding sago waste to cement brick characteristics was explored in this study. SFW was utilised to make five brick mixes with partial cement replacement percentages of 0%, 1%, 2%, 3%, 4%, and 5%. The mortar mix has a 1:3 ratio, consistent with Malaysian brick production regulations. All specimens had a water-cement ratio of 0.6 and had been cured for 7, 28, and 56 days for compressive strength tests and density, while water absorption tests were performed on the specimens at cured 28 days. As a result, SFW2 produces the greatest results compared to control bricks, where the compressive strength is 15.8MPa and density is 2157kg/m^3 . SFW generally decreased the strength of the brick. However, it was discovered that replacing a maximum of 5% SFW can be used for load-bearing internal wall class 1 because the strength is more than 7 MPa, according to MS 1933: Part 1: 2007. Therefore, This proves the potential of SFW as a new pozzolanic material that can produce more sustainable bricks.

Keywords: Cement brick; Partial cement replacement; Sago fine waste; Brick strength; Pozzolanic material

INTRODUCTION

The stems of the *rumbia* tree (Metroxylon sago) or a sago tree are used to make sago flour. The sago palm tree is native to Malaysia, Indonesia, Papua New Guinea, and other Southeast Asian countries. Sarawak is one of the many Malaysian states where sago is grown and marketed.

Sarawak has 51,518 hectares of sago agriculture, of which 45,393 hectares are in the Mukah district. Mukah district accounts for 88.1% of the total area under the sago plant area (Dayang Norhafizah, 2019). The land in Sarawak is mainly swampy, ideal for planting and cultivating Sago. As a result, Sarawak's sago business has thrived and is a significant source of export revenue (Karim et al. 2008). Today, Sarawak is one of the world's leading exporters of sago starch and ships about 40,000 tonnes to other countries each year, including Peninsular Malaysia (Amin et al. 2019).

In processing sago logs into sago starch, the water separates the sago starch from the fibre (Rasyid et al. 2020). Sago flour is made by sifting the logs of the sago tree with water and pressing them like coconut milk. The waste, known as *'pow'* or sago waste, is dumped into the river after extraction and is believed to be harmful to the environment. The extraction of sago starch is shown in Figure 1.

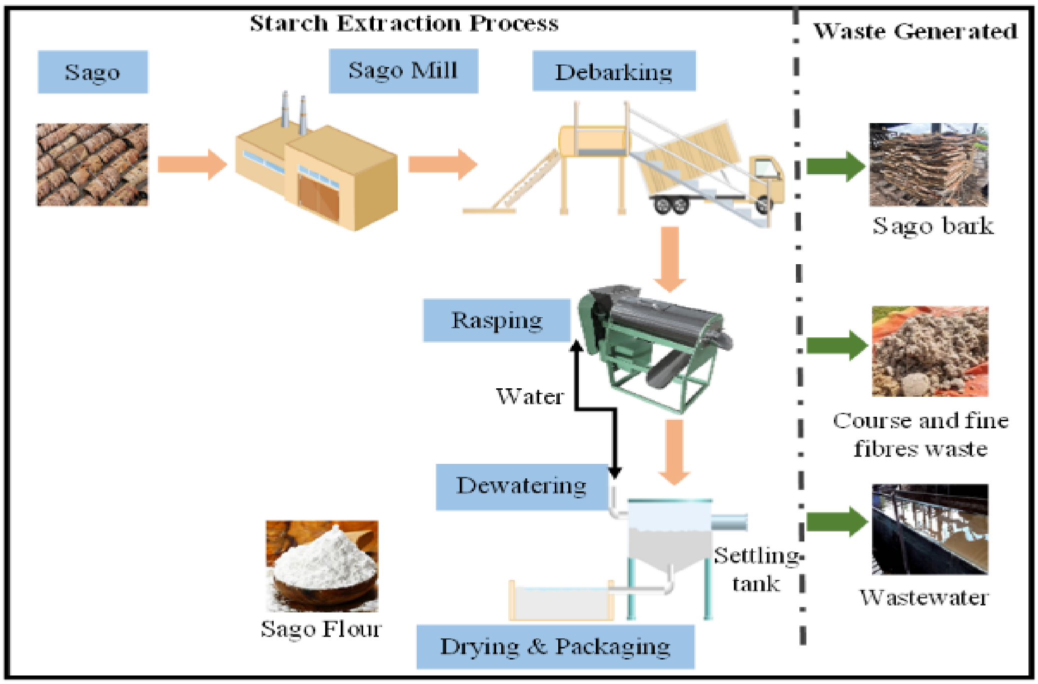


FIGURE 1. Schematic flow diagram of sago starch extraction (Norhayati et al. 2022)

After processing 8 to 12 logs on an industrial scale, 3 to 5 tons of waste may be generated daily (Rasyid et al. 2020). Every day in Sarawak, about 60 tonnes of sago waste is dumped, which causes many issues. Most of it is dumped into the river because people mistake it for fish food, which it is not (Azman Zakaria, 2020). Figure 2 shows the sago waste dumped into the nearest river by small sago processing industries.

High organic compounds, chemical oxygen demand (COD), and biochemical oxygen demand (BOD) are all indicators of sago waste associated with sago fibre, all of which violate the discharge requirements outlined in the Environmental Quality Act of 1974 (Bujang & Hassan 2013).

The high demand for biological oxygen (about 5820 mg/L) and chemical oxygen (about 10,220 mg/L) in wastewater has an impact on marine life and water quality by consuming dissolved oxygen in the water (Norpadzlihatun Manap, 2020). Furthermore, the action resulted in the river water becoming acidic due to the high sugar content and proliferation of bacteria in the sago waste. This causes the river to become sour, threatening the lives of animals and plants. Therefore, sago waste needs to be researched by academics to improve the population's living standards and protect the environment through green technology.

FIGURE 2. Sago waste dumped into a nearby river

Cement bricks are widely acknowledged as a primary building material. However, due to population expansion, demand for building materials has surged over the last decade, resulting in an ongoing shortage. Cement is a common flexible material frequently used in the building sector for various purposes. The construction sector's global development needs an increasing amount of Portland cement for long-term development (Ashok Kumar & Velayutham, 2019). Environmental pollution generated by cement manufacturing was a significant source of pollution to the environment. For example, making Portland cement is an energy-intensive operation that emits greenhouse gases into the atmosphere, affecting the Earth's ecology (Alex et al. 2016).

This can be accomplished by using appropriate, low-cost, readily available supplemental cementitious materials (SCM), which can be used as a partial replacement for cement without altering the concrete's properties. Many solid wastes, such as industrial by-products, natural pozzolanic materials, agricultural wastes, and so on, are classified as supplemental cementitious materials in nature (Aprianti et al. 2015).

The use of waste materials in today's construction is becoming increasingly popular among scholars and practitioners. As a result, numerous waste materials are used in construction bricks (Shakir et al. 2013). Sago waste is produced as a by-product when sago logs are washed, debarked, and rasped before being processed into pulp to obtain sago starch. Usually, sago waste is dumped into a river (Rasyid et al. 2020). According to the Malaysian Department of Statistics, the total production of sago was expected to be 201 241 tonnes in 2020 (Ministry of Plantation Industries and Commodities, 2021). Agricultural waste is frequently produced due to the development of the agricultural industry, and the increase in sago production is directly related to the rise in waste generation (Rasyid et al. 2020).

Previous research has shown that sago waste could be used as a material replacement in the industry in the future. For example, a study shows that lightweight concrete bricks made from sago waste are more cost-effective (M. Kusuma, 2015). In addition, the authors discovered that a 1:4.5:1.5 ratio with a composition of 75% sand and 25% sago pulp exceeded the minimum compressive strength requirements of SNI 03-0349-1989 (M. Kusuma 2015). Furthermore, in another study (Rahayu, 2016), the physical properties of a composite board made from sago dregs waste were found to meet the requirements of SNI 03-2105-2006. According to the study, the composite panel was made from 9%, 13%, and 17% sago dregs.

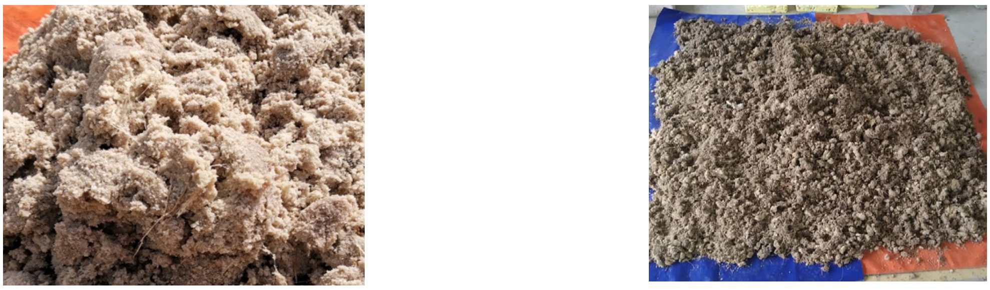
In another study (Ornam et al. 2017), sago waste was used, sago and fly ash were combined, and sago husks were used as fillers for fly ash bricks. The highest compressive strength was obtained by blending 1.3% sago husk, and the lowest was accepted by combining 3.3%. Nevertheless, all combinations met the requirements of ASTM C 67-14, ASTM D 2487-06, and SNI 15-2094-2000 (Ornam et al. 2017).

Therefore, this study used another pozzolanic material, sago fine waste (SFW), as a cement replacement in cement brick production. Therefore, this study focuses on producing cement brick containing SFW in different replacement percentages. The bricks' properties include density, compressive strength, and water absorption rate.

METHODOLOGY

MATERIAL PREPARATION

To produce sago fine waste (SFW), the waste was subjected to physical treatment, such as sun drying, grinding and sieving. Sago waste was collected from the factory River Link Sago Resources Sdn. Bhd. in Kampung Dalat, Mukah, Sarawak. As a result, the new sago waste was wet, greyish, and light brown and turned brown after drying, as shown in Figure 3.



(a) (b)

FIGURE 3. (a) Wet sago waste and (b) Dried sago waste

The moisture content of sago waste must be reduced before reusing these products. Drying is a well-known method of inhibiting bacterial and microbial growth in numerous industries, including food. In addition, this preserves product quality, including colour, texture, and residual polyphenol content (Rosli et al. 2018). The wet sago waste from the factory was first dried under sunlight for at least 18 hours and then ground into a fine powder using a grinding machine.

After grinding, SFW was sieved through a 300µm sieveto obtain the fineness complying with ASTM C618-17a. Next, the SFW was dried in an oven at 105°C for six hours before mixing to ensure all the moisture was gone as reported by past researchers (Lai et al. 2013).

In this research, cement from a single supplier has been used for binding purposes. According to MS EN 197 Part 1, the OPC types YTL cement utilised in this study is categorised as Type 1 cement.

Table 1 shows the chemical composition of SFW as obtained by the XRF analysis. The content of calcium oxide (CaO) and silicon dioxide (SiO_2) in SFW indicates that they can be replaced as it is similar the content found in cement (Suraya Hani et al. 2019). Figure 4 depicts an SEM image of SFW.

TABLE 1. Chemical composition of SFW

Chemical Composition	SFW
Silicon Dioxide (SiO_2)	63.8
Aluminium Oxide (Al_2O_3)	0.584
Ferric Oxide (Fe_2O_3)	0.866
Calcium Oxide (CaO)	23.5
Potassium Oxide (K_2O)	1.68
Magnesium Oxide (MgO)	2.23
Sulphur Trioxide (SO_3)	0.992

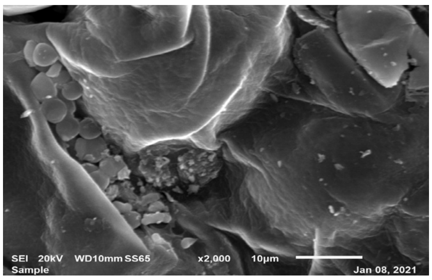


FIGURE 4. SEM image of SFW

SAMPLE PREPARATION

The sample size for density, compressive strength, and water absorption testing is based on the typical brick size of 215mm x 102.5mm x 65mm. This measurement complies with the BS 4729-1990 brick standard. Figure 5 depicts the mould used to make the brick of the specified size. Various cement mortar mixes with varying SFW percentages were prepared to manufacture bricks. The mortar mix design, based on a 1:3 mixing ratio, conforms with Malaysian brick production standards. A control sample without SFW replacement was cast to compare with the other samples with SFW replacement.

Six different types of cement brick samples were prepared for this study. The percentages of SFW are 0%, 1%, 2%, 3%, 4%, and 5%, respectively. For All mix proportions, three samples were produced by volume. For this study, the water-cement ratio is 0.6, and the sand-cement ratio of brick manufacture is 1:3. Table 2 shows the bricks' mixing proportions.

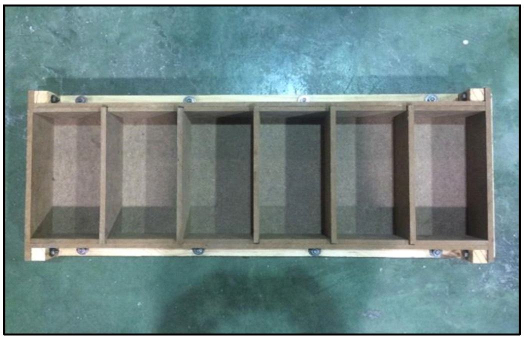


FIGURE 5. Brick mould

TABLE 2. Mix proportions for 1 brick

Samples	Cement		SFW	
	%	kg	%	kg
SFW0	100	0.521	0	0.000
SFW1	99	0.515	1	0.006
SFW2	98	0.510	2	0.011
SFW3	97	0.505	3	0.016
SFW4	96	0.500	4	0.021
SFW5	95	0.495	5	0.026

TESTING METHOD

This section focuses on the physical behaviours of SFW-containing bricks and control specimens. The brick samples' density test followed BS EN 12390-7, and the brick mass was measured in the as-received state. The density was measured at 7, 28 and 56 days of age.

The compressive strength test in this investigation was carried out following ASTM C140-11a. The sample's compressive strength is the maximum stress it can withstand when crushed. Before they fall, the sand cement bricks are tested to check their sturdy. The compressive strength of a brick is found by dividing its entire load by its original cross-sectional area. This compressive strength test was performed at GEOLAB (M) Sdn. Bhd., located on Jalan Perling in Johor Baharu, with the equipment illustrated in Figure 6.

FIGURE 6. Universal Testing Machine

Three brick samples were created for each mixing ratio for this test, and all examined samples were full-sized. Before conducting the test, excess moisture or particles must be removed from the brick surface and the machine's loading plate. Therefore, until the day of testing, all brick samples were air-cured in the laboratory. Samples were also analysed for this test at 7, 28 and 56 days of age.

The proportion of water absorption by the brick was determined using a water absorption test. The test was carried out following BS 1881: Part 122. The brick samples were dried for 24 hours in an oven set at 100°C + 5°C. After cooling for 24 hours, the samples were reintroduced into the water tank. The weight of the samples was measured before and after immersion in the tank to calculate the percentage of water absorption at 28 days.

RESULTS AND DISCUSSION

As previously stated, the density and compressive strength tests were performed at 7, 28 and 56 days of age, respectively, whereas the water absorption test was performed at 28 days. This is because all brick kinds use a constant water-cement ratio of 0.6. The following subsections go over the study's findings.

BRICK DENSITY

The density of 54 samples was measured, as shown in Figure 7. The graph shows that as the proportion of replacement grew, the density of the brick samples decreased. After 56 days, the density of the control brick SFW0 is 2327 kg/m^3. As the SFW percentage increased, the brick specimens' density reduced by 3.3 to 16.1% for every 1% rise in SFW. The brick density for SFW5 with 5% SFW replacement (maximum replacement) is 2035 kg/m^3, 14.3% less than a control brick. This indicates how agricultural waste materials, such as SFW, can be utilised to reduce brick density. It is consistent with previous studies that have employed agricultural waste as a brick construction material (Kamarulzaman et al. 2018) (Loong et al. 2020) (Ahmada et al. 2021)

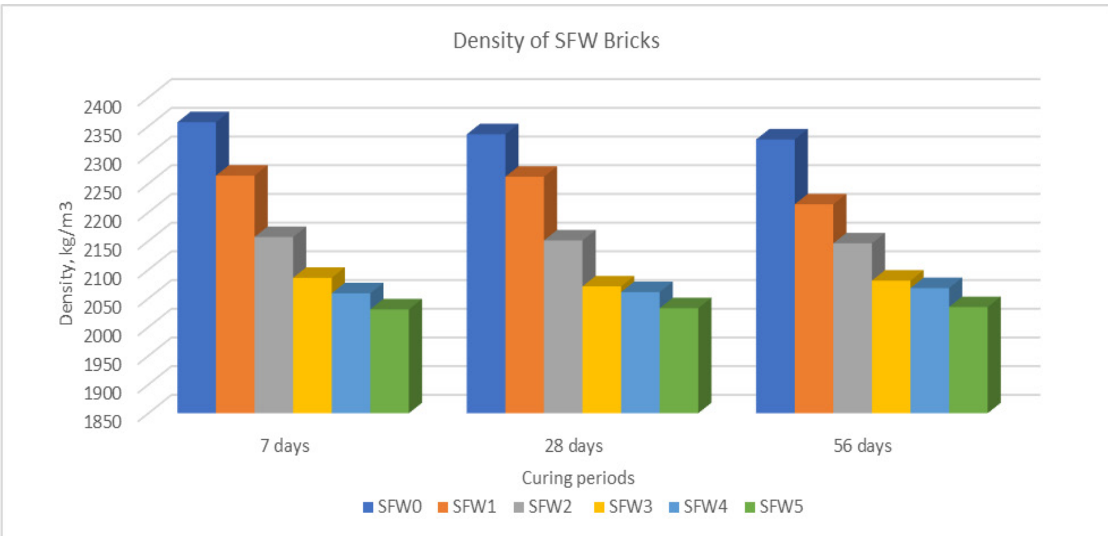


FIGURE 7. The density of bricks sample for 7, 28 and 56 days of curing

COMPRESSIVE STRENGTH

The strength of 54 different types of bricks with a curing period of 7, 28 and 56 days is shown in Fig. 8. According to the graph, the overall strength of the brick diminishes as the ratio of replacement materials increases. However, it is also observed that the strength of the brick strengths fluctuates. This is because the percentage of replacement materials affects the irregular increase and decrease in strength.

Figure 9 shows that the strength of the control brick, SFW0, is 15.3 MPa, 25.3 MPa and 27.5 MPa, respectively. It was observed that the strength of the brick decreases continuously as the percentage of SFW increases for all days of the curing period. For example, the strength of SFW5 is 11.6 MPa for 7 days of curing. The reduction in strength is about 31.6% compared to the control brick. Natural waste resources such as coconut fibre (Rangkuti & Siregar, 2020) and rice husk ash (Ali et al. 2015) were used to achieve a comparable result. However, bricks with 1% and 2 % SFW, after 7 days of curing, has a strength of 15.6 MPa and 15.8 MPa, respectively, which has a high strength compared to the control brick.

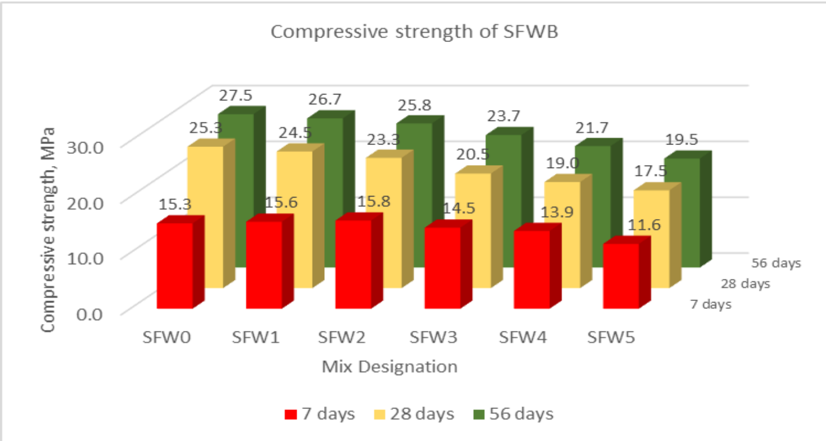


FIGURE 8. Compressive strength graph for 7, 28 and 56 days

WATER ABSORPTION

Figure 9 shows how using SFW as a partial cement replacement affects the amount of water the brick absorbs. The internal structure of the brick is altered when part of the cement is replaced with SFW, which leads to greater water absorption by the brick. Compared to the control bricks, the water absorption increased to 37%. In addition, the gaps in the SFW particles result in the brick absorbing more water than a brick made with 100% cement. It is because the existing microstructure pore in SFW is larger. Lu et al. 2020 describe the absorption and liquid transfer rate to porous materials and permeability. As a result, high-permeability materials will have a high rate of absorption.

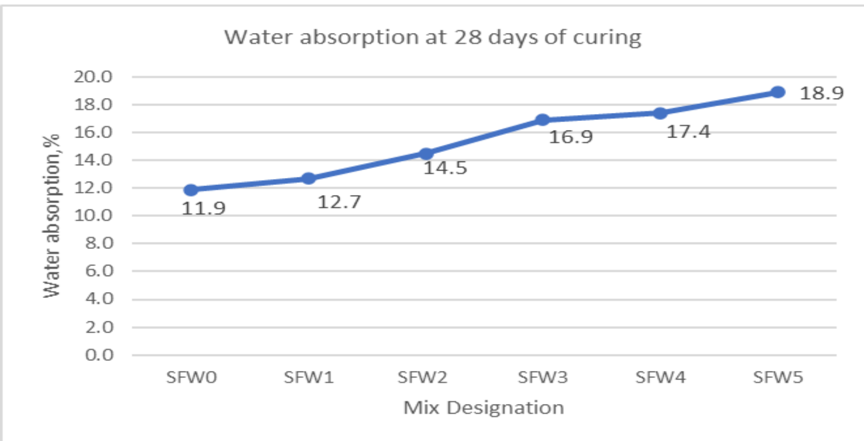


FIGURE 9. Percentage of water absorption ratios at 28 days of brick

CONCLUSION

The replacement of SFW in the brick affects the density of the brick. The density of the brick decreases as the percentage of replacement materials increases. In this investigation, the biggest material replacement was 5% SFW, which reduced the density of the brick by 14.3 to 16.1% compared to the control brick. The presence of SFW in the brick significantly affects the brick's mechanical properties, mainly compressive strength. According to the findings, the replacement of SFW generally decreased the strength of the brick. However, it was discovered that replacing a maximum of 5% SFW can be used for load-bearing internal wall class 1 because the strength is more than 7 MPa, according to MS 1933: Part 1: 2007. This has proved the potential of SFW as a pozzolanic material to improve the strength of bricks. A substance with a lower density has a lower strength in general.

In terms of water absorption properties, the data demonstrate that as the amount of SFW increases, so does the water absorption. This is owing to the coarser structure of SFW, which contributes to the production of high porosity in the brick. In conclusion, the optimum percentage of SFW in making cement brick is 2%. Therefore, SFW2 produces the greatest results compared to control bricks.

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DECLARATION OF COMPETING INTEREST

None

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