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A Study on Performance of Sago Fine Waste (SFW) as Cement Replacement for Cement Brick

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Abstract: One of the new concepts for the production of bricks is the reuse and recycling of construction and demolition waste. Due to the lack of natural aggregates, it is difficult for manufacturers in emerging regions to find suitable bricks. Recycled construction waste can replace natural resources or other competitive raw materials. The purpose of this research is to determine the sustainable properties of cement brick using Sago Fine Waste (SFW) as a cement replacement to reduce chemical emissions from cement. It also aims to use system reuse, reduce and recycle organic material, and prevent SFW from being improperly treated. The objective of this study is to determine the density, sound absorption test and initial absorption rate (IRA) of sago fine waste (SFW) for cement bricks, as well as to determine the best optimum percentage of sago fine waste (SFW) as cement replacement material for cement bricks. For this study, cement brick samples were prepared with a control, 2%, 4%, 6%, 8%, and 10% SFW with water cement ratios of 0.5 and 0.6. The size of the SFW was less than 0.6 mm. The brick was cast in a mould with a length of 215 mm, a width of 103 mm and a depth of 65 mm, while a size of 28 mm diameter was used for the cylindrical mould. In the first phase of the study, tests on density, sound absorption and initial absorption rate (IRA) were carried out in the Laboratory, UTHM Pagoh. The optimum percentage of SFW was determined based on the density test, sound absorption and initial absorption rate (IRA). The results of the density test show that the best lightweight brick and the optimum percentage is SFW10% with a water-cement ratio of 0.5. Besides, for the sound absorption test, the best optimum percentage is SFW10% with water-cement ratio of 0.5, which can absorb sound efficiently, while the best optimum percentage for initial absorption rate (IRA) is SFW2% with water-cement ratio of 0.5, which absorbs less water in one minute. It can be concluded that all sample bricks were satisfactory and met the standard values.

Keywords: Cement brick, SFW, Water Cement Ratio, Test

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1. Introduction

Companies are focusing on using waste material as a new construction material to pursue an excellent approach to sustainability issues in the construction industry. Therefore, there should be a proper system to manage construction waste, and one option is to reduce, reuse, and recycle construction waste. Cement bricks are an essential material commonly used in low and medium-cost housing development and commercial for the construction industry. Large quantities of cement are required to produce large amounts of cement bricks, but this approach has environmental consequences due to increased carbon emissions. The alternative to reduce cement in cement brick is used Sago Fine Waste (SFW). This material was chosen for use in cement brick because sago has inherent strength and can potentially replace half of the cement to reduce chemicals.

This research aims to promote sustainable materials in the production of bricks using waste materials as a partial cement replacement for the Malaysian construction industry. The following objectives are outlined to achieve the goals. First, is to determine density, sound absorption test and initial rate of absorption (IRA) test by Sago Fine Waste (SFW) for cement brick and secondly is, to obtain the best optimum percentage of Sago Fine Waste (SFW) as a cement replacement material for cement brick.

2. Literature Review

Density is the measure of the weight per unit volume of solid or liquid samples. According to result density of samples (Hadi Izaan et al., 2022), generally density the samples decreased as the replacement materials increased [11]. Besides, according to (Ngaini, 2014) the higher of density than the brick can be sink when placed in water [13]. According to the standard ASTM C90 (2012), the most lightweight brick is the density must less than 1680 kg/m^3 while for medium weight is between 1,680 kg/m^3 to 2,000 kg/m^3 then for normal weight is density must 2,000 kg/m^3 or more [5].

Initial rate of absorption (IRA) is the amount of water that goes through the brick's bed face in one minute. It is a measure of how well the brick sticks together and can be used to make mortars that stick well to units. The ability of the brick to soak up water and the ability of the mortar to hold on to the water needed for the cement to hydrate will have a big impact on how well the brick and mortar stick together. If the brick pulls the water out of the mortar too quickly, the next course might not be set up right. If the mortar holds on to too much water, the bricks tend to float on the mortar bed, which makes it hard to build straight walls at a reasonable pace. In both cases, the bond will be bad. The best value for IRA should be less than 2 kg/m2.min [2].

In the sound absorption test, it is the number of pressure variations per second called the frequency of the sound and measured in Hertz (Hz). Sound absorption test is used impedance tube to testing. It has two microphones transfer function to obtained sound absorption coefficient. The value of absorption coefficient, α is given from 0 to 1. Which means sound absorption is none in value 0 and the maximum value is 1. This can be confirmed as the brick with 1 coefficient value can absorb sound 100% effectively [9].

3. Materials and Methods

The raw materials and waste materials that have been used for the production of cement brick are sand, Ordinary Portland Cement (OPC), water and Sago Fine Waste (SFW). The methods on this study are divided with testing material and laboratory testing.

3.1 Materials

In this study, raw materials that have been used for the production of cement brick are sand, Ordinary Portland Cement (OPC), water and Sago Fine Waste (SFW).

3.1.1 Sand

A fine aggregate, natural white sand, is used. The maximum sand size used in the production of cement bricks is 5 mm. The particles size that been used is 2.36 mm. The sand is stored dry in the designated storage room in concrete laboratory UTHM.

3.1.2 Ordinary Portland Cement (OPC)

Cement is used as a binder for the production of cement bricks. The cement used in this study is Ordinary Portland Cement (OPC), which is mainly composed of lime, silica, alumina, and iron oxide. The OPC used in this study shall comply with Malaysian Standard [12]. To prevent the cement from being exposed to moisture and hardening before use, it was stored in an airtight steel drum in the laboratory.

3.1.3 Water

Water is an essential factor that improves cement's function as a sand and other materials binder. The water used in this study is treated and supplied by Syarikat Air Johor in Malaysia.

3.1.4 Sago Fine Waste (SFW)

Sago Fine Waste (SFW) is a waste material in this study. The sago waste is collected from Factory River Link Sago Resources Sdn Bhd in Kampung Dalat, Mukah, Sarawak. The raw sago waste from the factory was first dried in the sun for at least 18 hours before being ground into a fine powder using a grinder machine. The particle size that been used for testing is 600 micrometers.

3.2 Methods

3.2.1 Material Testing

Material testing is carried out to determine the best sand, cement and Sago Fine Waste (SFW) material in density (ρ)

- Sieve analysis

This testing is a process that determines the percentage of particles of different sizes in the aggregates. As a rule, the grain size of fine aggregate must be within the limits specified in BS 882 (1983) and must be less than 5 mm [7]. Fine aggregate for testing is sand that use 1000g weight while SFW is 500g. The cumulative percentage of material that has passed through each sieve is reported in numerical and graphical form.

- Specific gravity test

The mass of one unit of a material's volume to the mass of the same volume of water at a given temperature. It is possible to determine the specific gravity of fine aggregate by following the guidelines of standard ASTM C128 (2018) using Equation 3.1 [4]. This testing is used 2000g for sand and 2000g for SFW by used pycnometer tool.

$$\text{Bulk Specific Gravity} = A/(B+500-C) \qquad \text{Eq 3.1}$$

Where;
A = mass of oven-dry specimen in air, g
B = mass of pycnometer filled with water, g
C = mass of pycnometer with specimen and water to calibration mark, g

• Bulk density test

According to BS 812: Part 2:1995, we will determine the fine aggregate's bulk density and the void content [9]. The bulk density of a unit weight can be expressed as the weight per volume of that unit (mass per volume or density). This test must be calculated based on Equation 3.2.

$$\text{Bulk density} = \frac{\text{weight cylinder+fine aggregate}-\text{empty weight cylinder (kg)}}{\text{volume of cylinder } (\text{m}^3)} \quad \text{Eq 3.2}$$

3.2.2 Laboratory testing

• Density test

The density of the brick samples was measured by dividing the weight by the volume of the bricks. A total of 72 samples aged 7 and 28 days were tested. First, the sample was dried in curing period at room temperature and its weight was measured. As stated in ASTM C90 (2012), the lightweight brick density should less than 1680 kg/m^3[5].

$$\text{Brick density} \left(\frac{\text{kg}}{\text{m}^3}\right) \frac{\text{Weight of sample (kg)}}{\text{Volume of brick } (\text{m}^3)} \quad \text{Eq 3.3}$$

• Initial rate of absorption (IRA)

According to the ASTM C67-14 (2017), the samples were heated in an oven to approximately 105°C and 5° for 24 hours [3]. Then the samples were allowed to cool to ambient temperature. Soaking the entire surface brick in contact with water in (1 ± 0.2) minutes. Once the time is up, the samples are removed from the water and the bricks are weighed. The excellent initial water absorption is between 0.25 kg/m^2.min and 2.00 kg/m^2.min. The samples for this testing are 72 pcs with different percentages SFW and water cement ratio.

$$IRA\ (kg/m^2.min)\ \frac{Mass_f - Mass_i}{A.t} \quad \text{Eq 3.4}$$

• Sound absorption test

This type of testing involves the use of an impedance tube, in addition to two places for microphones (red and black color) and digital frequency analysis. According to ASTM E1050-19 (2019), sound absorption is to determines the surface acoustic impedance and surface admittance of sound [6]. This testing uses 24 samples with different percentage SFW and water cement ratio. After curing in 28 days, the samples must be test using AED 1001 software to identify the sound absorption coefficient, α and frequency (Hz).

4. Results and Discussion

This chapter presents the results of the experiments conducted based on the methods and procedures described in Chapter 3. The data obtained during the experiments were analyzed and interpreted. All the data collected are presented in tables, diagrams, or photographs to ensure a better understanding of the results obtained.

4.1 Material Testing

Material testing is aims to determine the density of each material. The test is divided into sieve analysis test, specific gravity test and bulk density test.

• Sieve analysis

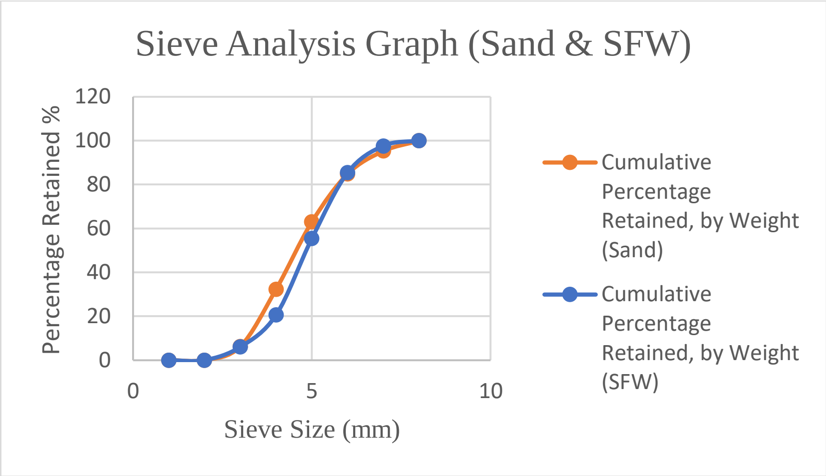

Figure 4.3: Graph sieve analysis of SFW and Sand

The cumulative weight percentage for SFW and sand increased slightly in the graph. Since 3.2 is the upper limit for the fineness modulus of sand, this will also be the upper limit for SFW. In Figure 4.3, we see that the fineness modulus is 2.65, indicating that this material has the potential to be a fine aggregate. If the value is above 3.2, it is not a fine aggregate.

• Specific gravity test

Table 3.1 Specific Gravity value

Materials	Specific Gravity	Previous study value	Previous study researcher
Sand	2.683	2.66	Albano et al., (2009)
SFW	0.75	0.45	Hadi Izaan et al., (2022)

The specific gravity of sand was determined using the accepted test technique for relative density (specific gravity) and absorption of fine aggregates [4]. According Table 4.1, sand has a specific gravity of 2.68, while SFW has a specific gravity of 0.75. This is possibly because sand has a greater capacity to absorb water, which results in more porosity in the brick than SFW. In a prior study, Albano et al. (2009) determined the specific gravity to be 2.66 while Hadi Izaan et al., (2022) determined it to be 0.45. It is comparable to the specific gravity value that is obtained and can be used to calculate brick mix density [1] [11].

• Bulk density test

Bulk Density is dependent on the aggregate's packing density. It also depends on the particle's size, dispersion, and shape. If particles are the same size, they can only be packed to a certain extent; however, when smaller particles are added, the voids are filled with them, resulting in a rise in bulk density. Sand has a bulk density of 2237kg/m^3, SFW is 1270kg/m^3 and cement is 1838kg/m^3 respectively.

4.2 Laboratory Testing

All tests for samples must be tested in the laboratory, in the Concrete Laboratory and in the Building Services Laboratory

• Density test

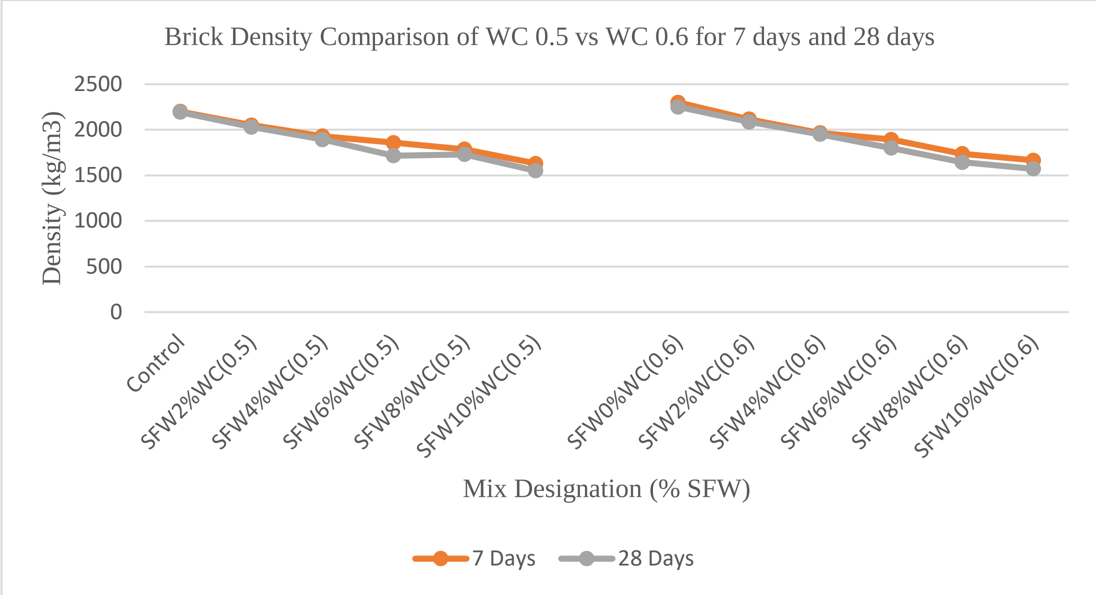

Figure 1: Brick Density Comparison of WC 0.5 vs WC 0.6 for 7 days and 28 days

The overall results of the study helped determine the optimum percentage of sago fine waste (SFW) for cement bricks. According to the Figure 1, the density results for optimum percentage of SFW is 10% with water cement 0.5. This is because, according to the ASTM C90-12 (2012) standard, the lightest brick must be less than 1680 kg/m^3, and the result obtained from this test for both water-cement ratios is less than 1680 kg/m^3 [5]. In addition, according to previous research, a too-high water-cement ratio can reduce the compressive strength of the manufactured brick [2]. When the percentage of SFW increases, the density test results in an increase in brick production, resulting in lightweight brick. Furthermore, the compressive strength of the brick increases as the water-cement ratio decreases [2]. At the same time, the increasing curing process affected the density of the brick. As a result, the longer the curing period, the lighter the density.

- Initial rate of absorption (IRA) test

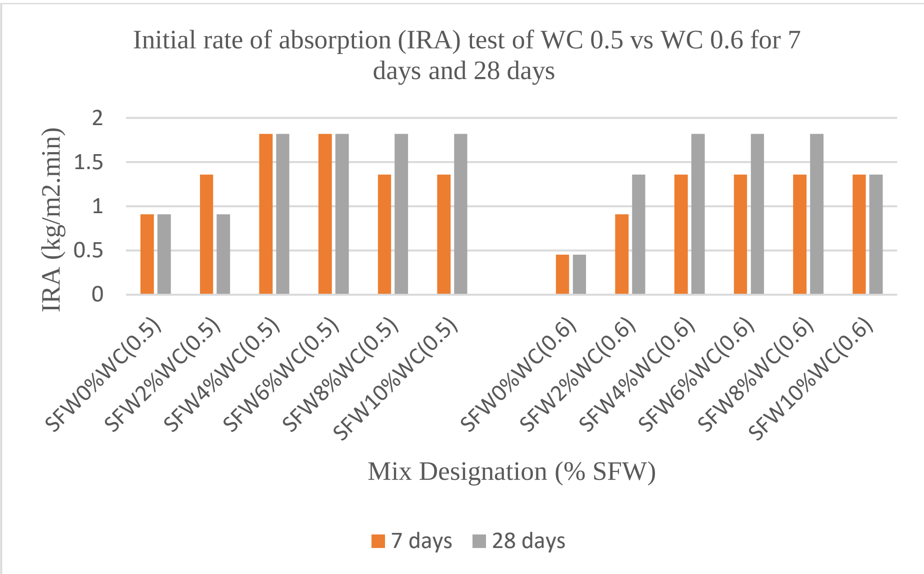

Figure 2: Initial rate of absorption (IRA) test of WC 0.5 vs WC 0.6 for 7 days and 28 days

Based on the Figure 2, the optimum percentage of SFW for both water-cement ratios, which are 0.5 and 0.6, and the best curing time are determined based on the result of the initial absorption rate. As a result, the best IRA value is obtained at a curing time of 28 days and a water-cement ratio of 0.5, with the control and SFW 2% showing much lower water absorption in one minute for the IRA test. According to previous studies by Ali et al. (2017), the best initial absorption rate ranges from 0.25 kg/m^2.min to 2.00 kg/m^2.min [2]. Consequently, all initial absorption rates obtained from the results are below 2.00 kg/m^2.min. In comparison, the absorption is lower at a water-cement ratio of 0.5; even if it was baked for 24 hours before testing, the void content is not higher than a water-cement ratio of 0.6. In addition, it can be concluded that the use of a water-cement ratio in the manufacture of bricks has an impact on increasing the percentage of water absorption in the SFW brick. This is because water is the agent for chemical reactions in cement to bind all raw materials when mixing a brick [2]. If it meets the standards BS EN 771 and ASTM C67-14, this brick is suitable for use in the industrial sector [3][8].

- Sound absorption test

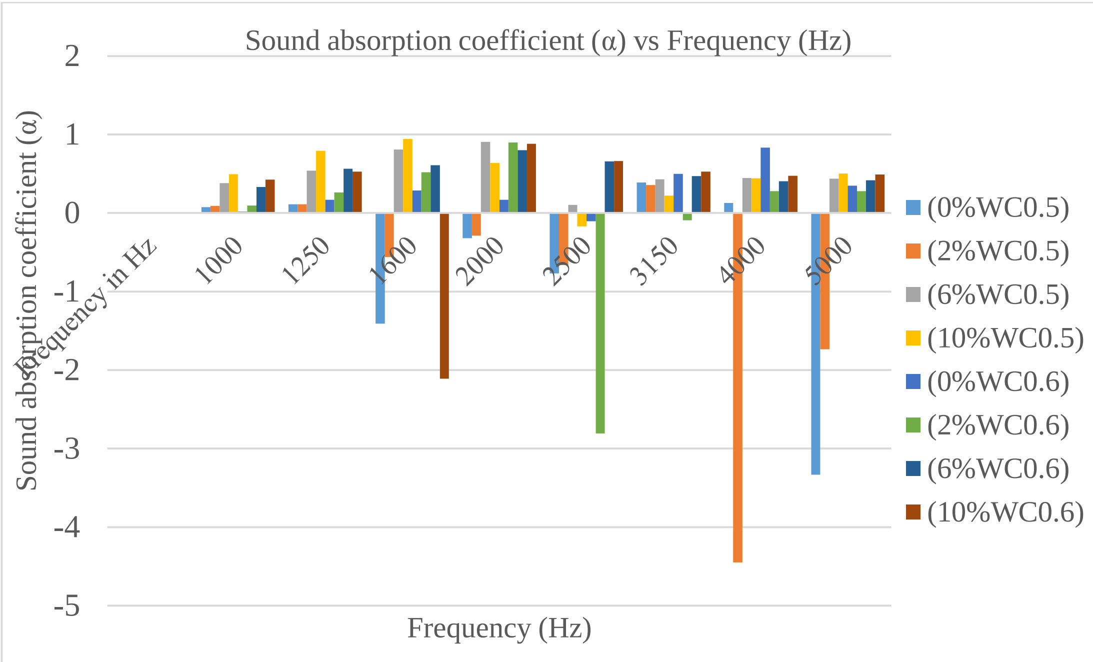

Figure 3: Graph sound absorption coefficient (α) vs frequency (Hz) for WC 0.5 and WC 0.6

A high sound absorption coefficient indicates that most of the sound waves were absorbed and only a small portion was reflected or transmitted by the surfaces. The best absorption value was near the 1 value. According to the Figure 3, the lowest sound absorption coefficient value for 28-day curing is 0.02 in control water cement 0.6 with 1000 Hz, while the highest sound absorption coefficient value is 0.94 in SFW10% in water cement 0.5 with 1600 Hz, indicating that the soundest waves were absorbed and that the best optimum sound absorption coefficient was obtained. Moreover, according to Fauzi M.F. (2018), the best coefficient value for sound absorption that needs to be achieved from the tests is 1 [10]. This can be confirmed, as the brick with a 1 coefficient value can absorb sound 100% effectively. The results show that curing after 28 days gives a different sound absorption value.

Based on the result, the best optimum value for both water cement ratios are SFW 10% in water cement ratio 0.5 because it is closest to 1 and can be absorbed effectively. The optimal level of sound absorption is represented by a value of 1. Sago fine waste (SFW) of 10% WC0.6 can effectively absorb sound as the value is close to 1, while the other sample is the closest to the best optimum value of sound absorption but a little away from value 1. This sample shows the best performance at an optimum frequency of 1600 hertz (Hz). In conclusion, all samples are closest to the value 1. However, this does not mean that this SFW material is not capable of absorbing sound; it just needs some improvement in the future so that it can absorb sound better. This brick can be used in industry as long as it complies with the standard.

5. Conclusion

In this study, replacement of cement with SFW (2%, 4%, 6%, 8% and 10%) in cement brick production has been observed.

In laboratory test for density, SFW might be a potential material to produce lightweight brick. Besides, for initial rate of absorption (IRA) shows all initial absorption rates are below 2.00 kg/m^2.min. The decrease absorption water in one minute for cement brick, the more potential of cement brick low of porosity affected by void and it can be more strength. Then, for sound absorption test is highly affected by the existence of SFW in brick. From the data obtained, increasing percentage of SFW, increase the ability of sound absorb coefficient of cement brick. It can be seen that all samples are very close to 1, as the best sound absorption value was 1.0. This can be confirmed as the brick with 1 coefficient value can absorb sound 100% effectively. The optimum percentage for testing density and sound absorption is SFW10% with water cement 0.5 while for testing IRA, the optimum percentage is SFW2% with water cement 0.5. All of the objective are achieved with precise data and result.

There are some recommendations has been suggested for further research to significances the findings for a better refinement. The recommendation is the SFW can be try a new technique to improve the properties and quality of cement brick. Extend the study with another test such as thermal. Besides, other recommendation in this study, it only addresses the density, initial rate absorption (IRA) and sound absorption associated with Sago Fine Waste (SFW). Further investigation should be conducted on the mechanical and chemical properties of the brick containing SFW.

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