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The Study on Sugarcane Bagasse Fibres as Partial Aggregate Replacement in Lightweight Concrete Brick

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Abstract: Bricks have been playing a significant role in building and construction for thousands of years. Nowadays, conventional bricks are produced from clay by using a high temperature of kiln firing and at the same time it releases large quantity of greenhouse gases. The excessive used of aggregates in brick mixture could make it rapidly diminished and effecting our construction industry in the future and besides, the waste management of agriculture or natural fiber such as sugarcane bagasse fiber are poorly handled. In this study, research was conducted on the performance of sugarcane bagasse fiber as partial aggregate replacement in lightweight concrete brick. The objectives of this research were to identifying optimum percentage for partial aggregate replacement using sugarcane bagasse fiber, to compare the strength of sugarcane bagasse fiber bricks with standard concrete brick and to observe the acceptance of sugarcane bagasse fiber as replacement material in concrete brick among the brick manufacturer. Qualitative method such as interview session was also applied in order to achieve the third objective of this research. There were two respondents involved which is one was from the brick manufacturer and the other one was a researcher in Johor area. There were four brick specimens casted for several proportions of 0%, 0.5%, 1% and 1.5% sugarcane bagasse fiber as partial aggregate replacement. Then, the compressive strength was conducted to determine the strength of the brick specimens. The finding shows that 0.5% of sugarcane bagasse fiber was the highest percentage of optimum strength with 2.5MPa than the others. From the qualitative analysis, both respondents agreed that this research required a lot more of improvement in order to increase the strength of the sugarcane bagasse fiber brick. This study would reduce the amount of sugarcane bagasse fiber disposed on the land

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for dumping purpose and could act as alternative material to lightweight concrete brick that have high standard and quality that can be proposed to the stakeholders.

Keywords: Aggregate Replacement, Construction, Lightweight Brick, Sugarcane Bagasse Fiber

1. Introduction

Brick is one of the important materials in the construction of which is widely used and highly demand in the construction of a structure in the civil engineering sector (Shahidan *et al*., 2018). The brick was anciently produced by mixing the virgin resources, forming the bricks, drying them and then firing them (Allen *et al*., 2011). The construction sector is a major contributor to environmental pollution, mainly in the emission of greenhouse effect gases (Salas, 2009), which is why it is important to look for new materials that reuse by-products or introduce renewable materials. The rational use of agriculture fibers can be an alternative solution for the production of durable, more sustainable goods and green construction materials (Savastano *et al*., 2009). In comparison with the synthetic fibers that are commonly used, agriculture fibers such as sugarcane bagasse fiber and banana leave fibers are recyclable, low cost, low density and biodegradable, although their use is limited due to their relatively low mechanical properties compared to synthetic fibers (Rosamaria, 20013). The mechanical properties of the sugarcane bagasse fiber have shown their potential to be used in building materials with suitable properties (Sain, 2015).

Sugarcane bagasse is the fiber that remains after the sugars have been extracted. Approximately 250 kg to 280 kg of bagasse is generated from processing each ton of sugarcane which roughly yielded 54 million tons of bagasse annually (Canilha *et al*., 2012). Traditionally, bagasse has been used as a fuel for boilers in sugar factories and in smaller quantities for paper and board production (Huang *et al*., 2012). However, it was later shown that this bagasse is not used and typically is just placed in landfills decreasing the waste site life (Zapata, 2019).

1.1 Research Background

The concept of using natural fibres is not new in the construction industry, as the utilisation of fibres in materials and construction can be traced back too many centuries ago (Chukwuma *et al.*, 2013). Requirement for economical and environment-friendly materials has extended an interest in natural fibers (Ghazali, 2008). The application of natural fibres has been widely used in cement bricks as construction materials for many years in developing countries due to the availability and low cost of fibres (Aziz, 2016). A wide variety of waste materials have been studied, including fly ash, mine tailings, slags, construction and demolition (C&D) waste, wood sawdust, cotton waste, limestone powder, paper production residue, petroleum, effluent treatment plant sludge, kraft pulp production residue, cigarette butts, waste tea, rice husk ash, crumb rubber, and cement kiln dust (Zhang, 2013).

1.2 Problem Statements

Manufacturing of commercial brick produce a lot of air pollution (Kumar *et al*., 2014). The high temperature kiln firing not only consumes significant amount of energy, but releases large quantity of greenhouse gases (Pawade, 2014). Worldwide, production of Ordinary Portland Cement (OPC) is responsible for about 7% of all carbon dioxide generated as production of 1 kg of Ordinary Portland Cement consumes approximately 1.5 kWh of energy and releases about 1 kg of carbon dioxide to the atmosphere (Zhang, 2013). Thus, according to Patel and Shah (2018), high usage of OPC is responsible for air pollution as it increases the emission of carbon dioxide in the atmosphere.

On the other hand, there are some issues regarding the waste management of sugarcane bagasse fibre. According to Ozturk *et al*. (2017), Malaysia produce annually approximately 168 million tons of biomass, including timber, oil palm waste, rice husk, coconut trunks fibres, municipal and sugarcane waste. In general, 1 ton of sugarcane bagasse generates 280kg of bagasse, the fibrous by-product remaining after sugar extraction from sugarcane (Sun, 2004). This could increase concern that some of sugarcane bagasse fibre waste from time to time cause harmed to the environment. The high rate of population growth has resulted in rapid increase in solid waste generation which is usually dumped in landfills or burned in sugarcane mill (Suddell, 2003).

As an alternative, the fibres can be used as partially replaced the non-renewable aggregate in the lightweight brick. The moisture content during the mixing stage state is a major concern for lightweight aggregate concrete (Dinakar and Manu, 2017). Porous lightweight aggregates have become highly sensitive as the water cement ratio is varies and this is the difficulty during the production of lightweight aggregate concrete in practical situations. In this study, by using the sugarcane bagasse fiber in the lightweight brick as partial aggregate replacement could act as an alternative for these problems.

1.3 Research Questions

The research questions in this study are as follows:

(i) What is the optimum percentage of sugarcane bagasse fibres as partial aggregate replacement in making lightweight concrete brick?
(ii) Is there a difference in strength between sugarcane bagasse fibres concrete brick and ordinary concrete brick?
(iii) What is the brick manufactures feedback about the performance of sugarcane bagasse fibres in lightweight brick?

1.4 Research Objectives

The objectives of this study are as follows:

(i) To identify the optimum percentage of sugarcane bagasse fibres as aggregate partial replacement in making lightweight concrete brick.
(ii) To compare the strength of sugarcane bagasse fibres lightweight concrete brick with the standard concrete brick.
(iii) To observe the acceptance of sugarcane bagasse fiber as replacement material in concrete brick among brick manufacturer.

1.5 Significance of the Study

The significant of the study are:

(i) Sugarcane bagasse fiber brick was an alternative material to lightweight brick that have high standards and quality that can be proposed to the stakeholder such as contractor, JKR, CIDB.
(ii) This research was an input of knowledge for the waste material management and strength of brick.
(iii) The reduction of waste and saved the renewable natural resources by producing the sugarcane bagasse fiber brick is going to give a cleaned environment to the community.
(iv) The increased of waste landfills in Malaysia was reduced as there are a better solution for the waste management of sugarcane bagasse fiber.

1.6 Scope of the Study

The scope of the research involving the testing in the laboratories, there were some scope of the research:

(i) This study only focuses on the use of Sugarcane Bagasse Fiber only.
(ii) The test involved in this study are compression strength test and flow table test, water absorption test and density test.
(iii) The specimen will be used in this study is brick specimen.
(iv) This study only focuses on the use of sugarcane bagasse fiber as partial replacement of aggregate only.
(v) This study will conduct an interview with IBS manufacturer.
(vi) The standard will be used in this study are ASTM C1437-15 Standard Test Method for Flow of Hydraulic Cement Mortar, BS 1881: Part 116: 1983 for compression strength test, MS 7.6:1972 for general brick specification.

2. Literature Review

2.1 Sugarcane Bagasse Fiber

Aminudin (2017), studied the utilization of bagasse waste-based materials as improvement for thermal insulation of cement brick. The materials used in this study are cement, sand, sugarcane bagasse and water. Boiling water containing Sodium Hydroxide (NaOH) are used as the fibre treatment. Then in order to determine the surface and the chemical composition, the fibres are tested with SEM and XRF respectively. Mix ratio of 1:3 is used to represent the cement to sand and for water cement ratio the research used 0.45% as the material preparation for cement brick production. Fibres are added into mortar mixture from 0%, 2%, 4%, 6%, 8% and 10%. There are two type of dimensions created for the specimen. 50mm × 50mm × 50mm dimension were produced for compressive strength test and 102.5mm × 215mm × 65mm dimension were used to test the thermal conductivity of the samples. From the result of the research, compressive strength for 28 days of curing are 13.29 MPa for 0%, 15.13 MPa for 2% and 17.23 for 4%. However, the strength started to decrease by 14.42 MPa for 6% of sugarcane bagasse and continuously drop from 8% and 10% which is 13.80 MPa, and 12.01 MPa respectively (Aminudin *et al*., 2017). The 4% additional percentage for sugarcane bagasse will result in decreasing of the strength of the samples. It was due to poor workability and less bonding between sugarcane bagasse and mortar. going

2.2 Waste management of Sugarcane Bagasse Fiber

In general, sugarcane bagasse has been mostly utilized in power production and steam for domestic sugar mills. Kiatkittipong (2009), studied on life cycle assessment of bagasse waste management options. A comparative by using life cycle assessment have study the bagasse waste management in four kind of scenarios. It is landfilling with utilization of landfilled gas, anaerobic decomposition in a reactor, incineration for power generation and pulp production. One of the environmental indicators used was global warming potential. It shows that bagasse waste management for pulp production have the least impact toward all environmental aspects. The most unfavourable option was proven to be landfilling. This is because it not only taking up useful space, it also generates a large quantity of methane and ammonia. This could lead to a worst scenario if there was no proper control toward such emissions for example global warming and photochemical smog.

2.3 Waste material replacement in brick manufacturing

(a) Wood saw dust

Sawdust is usually disposed of by open burning. Producing and causing a harmful smoke that threatens human health. A more environmentally desirable way of disposing it is to use it in cement composites. Demir (2008), studied the usage of organic residues such as sawdust, tobacco residues and grass in clay brick. Firstly, diverse number of residues started with 0%, 2.5%, 5% and 10% were selected. Shaped samples were dried at room temperature with 60% humidity for three days then dried at 110°C in an oven. Then, samples were separated into two groups, fired samples and unfired. First group was fired at 600°C temperature with heating rate of 2°C/min and then they were left at 900°C with 4°C/min for 60 minutes. Archimedes method are used for determination of physical and mechanical properties of the samples. From this research, results showed that organic residues increased the essential water content for extrusion. The fibrous characteristic of residues did not induce problems for extrusion when were used up to 10% by weight. Drying shrinkage was increased. 10 % residue addition was not recommended due to extreme drying shrinkage. The compressive strength was decreased. Organic residues improved thermal conductivity of bricks and increased the open porosity and caused to reduction of the bulk density. The optimum percentage recommended is by 5% of residue addition.

(b) Fly Ash

Fly Ash is finely divided residue resulting from the combustion of powdered coal, transported by the flue gases and collected by electrostatic precipitators. Fly ash is available as a waste thermal power plant. Fly ash can also increase the strength of clay bricks and reduces the water absorption (Kumar, 2014) and it helps toward the strength of the bricks due to its silicate constituent. Lingling *et al*., (2005) studied the effect of fly ash that was used as raw material with high replacing proportion of clay by volume on properties and firing parameters of bricks. Specimens were dried in three levels, at ambient temperature for 2 days, 60°C for 4 hour and 100°C for 6 hours. Based on heating program, specimens were fired until about 1100°C with diverse heating rate for 8h. Results indicated that 4-6% of an additive compensated or improved the plasticity index of mixture. Suitable sintering temperature of brick was about 1050°C. Fly ash caused to cease cracking due to lime, decreased water absorption and heightened the resistance versus freezing and melting.

2.4 Fine Aggregate Replacement

The widely used material in infrastructure development and construction throughout the world are concrete and bricks. A significant role in the mix design played by fine aggregate which are the prime material used for the preparation of concrete and brick. Sand has been used as a fine aggregate since ages as one of the construction materials. (Ali & Alam, 2019) stated that know days, river sand has becoming a scarce commodity. It is estimated that 60-70% of the quantity is aggregate which is natural rock, 18% is water, and 15-20% is cementations binder for yearly production of concrete (Ali & Alam, 2019). This excessive use of natural resources could make it rapidly diminished and shortage of fine aggregate may directly affect our construction industry. Therefore, there is a need to find an alternative material which can act as a fully replacement or partial replacement and prevent damage to the environment. Alternative material that can meet the technical properties of fine aggregate and should be available economically and domestically with great amount is needed for sustainable infrastructure development.

2.5 Previous Research on Lightweight Brick

Gencel (2015) investigated the production of porous and lightweight clay-pumice bricks that pumice was used as an additive. Pumice was added in the ratio of (10-40%) by weight in powder form. Pretreatment such as drying, milling, and sieving was applied for clay and pumice particles, smaller than 150μm in size were acceptable and used for brick production. Semi-dry samples were pressed into the mold under 20Mpa compression. Then samples were kept in ambient condition for a night and were dried at 40°C for 20h and 100°C for 18h in oven. Firing process was performed at 900°C and 1000°C for 2h at the rate of 5 °C/min. Results indicated that bulk density lessened up to 1.58g/cm3 at 900°C and 1.61gr/cm3 at 1000°C temperature. The 39.6% pumice was effective and increased the porosity of fired bricks. The temperature was not effective on the porosity of bricks. With about 10-40% addition of pumice, compressive strength was obtained 18.5-30.3Mpa.

Pimraksa & Chindaprasirt (2009) studied the production of lightweight bricks that composed of lime, gypsum and diatomite. The components were blended to form homogeneous mixtures and pressed into the molds under 3.5Mpa compression. Procuring temperature was 27-28°C with 90% moisture in order to avoid cracking and gaining primarily strength. Specimens were autoclaved at 0.14Mpa and 130°C temperature for about 4h. 0-15% Gypsum was added into the mixtures with water content of 50% and 6 days pre-curing. Results indicated that the optimum content of water was 50% and precuring period was 6 days. There was a positive correlation between lime content and strength or density of the brick. Strength of 17.5Mpa, density of 0.73g/cm3 and water absorption of 46% were obtained due to calcined Lampang diatomaceous earth (CLDE): lime: gypsum ratio of 80:15:5 for 4h.

2.6 Environmental Effect of Commercial Brick

The conventional method of producing commercial brick has brought a shortcoming of earth-based materials such as shale, clay and sand. It also has caused resource depletion, energy consumption and environmental degradation. The conventional method on commercial brick making has caused serious environmental contamination represented by the enormous emissions of greenhouse gases resulted in unusual climate changes as smog, acid rain and global warming. As a vitrified or semi vitrified ceramic, clay brick achieves a crystalline or semi-crystalline structure due to the actions of heat, it becomes hard and durable by firing in a kiln. Therefore, the fired brick was more favourable than the sun-dried brick. High temperature in the kiln is responsible to produce thermal Nitrogen Oxide (NOx) gases which is a poisonous gas derived from nitrogen and oxygen combustion under high pressure and temperature (Shakir, 2013).

3. Research Methodology

3.1 Research Framework

The research methodology is carried out systematically with the guidelines by the flowchart of research framework as shown in Figure 1 in appendix. The process starts with preparing the materials, conducting pilot study and followed by preparing the sample bricks according to Malaysia Standard (MS EN197-1:2007), performing flow table test with referring to ASTM C1437-17 and conducting density test, water absorption test and compression strength test by referring to BS1881: Partm116:1983. Afterwards, an interview with brick manufacturer was performed to procured feedback regarding the sample brick that was made. This laboratory framework process was a guide for the process of experimental work and testing process.

3.2 Preparation of Materials

(a) Treatment of Sugarcane Bagasse Fiber

Figure 2 below shows the treatment of sugarcane bagasse fiber.

(a) (b) (c)

Figure 2: Process of sugarcane bagasse fiber treatment

Based on figure 2 (a), sugarcane bagasse fiber is dried under the sun until it is completely drying. Then, on figure 2 (b) the dried sugarcane bagasse fiber is then soaked with 300ml of Sodium Hydroxide (NaOH) for 6 hours. Next, on figure 2 (c) treated sugarcane bagasse fiber are dried in an oven for 30 minutes at 200 °C. The function of the treatment is to remove the impurities and to ensure that the fibers are able to long-lasting.

(b) Process of Grinding Sugarcane Bagasse Fiber

Figure 3 below shows a process of grinding sugarcane bagasse fiber.

(a) (b) (c)

Figure 3: Process of grinding sugarcane bagasse fiber

As the sugarcane bagasse fiber that receive from the hawker is still in the state of damp and moist, it needs to be dried immediately in order to prevent odour and fungus. Based on figure 3 (a) above, it shows a treated sugarcane bagasse fiber. Next, on figure 3 (b) the dry treated sugarcane bagasse fiber will be grind in the grind machine at laboratory of FKAAS in UTHM. Lastly, based on figure 3 (c), it shows the last look of grinded sugarcane bagasse fiber.

(c) Brick Proportions

Table 1 below shows a proportion of making bricks for this research.

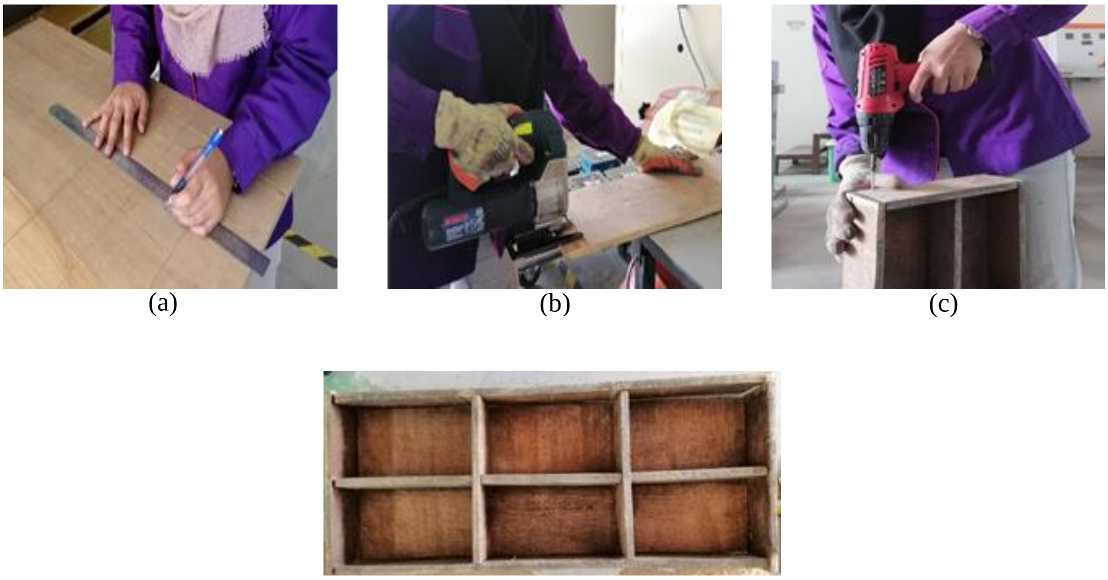
Table 1: Proportion for making bricks

Sugarcane Bagasse Fiber Proportion (%)	Fine Aggregates (kg)	Cement (kg)	W/C Ratio
0	2.40	0.8	0.45
1	2.38	0.8	0.45
1.5	2.36	0.8	0.45
2	2.35	0.8	0.45
1	2.39	0.8	0.45
1.5	2.38	0.8	0.45
2	2.36	0.8	0.45

Each percentages of aggregate partial replacement using sugarcane bagasse fiber are different with each other. The water ratio used in this study was 0.45. Thus, the mix design for each brick are prepared in order to collect average data for the compressive strength of each proportion of concrete brick.

(d) Brick Formwork

The process of making the brick formwork is shown as in the Figure 4 below. Plywood is the type of wood that will be use as the brick formwork. The brick formwork can be used for twice.



(a) (b) (c) (d)

Figure 4: Process of making formwork

Based on figure 4 (a), plywood is measured as 215mm × 102.5mm × 65mm according to MS EN197-1:2007. Next, on figure 4 (b), plywood is cut by using jig saw wood cutting machine into pieces according to the measurement made. Not to forget the plywood is secured by the G-clamp so that it does not moving during the cutting process. Lastly, on figure 4 (c) all plywood pieces are screwed together to form a formwork as in figure 4 (d).

3.3 Concrete Mix Process

Concrete mixing process involved Ordinary Portland Cement, fine aggregate, sugarcane bagasse fiber and water. The mixing process follows the standard from MS EN197-1:2007. The proportion of sand and cement used is 1:3 ratio.

(a) (b) (c) (d)

Figure 5: Concrete mix process

Figure 5 above shows the concrete mix process. Based on figure 5 (a), Ordinary Portland Cement (OPC), sand and water are weighted by using weighing scale. Next, on figure 5 (b) sugarcane bagasse fiber is weighted by using analytical balance weighing scales in order to obtained more accurate reading. Then, on figure 5 (c) all dry materials are place inside a large pan so that the mixing process could be easier. Lastly, on figure 5 (d) all materials are mixed together by appropriate tools and proceed for the flow table test.

(a) Flow Table Test

This method is used to determine the consistence of fresh concrete. The test is conducted by referring the ASTM C1437-17 Standard Test Method for Flow of Hydraulic Cement Mortar. The result of this flow table test was shown as in *Appendix 3- Table 3*. The acceptable reading for flow table test is at the range of 110-130.

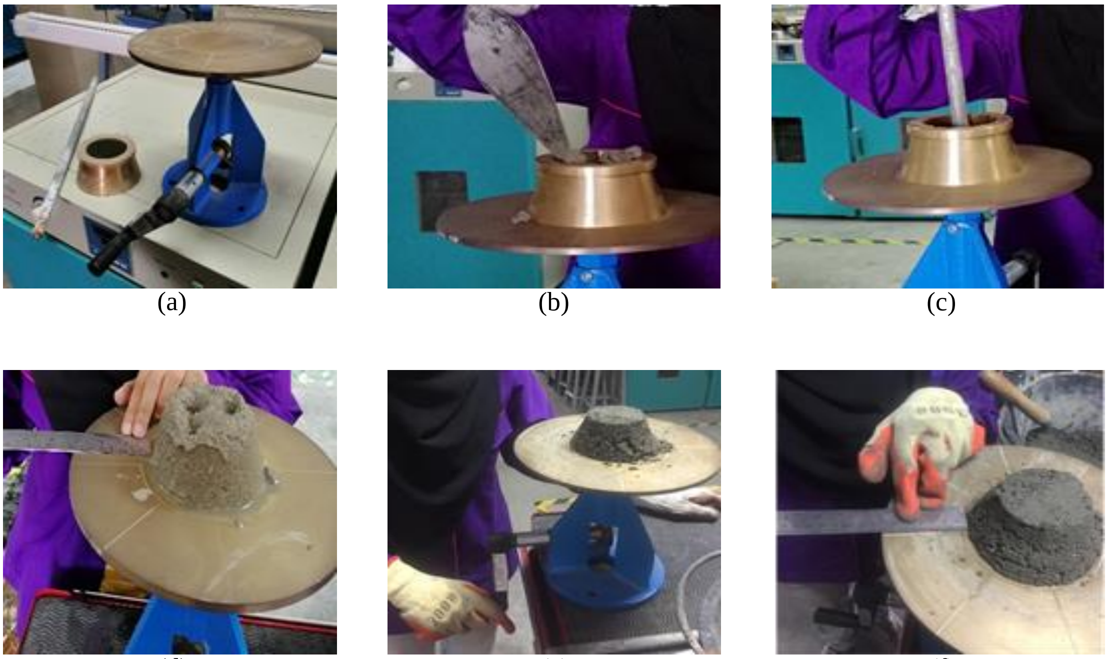

(a) (b) (c)
(d) (e) (f)

Figure 6: Process of flow table test

Based on figure 6 above, it shows the process of flow table test. Based on figure 6 (a), all the tools needed for conducting the flow table test is prepared. Next, on figure 6 (b), the diameter of the platform is measured by using metal ruler. Then, on figure 6 (c), the mortar is placed inside the mould until it reached ½ of the mould before it is stamped by tamping rod. It is started with 20 times of tamping to compacting the mortar inside the mould. Next, the same step is repeated until the mould is full. On figure 6 (d), the initial diameter of the mortar is taken and record from the end of the mortar until the end of the platform. Based on figure 6 (e), the mould is lifted and in 15 minutes the table is dropped for 25 times by rotating the handle. Finally, on figure 6 (f), the final diameter of the mortar and expansion of mortar is taken and recorded.

(b) Brick Casting

Figure 7 below shows a process of brick casting for this research.

(a) (b)

Figure 7: (a) and (b) brick casting process

Based on figure 7 above, it shows a process of brick casting. On figure 7 (a), a layer of grease oil was applied on the inside of the formwork in order to ensure that the mixture does not stick to the formwork. Next, every layer of concrete mix is compacted by using tam rod for a better compaction. Lastly, based on figure 7 (b), concrete mix are filled up the formwork by using a scoop.

(c) Curing Process

In this research study the concrete brick will undergo an air curing for 7 and 28 days. The first 7 days of air curing, the data can be representing 2/3 from the total strength that recorded for 28 days of air curing. Air curing process are done by letting the concrete brick to dry and cured under the exposed of the sun.

Figure 8: Air curing

3.4 Experimental Test

There are three type of experimental test that performed on the sugarcane bagasse fiber brick. For instance, compression strength test, water absorption test and density test.

(a) Compressive Strength Test

By using the BS 1881: Part 116: 1983, this method is performed in order to determine the compression strength of the concrete brick (Figure 9).

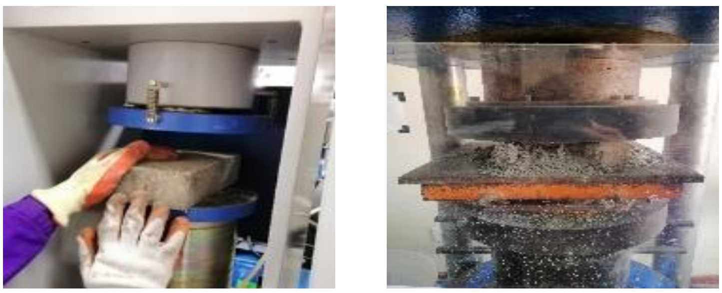


Figure 9: Compressive strength test

(b) Water Absorption and Density Test

The initial weight of the brick sample is taken by using the weighing scale. Next, on figure 10, the brick sample are then immersed into the water tank for half an hour before the final weight of wet brick sample is taken and the percentage of water absorption of the brick sample is recorded.

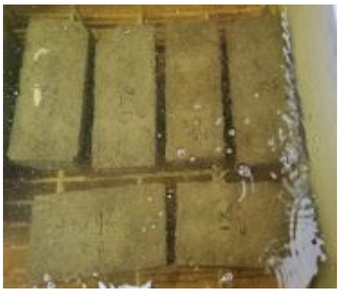


Figure 10: Bricks are immersed into water tank

Figure 11: Brick is measured using vernier calliper

For more accuracy, the volume of the brick sample is measured by using vernier caliper (Figure 11). Then the mass of the brick sample is recorded by using weighing scale before the density of the brick sample calculated.

3.5 Qualitative Method

In order to achieve objective 3, qualitative in terms of interview session was conducted. This kind of method was conducted by meeting interviewer in order to get information directly.

3.6 Research Instrument

In this research, semi-structured interview was conducted in order to obtain a desire answer and information from the respondents. In this interview questions, it contained two parts which is Section A and Section B. Section A was about respondent's background and Section B was about feedback from the respondents about the performance of sugarcane bagasse fiber brick.

3.7 Research Respondent

Respondents are selected for interviews are limited to brick manufacturer and a researcher in Johor area. The respondent was selected based on their experiences, expertise and positions. There are two respondents involved in this interview such as a director that worked in brick manufacturer and a researcher from FKAAS, UTHM.

4. Data Analysis and Results

4.1 Results

In this chapter, the results of the research will be analysed to formulate several relationships.

(a) Result from Pilot Study

The percentage of sugarcane bagasse fiber that have been used for the pilot test was 1%, 1.5% and 2% by referring on previous study. The results for pilot test are performed for 28 days only as stated in the Table 2 below.

Table 2: Pilot study compression strength test result

No. of Brick Tested	Proportion of Sugarcane Bagasse Fiber (%)	Compression Strength (MPa)	Average Compression Strength (MPa)	Age (Days)
2	1 1	2.6 2.6	2.6	28
2	1.5 1.5	1.4 1.4	1.4	28
2	2 2	- -	-	28

Table 2 above shows the compression strength test result of pilot study. As can be seen from table above, the average compression strength test result for 1% of sugarcane bagasse fiber as partial aggregate replacement in lightweight brick is the highest with 2.6 MPa. However, for 1.5% of partial replacement the result obtained is 1.4 MPa and results for 2% of partial replacement is unidentified. It is unidentified because the brick is too crumbly to be tested on compression strength test.

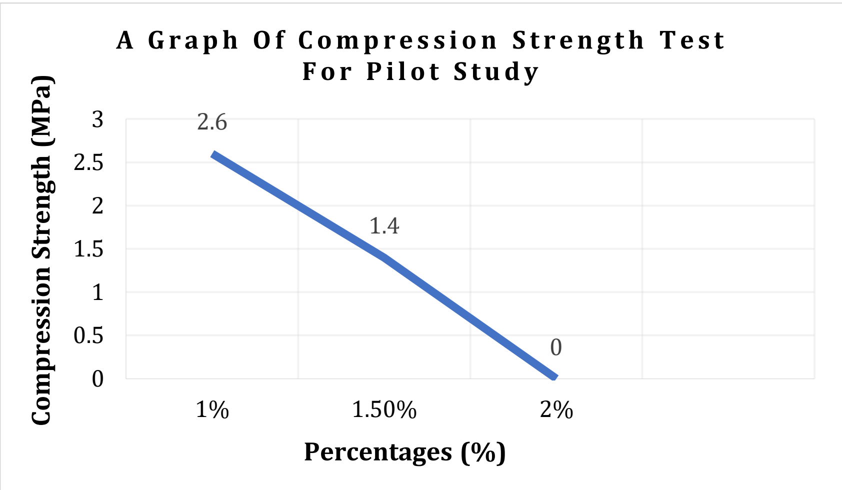


Figure 12: Compression strength test for pilot study

From the figure 12 above, it shows a graph of compression strength test for pilot study. The result of the pilot study compression strength test shows that it is linearly decreasing. It can be seen that, the higher the proportion of sugarcane bagasse fiber as partial aggregate replacement, the lower the average of compression strength obtained. The 2% partial aggregate replacement does not have any data to be recorded as the brick was to crumbly to be tested.

(b) Result from Standard Cement Brick

Standard cement brick is designed based on Malaysia Standard MS EN197-1:2007. Table 4 below present the result obtained from the compressive strength test that performed on Faculty of Civil Engineering and Environment (FKAAS) UTHM.

Table 4: Result of compression strength test of standard cement brick

Number of samples for standard cement brick	Compression Strength (MPa)	Average of Compression Strength (MPa)	Age (Days)
1	40.0		28
2	31.9	35.7	28
3	35.1		28

Based on Table 4 above, it presents the result of compression strength test of standard cement brick. It shows that the average of compressive strength for all the three standard bricks for 28 days are 35.7 MPa.

(c) Result from Sugarcane Bagasse Fiber Brick for 7 and 28 Days

Appendix 2 – Table 5 illustrates the result of compression strength test for sugarcane bagasse fiber bricks for 7 days. As can be seen from table above, the average compression strength for 0.5% of partial aggregate replacement is the highest with 1.2 MPa. On the other hand, the average compression strength for 1% and 1.5% are 1.1 MPa and 0.8 MPa.

As can be seen from table above, the average compression strength test result for 0.5% of sugarcane bagasse fiber as partial aggregate replacement in lightweight brick is the highest with 2.5 MPa. However, for 1% of partial replacement the result obtained is 1.3 MPa and results for 1.5% of partial replacement is 0.9 MPa.

(d) Strength Comparison between Standard Concrete Brick with Sugarcane Bagasse Fiber Brick

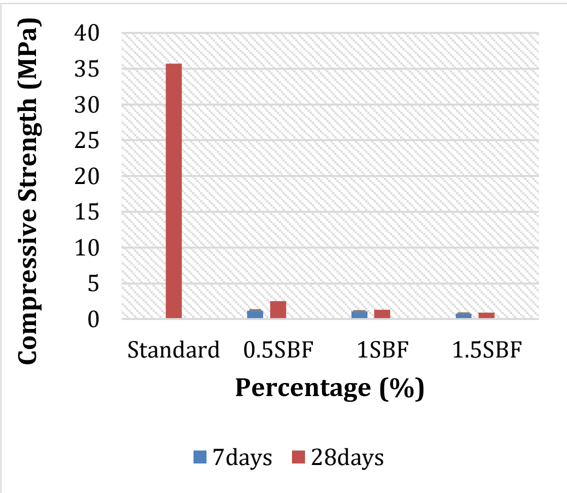


Figure 13: Strength Comparison between standard cement brick with sugarcane bagasse fiber brick

Figure 13 shown a comparison of compressive strength between sugarcane bagasse fiber bricks with standard brick. The relationship between the compressive strength and percentages were sketched. From the bar chart, it is clearly shown that the compressive strength is increasing at 0.5% which is 2.5MPa before decrease when the percentage is increase. The highest compressive strength was gathered from 0.5% of sugarcane bagasse fiber as partial aggregate replacement, while the lowest compressive strength was from 1% which is 1.3MPa to 1.5% which is 0.9MPa. However, the highest percentage of compressive strength of sugarcane bagasse fiber brick which is 0.5% with 2.5MPa still could not matched the compressive strength of standard cement brick which is 35.7MPa. This is because, the great reduction in strength is due to poor workability and less bonding between sugarcane bagasse and mortar. The same observation was found by (Aminudin et al, 2017) where in their studies the partial replacement of aggregates by sugarcane bagasse fiber was 2%, 4%, 6%, 8% and 10%. According to their findings, the compressive strength of the concrete was drop starting from 6% until 10% of sugarcane bagasse fiber as partial aggregate replacement. This has shown that, the replacement of sand by sugarcane bagasse fiber also significantly reduced the brick strength.

Furthermore, for brick samples at 28 days, it can be observed that all types of brick have higher strength as compared to the earlier strength. This was due to hydration process by the cement paste of brick at the later age. Despite sugarcane bagasse fiber has greatly reduced the brick strength, yet it was found that the brick strength of 0.5% of sugarcane bagasse fiber is 2.5 MPa whilst the strength for 1% and 1.5% partial replacement are drop from 1.3% to 0.9%.

(e) Water Absorption Test

Water absorption was conducted in order to determine the percentage of the water absorption by the bricks. The test was accordance to the BS 1881:122. The result for water absorption test of sugarcane bagasse fiber brick can be referred on *Appendix 3- Table 6*.

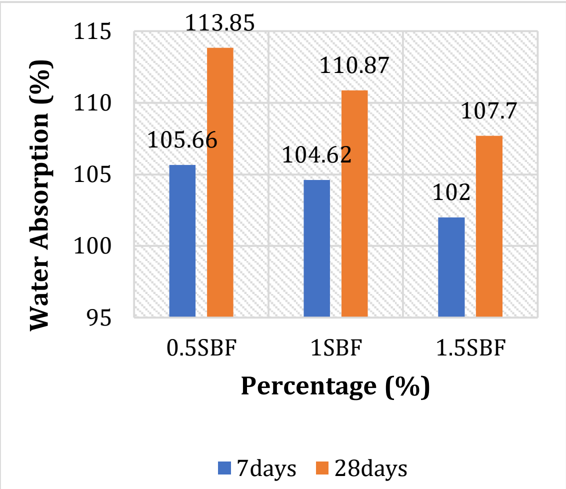


Figure 14: Water absorption test for sugarcane bagasse fiber bricks

Figure 14 above shown a bar chart of water absorption of sugarcane bagasse fiber bricks. The relationship between water absorption and percentages were sketched. From the figure, it is clearly shown that the water absorption is increasing at 0.50% which is 113.85% before decrease when the percentages of sugarcane bagasse fiber as partial aggregate replacement in lightweight concrete brick increase. The highest water absorption was gathered from 0.50% of partial aggregate replacement, while the lowest water absorption was from 1% which is 110.87% to 1.50% of partial aggregate replacement that is 107.7%. This is because, the reduction of percentage of water absorption with the increment of sugarcane bagasse fiber was due to absorbent characteristic of sugarcane bagasse fiber.

(f) Density Test

In determining the density of the brick samples, the test was conducted accordance to BS EN 12390-7 in which determination of the brick mass will be as-received condition. In *Appendix 4-Table 7*, shows the result of density test for sugarcane bagasse fiber of 7 and 28 days.

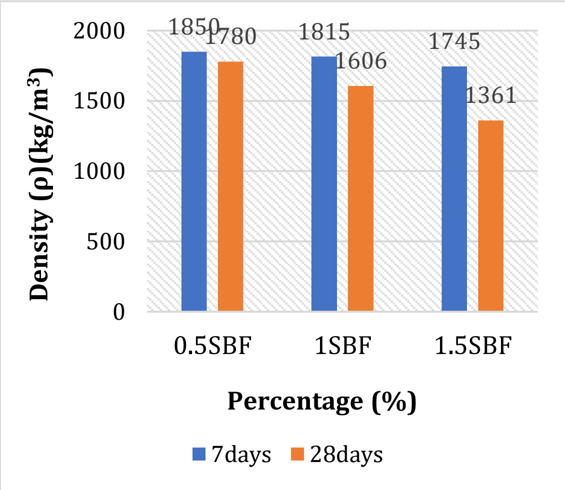


Figure 15: Density test of sugarcane bagasse fiber brick

Figure 15 above shown a bar chart of density test of sugarcane bagasse fiber bricks. The relationship between density and percentages were sketched. From the figure, it is clearly shown that the density is increasing at 0.50% which is 1780 kg/m3 before decrease when the percentages of sugarcane bagasse fiber as partial aggregate replacement in lightweight concrete brick increase. The highest water absorption was gathered from 0.50% of partial aggregate replacement, while the lowest water absorption was from 1% to 1.50% which is 1606 kg/m3 and 1361 kg/m3 of partial aggregate replacement. This has verified that, sugarcane bagasse fiber has significantly reduced the brick density due to its characteristic which is low in density. The reduction of brick density was due to loss of water content throughout the air curing process. According to ASTM C90, density for lightweight masonry brick should be less than 1680 kg/m3. Therefore, from Figure 14, it can be observed that density of brick with 1% and 1.5% of partial aggregate replacement has achieved the lightweight density as stated in the ASTMC90.

4.2 Data Analysis and Discussion of Qualitative Method

(a) Respondent's Background

An interview session has been made with both respondents according to their position and expertise. Therefore, more accurate and reliable feedback was received.

Respondent 1 was a director that worked in Unipertiwi Sdn Bhd. Unipertiwi Sdn Bhd was a claybrick manufacturer that manufactured and supplied claybrick. He has working for the company for 10 years and his expertise was in manufacturing. Next, respondent 2 was a researcher with 15 years of working experiences in UTHM and his expertise was in engineering and technology.

(b) Comment on the Result Performance of Sugarcane Bagasse Fiber Brick

According to Respondent 1 and Respondent 2, they are agreed that the strength of sugarcane bagasse fiber brick are very weak compared to the standard cement brick. They also added that there must be few factors or an error that occurred during the process of making the sugarcane bagasse fiber brick.

"Based on result shown, it can be seen that different between strength of sugarcane bagasse fiber brick and standard cement brick is higher. This is likely to happen when there are mistake during the compaction of the sugarcane bagasse fiber brick" (Respondent 1).

"Based on the overall test result shown, the low strength of sugarcane bagasse fiber brick could happen when sugarcane bagasse fiber was not fully treated, the mixing process was conducted wrongly or the water content inside the sugarcane bagasse fiber was not controlled" (Respondent 2).

As a conclusion, the process of making the sugarcane bagasse fiber brick plays an important role on the performance of sugarcane bagasse fiber brick. Few mistakes during the making process could affecting the strength of the sugarcane bagasse fiber brick. From this, future researcher can obtain focus on this information in order to make an improvement on this research.

(c) Acknowledge of sugarcane Bagasse Fiber Brick Potential on the Marketability of IBS Industry in the Future

According to Respondent 1 and Respondent 2, both of them agreed and supported that sugarcane bagasse fiber bricks does suitable to be marketed in brick manufacturer. They both agreed that this brick was more environmentally friendly than the standard brick. However, they mention that more improvements need to be done in order to produce a strong sugarcane bagasse fiber brick.

"This product does suitable to be marketed in brick manufacturer because it used bagasse waste as a replacement for the aggregates. However, the strength of the product is still need to be improved than the current strength" (Respondent 1).

"It is suitable for this product to be marketed in brick manufacturer because sugarcane bagasse fiber can act as an alternative material on producing lightweight brick. However, the strength of the product needs to be comparable with the standard brick" (Respondent 2).

As a conclusion, both respondents agree that sugarcane bagasse fiber brick does suitable to be marketed in brick manufacturer. However, in the future the strength of the sugarcane bagasse fiber brick needs to be stronger than the standard brick.

(d) Opinion on Improvement

According to Respondent 1, he suggested that the compaction process of the sugarcane bagasse fiber brick was made with compaction machine and also made a fire resistance test on the sugarcane bagasse fiber brick. The aim of fire resistance test on sugarcane bagasse fiber brick was to determine how long the brick can last with the presence of sugarcane bagasse fiber in the brick.

"In order to improve the brick, I would like to suggest for use a compaction machine when making the sugarcane bagasse fiber brick. I also want to suggest to add a fire resistance test to brick in order to see how long can it hold the fire when there is a fiber inside it" (Respondent 1).

According to Respondent 2, he suggested to keep on searching and try a good treatment for the sugarcane bagasse fiber before it is mixed with the other materials.

"I want to suggest to keep on searching and trying other treatment for this sugarcane bagasse fiber brick." (Respondent 2).

As a conclusion, both respondents have suggested several ideas that could improve this research. The improvement can be in terms of testing and other treatment on sugarcane bagasse fiber as partial aggregate replacement.

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5. Conclusion

This research has successfully met the objectives to find the optimum percentage of sugarcane bagasse fiber as partial aggregate replacement in lightweight. In order to obtained the optimum percentage, compression strength test have been tested on each type of sugarcane bagasse fiber percentage. The result shows that 0.50% is the most optimum percentage of sugarcane bagasse fiber in lightweight brick as it has the highest compressive strength which is 2.5 MPa compared to others.

The proportion on making standard cement brick is slightly different than sugarcane bagasse fiber brick. Thus, it shows a big different of compressive strength between both type of brick. The compressive strength of standard cement brick is higher than sugarcane bagasse fiber brick which is 35.7 MPa.

Positive feedbacks have been received from both respondents regarding the performance of sugarcane bagasse fibers in lightweight brick. More improvement needs to be done in order to improve the strength and quality of the brick.

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Appendix A

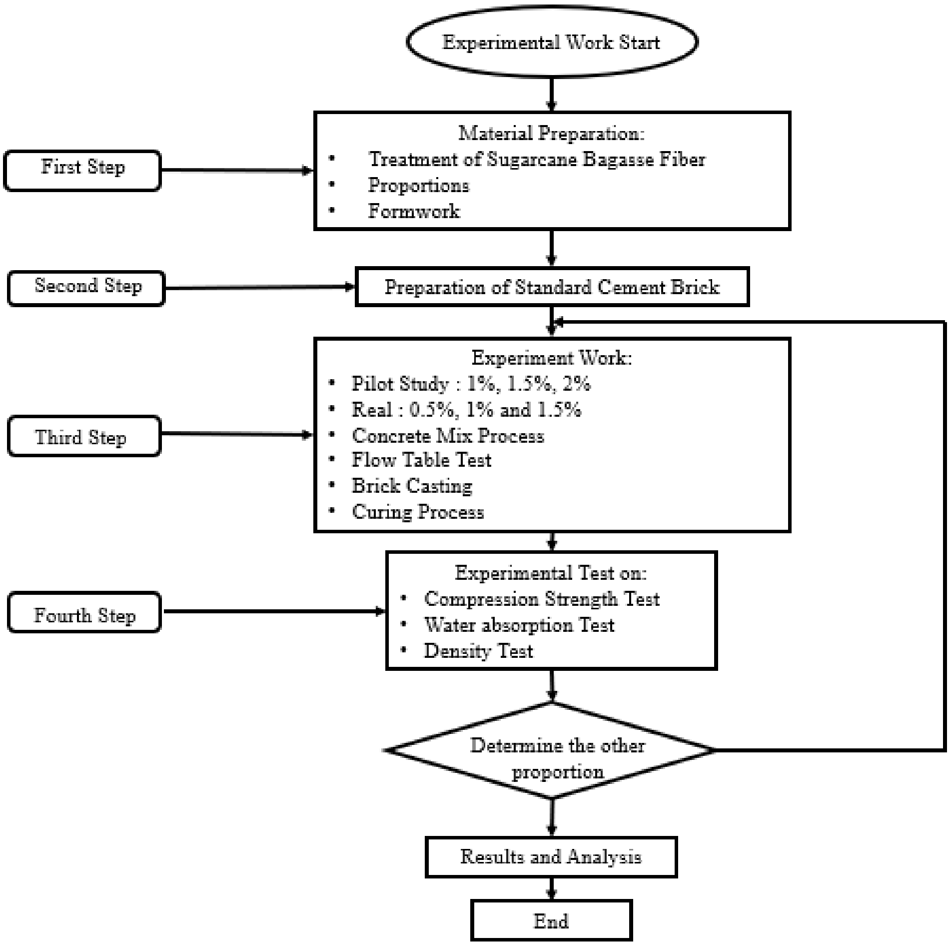

Figure 1: Research framework for experimental work

Appendix B

Table 5: Result of compression strength test for sugarcane bagasse fiber for 7 and 28 days

No. of Brick Tested	Proportion of Sugarcane Bagasse Fiber (%)	Compression Strength (MPa)	Average Compression Strength (MPa)	Age (Days)
2	0.5 0.5	0.9 1.5	1.2	7
2	1 1	1.3 0.8	1.1	7
2	1.5 1.5	0.8 0.8	0.8	7
2	0.5 0.5	2.8 2.2	2.5	28
2	1 1	1.3 1.3	1.3	28
2	1.5 1.5	0.8 0.9	0.9	28

Appendix C

Table 3: Result of flow table test

Proportion of Sugarcane Bagasse Fiber (%)	Initial Reading (mm)	Final Reading (mm)	Flow	Justification
0.5	75	68	119	Pass
1	77	66	124	Pass
1.5	78	64	130	Pass

Appendix D

Table 6: Result of water absorption test for sugarcane bagasse fiber of 7 and 28 days

No. of Brick Tested	Proportion of Sugarcane Bagasse Fiber (%)	Dried Mass (kg)	Mass After Immersed (kg)	Percentage of Water Absorption (%)	Percentage of Average Water Absorption (%)	Age (Days)
2	0.5 0.5	2.65 2.65	2.80 2.80	105.66 105.66	105.66	7
2	1 1	2.60 2.60	2.72 2.72	104.62 104.62	104.62	7
2	1.5 1.5	2.50 2.50	2.55 2.55	102.00 102.00	102.00	7
2	0.5 0.5	2.55 2.55	2.90 2.85	116.0 111.7	113.85	28
2	1 1	2.30 2.30	2.55 2.55	110.87 110.87	110.87	28
2	1.5 1.5	1.95 1.95	2.10 2.10	107.70 107.70	107.70	28

Appendix E

Table 7: Result of density test for sugarcane bagasse fiber of 7 and 28 days

No. of Brick Tested	Proportion of Sugarcane Bagasse Fiber (%)	Brick Mass (kg)	Density (ρ)(kg/m3)	Average Density (ρ)(kg/m3)	Age (Days)
2	0.5 0.5	2.65 2.65	1845 1845	1845	7
2	1 1	2.60 2.60	1815 1815	1815	7
2	1.5 1.5	2.50 2.50	1745 1745	1745	7
2	0.5 0.5	2.55 2.55	1780 1780	1780	28
2	1 1	2.30 2.30	1606 1606	1606	28
2	1.5 1.5	1.95 1.95	1361 1361	1361	28