A STUDY OF OPTIMUM OIL PALM FROND (OPF) RATIO IN CEMENT SAND BRICK.

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DEDICATION

Praise to Allah because has given me strong to complete my studies.

Special thank you to my parents,

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who have always been here for me throughout my studies and give me a wonderful of their eternal and unconditional support, patience and love. Also to my siblings.

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ABSTRACT

This paper is an overview to investigate the properties of oil palm frond (OPF) fiber content in cement sand bricks. The objective of this thesis is to determine the optimum ratio of the OPF in the production of cement sand brick. This thesis also wants to determine the characteristic of the cement sand brick with OPF fiber content in term of compressive strength, density and water absorption. From the results, it shows that the mix proportion 1:5:1 (OPF1.0) was the optimum ratio of OPF fiber content because it give the highest compressive strength which is 8.000 Mpa at 28 days. The results indicate that the compressive strength of cement sand bricks with OPF fiber content is decreased as the OPF fiber content increased in the mix ratio. In addition, the mix proportion 1:5:1 (OPF1.0) gives the highest density result which is 1658.08 kg/m^3 and the lowest water absorption result which is 9.83%. Generally, the properties of OPF cement sand brick are slightly lower that plain cement sand brick (OPF0). The density of cement sand bricks with OPF fiber content was decreased with the increasing additional of OPF fiber content and it is decreasing linearly with the increasing of OPF fiber content. The percentage of water absorption also found to be increased linearly with the increasing of OPF fiber content. Besides that, it is also found that additional of excessive OPF fiber content in the production of cement sand brick was decrease the compressive strength and continues to increase the water absorption hence decrease the density. It can be concluded that the usage of OPF has a great potential in the production of cement sand brick and also in the construction industry. It is also may help to maximize the usage of OPF and can minimize the OPF to be thrown away in landfills.

ABSTRAK

Kertas kerja ini adalah gambaran keseluruhan mengenai sifat-sifat bata simen yang mengandungi serat pelepah kelapa sawit. Objektif kertas kerja ini dibuat bagi mengenalpasti nisbah yang paling sesuai dalam pembuatan bata simen yang mengandungi serat pelepah kelapa sawit. Tujuan kertas kerja ini juga adalah untuk mengenalpasti ciri-ciri bata simen yang mengandungi serat pelepah kelapa sawit dari segi kadar kekuatan mampatana, ketumpatan dan kadar penyerapan kelembapan. Daripada hasil keputusan, ini menunjukkan bahawa bahagian campuran 1:5:1 (OPF1.0) ialah nisbah yang paling sesuai untuk pembuatan bata simen yang mengandungi serat pelepah kelapa sawit kerana ia memberikan kadar kekuatan mampatan yang paling tinggi iaitu 8.000MPa pada hari yang ke 28. Keputusan menunjukkan kadar kekuatan mampatan untuk bata simen yang mengandungi serat pelepah kelapa sawit akan menurun jika kandungan serat pelepah kelapa sawit meningkat. Tambahan pula, kadar campuran 1:5:1 (OPF1.0) menunjukkan nilai ketumpatan yang paling tinggi iaitu 1658.08 kg/m^3 dan kadar penyerapan kelembapan yang paling rendah iaitu 9.83%. Kebiasaannya, sifat bata simen yang mengandungi serat pelepah kelapa sawit ialah lebih rendah daripada bata simen yang biasa (OPF0). Kadar ketumpatan bata simen yang mengandungi serat pelepah kelapa sawit akan menurun jika serat pelepah kelapa sawit meningkat dan ianya akan menyebabkan penurunan secara berterusan jika serat pelepah kelapa sawit bertambah. Peratusan kadar penyerapan kelembapan juga akan menyebabkan kenaikan secara berterusan dengan peningkatan serat pelepah kelapa sawit. Selain daripada itu, jika penambahan serat kelapa sawit secara berlebihan dalam pembuatan bata simen akan menyebabkan berlakunya penyusutan kadar mampatan dan peningkatan kadar penyerapan kelembapan. Oleh itu ianya akan menyebabkan pengurangan pada ketumpatan. Kesimpulannya, penggunaan serat kelapa sawit mempunyai potensi yang bagus dalam pembuatan bata simen dan juga untuk industri pembinaan. Ini juga dapat membantu meningkatan penggunaan serat pelepah kelapa sawit dan dapat mengurangkan pelepah kelapa sawit dari di buang ke tapak pelupusan.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials.
EFB	Empty Fruit Bunches
OPF	Palm Oil Fronds
OPFB	Oil Palm Fruit Brunch
OPT	Palm Oil Trunks
OPS	Oil Palm Shells
PKC	Palm Kernel Cake
POFA	Palm Oil Fly Ash
POME	Palm Oil Mill Effluent
PPF	Palm Press Fiber
PWD	Public Work Department

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The construction industry is one of the most active sectors in Malaysia and it is contributing a major sector of employment in the countries. Unfortunately, this construction industry can cause global pollution to the environment because this industry produces a large amount of nonrenewable resources and release almost 30% of carbon dioxide to the environment. This situation is a serious issue in this century because it will give effects of the climate change such as increasing of the sea water level, increasing temperature, increase the risks of floods and others. The estimate of global pollution that can be attributed to the building is air pollution 23%, climate change gases 50%, drinking water pollution 40%, landfill waste 50% and ozone depletion 50%.

In order to overcome the more sustainable construction industry, the production of waste and the raw material consumption of construction industry must be reduced. There are some ways to reduce the use of nonrenewable resources and to achieve more sustainable construction industry such as by using natural fiber. Example of natural fiber that can be used as the alternative such as coconut, palm, bamboo, jute and sisal are readily available in the most of the countries. This natural fiber only required a low degree of industrialization, easy to get and it can reduce the cost of construction. According to Alida (2013) the use of natural fiber as element in construction material is one of the alternatives to reduce the use of nonrenewable resources. Besides, the use of natural fiber to reinforced cement composite is also low cost and this constitutes a very interesting option for the building industry.

In order to reduce nonrenewable material consumption as well as to maintaining natural resources, the concept of recycling and sustainability were introduced. The concept of recycling also may solve the agro-waste problem. Normally, most of the agricultural waste will end up to the landfill. Therefore, this research will investigate alternative environmentally sustainable application of these waste materials. To build environmentally sustainable structures, the possibility of using some agricultural wastes and industrial byproduct from different industries as construction materials will be highly desirable and economic advantages (Shafigh, 2010).

Malaysia is well known as the largest palm oil producers in the world. However, as the largest palm oil producers, one significant problem during make processing the palm oil in large amounts. The agricultural wastes of palm oil such as Empty Fruit Bunches (EFB), Oil Palm Shells (OPS), Palm Oil Mill Effluent (POME), Palm Oil Fronds (OPF), Palm Oil Trunks (OPT) and others will become arising and this is one of the main contributors to the nation's pollution problem. All these wastes needs to be disposed properly for the purpose of environmental sustainability.

1.2 PROBLEM STATEMNET

Malaysia is one of the world leaders in the production and export of the palm oil and contributes about 57.6% of the total supply of the palm oil in the world. As the largest palm oil producers, it will cause the increasing level of agricultural waste from the palm oil industry. In order to overcome this problem, one of the palm oil agricultural wastes has been used in this research which is OPF wasted.

As the alternative of this study, this research investigated the ability of the OPF as the additional raw material in the manufacturing of the cement sand bricks. In additional, this study also wants to minimize the OPF to be thrown away in landfills by recycling the

OPF waste. The OPF have the high potential used in the construction industries due to its capability. Due to limited usage and commercialization, lack of research work attempted on the OPF as compared with other oil palm wastes.

Furthermore, in the manufacturing of the brick, sand is one of the important raw materials especially for cement sand brick. Unfortunately, due to high demand of the sand in the construction industry has resulted to rapidly decreasing resources of the materials. This situation seems to be a global trend except to some locations which is near to the natural sand resources. There is some factor are contributing to the natural sand become decreasing such as rapid urbanization, high demand but have limited resources, expensive and cost to process.

All these problems will cause a rising cost for the construction industry because prices of sand become increasingly in every year. The high cost of the sand gives some effects to the construction industry. This alternative study also wants to compare the compressive strength, density and water adsorption of OPF cement sand brick with the standard cement sand brick.

1.3 OBJECTIVE OF STUDY

The objectives of this study are:-

i. To determine the optimum ratio of OPF in the production of cement sand brick.

ii. To determine the characteristic of the cement sand brick with OPF in term of compressive strength, water absorption and density.

1.4 SCOPE OF STUDY

The OPF that has been used in this research was taken from Bandar Tasik Puteri, Rawang, Selangor. This raw material was added into the other four raw materials in the making of cement sand brick. The other four raw materials included Ordinary Portland cement, sand, OPF and plain water. The OPF will be binder together with cement, sand and water by using a basic ratio of brick manufacturing which is 1:6. In this research, the mix proportions of 1:5:1, 1:4.5:1.5, and 1:4:2 by volume of cement, sand and OPF. The compression testing is according to ASTM C 39-03 by using compressive testing machines. The testing of density test is according to ASTM C 373-88 and water absorption testing is according to ASTM C67.

In this study, the OPF is a new raw material that was used in the cement sand brick. The cement sand brick which consists of OPF might give some effect to the strength, density and water absorption. The scope of study is to study the optimum ratio of OPF cement sand brick and compare the properties of OPF brick with standard control brick.

1.5 SIGNIFICANT OF STUDY

This research will be a significant attempt at developing a new alternative material in the construction industry, especially in the country which has a huge amount of agricultural wastes abundantly available such as in Malaysia. This alternative may minimize the agricultural waste to be thrown away in landfills by recycling the waste and at the same times it also can maximize the usage of agricultural waste in the future.

In addition, this research was done to explore the new constituent to produce sustainable and environmentally friendly construction material. In order to achieve a sustainable construction industry, the raw materials consumption and the waste of the production must be minimal. Due to high demand of the raw materials has resulted in a rapid decrease of the materials and it will cause an ecological imbalance. In order to overcome this situation, the new optional need to be explored as the alternative materials that could be used as a replacement to the conventional materials. Moreover, if this study can be done in successful, this material can be used as the alternative way to replacing the raw materials that might be expensive in the future.

CHAPTER 2

LITERATURE REVIEWS

2.1 INTRODUCTION

Brick is one of the oldest manufactured building materials in the world and the most important components in the construction industry. In the meantime, the demand of the brick using a large amount of natural resources harvested from the nature is increasingly throughout in the years. The conventional production of brick has brought some shortcomings and causes damage to the environment due to continue exploration and depletion of natural resources. Most of the source materials are mined from riverbed and hillsides, then leaving the mines area in un-reclaimed conditions.

Due to this situation, there are many research have been done to investigate the potential materials that can be used in the construction industries. Many researchers are lately working to have the privilege of using recycled waste in construction industry. The continuous research in brick material has resulted in production of many types of brick known in various name which have their own unique characteristic to fulfill the current construction industry demand. Table 2.1 shows the different types of wastes and their utilization potentials for construction materials.

Table 2.1: Different types of wastes and their utilization potentials for construction materials

S/No.	Type of solid wastes	Source details	Recycling and utilization potentials
1	Agro-waste (organic)	Baggage, rice and wheat straw and husk, saw mill waste, ground nut shell, jute, sisal, cotton stalk, vegetable residues	Cement boards, particle boards, insulation boards, wall panels, roof sheets, binder, fibrous building panels, bricks, acid-proof cement, coir fiber, reinforced composites, polymer composites
2	Industrial waste (inorganic)	Coal combustion residues, steel slag, bauxite red mud, construction debris	Bricks, blocks, tiles, cement, paint, fine and coarse aggregates, concrete, wood substitute products, ceramic products
3	Mining/mineral waste	Coal washeries waste; mining waste tailing from iron, copper, zinc, gold and aluminium industries	Bricks, fine and coarse lightweight aggregates, tiles
4	Non hazardous waste	Waste gypsum, lime sludge, lime stone waste, broken glass and ceramics, marble processing residues, kiln dust	Blocks, bricks, cement clinker, hydraulic binder, fibrous gypsum boards, gypsum plaster, super-sulfated cement
5	Hazardous waste	Contaminated blasting materials, galvanizing waste, metallurgical residues, sludge from waste water and waste treatment plants, tannery waste	Boards, bricks, cement, ceramics, tiles

Source: Safuiddin et al. (2010)

2.2 TYPE OF BRICK

Due to increasing cost of raw materials and the continuous depletion of natural resources, many researchers are focusing on utilization of waste and by-product. By focusing on the utilization of waste, it also may reduce the increasing waste to be dumped into the landfill and also resolves the problem related to managing disposal of waste products. This is one of the options to improve the use of the waste through the development on value-added product of the waste. It also may reduce the cost of the construction in the future. Even the materials used are recycled waste, but the quality of work is still in a good condition.

2.2.1 Fly Ash Brick

Fly ash brick is a brick made by using fly ash, sand/stone dust, lime, and gypsum in appropriate proportions mixed with water. Ordinary Portland cement can also be used in place of lime and gypsum. Fly ash brick has two different types. A first type consists of fly ash (60-65%), sand/stone dust (20-25%), hydrated lime (8-12%) and gypsum (5%). The second type of fly ash brick consist of fly ash (50-60%), sand/ stone dust (32-40%) and cement (8-1%).

The advantages of fly ash bricks are lightweight brick compared to clay bricks. So, these bricks are suitable for multi storey buildings used, means that this brick is less in weight and put less stress on the building. Then, fly ash bricks absorb less heat than normal bricks. Therefore, it keeps the building cool even in summer. The compressive strength of fly ash bricks is high compared to normal bricks and lastly, these bricks are less porous; therefore it is absorbed very little water compare to burnt clay bricks.

Properties of fly ash brick**:**

a. Size : 200 mm x 100 mm x 100 mm
b. Compressive strength : 100 to 120 Kg/cm^2
c. Water absorption : 15 to 20%

Sources: Fly Ash Bricks (2015)

2.2.2 Clay Brick

Clay bricks are formed by using a mould (the soft mud method), or in commercial mass production by extruding clay through a die and then by using wire-cutting it into the desired sizes (the stiff mud process). The shaped clay is then dried and fired either by burning in a kiln or by sun-drying until it achieves the final desired strength. The action of heat gives rise to a sintering process that causes the clay particles to fuse and thus develops extremely strong ceramic bonds in the burnt clay bodies. All this process will make the clay bricks can withstand the severe weathering action and are inert to almost all normal chemical attacks.

There are several advantages by using clay bricks which are these bricks do not require maintenance. This is because the clay brick will not rust, termites, peeling and splitting. Clay bricks are also a good sound insulation compare with other bricks. The thickness and density of clay brick will deaden noise transmission and will deflect noise. Then, these bricks are also very flexible in application. The fired clay bricks have high compressive strength and have good fire resistant. The fire resistance refers as the length of time a walling element to resist a fully developed fire.

Properties of clay brick:

a. Size : 215mm x 90mm x 70 mm
b. Compressive strength : > 45N/mm^2
c. Water absorption : < 8%

Sources: Clay Bricks (2009)

2.2.3 Sand Lime Brick

Sand lime bricks are produced by mixing of sand, fly ash and lime in the desired proportion depending by chemical acceleration during wet mixing. Then, the mixture will be moulded under pressure. The fly ash will react with lime at ordinary temperature and forms a compound possessing cementitious properties. After reactions between lime and fly ash occur, calcium silicate hydrates are produced which are responsible for the high strength of the compound. Bricks made by mixing of lime and fly ash, then chemically bonded bricks. Sand lime brick can also know as calcium silicate brick.

The advantages of sand lime brick are it is possessed adequate crushing strength as a load-bearing member. It has cement colour in appearance, are uniform in shape and smooth in finish and no need to do the plastering. It is also lighter in weight compared to ordinary clay brick. This sand lime bricks also a good sound insulation and fire resistances.

2.2.4 Interlocking Brick

Interlocking brick is commonly used for walkways, walls, potions and driveways. The difference between normal bricks and interlocking brick is that the pieces between brick must be adjoin at some point. Interlocking brick is like two adjoining pieces of a jigsaw puzzle. Each brick has a projection at one end and a depression on the other. The projection of each brick fit into the depression with another brick so it can fit well together. The bricks have vertical holes which have a two purpose. Firstly, the holes can reduce the amount of material required to make the block without compromising on its strength. Secondly, steel rods can be inserted and mortar poured inside the holes to increase the strength and stability. By using this method, it can save the cost because it can reduce the use of mortar.

There are many benefits by using interlocking brick such as this brick can withstand freezing and thaw because interlocking bricks are installed on a flexible base. So it can withstand freeze-thaw climates and any conditions. Secondly, this brick is more durable because it requires very little future repairs. It is also able to withstand an extremely high level of loading. Thirdly, by using the interlocking brick in the construction, it may save on labour cost, save on sand and cement used. It is also immune to termite and other insert damage.

2.2.5 Cement Sand Brick

Cement brick usually used as a building material in the construction of walls. Cement brick can divide into two types which is solid and hollow cavities, and their sides may be cast smooth or with a design. To use it, cement brick is stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall.

Advantages of cement sand brick are it a mature production technology because to the forming of bricks, high pressure is applied. So it makes the brick being low water absorption, have high density, high strength and good freezing resistance. It also has a low investment and easy to handle.

2.3 ORDINARY PORTLAND CEMENT

Cement is manufactured through a closely controlled chemical combination between calcium, silicon, aluminum, iron and other ingredients. Normally cement will be acting as a binder between materials, a substance that sets and hardens, and can bind other materials together. Cements used in construction can be divided into two, which is hydraulic and non-hydraulic because it is depending upon the ability of the cement to be used in the presence of water. For non-hydraulic cement, it will not set in wet conditions or underwater. For hydraulic cement it is made by replacing some of the cement in a mix with activated aluminium silicates, pozzolanas such as fly ash. Table 2.2 shows the types of Ordinary Portland cement. Any one of these types can be used for masonry, but Type I and II are generally used in mortar. The other types are usually used for mixing concrete.

Table 2.2: Types of Ordinary Portland cement

Type	Classification	Applications
Type I	General –purpose cement and is the one masons most often use.	Pavements, sidewalks, reinforced concrete bridge culverts, and masonry mortar.
Type II (Modified Portland Cement)	This cement hydrates at a lower heat than Type I and generates heat at a lower rate. However, have better resistance to sulfate than Type I.	Large piers, heavy abutments, and heavy retaining walls.

Type III (High-early-strength Portland Cement)	Although this cement requires as long to set as Type I, it achieves its full strength much sooner. Generally, when high strength is required in 1 to 3 days, this cement is recommended.	In cold weather when protection from freezing weather.
Type IV (Low-heat Portland Cement)	Use where the amount and rate of the heat generated must be kept to a minimum. It is critical to hold the temperature down to ensure that the concrete cures properly. Since the concrete does cure slowly, strength also develops at a slower rate. Too much heat in the hardening process causes a defective / weak concrete.	Huge masses of concrete, such as dams or large bridges.
Type V (Sulfate-resistant Portland Cement)	Used only in construction which is exposed to severe sulfate actions. It also gains strength at a slower rate than normal Portland cement	

Sources: Types of Portland cement (2008)

2.4 OIL PALM

One of the most important agricultural and commercial plantation crops in Malaysia is oil palm. The production of oil palm agricultural industry has expanded rapidly and is an important contribution to the national income. In Peninsular Malaysia, the oil palm planted area increased from 96,900 hectares in 1965 to 2.05 million hectares in 2000. In Sabah, about 38,433 hectares were planted with this crop in 1970 and with rapid expansion, the planted area rose to 1,000,777 hectares in 2000. In Sarawak, the planted area rose from 975 hectares in 1970 to 330,387 hectares in 2000 (Zahari et al., 2000).

Oil palm also known as ‘tree of life’ because all parts of the tree such as fruits, trunks, leaves, and others part can be effectively utilized for living. However, due to rapidly increasing of oil palm plantation in Malaysia, the by-product agricultural oil palm waste has been generated in excessive amount and it has been facing problems in disposing this by-product since many years ago (Sooraj, 2013).

There are several wastes of oil palm such as Oil Palm Trunk (OPT), Oil Palm Fronds (OPF), Empty Fruit Brunches (EFB), Palm Kernel Cake (PKC), Palm Oil Mill Effluent (POME), and Palm Press Fiber (PPF). In order to emphasize the usage of palm oil waste, efforts are going on to improve the use of these waste through the development of value-added product. One of the waste from the oil palm was chosen for this research which is OPF. Table 2.3 show the chemical composition of OPF in comparison with other oil palm by-product.

Table 2.3: Chemical composition of OPF in comparison with other oil palm by-product

By-products	CP	CF	NDF	ADF	EE	Ash	ME (MJ/kg)
Palm kernel cake	17.2	17.1	74.3	52.9	1.5	4.3	11.13
Palm oil mill effluent	12.5	20.1	63.0	51.8	11.7	19.5	8.37
Palm press fibre	5.4	41.2	84.5	69.3	3.5	5.3	4.21
Oil-palm fronds	4.7	38.5	78.7	55.6	2.1	3.2	5.65
Oil-palm trunks	2.8	37.6	79.8	52.4	1.1	2.8	5.95
Empty fruit bunches	3.7	48.8	81.8	61.6	3.2	-	-

Notes: CP: crude protein, CF: crude fibre, NDF: neutral detergent fibre, ADF: acid detergent fibre, EE: ether extract and ME: metabolisable energy. (Wong and Wan Zahari 1992; Wan Zahari et.al., 2000)

Source: Zahari et al. (2000)

2.4.1 Oil Palm Frond (OPF)

The OPF are one of the main waste of the oil palm industry in Malaysia. About 26 million metric tonnes of OPF are produced on dry matter basis annually during purring and replanting operations in the plantation (Zahari et al., 2000). So, it is always available daily throughout in every year. On an annual basis, about 24 fronds are pruned per palm tree and the weight of fronds varies considerably with age of the palm, with an average annual pruning of 82.5kg of fronds/palm/year (Zahari et al., 2000). Figure 2.1 shows the fresh OPF collected from the tree.

Figure 2.1: Fresh OPF collected from tree.

The dry matter content of OPF is about 31.0% and in vitro digestibility of dry matter of leaves and petioles was uniform throughout the length of the fronds with mean values of 35.6% (Zahari et al., 2000). The moisture content of chopped fresh OPF was 58.65 and the density value was 0.27 (Zahari et al., 2000). Table 2.4 shows the estimated availability of OPF in Malaysia. OPF has the great potential to be utilized as an alternative material in the production of bricks due to its abundant availability. Due to limited usage and less commercialization on it, lack of research work attempted on the OPF as compared with other oil palm wastes.

Table 2.4: Estimated availability of OPF (matric tones, dry matter basis) in Malaysia.

Year	Oil palm fronds production		Total
	Replanting	Pruning	
1990	0.25	16.92	18.49
1992	0.64	17.64	21.67
1994	0.88	17.89	22.37
1996	0.83	19.09	24.28
1998	1.42	18.18	27.08
2000	1.34	17.85	26.21

(Mohamad, H. et al., 1986)

Source: Zahari et al. (2000)

2.5 COMPRESSION TEST

The compression test is the most common parameter used to describe the performance of every concrete. Based on the test results, (Alida el al., 2013) concluded that the adding of OPT fiber can contribute the increase of the compressive strength, but the strength does not increase linearly with the fiber content. It means that the compressive strength of the brick will only increase up to certain fiber content. Small amount of fiber content can be dispersed well in cement composite and thus increase the density of cement composite and this will then increase the compressive strength. The decrease in compressive strength when up to certain fiber content may be caused by the creation of air void within the mixture with relatively high fiber content. According to Ismail. M (2010), the reason of fall to strength because of cement paste is less and the consequence could be that of weak bonds especially around the alternative particles with eventual early crack development during compressive tests.

Besides that, (Noorsaidi et al., 2010) the compressive strength of OPT fiber bricks was lower compared with the compressive strength of OPFB fiber bricks. The moisture content of the constituent of materials and fibers influence the compressive strength of the bricks. It is believed that the present of porosity in the bricks was influenced by the presence of moisture content in the constituent materials and fibers. Therefore, the bricks which contained high moisture content will reduce the strength of the bricks. The increase of fiber content may reduce the volume proportion of matrix mix and causes a decreasing in compressive strength. Moreover, the strength of a specimen decreases when too much of POFA in the mix. Evidently, replacement of 40% and 50% POFA cause the strength of concrete to decrease since the amount of Portland cement was greatly reduced. This is because the lower content of calcium oxide in POFA which is important for strength development tends to limit the use of ash (Muthusamy, el al., 2014).

2.6 DENSITY TEST

According to research done by (Liyana el al., 2010), the relative density of the concrete POFA was lower than the standard control specimens. This is because the weight of POFA is lighter than the weight of cement at the rate equal volume. Based on the research done by (Alida el al., 2013), the density of the specimen will decrease with the additional of OPT fiber. The mass of the specimens is the factor that will be affected the density and the mass is decreased with the increasing of fiber content. Specimen with fiber are found to be lighter because there is some portion of fine aggregate are replaced by fibers which have lower mass or density compared to fine aggregate whereas the control specimens are denser because it is prepare by 100% of fine aggregate. Higher fiber content gives higher void volume and thus lowers the density. The strength depends on the stiffness and density of course aggregates. Generally, lower density causes lower strength.

(Sobuz el al., 2014) reports that the increased percentage of OPS lower the density of concrete, hence, giving less compressive strength. Based on the research done by (Noorsaidi et al., 2010), the density of the bricks with OPT fibers was lower than bricks with OPFB fibers. This is because of the OPT fibers had a bigger width than the width of OPFB fibers. Therefore, the OPT fibers had displaced more heavy constituent materials, resulted in a lower density of OPT fiber bricks.

2.7 WATER ABSORPTION TEST

According to research, (Weeachart el al., 2007) oil palm has large particles with high porosity which result an increasing in the water-to-binder ratio of concrete and resulting an increasing water absorption of the sample. Based on the research done by (Alida el al., 2013), the additional of OPT fiber into the cement composite lead to increase in water absorption and it is increased linearly with the increasing of fiber content. As predicted, the control specimens show the lower average percentage (0.178%) of water absorption whereas specimens with 6% OPT fiber give the highest average percentage (0.796%) of water absorption. It is expected that specimens with OPT fiber are having a higher percentage of water absorption as compared to control specimens. Increase of water absorption of specimen with OPT fiber can be related to impurities and the void volume within the specimens. Thus, the increasing of fiber content will increase the impurities, void volume and the water absorption. In this research, the water ratio is fixed for the specimen preparation and the increasing of moisture content can be related to the water absorbing characteristic of fiber and extends exposure to moisture. Increase of fiber content will increase the water absorbed by the composite and thus increase the moisture content.

Besides that, (Noorsaidi et al., 2010) the moisture content of OPT was higher than OPFB fibers. It is believed that the OPT fibers were more porous and permeable. The porosity of the bricks was influenced by the presence of moisture content in the constituent materials and fibers. The moisture content caused the high porosity in bricks. The constituent materials and fibers that have more moisture content contribute to the porosity of the bricks and consequently reduce the strength of the bricks.

2.8 CONCLUSION

From all literature review, it can be concluded that the compressive strength of bricks will decreased as the percentage of the fiber content increased in the mix ratio. In addition, the density of bricks also was decreased with the additional of fiber content and it is decreasing linearly with the increasing of fiber content. The percentage of water absorption also increasing linearly with the increasing of fiber content. Besides that, it is found that additional of excessive of fiber content in brick will decrease the compressive strength and continues to increase the water absorption hence decrease the density.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss in detail the process of manufacturing OPF cement sand brick. There are one ratio of plain cement sand brick (standard control brick) and three different ratio of OPF used in manufacturing of cement sand brick. All the brick were prepared for compression test, density test and water absorption test. All the OPF cement sand brick specimen will compare with plain cement sand brick (standard control brick).

3.2 CONCEPTUAL FRAMEWORK OF RESEARCH

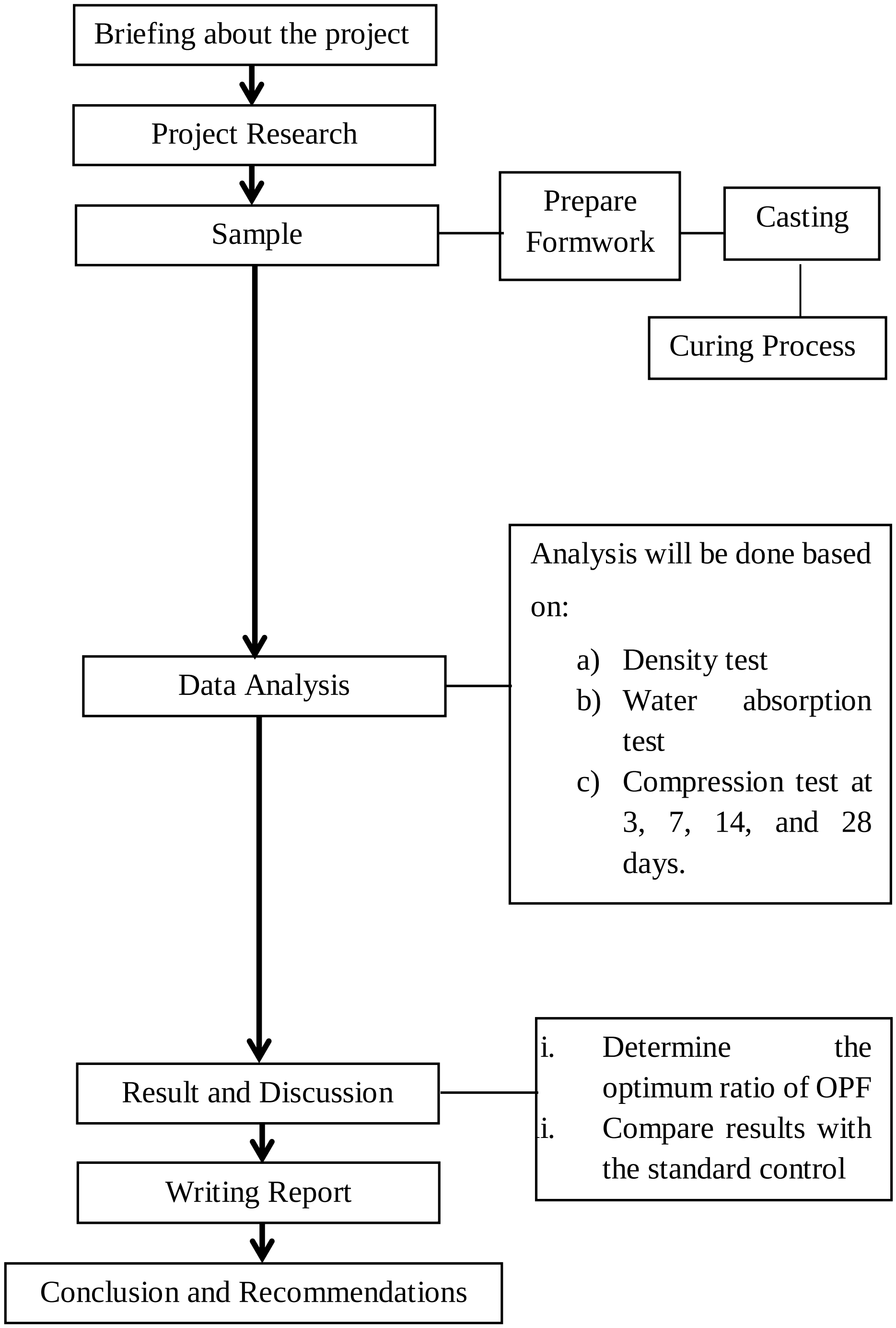

Figure 3.1: Conceptual framework of research

3.3 MATERIALS USED

In order to make OPF cement sand brick, it is consist of Ordinary Portland cement, sand, OPF and plain water.

3.3.1 Ordinary Portland cement

Ordinary Portland cement is the most common important materials used and one of the primarily material to manufacturing OPF cement sand brick and plain cement sand brick. The Ordinary Portland cement used was type I Portland cement as followed the ASTM C150 (2005).

3.3.2 Fine Aggregate

Fine aggregate used for manufacturing of OPF cement sand brick is river sand. River sand is used in manufacturing of OPF cement sand brick and plain cement sand brick (standard control brick).

3.3.3 Oil Palm Frond (OPF)

The OPF was used in this research collected from Bandar Tasik Puteri Rawang, Selangor Darul Ehsan. Before all the fresh OPF being used, all the fresh OPF was cut into smaller size using a cutter into a small piece around 2-3 cm in length. Then, all fresh OPF is dried under the sun. Figure 3.2 shown the **v**arious shapes of OPF after dry process.

Figure 3.2: Various shapes of OPF after dry process

The OPF is dried under the sun to eliminate the moisture content within the fronds. The purposes of drying the OPF also want to prevent the growth of microorganisms or fungus. Drying of OPF took minimum 24 hours to ensure all the moisture content had been eliminated. Figure 3.3 shows OPF before dried.

Figure 3.3: OPF before dried.

3.3.4 Water

In this study, the water ratio is fixed for the specimen preparation of all three difference ratio of OPF cement sand bricks. But, based on the observation during the casting process, the fresh concrete mix for OPF cement sand brick become a bit dry compare to plain cement sand brick mix. This situation can be related to increasing moisture content and water absorbing characteristic of OPF fiber.

3.4 PREPARATION OF SPECIMENS

Below is the calculation of specimen. For the specimen preparation, fine aggregate, cement, OPF and water were first weighted according to the proportion.

Size of mold = 225mm x 113 mm x 75 mm
Mold weight = 706.83 g

Sand + mold = 3847.01 g
Sand = 3140.18 g

Cement + mold =3513.81 g
Cement = 2806.98 g

OPF + mold = 1109.01 g
OPF = 402.18 g

Volume of brick = 225mm x 113 mm x 75 mm
= 0.0019 m^3

Cement = $\frac{2.806\ kg}{0.0019\ m^3}$ = 1476.64 kg/m^3

Sand = $\frac{3.140\ kg}{0.0019\ m^3}$ = 1652.63 kg/m^3

OPF = $\frac{0.402\ kg}{0.0019\ m^3}$ = 211.58 kg/m^3

Total volume sample = 0.0019 m^3 x 30 sample

= 0.057 m^3

1: 6 = $\frac{0.057m^3}{7}$ = 0.008143 m^3

3.4.1 Mix Proportion

There are two types of mixes has been used in this research that is plain cement sand brick specimen as standard control sample and OPF cement sand brick specimens. For the plain cement sand brick, the materials used consist of cement, sand and plain water. Then, three mixes of OPF cement sand brick which is consist mixture of cement, sand, plain water and OPF fiber. For plain cement sand brick (standard control sample) the mix proportions use are 1: 6 by volume of cement, sand and plain water. For the OPF cement sand bricks, the material use are three difference ratio of OPF fiber, cement, sand plain water. There are three mix proportions of OPF cement sand brick which are 1:5:1, 1:4.5:1.5, and 1:4:2 by volume of cement, sand and OPF fiber. Table 3.1 show mix proportions ratio of 1:5:1, Table 3.2 show mix proportions ratio of 1: 4.5: 1.5 and Table 3.3 show mix proportions ratio of 1:4:2.

Table 3.1: Mix proportions ratio of 1:5: 1

	Cement	Sand	OPF
Volume	0.008143 m^3	0.04071 m^3	0.008143 m^3
Weight	14.4 kg	80.4 kg	2.06 kg
1 sample			0.069 kg

Table 3.2: Mix proportions ratio of 1:4.5:1.5.

	Cement	Sand	OPF
Volume	0.008143 m^3	0.03664 m^3	0.01221m^3
Weight	14.4 kg	72 kg	3.1 kg
1 sample			0.100 kg

Table 3.3: Mix proportions ratio of 1:4:2.

	Cement	Sand	OPF
Volume	0.008143 m^3	0.03257 m^3	0.01629 m^3
Weight	14.4 kg	64.77 kg	4.08 kg
1 sample			0.136 kg

3.4.2 Number of Specimen

For plain cement sand brick (standard control sample), it has 18 specimens. For OPF bricks it has 30 bricks. All this brick was used for compression test, water absorption test and density test. Table 3.4 shows the total number of specimens according to the ratio.

Table 3.4: Total number of specimens according to the ratio.

Ratio	Number of specimens
1:5:1.	30
1:4.5:1.5	30
1:4:2.	30

3.4.3 Size of Specimen

This size of OPF cement sand bricks is 225mm x 113mm x 75mm. Table 3.5 shows the nominal size of cement sand bricks according to a Standard Specification for Building Work 2005, PWD. Figure 3.4 shows the plywood mold use for casting the brick.

Figure 3.4: The plywood mold use for casting the brick

Table 3.5: Nominal size of cement sand bricks according to Standard Specification for Building Work 2005, PWD.

Length (mm)	Width (mm)	Depth (mm)
225 ± 3.2	113 ± 1.6	75 ± 1.6

3.4.4 Mixture Process

The constituents of OPF cement sand brick are cement, sand, OPF fiber and plain water. For the specimen preparation, all materials used such as cement, sand, OPF fiber and plain water were first weighted according to the proportion in Table 3.1, Table 3.2 and Table 3.3. After that, the weighted sand and cement were then mixed dry in a pale until a homogeneous color of the mixture was formed. Then, the weighted of water was then added slowly into the mixture to avoid balling effect and the mixture was mixed until homogeneous slurry formed. After all the mixture mixed well, OPF fiber were added separately for each sample as according to the ratio. After all the OPF fiber were added into the mixture, continuous to mix until homogeneous mixture was formed. After all the mixtures mix well together, all the mixture was poured into the molds. Then, the mold was compacted to remove the air void. Compaction is a process of removing the entrapped air in the fresh concrete. If the fresh concrete does not expel the air void, it will result into honeycomb went the concrete is hard and it will reduce the strength of the concrete.

3.4.5 Mold and Curing Process

After all the wet mix was transferred into the molds, the mixture was compacted. The wet mix was kept in the mold for 24 hours and all the mold was covered with wet gunny to reduce losing the moisture content of the mixture. By placing the wet gunny onto the specimen, it may reduce the period of hydration of the specimens. If the curing process is neglected, it may affect the quality of the specimens. After that, the specimens formed were then being unmolded. All the brick was collected and marked speared according to the testing and curing process.

For all the compression test specimens, the specimens have been cured through air curing method through 3, 7, 14 and 28 days. The air curing method is chosen for this testing because to avoid the growth of microorganisms or fungus. Air curing method is a curing method where the specimens are left in open air to be cured at room temperature. All specimens for density test and the water absorption test were submerged into the water for curing process according to the procedure of the testing. The best curing method for concrete specimen is by the using water curing method because it satisfies all the requirements of curing which is for promotion of hydration, to eliminate of shrinkage and absorption of the heat of hydration. But it depends on the situation and the material used in the concrete.

3.5. COMPRESSION TEST

Compression test of brick mixes made with and without of OPF fiber was determined at 3,7,14 and 28 days. The compression tests on the OPF cement sand bricks were performed according to ASTM C 39-03 by using compressive strength machines.

3.6 DENSITY TEST

After all the specimen have been cured in the curing tank through 7 days, densities of each specimens are then determined. Densities of the four samples were determined, which the average is taken to determine the actual density of each sample. Function of density test is to determine the porosity and density of the bricks. This tests was performed according to ASTM C373-88. Precaution during handling this testing are used hand glove while removing the brick from the oven.

3.7 WATER ABSORPTION TEST

The water absorption test is to determine the percentage of water absorption of the brick specimens. This test helps in determining the amount of water which can be absorbed by the brick specimens. Normally, the value of water absorption is largely influenced the bond between brick and green material used. If water absorption in bricks is high and bricks are not soaked before it used, the water from freshly mortar is likely to be absorbed by the bricks. Precaution during handling this testing are use hand glove while removing the brick from the oven.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 INTRODUCTION

This chapter will show results of compression test, density test and water absorption test. All brick for compression test were tested on day 3,7,14 and 28. For density test, all the data were collected on day 14 and for in the water absorption test data were collected on day 14 and 15.

4.2 COMPRESSION TEST

The compression test results for plain cement sand brick as a standard control (OPF0), mix proportion 1:5:1 (OPF1.0), 1:4.5:1.5 (OPF1.5), and 1:4:2 (OPF2.0) as shown in Table 4.1 and Figure 4.1. For plain cement sand brick (OPF0), compressive strength data obtained on day 3 is 7.180 Mpa, day 7 is 7.364 Mpa, day 14 is 7.785 Mpa and on the day 28 is 8.330 Mpa. For OPF cement sand brick with mix proportion 1:5:1 (OPF1.0), compressive strength data obtained on day 3 is 4.284 Mpa, day 7 is 6.301 Mpa, day 14 is 7.062 Mpa and on the day 28 days is 8.000 Mpa. For OPF cement sand brick with mix proportion 1:4.5:1.5 (OPF1.5), compressive strength data obtained on day 3 is 3.229 Mpa, day 7 is 5.823 Mpa, day 14 is 6.959 Mpa and on the day 28 is 7.732 Mpa. For OPF cement sand brick with mix proportion 1:4:2 (OPF2.0), compressive strength data obtained on day 3 is 2.474 Mpa, day 7 is 4.792 Mpa, day 14 is 6.286 Mpa and on the day 28 is 6.424 Mpa.

Table 4.1: Compression Test Result

Sample	Day 3 (Mpa)	Day 7 (Mpa)	Day 14 (Mpa)	Day 28 (Mpa)
OPF0	7.180	7.364	7.785	8.330
OPF1.0	4.284	6.301	7.062	8.000
OPF1.5	3.229	5.823	6.959	7.732
OPF2.0	2.474	4.792	6.286	6.424

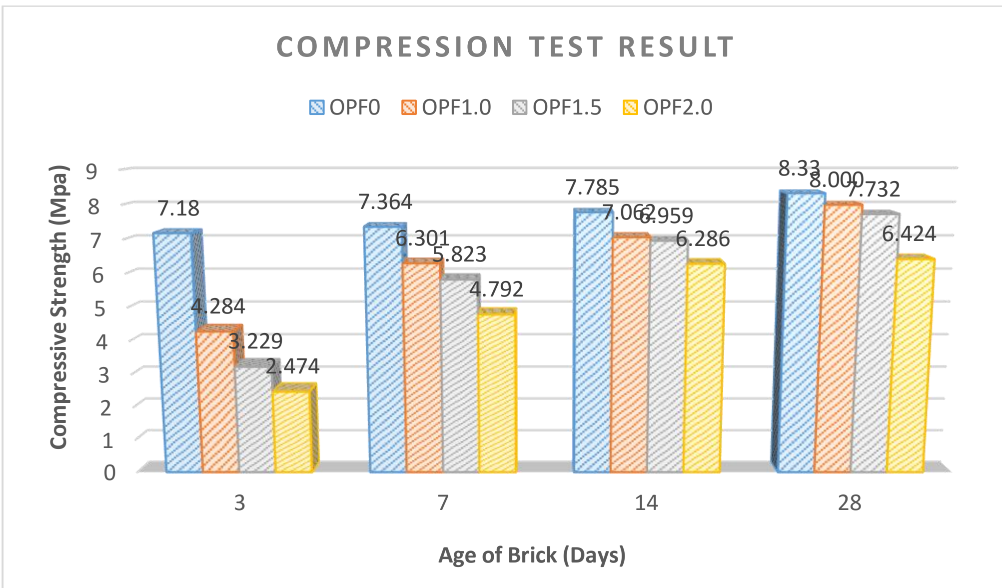

Figure 4.1: Compression Test Result

Generally, the compressive strength values were observed to decrease as the ratio of OPF fiber content increases. However, there was a continuous increase in strength with time. Based on the result, it was clearly shown that the compressive strength of OPF1.0, OPF1.5 and OPF2.0 is decreased gradually due to the increase ratio of OPF fiber content. The plain cement sand brick (OPF0) has the highest compressive strength values compared with the other three mix proportion. This can be attributed to the fact that since the plain cement sand brick (OPF0) is denser than the other three mix, the strength of the brick were decreased as the OPF fiber content increases. OPF1.0 shows a higher compressive strength compared to the other two mix proportion as shown in Figure 4.1. OPF2.0 shows the lowest compressive strength result. The decrease in compressive strength may be caused by the creation of air void within the mixture with relatively high fiber content.

Table 4.2: Compression Test Result of OPF1.0 and OPF1.5

Sample	Day 3 (Mpa)	Day 7 (Mpa)	Day 14 (Mpa)	Day 28 (Mpa)
OPF1.0	4.284	6.301	7.062	8.000
OPF1.5	3.229	5.823	6.959	7.732

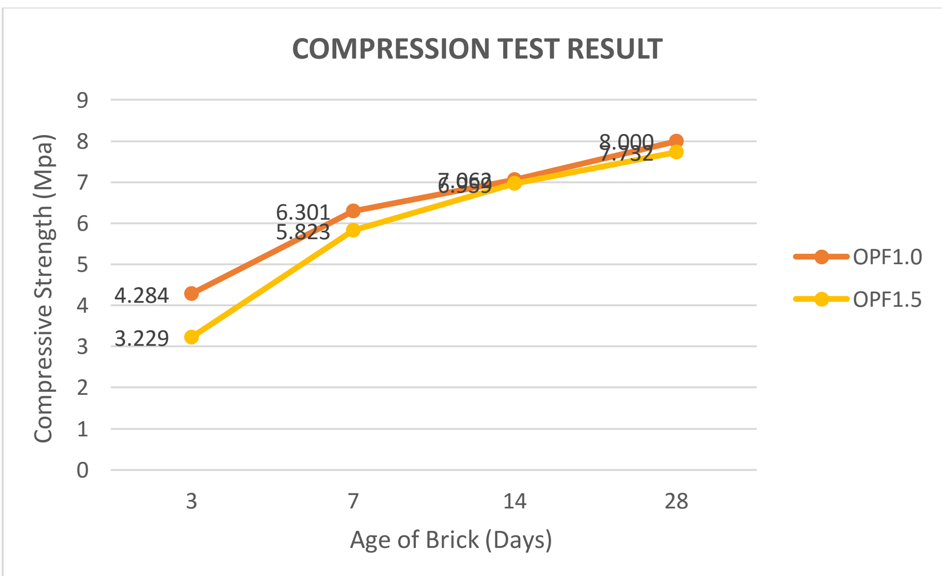

Figure 4.2: Compression Test Result of OPF1.0 and OPF1.5

Table 4.2 and Figure 4.2 show the development of compressive strength of brick between OPF1.0 and OPF1.5. It is clearly shown that the decrease of compressive strength result linearly with increase of OPF fiber content in the mix. From the Figure 4.2, it is clearly shown that at days 14 and 28, the compressive strength is more and less with each other. It means that a small amount of fiber content can be dispersed well in the mix and this will then increase the compressive strength of the brick.

Table 4.3: Compression Test Result of OPF1.5 and OPF2.0

Sample	Day 3 (Mpa)	Day 7 (Mpa)	Day 14 (Mpa)	Day 28 (Mpa)
OPF1.5	3.229	5.823	6.959	7.732
OPF2.0	2.474	4.792	6.286	6.424

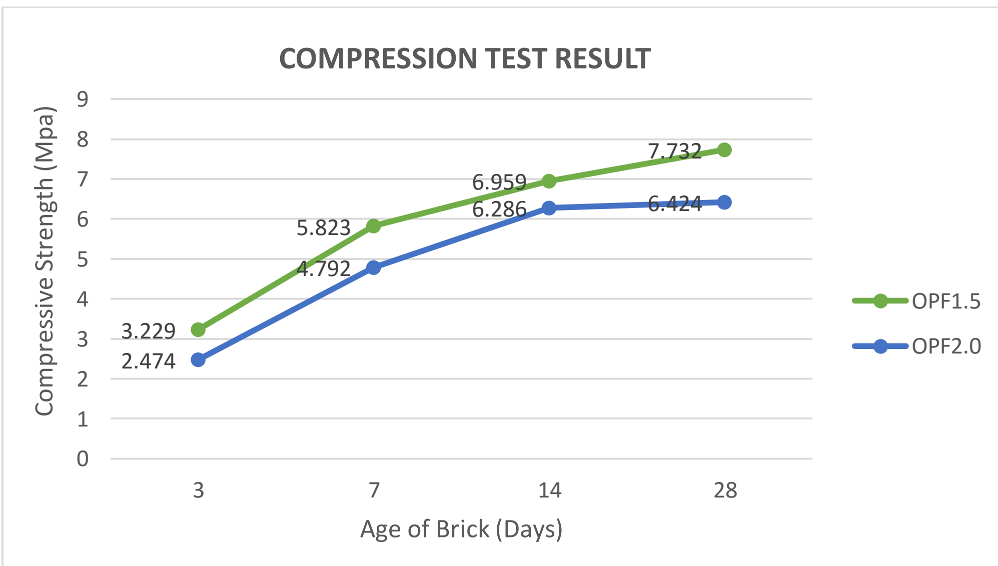

Figure 4.3: Compression Test Result of OPF1.5 and OPF2.0

Table 4.3 and Figure 4.3 show the development of compressive strength of bricks with age for OPF1.5 and OPF2.0. It is clearly shown that compressive strength of OPF1.5 and OPF2.0 is gradually dropped with increase of OPF fiber content.

It can be concluded that the compressive failure of the brick was mainly caused by the failure in the bond between the cement paste and the OPF fiber, where the crack path goes around the OPF fiber. The bond between OPF fiber and cement paste were not as strong as that of standard control. The reduction in strength could be attributed as a result of the highly irregular shapes of the OPF fiber, which prevent full compaction and give affected to the strength of the concrete. This result is also supported by Alida, (2013), although adding of materials does contribute to increase the compressive strength, but the strength does not increase linearly with the fiber content. In the other hand, the compressive strength only increases up to certain fiber content. An increase in fiber content may also lead to reduce the bonding between materials. In other words, increase of fiber content may reduce the volume proportion of matrix mix and cause a decreasing in compressive strength.

4.3 DENSITY TEST

Table 4.4 shows the average density of bricks with respect to OPF fiber content. The density of bricks were decreased with the additional of OPF fiber content and it is decreasing linearly with the increasing of OPF fiber content. From the result, it was known that the brick density will be reduced as the amount of OPF fiber content increases.

Table 4.4: Density Test Result

Sample	Density (kg/m³)
OPF0	1782.8
OPF1.0	1658.08
OPF1.5	1592.53
OPF2.0	1590.42

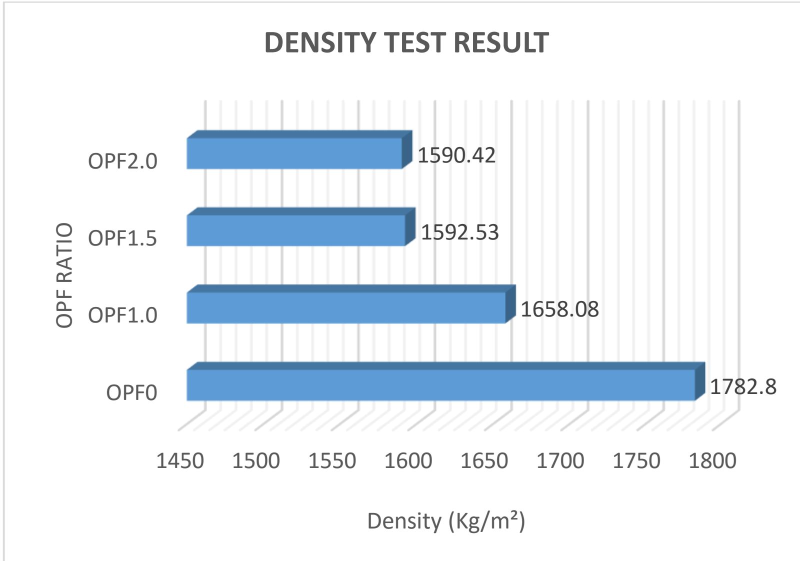

Figure 4.4: Effect of Fiber Content on Density Test

As illustrated in Figure 4.4, it clearly demonstrates that there is a reduction of density with increased of OPF fiber content. The standard control bricks (OPS0) show the highest density with the average of 1782.8 kg/m³. As predicted, the relative density of all OPF bricks was lower than the standard control bricks. The average density of bricks for OPF1.0 is reduced to 1658.08 kg/m³ and continuous to decrease with the increasing of OPF fiber content. Bricks for OPF2.0 give the lower density with the average of 1590.42 kg/m³. The difference average density of bricks between OPF1.0 with standard control bricks (OPF0) is 124.72 kg/m^3. Followed by the difference average density between OPF1.5 with standard control bricks (OPF0) is 190.27 kg/m^3. The difference average density between OPF2.0 with the standard control bricks (OPF0) is 192.38 kg/m^3. The difference average density between OPF1.5 with OPF2.0 is 2.11 kg/m^3. It showed that very little changed in density between OPF1.5 and OPF2.0.

Generally, the mass of the bricks is the factor that affected the density and the mass is decreased with the increasing of OPF fiber content. This result is also supported by Alida, (2013), which is specimens with fiber content are found to be lighter because there is some portion of sand are replaced by fibers which have lower mass or density compared to sand whereas the control specimens are denser because it prepared by 100% of sand.

4.4 WATER ABSORPTION

Figure 4.5 shows the average water absorption with respect to OPF fiber content. From the Table 4.5, it shows that additional of OPF fiber content into the mix leads to increase in water absorption of the bricks. In this research, all the bricks with OPF fiber content show a significant increase in water absorption. In addition, the percentage of water absorption increasing linearly with the increasing of fiber content.

Table 4.5: Water Absorption Test Result

Sample	Water Absorption (%)
OPF0	10.73
OPF1.0	9.83
OPF1.5	11.73
OPF2.0	11.81

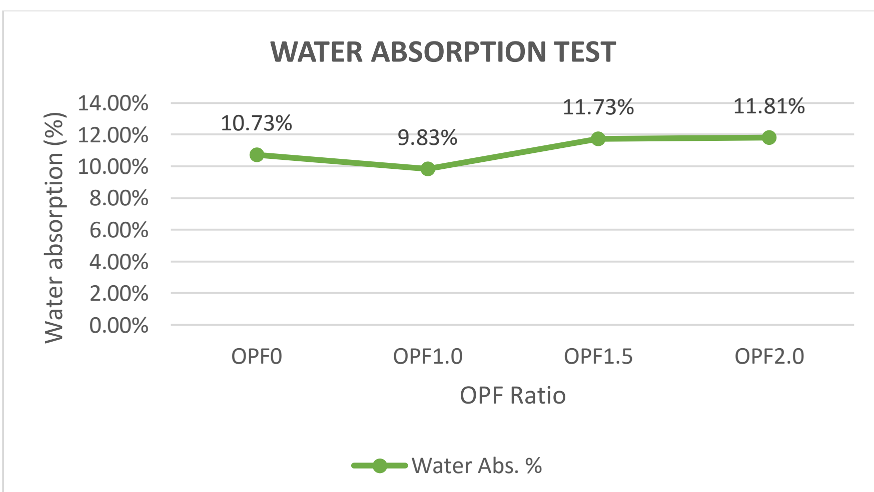

Figure 4.5: Water Absorption Verses OPF Ratio

Table 4.5 and Figure 4.5 shows the average water absorption result. From the Figure 4.5, it shows that OPF1.0 give the lower average percentage of water absorption which is 9.83%, whereas OPF2.0 give the highest average percentage of water absorption (11.81%). The different average of water absorption between OPF1.0 with standard control bricks (OPF0) is 0.9%. The different average of water absorption between OPF1.5 with standard control bricks (OPF0) is 1.0% and the different average of water absorption between OPF2.0 with standard control bricks (OPF0) is 1.08%. The different average of water absorption between OPF1.0 with OPF1.5 is 1.9%. This result shows the largest difference average of water absorption. The increasing of air void within the materials is one of the factors contributed the increase of water absorption of the bricks. The different average water absorption between OPF1.5 with OPF2.0 is 0.08%. It shows very little difference in water absorption between this two mix proportions.

Generally, increase of fiber content will increase the water absorbed by the composite and thus increase the moisture content of the brick. This result is also supported by Noorsaidi.M, (2010), which the water absorption of bricks with fiber content was higher water absorption because the fibers were more porous and permeable.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION.

As conclusion, all the objectives of this research were successfully accomplished and achieved. From this research, it was found that OPF fiber can be used as one of the main material in production of cement sand brick because it has good potential and it is also can be an alternative materials in the construction industry. By use OPF fiber it is also may help to reduce the consumption of nonrenewable resources and minimize the OPF to be thrown away in landfills. Based on this research, the following conclusions can be drawn.

As according to Standard Specifications for Building Works, the minimum permissible average compressive strength of the brick shall be 5.2 Mpa. In general, compressive strength for OPF1.0, OPF1.5 and OPF2.0 at 28 days reaching up to 5.2Mpa, which satisfies the requirement for brick strength according to standard. It was found that, OPF1.0 give the highest compressive strength at 28 days which reaching up to 8.000 Mpa. For OPF1.0 and OPF1.5 at 14 and 28 days the compressive strength is more and less with each other, but still able to bear the load. All compressive strength for OPF1.0, OPF1.5 and OPF2.0 are gradually dropped with increasing of OPF fiber content. For density test result, OPF1.0 give satisfies average density which is 1658.08 kg/m^3 and it keeps decreasing as increases the amount of OPF fiber content in the bricks. For water absorption test result, OPF1.0 contribute the lowest water absorption than the standard control which is 9.83%.

It is expected that bricks with the OPF fiber content are a having a higher percentage of water absorption as compared to standard control bricks.

From all testing results it can be concluded that the optimum ratio of OPF cement sand brick is OPF1.0 with mix proportion used was 1:5:1. From the result, OPF1.0 contributed to the highest compressive strength. This compressive strength is more and less with strength of standard control brick. It also has an acceptable average density and the lowest water absorption. The creation of another alternative construction material combined with OPF is expected able to reduce this agriculture waste material dumped at landfill which result in more environmentally friendly industry.

5.2 RECOMMENDATIONS

Among recommendations that can be made to improve this research is by reducing the size of OPF so that it is easier to do compaction process during the casting process of the brick. Secondly, OPF fiber must be completely dried up to prevent the growth of fungus because it will cause damage on OPF fiber or the other alternative, all the OPF fiber must be do chemical treatment process. If OPF fiber is not being dried properly, it will cause the growth of fungus during curing process either by air curing and water curing method. The last recommendation to increase strength of brick, the usage of plasticizers can be used into the mixture.

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Appendix A

Raw Data of Standard Control Brick

Data for Compression Test for Cement Sand Brick

Compression Test Result For OPF0				
Day / Sample	Day 3 (Mpa)	Day 7 (Mpa)	Day 14 (Mpa)	Day 28 (Mpa)
1	7.109	7.555	7.769	7.970
2	7.723	7.768	7.986	8.250
3	6.709	6.769	7.601	8.770

Data for Density Test for Cement Sand Brick

Density Test for OPF0	
Sample	Oven (g)
1	1760.69
2	1786.52
3	1801.19

Data for Water Absorption Test for Cement Sand Brick

Water Absorption Test Result for OPF0		
Sample	Oven (g)	Submerge 24 hours (g)
1	1753.66	1938.05
2	1747.89	1933.02
3	1731.75	1923.40

Appendix B

Raw Data of Parameters Obtained for Each Testing

Data for Compression Test for OPF Cement Sand Brick

Compression Test Result For OPF1.0 (Ratio 1.0)				
Day / Sample	**Day 3 (Mpa)**	**Day 7 (Mpa)**	**Day 14 (Mpa)**	**Day 28 (Mpa)**
1	6.666	5.326	7.023	8.722
2	1.644	7.070	6.630	7.714
3	3.564	5.100	6.660	7.763
4	3.115	6.973	7.410	8.230
5	6.427	7.064	7.589	7.569

Compression Test Result For OPF1.5 (Ratio 1.5)				
Day / Sample	**Day 3 (Mpa)**	**Day 7 (Mpa)**	**Day 14 (Mpa)**	**Day 28 (Mpa)**
1	4.371	4.910	7.507	6.771
2	4.433	5.260	6.000	7.770
3	1.318	7.004	7.143	8.010
4	3.425	6.470	7.220	7.889
5	2.597	5.471	6.924	8.222

Compression Test Result For OPF2.0 (Ratio 2.0)				
Day / Sample	**Day 3 (Mpa)**	**Day 7 (Mpa)**	**Day 14 (Mpa)**	**Day 28 (Mpa)**
1	3.241	6.795	6.360	7.900
2	3.920	4.256	7.310	7.562
3	1.508	5.796	6.877	6.090
4	2.652	3.938	6.050	5.494
5	1.050	3.173	4.831	5.075

Data for Density Test for OPF Cement Sand Brick

Density Test Result for OPF1.0 (Ratio 1.0)	
Sample	**Oven (g)**
1	2968.49
2	3072.86
3	3212.14
4	3394.15

Density Test Result for OPF1.5 (Ratio 1.5)	
Sample	**Oven (g)**
1	3539.37
2	3473.75
3	3844.33
4	3767.75

Density Test Result for OPF2.0 (Ratio 2.0)	
Sample	**Oven (g)**
1	2886.34
2	3189.71
3	3013.89
4	3043.73

Data for Water Absorption Test for OPF Cement Sand Brick

Water Absorption Test Result for OPF1.0 (Ratio 1.0)		
Sample	**Oven (g)**	**Submerge 24 hours (g)**
1	2767.39	3025.41
2	2495.49	2743.12
3	2648.50	2900.86
4	2452.21	2711.13

Water Absorption Test Result for OPF1.5 (Ratio 1.5)		
Sample	**Oven (g)**	**Submerge 24 hours (g)**
1	3269.11	3658.77
2	3453.73	3828.05
3	3205.64	3552.29
4	2570.43	2913.74

Water Absorption Test Result for OPF2.0 (Ratio 2.0)		
Sample	**Oven (g)**	**Submerge 24 hours (g)**
1	3016.29	3380.75
2	3051.06	3403.95
3	3384.05	3783.50
4	3231.16	3611.66