EXPERIMENTAL STUDY OF PROPERTIES FOR SAND BRICK WITH PALM OIL CLINKER AS PARTIAL REPLACEMENT FOR FINE AGGREGATE WITH RATIO OF 5%, 10% AND 15%

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Project submitted in fulfillment of the requirements
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ABSTRAK

Industri kelapa sawit di Malaysia menghasilkan berjuta-juta ton sisa industri dan sisa-sisa ini telah menyebabkan masalah penyimpanan dan alam sekitar yang besar. Oleh itu, eksperimen telah dijalankan untuk menyiasat keberkesanan klinker kelapa sawit (POC), iaitu penghasilan daripada industri kelapa sawit sebagai pengganti separa untuk agregat halus di dalam sifat-sifat bata pasir. Empat jenis sampel yang mempunyai peratusan klinker kelapa sawit yang berbeza iaitu 0%, 5%, 10% and 15% telah disediakan. Dalam kajian ini, terdapat dua jenis pengawetan iaitu pengawetan air dan pengawetan udara dan semua sampel ini akan diuji dalam masa 3, 7, 14 dan 28 hari. Sifat-sifat mekanikal yang berbeza yang dikaji di dalam kajian ini termasuklah kekuatan mampatan, kekuatan lenturan, ketumpatan dan penyerapan air. Bata pasir yang diganti dengan POC kemudiannya dibandingkan dengan bata pasir biasa. Hasil kajian ini menunjukkan bahawa penggantian dengan 15% klinker kelapa sawit mempunyai kekuatan mampatan, kekuatan lenturan, ketumpatan dan penyerapan air yang terbaik. Ketumpatan dan penyerapan air terhadap bata pasir semakin bertambah apabila klinker kelapa sawit digunakan sebagai penggantian separa. Pada keseluruhannya, kajian ini menunjukkan bahawa POC boleh digunakan sebagai pengganti separa untuk agregat halus di dalam pengeluaran bata pasir dan juga boleh digunakan untuk aplikasi tanpa galas beban. Ia juga menunjukkan bahawa penggunaan klinker kelapa sawit di dalam pengeluaran bata pasir boleh mengurangkan sisa-sisa ini dan mempromosikan kelestarian alam sekitar.

ABSTRACT

In Malaysia, the palm oil industry produces millions of tonnes of industrial wastes and these wastes create huge storage and environmental problems. Thus, experimental work has been conducted in order to investigate the effectiveness of palm oil clinker (POC), a by-product from palm oil industry as partial replacement for fine aggregate in the properties of sand brick. The four types of samples with different percentages of palm oil clinker which are 0%, 5%, 10% and 15% had been prepared. In this study, there were two types of curing which are water curing and air curing and all specimens were cured for the 3, 7, 14 and 28 days. Different mechanical properties were studies including compressive strength, flexural strength, density and water absorption. The sand brick with POC replacement then were compared with normal sand brick. The result of this study indicates that replacement with 15% of palm oil clinker was the best compression strength, flexural strength, density and water absorption. The density and water absorption of the sand brick were increase slightly when the palm oil clinker used as partial replacement. On overall, the study indicates that POC can be used as partial replacement for fine aggregate in the production of sand brick and also can be used for non load bearing application. It also noted that the using of palm oil clinker in the production of sand brick can manage the waste and promote the environmental sustainability.

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A	Cross sectional area
C	Compressive strength
M	Mass of specimen
V	Volume of specimen
W	Maximum load indicated by testing machine
ρ	Density

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
CPO	Crude palm oil
FFB	Fresh fruit bunch
JKR	Jabatan Kerja Raya
MPOB	Malaysian Palm Oil Board
MS	Malaysian Standard
OF	Oil palm fruit
OPS	Oil palm shell
PF	Pineapple leaves
POC	Palm oil clinker
SSD	Saturated surface dry
VSI	Vertical shaft impactor
XRF	X-ray Fluorescene

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Sustainable development was defined as the development that meets the needs of the present without the ability of future generation to meet their own needs. It consist three main aspects which are socio-economic development, cultural issues and environment protection (Marhani, Jaapar, Bari, & Zawawi, 2013). Waste material such as an industrial by-product has been attracted by researchers as a replacement for natural aggregates or cement in brick making.

Malaysia is one of the main producers of palm oil in Asia and the second country in the world that produce the largest palm oil which is contribute more than half of the world's palm oil annually (Abutaha, Abdul Razak, & Kanadasan, 2016). The by-product waste that produced from burning of palm oil fiber and oil palm shell inside the boiler under the high temperature was called as palm oil clinker (Arunima & Sreelekshmi, 2016). Due to the properties of palm oil clinker was similar to natural aggregates, it has been classified as an artificial aggregate (Ariffin, 2016). According to MPOB 2013, about 19.22 million tonnes of crude palm oil (CPO) were produced and its production increase to 2.3% compare to the previous years (Kanadasan & Razak, 2015). The palm oil clinker particles were physically flaky, porous, greyish in colour and irregularly shaped with rough and spiky broken edges (Fadil et al., 2012). Therefore, it was important to start the effort to utilize the palm oil clinker in brick making to minimize the environmental pollution and problems caused by dumping these wastes at the landfills (Abutaha, Abdul Razak, & Kanadasan, 2016). Its application can be used for filler material, aggregate and non load bearing application (Abutaha & Razak, 2017).

1.2 PROBLEM STATEMENT

The amount of the wastes and industrial by-product were getting higher for every year. This can contribute to the serious environmental problems due to the disposal of these wastes to the landfills and it will causes ecological imbalance and limitation of dumping space (Alengaram & Alamgirkabir, 2015). The waste materials that available in Malaysia were palm oil clinker and around 2.6 million tons of solid wastes were produced annually by the palm oil industry (Ahmad & Mohd, 2007). However, many researchers have provided an alternative solution by using this waste as partial material replacement in the development of cement sand brick (Sh, Erm, Awal, & Abubakar, 2011).

In addition, the excessive use of natural sand will causes river channel degradation and erosion, head cutting, increased turbidity, stream bank erosion and sedimentation of riffle areas (Kondolf & Swanson, 1993). Thus, this problem can be reduced by minimizing the usage of natural sand in construction industry and use the palm oil clinker as alternative sand in this industry (Ariffin, 2016). The successful use of palm oil clinker in the civil engineering construction will provide significant economic savings.

1.3 OBJECTIVE OF STUDY

The objectives of this project are:

i. To determine the compressive strength of the sand brick with palm oil clinker as a partial replacement for fine aggregate
ii. To determine the flexural strength of sand brick with palm oil clinker as a partial replacement for fine aggregate
iii. To determine the density of sand brick with palm oil clinker as a partial replacement for fine aggregate
iv. To determine the water absorption of sand brick with palm oil clinker as a partial replacement for fine aggregate

1.4 SCOPE OF STUDY

In this research, this project will focused on the compressive strength, flexural strength, density and water absorption test of sand brick with palm oil clinker. There are limitations of this project:

i. The methods of testing are accordance to JKR Standard Sand Brick, ASTM C67-03a, ASTM C642-97, ASTM C293 and ASTM C140-03
ii. The study will consist 3 sets of different percentage of sand brick with palm oil clinker, 5% of ratio of the fine aggregate, 10% of ratio of fine aggregate and 15% of ratio of fine aggregate
iii. The palm oil clinker is produced from incineration process of oil palm shells (OPS) and fibers at Lepar Hilir, Gambang, Pahang
iv. The specimens are cured for the 3, 7, 14 and 28 days
v. The test involved in this study will be conducted at FKASA concrete laboratory, UMP

1.5 SIGNIFICANT OF STUDY

This experimental study will provide a better exposure and understanding on the effectiveness of the compressive strength, flexural strength, density and water absorption of sand bricks with palm oil clinker as partial replacement for fine aggregates. In addition, as the bricks will be used in the construction industry, this will be the best solution in maintaining a good environment that will help to solve the pollution problems that related to disposal palm oil clinker at dumping site and this sand brick will contribute to the green technology development in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Industrial wastes have been disposed for many years on free land and partly deposited on landfills. This amount of waste was generated greatly because Malaysia one of the countries that produce the largest palm oil in the world (Sulaiman, Rahman, & Sam, n.d.). From the previous research, waste foundry sand and copper slag behaviour has been made extensively but it's rather limited to palm oil clinker that also classified as artificial aggregate. In Malaysia, there was limited research work on studying the behaviour of palm oil clinker and the usage of palm oil clinker in the application of civil engineering (Dash, Patro, & Rath, 2016).

2.2 PALM OIL CLINKER

Palm oil clinker was considered as a waste product that produces from the burning of palm oil fibers and oil palm shells inside the boiler under the high temperature in order to generate the steam engine for the process of extracting palm oil (Shahid, Syed-Mohsin, & Ghazali, 2016). According to these researchers also, the palm oil clinker was categorized under unprocessed by-product material. Generally, the boulder sizes of palm oil clinker in ranges between 100 to 300 mm and the palm oil fiber and oil palm shell was burnt with proportion 70: 30. In addition, palm oil clinker also can store water and it can act as internal reservoir for cement hydration due to huge of voids inside it (Sulaiman, Rahman, & Sam, n.d.). It was quite angular and irregular in shaped with grey in colour and also flaky for some particles (Kanadasan & Razak, 2015). Although palm oil clinker coarser than sand, but both of these have similar physical and chemical properties (Arunima & Sreelekshmi, 2016).

2.3 UTILIZATION OF PALM OIL CLINKER

Disposal of palm oil clinker in landfills was getting higher day by day. Due to this, the utilization of waste by-products need to apply or use in the construction industry in order to overcome the depletion of natural sources and this disposal problem can be reduced (Sh, Erm, Awal, & Abubakar, 2011). Figure 2.1 below shows the different types of biomass that produced by various types of industries in Malaysia. Based on this figure, the total fresh fruit bunch (FFB) mills in Malaysia were 440 mills. According to the previous studies, Malaysia together with Indonesia produces around 57 million tonnes of oil in 2012 which is about 85% of the overall global palm production (Kanadasan & Razak, 2015). Besides that, the palm oil clinker can be used as a partial or total fine aggregate replacement for natural sand (Arunima & Sreelekshmi, 2016).

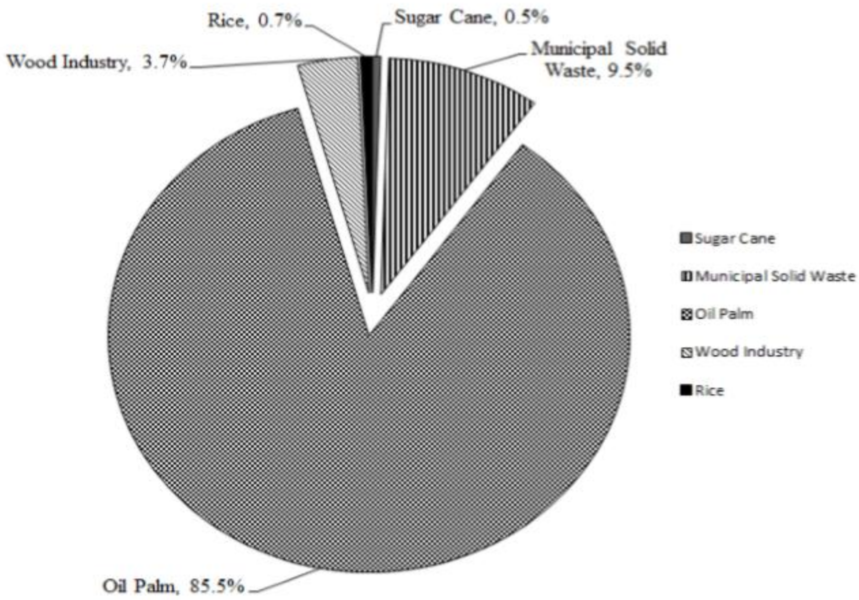

Figure 2.1: Biomass produced by different industries in Malaysia

Source: Kanadasan & Razak, 2015

2.4 PROBLEM OF PALM OIL CLINKER

The value of industrial by-product was contrary to environmental issues. The negative aspects of mining operations can cause concern among citizens group, government agencies and the mining industry. The conflicts tend to focus on the following issues:

i. Destruction of landscape
ii. Sedimentation erosion
iii. Destruction of agriculture and forest lands
iv. Dust

2.5 PROPERTIES OF PALM OIL CLINKER

2.5.1 Physical Properties

Palm oil industry typically produced the palm oil clinker around 80 million tonnes in 2010 and it was expected to increase up to 85 until 110 million tonnes in 2020 (Kanadasan & Razak, 2015). According to the laboratory investigations that have been carried out, palm oil clinker appeared in a grey material and look like porous stone with a rough and sharp broken surface and its particles size around 20 mm and 4.75 mm. These two types of sizes were used as coarse aggregate and fine aggregate respectively (Ahmad & Noor, 2007). Table 2.2 below shows the physical properties of fine and coarse palm oil clinker in palm oil mill factory in Selangor. According to Abutaha, Abdul Razak, & Kanadasan, 2016, palm oil clinker has the criteria as the structural lightweight aggregate due to its physical properties. From the Table 2.2**,** palm oil clinker has shown that the lower specific gravity was ranged in 2.17. Based on the previous research, palm oil clinker was categorized as lightweight aggregate when aggregates have the specific gravity lower than 2.2, bulk density less than 1200 kg/m^3 and usually the lightweight aggregate has the higher water absorption compare to conventional aggregate (Abutaha, Abdul Razak, & Kanadasan, 2016).

Table 2.1: Physical properties of fine and coarse POC

Physical properties	Fine	Crushed stone
Specific gravity (SSD condition)	2.17	2.60
Moisture content (%)	0.08	0.05
Water absorption (%)	4.65	1.79
Bulk density (kg/m^3)	863.65	1815.23
Fineness Modulus	2.84	2.65

Source: Ahmad & Mohd (2007)

The palm oil clinker commonly a well-graded material even though the particle size of sample that used was different which fine and coarse aggregate. Figure 2.2 below shows the plot of the grading analysis of fine and coarse palm oil clinker in Malaysia. Based on this figure, for fine aggregates, the sieve sizes that used were 1.18 mm, 300 µm and 150 µm while for coarse aggregates, the sieve sizes that used were 19.0 mm, 9.5 mm and 4.75 mm (Sh, Erm, Awal, & Abubakar, 2011). Their percentages by mass passing sieves sizes were 50.77%, 15.3% and 10.12% respectively for fine aggregate while for coarse aggregate, the percentage by mass passing sieve sizes were 100%, 24.93% and 0% respectively. The specimens of palm oil clinker were relatively similar and display well graded distribution when it performed in sieve analysis (Mohammed, Foo, & Abdullahi, 2014).

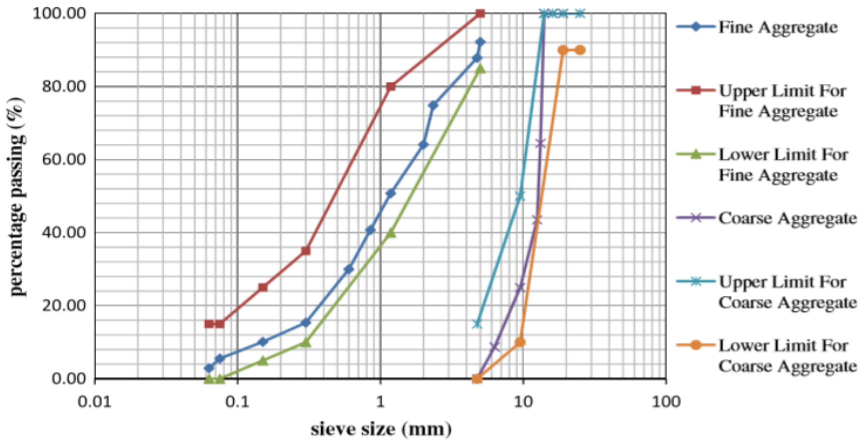

Figure 2.2: Sieve analysis of fine and coarse POC

Source: Mohammed, Foo, & Abdullahi (2014)

2.5.2 Chemical Properties

The X-ray Fluorescene (XRF) was used to determine the chemical analysis of palm oil clinker and the main chemical compounds that reveal from XRF was silica dioxide and the other compounds in smaller percentages. Table 2.3 and 2.4 shows the chemical properties of fine and coarse palm oil clinker in Malaysia based on the schedule that set out in the previous research.

Table 2.2: Chemical properties of fine POC

Element		Concentration (%)
Silica dioxide	SiO_2	81.8
Feric oxide	Fe_2O_3	5.18
Pottasium	K_2O	4.66
Aluminium oxide	Al_2O_3	3.5
Calcium oxide	CaO	2.3
Magnesium oxide	MgO	1.24
Phosphorus pentoxide	P_2O_5	0.76
Titanium dioxide	TiO_2	0.17
Natrium oxide	Na_2O	0.14

Source: Robani & Chan (2009)

Table 2.3: Chemical properties of coarse POC

Element		Concentration (%)
Silica dioxide	SiO_2	59.63
Feric oxide	Fe_2O_3	4.62
Pottasium	K_2O	4.66
Sulfur trioxide	SO_3	0.73
Calcium oxide	CaO	8.16
Magnesium oxide	MgO	5.01
Phosphorus pentoxide	P_2O_5	5.37
Titanium dioxide	TiO_2	0.22
Natrium oxide	Na_2O	0.32

Source: Jumaat & Bashar (2015)

2.6 APPLICATION OF PALM OIL CLINKER

Previously, palm oil clinker has been investigated for its suitability to utilize in building material and other civil engineering sectors such as building bricks and block, drainage layer in green roof system, soil stabilisation and road pavement (Chan & Shamsuddin, 2013). Application of palm oil clinker also used in the brick production like use it as a lightweight substitute for aggregate. This waste can give the benefit by reducing the dead load of the structures without loss a lot of strength of the structure and it improves the thermal, acoustic insulation and fire resistance of the structures (Abutaha, Abdul Razak, & Kanadasan, 2016). According to Shahid, Syed-Mohsin, & Ghazali, 2016, this industrial waste was the best material to be use as drainage layer due to low density and show well defined hydraulic conductivity than to conventional material.

2.7 SAND

Sand was produced by the rock-crushing techniques that used the state of the art plant and art machinery with first-class technology. It was formed from the specific natural rock and then it was crushed into three stages configuration that consist Jaw crusher, Cone crusher and Vertical Shaft Impactor (VSI) to obtain the consistent sand in cubical particles and grading (Thirumalai, Anantharajan, Kaleeswaran, Lakshmanakumar, & Logeswaran, 2016). River sand was used as fine aggregate which have 2.66, 2.89, 1.17% and 4.75 mm of specific gravity, fineness modulus, water absorption and grain size respectively (Ahmmad et al., 2016).

According to ASTM C33, fine aggregate consists of natural sand, combination of natural sand and manufactured sand while coarse aggregate consists of gravel, crushed gravel and others. Based on the laboratory investigations that have been carried out, natural river sand had a fine texture which is angular and irregular shapes even though the surface of river sand apparently compact with some deficiencies and attaches to smaller particles (Ramzi, Shahidan, Maarof, & Ali, 2016).

2.8 BRICK

Brick is the one of the most important materials for the construction industries. Most of the researchers continued to improve the quality and properties of clay bricks by mixing the clay with various recycling waste such as foundry sand, granite sawing waste, harbour sediment, sugarcane baggase ash, clay waste and other different wastes (Kumar & Lokesh, 2016). Clay bricks were produced by adding two nature fibers such as pineapple leaves (PF) and oil palm fruit (OF) to clay- water mixture with both baked and non baked condition in order to study the mechanical properties of this brick (Chan, 2011). This product was maintained in sufficient structural strength for construction applications. Based on the previous researchers, various ratios of palm oil clinker and sand together with Portland cement were used to make cast concrete products like bricks, blocks and structural purposes (Tun, Onn, & Pahat, 2007).

2.9 MECHANICAL PROPERTIES OF PALM OIL CLINKER

2.9.1 Compressive Strength

Previously, according to the Malaysian Standard for brick, the compressive strength that higher than 70 N/mm^2 were qualifies for the highest category of Class A Engineering Brick while the British Standard BS 3921: 1985, state that the minimum strength requirement for brick shall be less than 50 N/mm^2 for the same category. In addition, the minimum compressive strength shall be 5.2 N/mm^2 for conventional brick when the brick made none of the class (Chan & Shamsuddin, 2013). Figure 2.3 shows the test results for compressive strength of various percentages of palm oil clinker for bricks. From this table, the highest result of compressive strength was ratio 10% replacement of palm oil clinker. The strength was increase due to the ability of palm oil clinker to fill the void inside the specimen and this would make the brick denser and stronger (Ariffin, 2016). According to Arunima & Sreelekshmi, 2016, the compressive strength would decrease if content of palm oil clinker exceeds than 20% replacement due to reduction in cohesion governed by palm oil clinker.

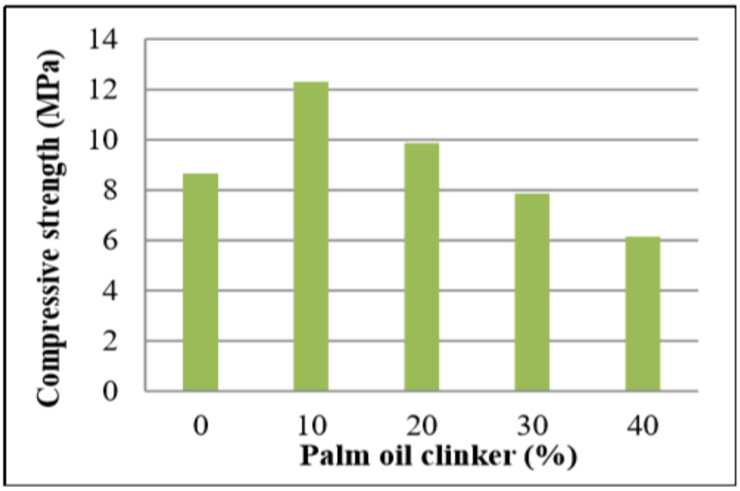

Figure 2.3: Compressive strength result up to 28 days

Source: Ariffin (2016)

2.9.2 Flexural Strength

Flexural strength was the method to measures the behaviour of materials that subjected to simple beam loading. The test result for flexural strength of various percentages of palm oil clinker was presented in Figure 2.6. From this figure, the highest flexural strength was ratio 10% replacement of palm oil clinker (Ariffin, 2016). The strength was increase due to the palm oil clinker improved the interfacial bond between paste and aggregate inside the specimens (Shahreen et al., n.d.). According to the previous research, the flexural strength was depending on the sizes of the palm oil clinker that was used. If the fine aggregate was replaced with fine or coarse aggregate, the modulus of rupture was decreased (Kanadasan & Razak, 2015). Based on Abutaha & Razak, 2017, with 20% substitution of palm oil clinker, the flexural strength was increases and then it was decreases if the substitution of palm oil clinker was higher than 20%.

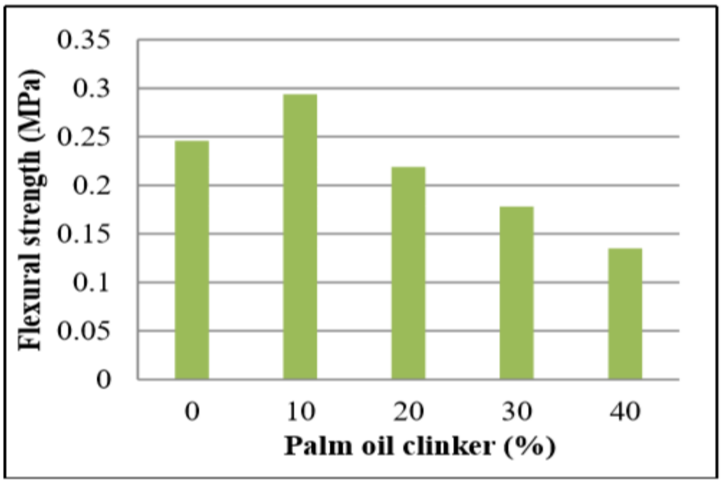

Figure 2.4: Flexural strength result up to 28 days

Sources: Ariffin (2016)

2.9.3 Density

Density is an important parameter that must be taken into account in order to measure the brick denseness. Table 2.4 below shows the density in saturated surface dry condition at the age of 28 days. According to Euro code Part 1-1, the concrete was considered as lightweight concrete if all the mix proportions less than 2200 kg/m^3 (Alengaram & Alamgirkabir, 2015). Based on the table 2.4, the density for normal concrete was 2486 kg/m^3 as state in series 1 while the series 2 and 4 that used coarse palm oil clinker and natural sand gave the densities around 2000 kg/m^3. For the series 3 and 5 that used palm oil clinker aggregates as coarse and fine aggregate, the densities were around 1850 kg/m^3 (H. Ahmad, Ahmad, Loon, & Noor, 2008). According to the previous researchers, due to low specific gravity, the density of concrete was decreased as compared to sand (Alengaram & Alamgirkabir, 2015). Besides that, the palm oil clinker has the best texture which has higher recycling rate and due to this, it becomes the best material to be used as replacement for fine aggregates (Kanadasan & Razak, 2015).

Table 2.4: Density of all series specified

Series	Density (kg/m^3)
S1	2486
S2	2057
S3	1846
S4	2035
S5	1825

Source: H. Ahmad, Ahmad, Loon, & Noor (2008)

2.9.4 Water Absorption

Water absorption was the method to determine the ability of specimen to absorb the water. Figure 2.7 below shows the percentages of water absorption of palm oil clinker as well for the control brick at 28 days. It was obvious that the water absorption increased as the percentages of palm oil clinker increased. This happens due to the porous structure of the palm oil clinker (Ariffin, 2016). This porous structure will help to store water for curing process and make it less sensitive to poor curing. In addition, the increases in percentage of palm oil clinker will increase the percentages of specimen porosity and then tends to more water to be absorbed by the specimen (Sh, Erm, Awal, & Abubakar, 2011). According to these researchers also, usually the brick must soaked for 24 hours before the weight of brick can be taken. Based on Abutaha & Razak, 2017, the water absorption increased if the voids increased because water absorption has a direct relationship with voids.

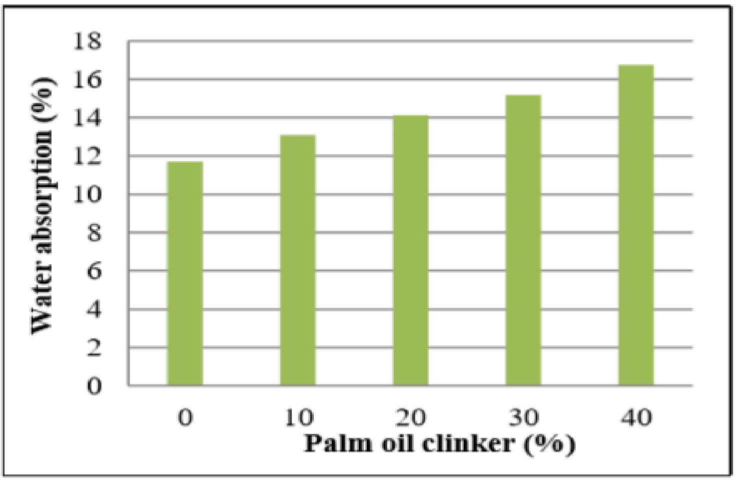

Figure 2.5: Water absorption result at 28 days

Source: Ariffin (2016)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Sand bricks were widely used in the construction and infrastructure in Malaysia. Various type of waste material by-product has been used in the production of the sand bricks where this material was used to add into the control brick. The methodology is a process of flow work that has been done from the start until to final of research. In this chapter, the experimental of the research will be carried out to determine the potential use of palm oil clinker as replacement for fine aggregate in order to produce the sand brick. The experimental that will be conduct is very important in order to obtain the data that related to the research such as the compressive strength, flexural strength, density and water absorption when using various percentages of palm oil clinker. Thus, the comparison between the control brick samples and the sand brick with various percentages of palm oil clinker will be made and decide.

3.2 RESEARCH DESIGN

The flow chart is arranging to shows the work that will be carried out in the research from the start until to final of the research as shown in Figure 3.1. Through this flow chart, the entire process can been easily to see. The detail at each section that state in the flow chart will be described more in this chapter.

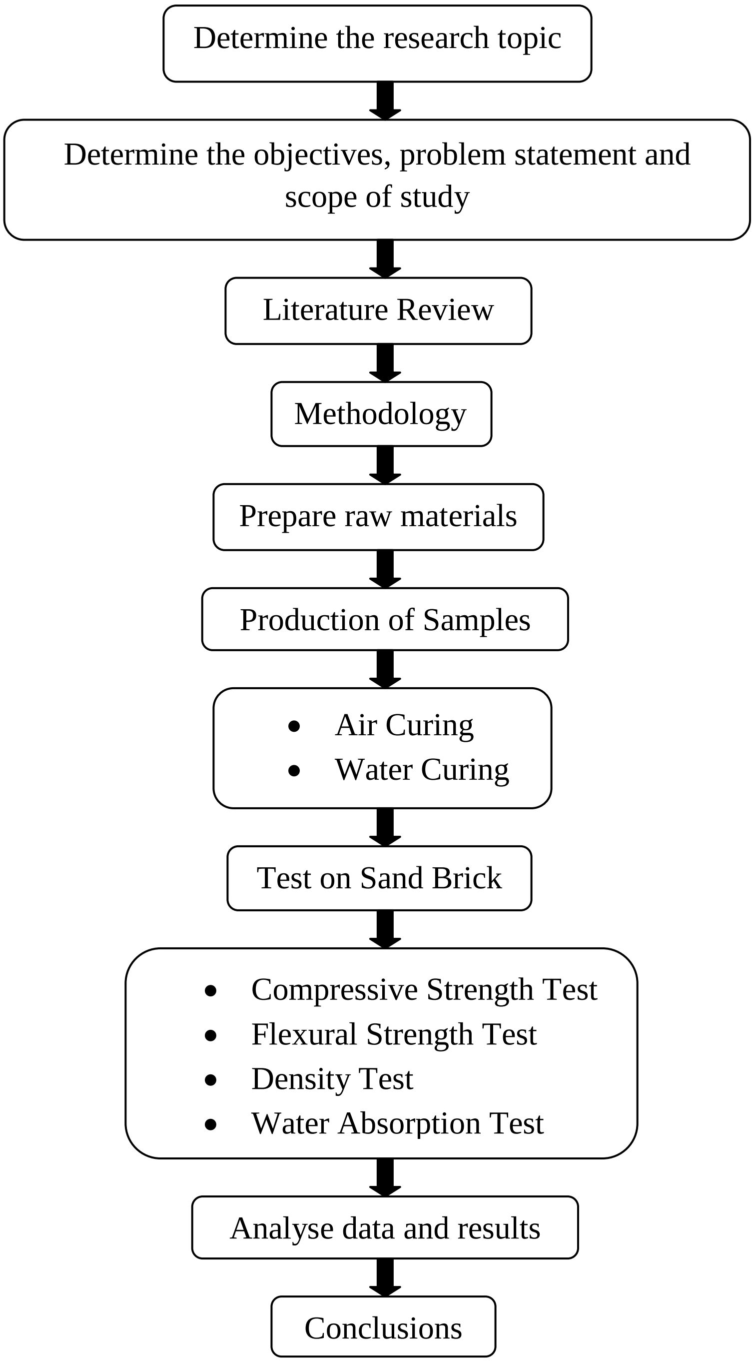

Figure 3.1: Flow chart of Final Year Project

3.3 PREPARATION OF MATERIALS

There are several types of materials that need to be prepare before can produce the sand bricks such as sand, water, cement and palm oil clinker as replacement for fine aggregate. The rate for mixing these materials was followed a predetermined ratio. The percentages of palm oil clinker were increase is different and it depends on the differences of 5%, 10% and 15% per brick that produced.

3.3.1 Sand

The sand that will use in this test is get at the Faculty of Civil Engineering concrete laboratory. At first, the sand needs to dry in order to remove any moisture content that exists in the particles. Due to the size of the sand, it sometimes will call as fine aggregates. The sand should sieved through 4.75 mm sieve because through this sieve, coarse aggregates or any another particles that contain in this sand can be removed. The sand was sieved by using sieve shaker at the concrete laboratory.

Figure 3.2: Sands

3.3.2 Water

Water is the one of the important elements in order to produce the sand bricks. In this test, the water shall be clean and free from any impurities because if the water contains any impurities, it can affect the cement hydration in the structure of brick. The impurities such as sulphate and organic will cause the unexpected things occur to the desired properties of the bricks especially when it become hardened. In the mixing process, the tap water was used in order to get the clean water and the mixture of water that be used in the mixing rate should be appropriate so that it does not weaken the bonding structure of the brick.

Figure 3.3: Tap water

3.3.3 Cement

In this test, the cement that will use is Portland Cement Cap Orang Kuat. This type of cement was prepared at the concrete laboratory by the technician staff. According to the JKR Standard for Building Works 2005, the ratio of the brick is 1:6, which is one part of cement and 6 parts of sand. The size for the sand brick that will use in this test is 225 x 113 x 75 mm as following in the Table 3.1 and the total volume for one brick is 0.001907 m^3. The total brick that produced is 240 bricks. Below shows the calculation for total volume of cement and sand that was used:

Ratio for sand brick is 1: 6

Cement: 1 = 0.0002724 m^3

Sand: 6 = 0.001635 m^3

Total cement and sand was used:

Cement = 0.0002724 = 0.31 kg

Sand = 0.001635 = 2.04 kg

Table 3.1: Size of sand brick follows the JKR Standard

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

Figure 3.4: Portland Cement Cap Orang Kuat

3.3.4 Palm Oil Clinker

In order to produce these sand bricks, palm oil clinker was used as partial replacement for fine aggregate. Palm oil clinker was collected at Lepar Hilir located in Gambang, Pahang. Generally, palm oil clinker was classified as an artificial aggregate that was produced from the incineration process of oil palm shells and fibers. The palm oil clinker should be cleaned first in order to remove any debris in the particles. After cleaned, the palm oil clinker must be pulverized into small particles using crushing machine. In this study, the required size for palm oil clinker was 4.75 mm.

Figure 3.5: Crushing machine that used to pulverize palm oil clinker

Figure 3.6: Palm oil clinker after pulverizing process

3.4 SPECIMEN PREPARATION

The sample was prepared and it was conducted in the FKASA concrete laboratory. Palm oil clinker was cleaned at first and after that, it should be stored in a dry place. The ratio of 5%, 10% and 15% of palm oil clinker was prepared to mixture the proportions of cement and sand. Every each of mixture proportion contains 3 bricks of samples and it was tested at 3, 7, 14 and 28 days. The control sample that used was 0% of palm oil clinker. The design of the mixture was measured to be mixed in order to produce a mixture of brick. It was important because through this, it can get the result and strength of brick. Table 3.2 below shows the mix design for each ingredient in the production of sand brick.

Table 3.2: Ratio of Mix Design Sand Brick

Mixture	**Ratio of Mixture**	
	Sand (%)	Palm Oil Clinker (%)
0	100%	0%
1	95%	5%
2	90%	10%
3	85%	15%

3.5 METHOD OF TESTING

3.5.1 Curing Process

Curing is very important process in order to maintain the moisture content and temperature in the bricks. Usually, the cured bricks have a sufficient amount of moisture for continued the hydration and the development of strength and volume stability. There are two types of curing test in this test which are water curing and air curing. The duration of being cured was 3, 7, 14 and 28 days. This test was conducted at FKASA concrete laboratory. Table 3.3 below shows the type of curing with type of tests for one ratio.

Table 3.3: Type of curing process, testing and its sample for one ratio

Testing	Curing	3 days	7 days	14 days	28 days	TOTAL
Compressive strength	Water Curing	3	3	3	3	12
	Air Curing	3	3	3	3	12
Flexural strength	Water Curing	3	3	3	3	12
	Air Curing	3	3	3	3	12
Density & Water absorption	Water Curing				3	3
	Air Curing				3	3
					TOTAL	54

Figure 3.7: Process of air curing

Figure 3.8: Process of water curing

3.5.2 Compressive Strength Test

Compressive strength test also known as compressive test that was used to measure the performance of brick sample compared to standard brick. The brick was considered strong if it can resist the crushing load better than the standard through maximum load achieved. This test was followed based on the ASTM C67-03a and the size of sample that used was 225 x 113 x 75 mm for the testing 3, 7, 14 and 28 days. The test needs to conduct immediately after the removal of sample from the curing tank. Then, put the sample into a compressive testing machine with thick plates placed above and below each sample to distribute load equally. The objective of this testing was to determine the compressive strength of sand brick**.** According to Malaysian Standard (MS27), the minimum permissible average compressive strength was about 5.2 N/mm^2 per 10 samples. The total number of samples was 240 brick of samples.

There are procedures of compressive strength test:

i. The sample was taken out from the curing tank then surface of sample was dried out using the cloth.
ii. The dimension and weight of the sample were measured and recorded.
iii. The sample then placed in flatwise position at the center of bearing plate so that the load applied in the direction of depth of the sample.
iv. The sample was capped with the bottom and upper flat steel for the equal load distribution.
v. After that, the load was applied in uniform rate until the sample reached the failure state where the sample fail to produce any increase indicator reading on testing machine.
vi. The reading was recorded.
vii. Step (ii) to (vii) was repeated on other sample for control sample, 5%, 10% and 15% palm oil clinker of 3, 7, 14 and 28 days for water curing and air curing.

Figure 3.9: Compressive testing machine

3.5.3 Flexural Strength Test

Flexural test was the method to evaluate the tensile strength of sand brick indirectly. This method was test the ability of sand brick to withstand the failure in bending. The results of flexural test on sand brick was expressed as a modulus of rupture which denotes as (MR) in MPa or psi. Theoretically, the flexural strength was derived from the elastic beam theory, where the stress-strain relation was assumed to be linear. Thus, the modulus of rupture was commonly presenting the overestimating value of brick tensile strength. This testing was conducted using the center-point loading test as according to the ASTM C293. The objective of this testing was to determine the flexural strength and modulus of rupture for sand brick.

There are procedures of flexural strength test:

i. The flexural test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.
ii. Placed the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.
iii. Centered the loading system in relation to the applied force.
iv. Bring the block applying force in contact with the specimen surface at the loading points.
v. Applied loads between 3 to 6 percent of the computed ultimate load.
vi. Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.
vii. Eliminate any gap greater than 0.10 mm using leather shims (6.4 mm thick and 25 to 50 mm long) and it should extend the full width of the specimen.
viii. Capping or grinding should be considered to remove gaps in excess of 0.38 mm.
ix. Load the specimen continuously without shock till the point of failure at a constant rate to the breaking point.
x. Applied the load at aerate that constantly increase the extreme fiber stress between 125 and 175 psi/min (0.86 and 1.21 MPa/min) until rupture occurs.

xi. The loading rate as per ASTM standard can be computed based on the following equation:

$$r = \frac{2Sbd^2}{3L}$$

Where: *r*: loading rate, lb/min (MN/min)

S: rate of increase of extreme fiber, psi/min (MPa/min)

b: average specimen width, in. (mm)

d: average specimen depth, in. (mm)

L: span length, in (mm)

xii. Finally, measure the cross section of the tested specimen at each end at center to calculate average depth and height.

Figure 3.10: Flexural strength testing machine

3.5.4 Density Test

Density test was the method to determine of density, percent absorption and percent voids in sand brick. This test was followed based on the ASTM C642-97: Standard Test Method for Density Absorption and Voids in Hardened.

There are procedures of density test:

1. Oven-Dry Mass
    - i. Determine the mass of the portion.
    - ii. Dry the specimens in an oven at a temperature of 100-110°C for not less than 24 hour.
    - iii. After removing each specimen from the oven, cool in dry air (preferably in desiccators) to a temperature of 20-25°C. Then, determine the mass.
    - iv. If the specimen is comparatively dry when its mass was first determined and the second mass closely agrees with the first, consider it dry.
    - v. If the specimen is wet when its mass was first determined, place it in the oven for a second drying treatment of 24 hour and again determine the mass.
    - vi. If the third value checks the second, consider the specimen dry.
    - vii. In case of any doubt, re-dry the specimen for 24 hour periods until check values of mass are obtained.
    - viii. If the difference between values are obtained from two successive values of mass exceed 0.5% of the lesser value, return the specimens to the oven for an additional 24 hour drying period.
    - ix. Repeat the procedure until the difference between any two successive values is less than 0.5% of the lowest value is obtained.
    - x. Designate this last value A.

3.5.5 Water Absorption Test

Water absorption test was the method to determine the relative water absorption properties over time of sand brick. This is because the samples are made under laboratory conditions. This test was conducted at FKASA concrete laboratory. The sample of bricks required for each ratio for this test is 3 samples. Meanwhile, the specimen needs to dry for a 3, 7, 14 and 28 days. Based on ASTM C140-03, there are two main procedures of absorption testing that need to be carried out.

There are procedures of water absorption test:

1. Saturation
   - i. Immerse the test specimens in water at a temperature of 15.6°C - 26.7°C for 24hours.
   - ii. Weight the specimen while suspended by a metal wire and completely submerged in water.
   - iii. Record the weight of immersed specimen as Wi (immersed weight)
   - iv. Then, remove it from the water and allow draining for 1 min by placing them on a 9.5 mm or coarser wire mesh.
   - v. Remove visible surface water with a damp cloth and record as Ws (saturated weight)

2. Drying
   - i. Subsequent to saturation, dry all specimens in a ventilated at 100°C to 115°C for not less than 24 h and until two successive weighing at intervals of 2h shows an increment of loss not greater than 0.2 % show an increment of loss not greater than 0.2 % of last previously determined weight of specimen.
   - ii. Record weight of dried specimen as Wd (Oven-dry weight)

In conclusion, the water absorbed can be obtained between the weights recorded from this test. The qualities of brick are determined by the percentages of water absorbed. If water was less absorbed the brick can be classified as good quality brick.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss the results of laboratory testing that conducted on the control samples and with different ratios. The total of the sand brick that conducted in concrete laboratory is 240 samples and it had been use for four ratios of 0%, 5%, 10% and 15%. There are two types of curing method in this process which are water curing and air curing that cured for 3, 7, 14 and 28 days. In this chapter, the results of testing for compressive strength, flexural strength, density and water absorption will be shown by doing comparison between control samples and ratios. The results for the average brick were calculated for all testing and it was compared between control samples and ratios. Microsoft Excel was used to make the graph based on the data that get from the testing.

4.2 SAND BRICK TESTS

There are four tests were conducted on the sand bricks which are compressive strength, flexural strength, density and water absorption test. These tests were accordance to the JKR Standard for Building Works 2005 and these tests were carried out for 3, 7, 14 and 28 days. These tests were conducted to achieve the objectives of this study.

4.2.1 Compressive Strength Test

Compressive strength tests were conducted by using Compression Machine at concrete laboratory that has been designed to obtain the compression strength of the brick. Through this test, the 3 units of brick samples for each percentage ratios were tested after this brick reached the maturity at 3, 7, 14 and 28 days. Then, the value of the brick samples were recorded based on its maximum load. Formula compressive strength is:

$$C = \frac{W}{A}$$

Where;

C = compressive strength of the sample (N/mm^2)

W = maximum load indicated by testing machine (N)

A = cross sectional area of the sample (mm^2)

Table 4.1: Compressive Strength for Water Curing

Days	**Compression Strength (N/mm^2)**			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
3	4.500	4.041	5.937	5.432
7	5.490	6.151	5.347	6.107
14	5.940	5.495	7.263	7.153
28	8.469	7.822	7.599	8.309

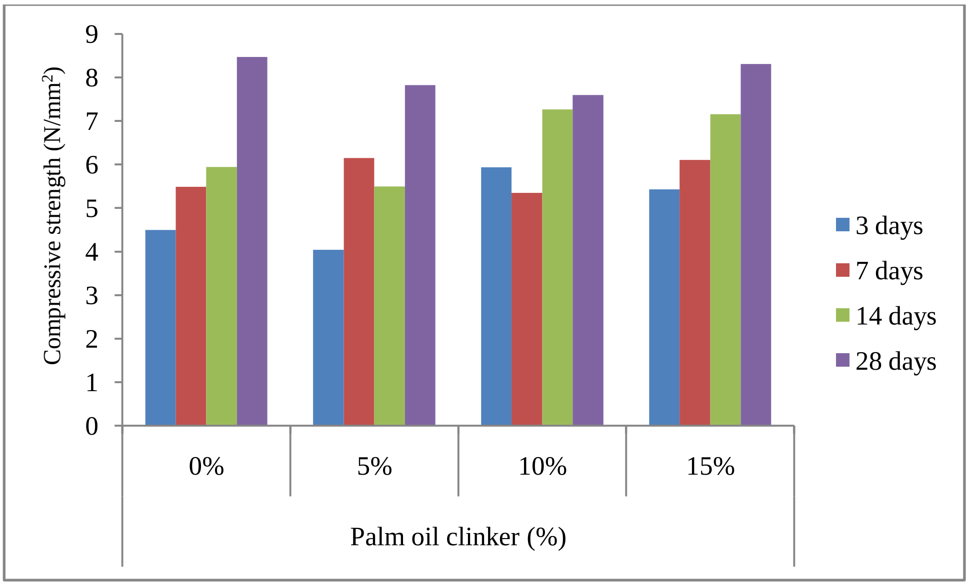

Figure 4.1: Compressive Strength against different percentages ratio of POC for Water Curing

Table 4.1 and figure 4.1 shows the compressive strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart indicates the changes in the compressive strength of four different ratios of palm oil clinker for water curing. After 28 days, the control brick has the highest strength with 8.469 N/mm^2 compared to the other brick. This graph shows the result increase rapidly for control brick and ratio 15% of palm oil clinker at 3, 7, 14 and 28 days. But, the result of ratio 5% of palm oil clinker is shown that at first it slightly increase from 4.041 N/mm^2 at 3 days to 6.151 N/mm^2 at 7 days, but then decrease to 5.495 N/mm^2 at 14 days and then climbing back to reach 7.822 N/mm^2 at 28 days. On the other hand, the ratio 10% of palm oil clinker has been relatively stable, falling from 5.937 N/mm^2 at 3 days to 5.347 N/mm^2 at 7 days but climbing back to reach 7.263 N/mm^2 and 7.599 N/mm^2 at 14 days and 28 days. The lowest result in water curing is ratio 5% of palm oil clinker with 4.041 N/mm^2 at 3 days.

Table 4.2: Compressive Strength for Air Curing

Days	Compression Strength (N/mm²)			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
3	5.310	4.195	5.412	4.371
7	4.640	6.088	6.321	6.637
14	6.853	7.761	8.672	8.731
28	8.845	8.321	8.852	9.094

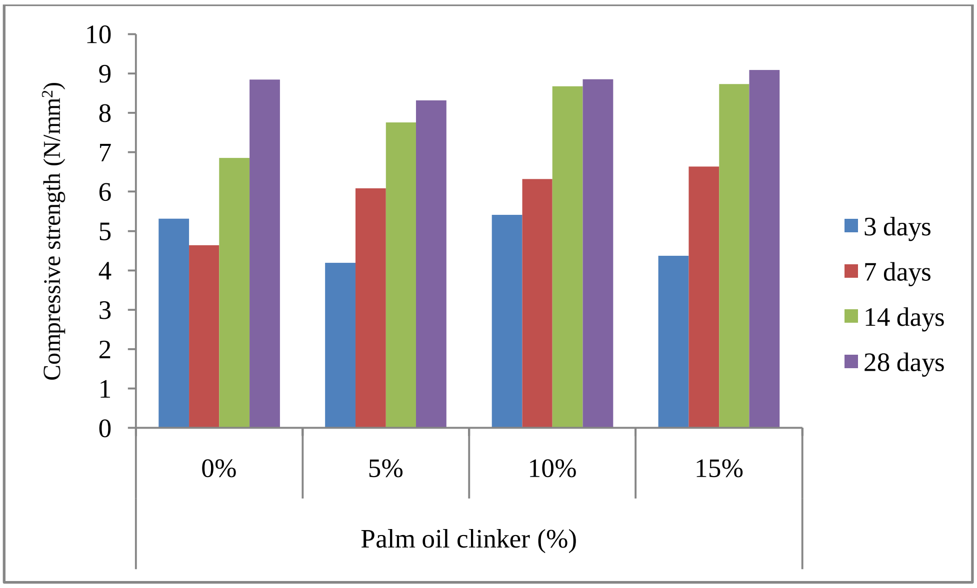

Figure 4.2: Compressive Strength against different percentages ratio of POC for Air Curing

Table 4.2 and figure 4.2 shows the compressive strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart illustrates the changes in the compressive strength of four different ratios of palm oil clinker for air curing. After 28 days, the ratio 15% of palm oil clinker has the highest strength with 9.094 N/mm^2 compared to the other brick. This graph shows the result increased sharply for three different ratios of palm oil clinker at 3, 7, 14 and 28 days. But, the result of control brick is shown that it drop from 5.310 N/mm^2 at 3 days to 4.640 N/mm^2 at 7 days then slightly increases to 6.853 N/mm^2 and 8.845 N/mm^2 at 14 days and 28 days. The lowest result in air curing is ratio 5% of palm oil clinker with 4.195 N/mm^2 at 3 days.

Table 4.3: Compressive Strength for Water and Air Curing

Types	Water Curing				Air Curing			
Days	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
3	4.500	4.041	5.937	5.432	5.310	4.195	5.412	4.371
7	5.490	6.151	5.347	6.107	4.640	6.088	6.321	6.637
14	5.940	5.495	7.263	7.153	6.853	7.761	8.672	8.731
28	8.469	7.822	7.599	8.309	8.845	8.321	8.852	9.094

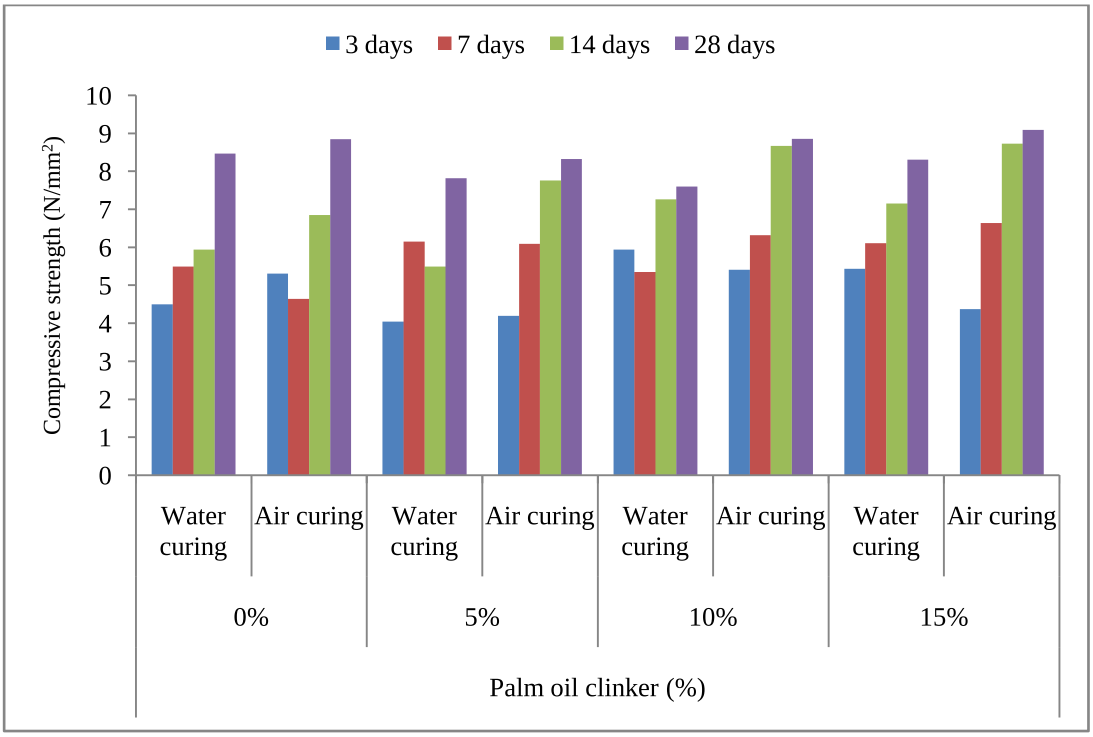

Figure 4.3: Compressive Strength against different percentages ratio of POC for Water and Air Curing

Table 4.3 and figure 4.3 shows the compressive strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart indicates the changes in the compressive strength of four different ratios of palm oil clinker for water and air curing. After 28 days, the control brick has the highest strength which is 8.469 N/mm^2 for water curing while for air curing, the highest strength is 9.094 N/mm^2 at ratio 15% of palm oil clinker compared to the other brick. This graph has shown the result increase rapidly for ratio 15% of palm oil clinker at 3, 7, 14 and 28 days for both of curing. But, the results of control brick, ratio of 5% and 10% of palm oil clinker have slightly different in both of curing. The lowest result in water curing is ratio 5% of palm oil clinker which is 4.041 N/mm^2 at 3 days.

4.2.2 Flexural Strength Test

Flexural strength tests were conducted by using Flexural Machine at concrete laboratory that has been designed to get the flexural strength of the brick. Through this test, the 3 units of brick samples for each percentage of ratios were tested after this brick reached the maturity at 3 days, 7 days, 14 days and 28 days. Then, the value of the brick samples were recorded based on its maximum load.

Table 4.4: Flexural Strength for Water Curing

Days	Flexural Strength (N/mm^2)			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
3	0.1704	0.1109	0.1627	0.1490
7	0.1675	0.2169	0.1856	0.1902
14	0.2095	0.2241	0.2501	0.2220
28	0.2669	0.2574	0.2622	0.2634

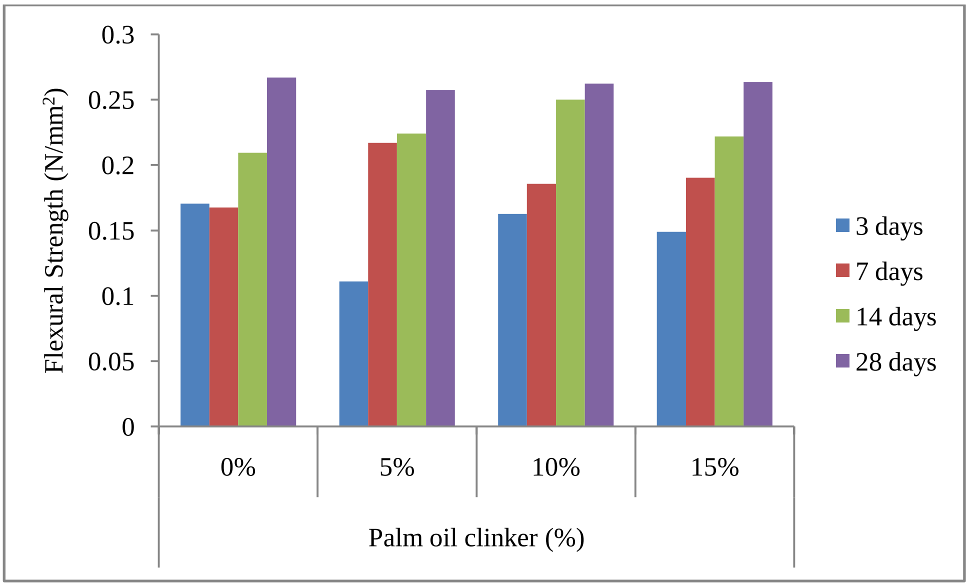

Figure 4.4: Flexural Strength against different percentages ratio of POC for Water Curing

Table 4.4 and figure 4.4 shows the flexural strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart indicates the changes in the flexural strength of four different ratios of palm oil clinker for water curing. After 28 days, the control brick has the highest strength with 0.2669 N/mm^2 compared to the other brick. This graph shows the result increase rapidly for three different ratios of palm oil clinker at 3, 7, 14 and 28 days. But, the result of control brick is shows that it slightly decrease from 0.1704 N/mm^2 at 3 days to 0.1675 N/mm^2 at 7 days but then climbing back to reach 0.2095 N/mm^2 and 0.2669 N/mm^2 at 14 days and 28 days. The lowest result in water curing is ratio 5% of palm oil clinker with 0.1109 N/mm^2 at 3 days.

Table 4.5: Flexural Strength for Air Curing

Days	Flexural Strength (N/mm^2)			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
3	0.1586	0.1203	0.1680	0.1650
7	0.1699	0.1860	0.1483	0.1528
14	0.1786	0.2149	0.2235	0.2069
28	0.2085	0.2502	0.2498	0.2671

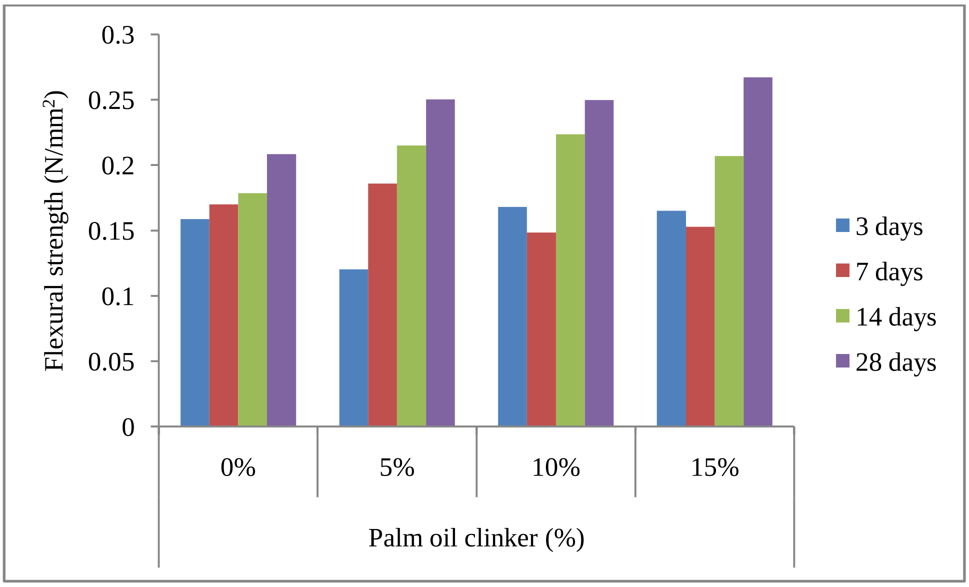

Figure 4.5: Flexural Strength against different percentages ratio of POC for Air Curing

Table 4.5 and figure 4.5 shows the flexural strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart illustrates the changes in the flexural strength of four different ratios of palm oil clinker for air curing. After 28 days, the ratio 15% of palm oil clinker has the highest strength with 0.2671 N/mm^2 compared to the other brick. This graph shows the result increase rapidly for control brick and ratio 5% of palm oil clinker at 3, 7, 14 and 28 days. But, the result of ratio 10% and 15% of palm oil clinker are shown that it declined from 3 days to 7 days, but then increased rapidly at 14 days to 28 days. The lowest result in air curing is ratio 5% of palm oil clinker with 0.1203 N/mm^2 at 3 days.

Table 4.6: Flexural Strength for Water and Air Curing

Types	**Water Curing**				**Air Curing**			
Days	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
3	0.1704	0.1109	0.1627	0.1490	0.1586	0.1203	0.1680	0.1650
7	0.1675	0.2169	0.1856	0.1902	0.1699	0.1860	0.1483	0.1528
14	0.2095	0.2241	0.2501	0.2220	0.1786	0.2149	0.2235	0.2069
28	0.2669	0.2574	0.2622	0.2634	0.2085	0.2502	0.2498	0.2671

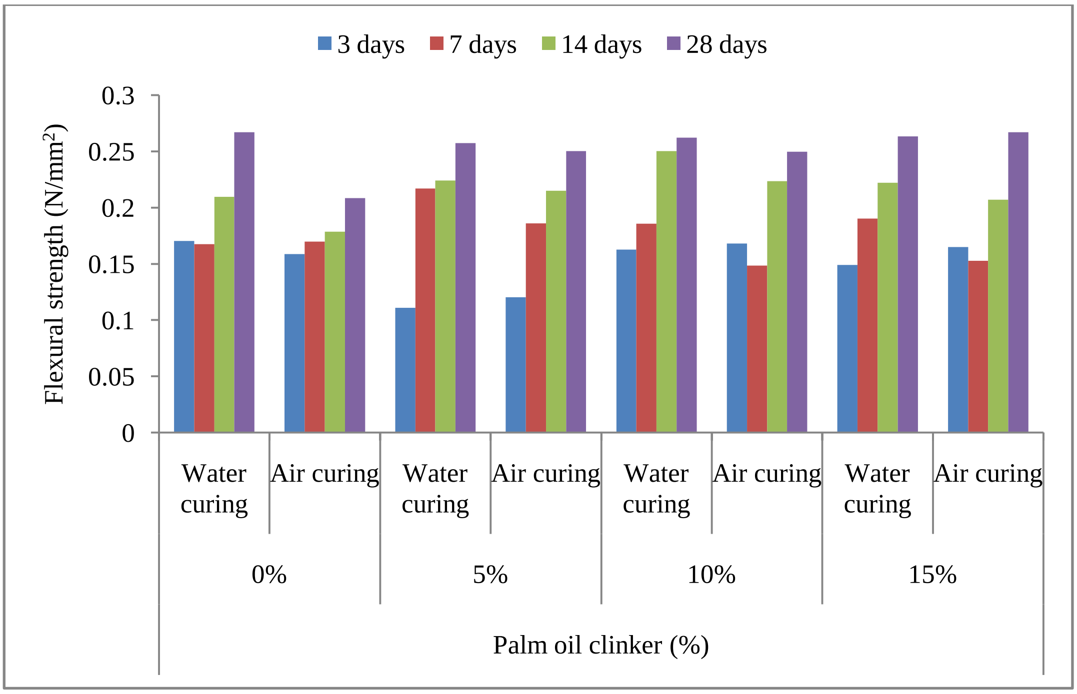

Figure 4.6: Flexural Strength against different percentages ratio of POC for Water and Air Curing

Table 4.6 and figure 4.6 shows the flexural strength of different percentages ratio of palm oil clinker for 3, 7, 14 and 28 days. The bar chart indicates the changes in the flexural strength of four different ratios of palm oil clinker for water and air curing. After 28 days, the control brick has the highest strength which is 0.2669 N/mm^2 for water curing while for air curing, the highest strength is 0.2671 N/mm^2 at ratio 15% of palm oil clinker compared to the other brick. This graph has shown the result went up gradually for ratio 5% of palm oil clinker at 3, 7, 14 and 28 days for both of curing. But, the results of control brick, ratio of 10% and 15% of palm oil clinker have slightly different in both of curing. The lowest result in water curing is ratio 5% of palm oil clinker which is 0.1109 N/mm^2 at 3 days.

4.2.3 Density Test

Density test were conducted after it was curing at 28 days. In order to obtain the result of the samples, the samples should be weighed after oven-dry the samples in oven. Results for density can get after the weight of sand brick was calculating by using formula of density. Formula density is:

Density, $\rho = \frac{M}{V}$

Where;

ρ = density of sand brick (kN/m^3)

m = mass of sand brick after oven-dry, (kN)

v = volume of sand brick, (m^3)

Table 4.7: Density for Water Curing

	Density (kN/m^3)			
Days	**0% Control Sample**	**5% POC**	**10% POC**	**15% POC**
28	19.17	20.48	20.51	20.70

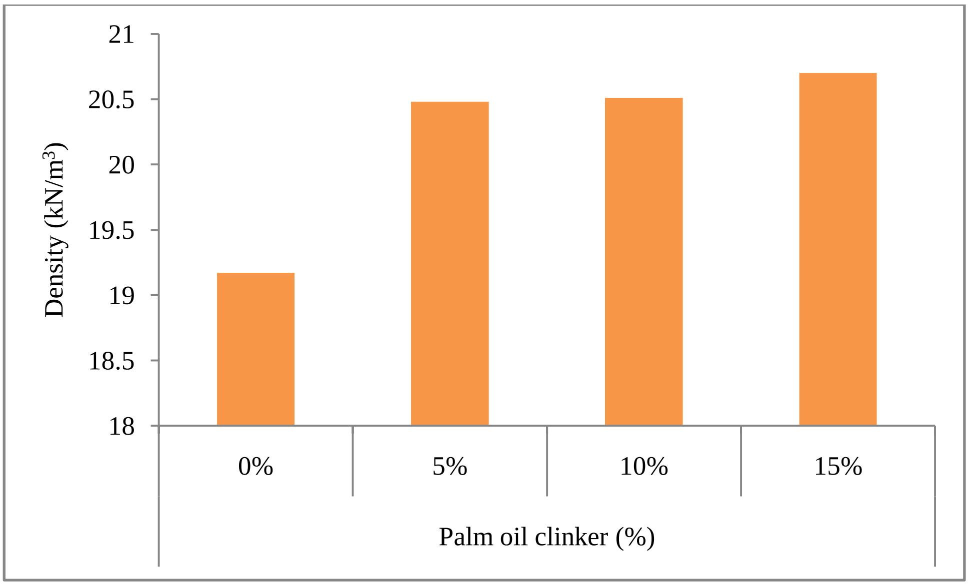

Figure 4.7: Density against different percentages ratio of POC for Water Curing

Table 4.7 and figure 4.7 shows the density of different percentages ratio of palm oil clinker for 28 days. The bar chart indicates the changes in the density of four different ratios of palm oil clinker for water curing. After 28 days, the ratio 15% of palm oil clinker has the highest density with 20.70 kN/m^3 compared to the other brick. This graph shows the result went up gradually for four different ratios of palm oil clinker at 28 days. The lowest result in water curing is control brick which is 19.17kN/m^3.

Table 4.8: Density for Air Curing

Days	**Density (kN/m^3)**			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
28	19.06	20.74	21.01	21.81

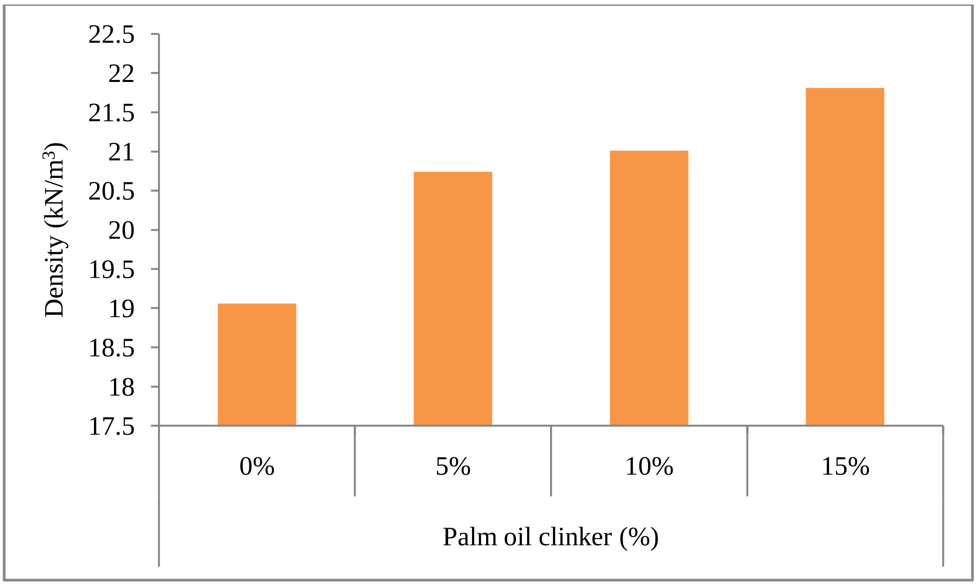

Figure 4.8: Density against different percentages ratio of POC for Air Curing

Table 4.8 and figure 4.8 shows the density of different percentages ratio of palm oil clinker for 28 days. The bar chart illustrates the changes in the density of four different ratios of palm oil clinker for air curing. After 28 days, the ratio 15% of palm oil clinker has the highest density with 21.81 kN/m^3 compared to the other brick. The density for four different ratios of palm oil clinker increased steadily at 28 days. The lowest result in air curing is control brick with 19.06kN/m^3.

Table 4.9: Density for Water and Air Curing

Types	**Water Curing**				**Air Curing**			
Days	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
28	19.17	20.48	20.51	20.70	19.06	20.74	21.01	21.81

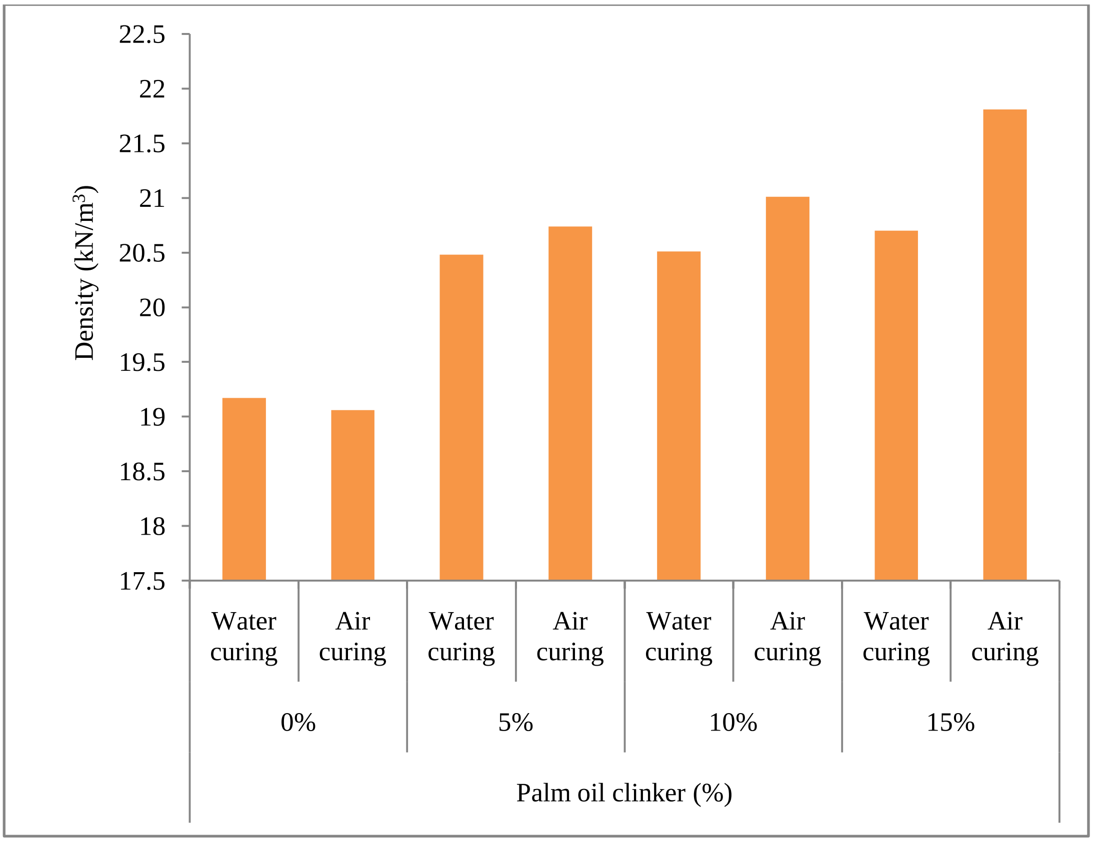

Figure 4.9: Density against different percentages ratio of POC for Water and Air Curing

Table 4.9 and figure 4.9 shows the density of different percentages ratio of palm oil clinker for 28 days. The bar chart indicates the changes in the density of four different ratios of palm oil clinker for water and air curing. After 28 days, the ratio 15% of palm oil clinker has the highest density which is 20.70kN/m^3 for water curing while for air curing is 21.81kN/m^3 compare to the other brick. The density from control brick until ratio 15% of palm oil clinker increased sharply for both of curing. The lowest result in air curing is control brick which is 19.06 kN/m^3.

4.2.4 Water Absorption Test

Water absorption test was conducted after it was curing at 28 days. In order to obtain the result of the samples, the samples should be weighed after oven-dry the samples in oven and after immersed the samples in water. Results for water absorption can get after the weight of sand brick was calculating by using formula of water absorption. Formula water absorption is:

$$\text{Water absorption, } W = \frac{(W_2 - W_1)}{W_1} X 100\%$$

Where;

W_1 = weight of sand brick after oven-dry

W_2 = weight of sand brick after immersed

Table 4.10: Water absorption for Water Curing

Days	Water Absorption (%)			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
28	11.88	12.67	12.78	14.44

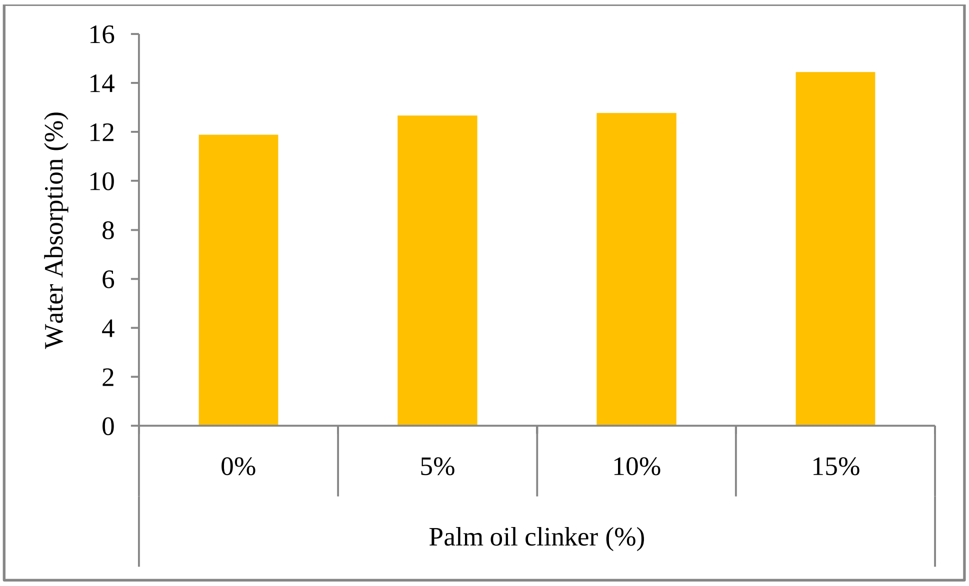

Figure 4.10: Water absorption against different percentages ratio of POC for Water Curing

Table 4.10 and figure 4.10 shows the water absorption of different percentages ratio of palm oil clinker for 28 days. The bar chart indicates the changes in the water absorption of four different ratios of palm oil clinker for water curing. After 28 days, the ratio 15% of palm oil clinker has the highest water absorption with 14.44% compared to the other brick. This graph shows the result increase rapidly for four different ratios of palm oil clinker at 28 days. The lowest result in water curing is control brick which is 11.88%.

Table 4.11: Water absorption for Air Curing

Days	**Water Absorption (%)**			
	0% Control Sample	**5% POC**	**10% POC**	**15% POC**
28	11.22	12.50	13.44	14.14

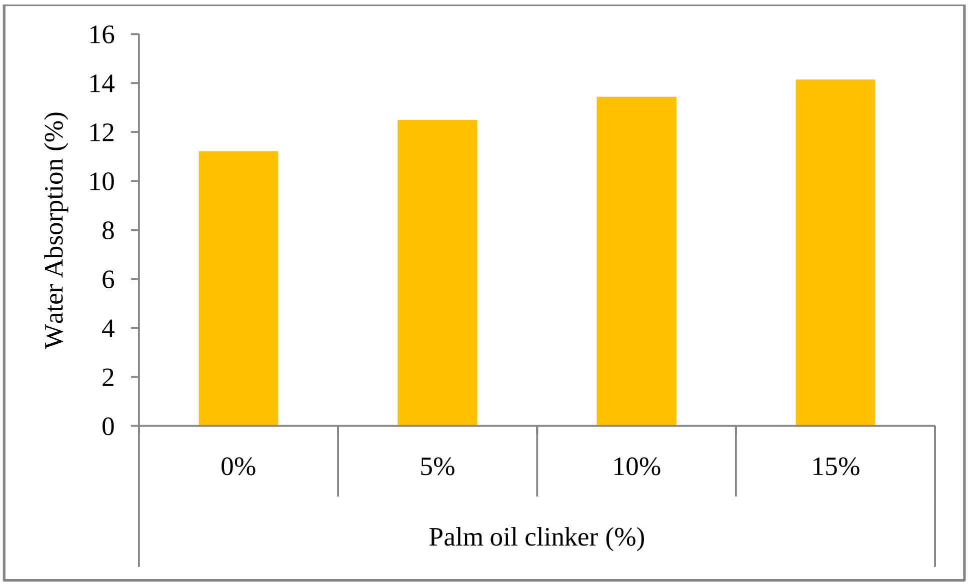

Figure 4.11: Water absorption against different percentages ratio of POC for Air Curing

Table 4.11 and figure 4.11 shows the water absorption of different percentages ratio of palm oil clinker for 28 days. The bar chart illustrates the changes in the water absorption of four different ratios of palm oil clinker for air curing. After 28 days, the ratio 15% of palm oil clinker has the highest water absorption with 14.14% compared to the other brick. The water absorption for four different ratios of palm oil clinker increased steadily at 28 days. The lowest result in air curing is control brick with 11.22%.

Table 4.12: Water absorption for Water and Air Curing

Types	**Water Curing**				**Air Curing**			
Days	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
28	11.88	12.67	12.78	14.44	11.22	12.50	13.44	14.14

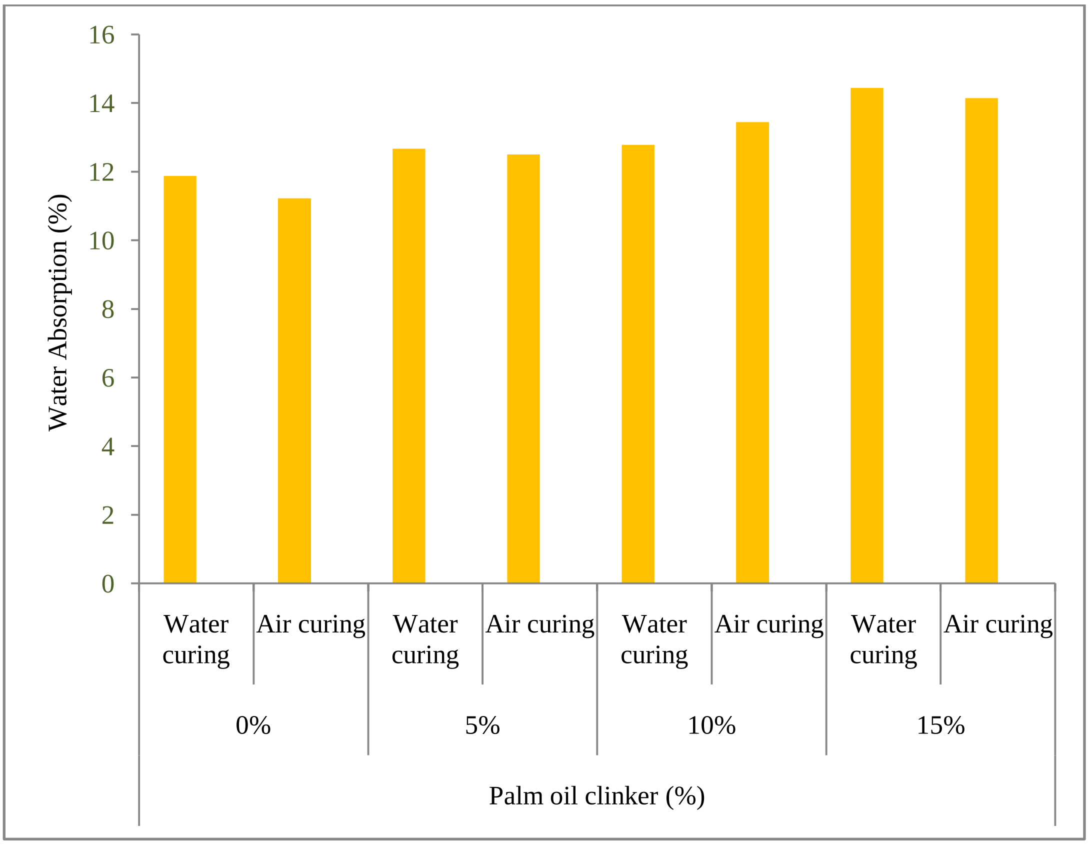

Figure 4.12: Water absorption against different percentages ratio of POC for Water and Air Curing

Table 4.12 and figure 4.12 shows the water absorption of different percentages ratio of palm oil clinker for 28 days. The bar chart indicates the changes in the water absorption of four different ratios of palm oil clinker for water and air curing. After 28 days, the ratio 15% of palm oil clinker has the highest water absorption which is 14.44% for water curing while for air curing is 14.14% compare to the other brick. The water absorption from control brick until ratio 15% of palm oil clinker went up gradually for both of curing. The lowest result in air curing is control brick which is 11.22%.

4.3 DISCUSSION

The result of laboratory testing of compressive strength, flexural strength, density and water absorption for 240 samples of sand brick were analysed for two types of curing method which are water curing and air curing. This sand brick were cured on 3, 7, 14 and 28 days. According to this study, these four types of testing will be discussed based on the objectives of this study which are to determine the compressive strength, flexural strength, density and water absorption of the sand brick with palm oil clinker as a partial replacement for fine aggregate.

The best compressive strength for water curing is control brick which is 8.469 N/mm^2 while the best compressive strength for air curing is 9.094 N/mm^2 at ratio 15% of palm oil clinker. On the other hand, the best flexural strength for water curing is control brick which is 0.2669 N/mm^2 while the best flexural strength for air curing is 0.2671 N/mm^2 at ratio 15% of palm oil clinker. The compressive and flexural strength results are supposed to be increase as more palm oil clinker was added into the sand brick. This is because the palm oil clinker has the ability to fill the voids inside the specimen to make the brick denser and stronger.

But, the graph pattern is not smoothly increase due to some error during the sample preparation like the sand that use is not totally dry which is still moist sand. It also happens due to an error of laboratory equipments. In addition, as it continues use the same formwork for the next bricks, the brick formwork has a loose problem at the side of the formwork. This problem makes the results not uniformed increases for these two testing.

The density pattern increase as the percentages ratio of palm oil clinker was added into the sand brick increase. In this study, the higher the mass per volume of sand brick, the higher the density of sand brick. Therefore, the best density is ratio 15% of palm oil clinker for both water and air curing which are 20.70 kN/m^3 and 21.81 kN/m^3.

The water absorption patterns increase when more palm oil clinker was added as partial replacement. Thus, the best water absorption is ratio 15% of palm oil clinker for both water and air curing which are 14.44% and 14.14%. At the same time, the increases in the percentages ratio of palm oil clinker will result in increased percentage of specimen porosity. The increases in the specimen porosity will cause the specimen absorbed more water and it will increase the percentage of water absorption.

Overall, this study is accepted but the ratio of percentage of palm oil clinker need to increase in order to obtain the best results for sand bricks.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

In this chapter, the conclusion was made by making a summary of results from the overall of this project. All the steps and process that involves in this project from prepares the raw materials until the data analysis discussed in this conclusion. In addition, this chapter also discuss the recommendations in order to improve the next project based on the observation from this project.

5.2 CONCLUSION

In conclusion, sand bricks are widely used in the construction industry in Malaysia. Overall, the objective of this study was achieved based on JKR Standard for Building Works 2005. In this JKR Standard stated that the minimum permissible average compressive strength shall be 5.2 N/mm^2 and the results of the compressive strength with different ratio of palm oil clinker is reach and better than control brick, only in the certain days of curing the results of compressive strength with different ratio of palm oil clinker cannot reach the compressive strength of control brick. Therefore, due to the compressive strength give a good result, palm oil clinker has the potential to be used in the manufacture of bricks.

The outcome of these results is to compare the compressive strength, flexural strength, density and water absorption of control brick with different ratio of palm oil clinker. From the results, the best compressive strength is control brick for water curing which is 8.469 N/mm^2 while ratio 15% of palm oil clinker is the best compressive strength for air curing with 9.094 N/mm^2. Then, for the best flexural strength for water curing is control brick which is 0.2669 N/mm^2 while ratio 15% of palm oil clinker is the best flexural strength for air curing with 0.2671 N/mm^2. According to the MS EN 1991-1-1: 2010, the standard density is around 19 to 23 kN/m^3, thus the overall results of the density for the control brick and with different ratio of palm oil clinker is reach and the best density is ratio 15% of palm oil clinker for both water and air curing which are 20.70 kN/m^3 and 21.81 kN/m^3. On the other hand, the best water absorption is ratio 15% of palm oil clinker for both water and air curing which are 14.44% and 14.14%.

In addition, the devaluation of the results in the certain days of curing in the compressive strength and flexural strength of the bricks sample may due to some error during the sample preparation like the sand that use is not totally dry which is still moist sand. It also happens due to an error of laboratory equipments. On the other hand, as it continues use the same formwork for the next bricks, the brick formwork has a loose problem at the side of the formwork. This problem makes the result not uniformed but still gets the best result for this two testing.

Last but not least, the result still acceptable and can be used for the future in the construction industry because the overall result is still good and the certain result for testing is accepted based on the JKR Standard.

5.3 RECOMMENDATIONS

Based on the studies that have been conducted, there are several suggestions that can be taken as an enhancement for the future study. Below are some suggestions that can be used to reinforce data analysis, study and to achieve the objectives;

i. From this study, sometimes the raw material that be used such as sand is moist sand which mean the sand still have water content and don't know the value for water content. Therefore, for future study, it better to make sure that the sand is dry before use the sand to mix the materials.

ii. According to this study, the students need to provide their own formwork for brick by using the plywood. This formwork make the dimension of the bricks not uniformly for all dimension thus it have been affected the results of compressive strength, flexural strength, density and also water absorption. Therefore, in order to get the better result, the formwork should be provided at concrete laboratory for the next study.

iii. In carrying out the study in the future, the laboratory assistant need to constantly monitor and check the equipment and machinery in laboratory and repair the equipment that has been damaged. Thus, from this, the students for the next study do not have any problem when using this equipment and machinery like compression strength and flexural strength machines.

iv. The percentages ratios from this study were 0%, 5%, 10% and 15% of palm oil clinker. In this study, the percentages ratios that were used are good because the strength of brick was increase compared to the control samples. Therefore, for the next study, use the bigger ratio of palm oil clinker to see whether the bigger ratio will give the better strength or not.

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APPENDIX A

Compressive Strength Test Result for Water Curing at 3 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	4.075	146600	4.540
Clinker	225 x 113 x 75	25425	3.977	114100	3.850
	225 x 113 x 75	25425	4.164	161000	4.720
	225 x 113 x 75	25425	4.161	152600	4.880
5%	225 x 113 x 75	25425	3.979	110300	4.338
Clinker	225 x 113 x 75	25425	3.906	95200	3.744
10%	225 x 113 x 75	25425	4.130	166100	6.533
Clinker	225 x 113 x 75	25425	4.064	135800	5.341
15%	225 x 113 x 75	25425	4.016	138600	5.451
Clinker	225 x 113 x 75	25425	4.156	137600	5.412

APPENDIX B

Compressive Strength Test Result for Air Curing at 3 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	3.915	127700	5.020
Clinker	225 x 113 x 75	25425	3.867	128700	5.060
	225 x 113 x 75	25425	3.907	138500	5.460
	225 x 113 x 75	25425	3.967	145000	5.700
5%	225 x 113 x 75	25425	4.075	112400	4.421
Clinker	225 x 113 x 75	25425	3.829	100900	3.969
10%	225 x 113 x 75	25425	3.886	131700	5.180
Clinker	225 x 113 x 75	25425	3.818	143500	5.644
15%	225 x 113 x 75	25425	3.886	124100	4.881
Clinker	225 x 113 x 75	25425	3.928	115600	4.547
	225 x 113 x 75	25425	4.089	93700	3.685

APPENDIX C

Compressive Strength Test Result for Water Curing at 7 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	3.988	146600	5.770
Clinker	225 x 113 x 75	25425	4.108	114100	3.850
	225 x 113 x 75	25425	4.069	161000	6.330
	225 x 113 x 75	25425	4.054	152600	6.000
5%	225 x 113 x 75	25425	4.431	145300	5.715
Clinker	225 x 113 x 75	25425	4.593	178000	7.001
	225 x 113 x 75	25425	4.453	163300	6.423
	225 x 113 x 75	25425	4.403	138900	5.463
10%	225 x 113 x 75	25425	3.933	127400	5.011
Clinker	225 x 113 x 75	25425	4.076	124200	4.885
	225 x 113 x 75	25425	4.112	129300	5.086
	225 x 113 x 75	25425	4.118	162900	6.407
15%	225 x 113 x 75	25425	3.986	149900	5.896
Clinker	225 x 113 x 75	25425	3.994	158500	6.234
	225 x 113 x 75	25425	3.935	167400	6.584
	225 x 113 x 75	25425	4.009	145300	5.715

APPENDIX D

Compressive Strength Test Result for Air Curing at 7 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0% Clinker	225 x 113 x 75	25425	3.758	113100	4.450
	225 x 113 x 75	25425	3.634	107100	4.210
	225 x 113 x 75	25425	3.677	108300	4.260
	225 x 113 x 75	25425	3.830	143100	5.630
5% Clinker	225 x 113 x 75	25425	4.047	133400	5.247
	225 x 113 x 75	25425	3.939	132300	5.204
	225 x 113 x 75	25425	4.134	167200	6.576
	225 x 113 x 75	25425	3.908	186200	7.324
10% Clinker	225 x 113 x 75	25425	3.890	166700	6.557
	225 x 113 x 75	25425	3.960	143600	5.648
	225 x 113 x 75	25425	3.949	170300	6.698
	225 x 113 x 75	25425	3.959	162200	6.380
15% Clinker	225 x 113 x 75	25425	3.899	196700	7.736
	225 x 113 x 75	25425	4.048	150100	5.904
	225 x 113 x 75	25425	3.891	169800	6.678
	225 x 113 x 75	25425	3.895	158400	6.230

APPENDIX E

Compressive Strength Test Result for Water Curing at 14 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	4.081	177800	6.993
Clinker	225 x 113 x 75	25425	3.930	157300	6.187
	225 x 113 x 75	25425	4.005	118000	4.641
5%	225 x 113 x 75	25425	4.031	133900	5.266
Clinker	225 x 113 x 75	25425	4.055	128300	5.046
	225 x 113 x 75	25425	4.130	151100	5.943
	225 x 113 x 75	25425	4.118	145500	5.723
10%	225 x 113 x 75	25425	3.821	186800	7.347
Clinker	225 x 113 x 75	25425	4.032	217300	8.547
	225 x 113 x 75	25425	4.080	182800	7.190
	225 x 113 x 75	25425	3.908	151700	5.967
15%	225 x 113 x 75	25425	4.022	233700	9.192
Clinker	225 x 113 x 75	25425	3.793	174500	6.863
	225 x 113 x 75	25425	3.876	140400	5.522
	225 x 113 x 75	25425	4.077	178900	7.036

APPENDIX F

Compressive Strength Test Result for Air Curing at 14 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	3.723	181000	7.119
Clinker	225 x 113 x 75	25425	3.685	178800	6.954
	225 x 113 x 75	25425	3.727	164800	6.482
5%	225 x 113 x 75	25425	4.029	187100	7.359
Clinker	225 x 113 x 75	25425	3.892	218600	8.598
	225 x 113 x 75	25425	3.794	212400	8.354
	225 x 113 x 75	25425	3.791	171200	6.734
10%	225 x 113 x 75	25425	3.584	244100	9.601
Clinker	225 x 113 x 75	25425	3.818	213200	8.385
	225 x 113 x 75	25425	3.866	182200	7.166
	225 x 113 x 75	25425	3.893	242400	9.534
15%	225 x 113 x 75	25425	3.873	254300	10.000
Clinker	225 x 113 x 75	25425	3.837	190100	7.477
	225 x 113 x 75	25425	3.981	234900	9.239
	225 x 113 x 75	25425	3.821	208700	8.208

APPENDIX G

Compressive Strength Test Result for Water Curing at 28 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0% Clinker	225 x 113 x 75	25425	4.263	245900	9.672
	225 x 113 x 75	25425	4.292	214100	8.421
	225 x 113 x 75	25425	4.212	192500	7.571
	225 x 113 x 75	25425	4.293	208800	8.212
5% Clinker	225 x 113 x 75	25425	4.212	228400	8.983
	225 x 113 x 75	25425	4.105	189600	7.457
	225 x 113 x 75	25425	4.197	178600	7.025
10% Clinker	225 x 113 x 75	25425	4.159	193000	7.591
	225 x 113 x 75	25425	4.221	218200	8.582
	225 x 113 x 75	25425	4.096	168400	6.623
15% Clinker	225 x 113 x 75	25425	3.937	189100	7.438
	225 x 113 x 75	25425	3.996	223700	8.798
	225 x 113 x 75	25425	4.032	221000	8.692

APPENDIX H

Compressive Strength Test Result for Air Curing at 28 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Compressive strength (N/mm^2)
0%	225 x 113 x 75	25425	3.846	228500	8.987
Clinker	225 x 113 x 75	25425	3.805	199200	7.835
	225 x 113 x 75	25425	3.890	219400	8.629
	225 x 113 x 75	25425	3.954	252400	9.927
5%	225 x 113 x 75	25425	3.633	217800	8.566
Clinker	225 x 113 x 75	25425	3.556	215800	8.488
	225 x 113 x 75	25425	3.616	201100	7.910
10%	225 x 113 x 75	25425	3.680	195800	7.701
Clinker	225 x 113 x 75	25425	3.589	236000	9.282
	225 x 113 x 75	25425	3.906	243400	9.573
15%	225 x 113 x 75	25425	3.640	242600	9.542
Clinker	225 x 113 x 75	25425	3.778	241400	9.495
	225 x 113 x 75	25425	3.769	209600	8.244

APPENDIX I

Flexural Strength Test Result for Water Curing at 3 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	4.223	4190	0.1931
Clinker	225 x 113 x 75	25425	4.200	4520	0.1778
	225 x 113 x 75	25425	4.095	4310	0.1695
	225 x 113 x 75	25425	4.073	3590	0.1412
5%	225 x 113 x 75	25425	3.899	2860	0.1125
Clinker	225 x 113 x 75	25425	4.039	2970	0.1168
	225 x 113 x 75	25425	3.952	2630	0.1034
10%	225 x 113 x 75	25425	4.099	4340	0.1707
Clinker	225 x 113 x 75	25425	4.150	4360	0.1715
	225 x 113 x 75	25425	4.103	3710	0.1459
15%	225 x 113 x 75	25425	4.120	4380	0.1723
Clinker	225 x 113 x 75	25425	4.050	3920	0.1542
	225 x 113 x 75	25425	3.992	3060	0.1204

APPENDIX J

Flexural Strength Test Result for Air Curing at 3 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	4.037	4360	0.1715
Clinker	225 x 113 x 75	25425	3.899	3230	0.1270
	225 x 113 x 75	25425	4.020	4510	0.1774
5%	225 x 113 x 75	25425	3.933	3230	0.1270
Clinker	225 x 113 x 75	25425	3.730	2730	0.1074
	225 x 113 x 75	25425	3.876	3220	0.1266
10%	225 x 113 x 75	25425	3.801	4040	0.1589
Clinker	225 x 113 x 75	25425	3.887	4370	0.1719
	225 x 113 x 75	25425	3.870	4400	0.1731
15%	225 x 113 x 75	25425	4.165	4660	0.1833
Clinker	225 x 113 x 75	25425	3.792	3730	0.1467

APPENDIX K

Flexural Strength Test Result for Water Curing at 7 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0% Clinker	225 x 113 x 75	25425	3.804	3560	0.1400
	225 x 113 x 75	25425	3.994	5420	0.2132
	225 x 113 x 75	25425	3.684	2730	0.1074
	225 x 113 x 75	25425	4.077	5320	0.2092
5% Clinker	225 x 113 x 75	25425	4.451	4670	0.1837
	225 x 113 x 75	25425	4.327	6590	0.2592
	225 x 113 x 75	25425	4.307	5120	0.2014
	225 x 113 x 75	25425	4.024	5680	0.2234
10% Clinker	225 x 113 x 75	25425	4.046	5030	0.1978
	225 x 113 x 75	25425	4.195	4960	0.1951
	225 x 113 x 75	25425	4.109	4440	0.1746
	225 x 113 x 75	25425	4.105	4450	0.1750
15% Clinker	225 x 113 x 75	25425	4.069	4580	0.1801
	225 x 113 x 75	25425	4.278	4960	0.1951
	225 x 113 x 75	25425	4.029	4460	0.1754
	225 x 113 x 75	25425	4.100	5340	0.2100

APPENDIX L

Flexural Strength Test Result for Air Curing at 7 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	3.583	3740	0.1471
Clinker	225 x 113 x 75	25425	3.840	4070	0.1601
	225 x 113 x 75	25425	3.913	5150	0.2026
5%	225 x 113 x 75	25425	4.142	4880	0.1919
Clinker	225 x 113 x 75	25425	3.990	5670	0.2230
	225 x 113 x 75	25425	3.636	3640	0.1432
10%	225 x 113 x 75	25425	3.732	3770	0.1483
Clinker	225 x 113 x 75	25425	3.921	3590	0.1412
	225 x 113 x 75	25425	3.818	3920	0.1542
	225 x 113 x 75	25425	3.799	3800	0.1495
15%	225 x 113 x 75	25425	3.697	4190	0.1648
Clinker	225 x 113 x 75	25425	3.722	4030	0.1585
	225 x 113 x 75	25425	3.853	3300	0.1298
	225 x 113 x 75	25425	3.769	4020	0.1581

APPENDIX M

Flexural Strength Test Result for Water Curing at 14 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	3.841	5300	0.2085
Clinker	225 x 113 x 75	25425	4.039	6010	0.2364
	225 x 113 x 75	25425	3.883	4670	0.1837
5%	225 x 113 x 75	25425	4.116	5290	0.2081
Clinker	225 x 113 x 75	25425	4.038	6560	0.2580
	225 x 113 x 75	25425	4.065	5950	0.2340
	225 x 113 x 75	25425	4.105	4990	0.1963
10%	225 x 113 x 75	25425	4.171	6690	0.2631
Clinker	225 x 113 x 75	25425	4.043	6320	0.2486
	225 x 113 x 75	25425	4.177	6370	0.2505
	225 x 113 x 75	25425	4.095	6060	0.2383
15%	225 x 113 x 75	25425	3.930	7150	0.2812
Clinker	225 x 113 x 75	25425	3.962	6020	0.2368
	225 x 113 x 75	25425	3.774	4070	0.1601
	225 x 113 x 75	25425	4.025	5340	0.2100

APPENDIX N

Flexural Strength Test Result for Air Curing at 14 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	3.841	5240	0.2061
Clinker	225 x 113 x 75	25425	3.681	4350	0.1711
	225 x 113 x 75	25425	3.316	4030	0.1585
5%	225 x 113 x 75	25425	3.760	4950	0.1947
Clinker	225 x 113 x 75	25425	3.759	5070	0.1994
	225 x 113 x 75	25425	4.116	6300	0.2478
	225 x 113 x 75	25425	3.870	5530	0.2175
10%	225 x 113 x 75	25425	3.888	5730	0.2254
Clinker	225 x 113 x 75	25425	4.051	6940	0.2730
	225 x 113 x 75	25425	3.937	4870	0.1915
	225 x 113 x 75	25425	4.078	5190	0.2041
15%	225 x 113 x 75	25425	3.647	5330	0.2096
Clinker	225 x 113 x 75	25425	3.871	5190	0.2041
	225 x 113 x 75	25425	3.756	5570	0.2191
	225 x 113 x 75	25425	3.669	4950	0.1947

APPENDIX O

Flexural Strength Test Result for Water Curing at 28 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0% Clinker	225 x 113 x 75	25425	4.212	7040	0.2769
	225 x 113 x 75	25425	4.339	7010	0.2757
	225 x 113 x 75	25425	4.257	6310	0.2482
	225 x 113 x 75	25425	4.222	6180	0.2669
5% Clinker	225 x 113 x 75	25425	4.065	6430	0.2529
	225 x 113 x 75	25425	4.117	6100	0.2399
	225 x 113 x 75	25425	4.220	7100	0.2793
10% Clinker	225 x 113 x 75	25425	4.108	7170	0.2820
	225 x 113 x 75	25425	3.932	6310	0.2482
	225 x 113 x 75	25425	3.911	6520	0.2564
15% Clinker	225 x 113 x 75	25425	3.987	7220	0.2840
	225 x 113 x 75	25425	4.126	6680	0.2627
	225 x 113 x 75	25425	3.971	6190	0.2435

APPENDIX P

Flexural Strength Test Result for Air Curing at 28 Days

Ratio	Dimension (mm)	Area (mm^2)	Weight (kg)	Maximum load (N)	Flexural strength (N/mm^2)
0%	225 x 113 x 75	25425	3.942	5070	0.1994
Clinker	225 x 113 x 75	25425	3.928	5140	0.2022
	225 x 113 x 75	25425	3.885	5690	0.2238
5%	225 x 113 x 75	25425	3.773	6620	0.2604
Clinker	225 x 113 x 75	25425	3.899	6710	0.2639
	225 x 113 x 75	25425	3.766	5750	0.2262
10%	225 x 113 x 75	25425	3.976	6500	0.2557
Clinker	225 x 113 x 75	25425	3.785	6730	0.2647
	225 x 113 x 75	25425	3.812	5820	0.2289
15%	225 x 113 x 75	25425	3.956	6840	0.2690
Clinker	225 x 113 x 75	25425	3.798	6990	0.2749
	225 x 113 x 75	25425	3.761	6550	0.2576

APPENDIX Q

Density Test Result at 28 Days

Ratio	Types of Curing	Dimension (mm)	Weight after oven (kg)	Density (kg/m^3)	Density (kN/m^3)
0%	Water	225 x 113 x 75	3.727	1954.51	19.17
Clinker	Air	225 x 113 x 75	3.705	1942.97	19.06
5%	Water	225 x 113 x 75	3.980	2087.18	20.48
Clinker	Air	225 x 113 x 75	4.031	2113.93	20.74
10%	Water	225 x 113 x 75	3.986	2090.33	20.51
Clinker	Air	225 x 113 x 75	4.083	2141.20	21.01
15%	Water	225 x 113 x 75	4.024	2110.96	20.70
Clinker	Air	225 x 113 x 75	4.239	2223.01	21.81

APPENDIX R

Water Absorption Test Result at 28 Days

Ratio	Types of Curing	Dimension (mm)	Weight after oven (kg)	Weight after immersed (kg)	Rate of water absorption (%)
0%	Water	225 x 113 x 75	3.593	4.020	11.88
Clinker	Air	225 x 113 x 75	3.592	3.995	11.22
5%	Water	225 x 113 x 75	3.671	4.136	12.67
Clinker	Air	225 x 113 x 75	3.551	3.995	12.50
10%	Water	225 x 113 x 75	3.748	4.227	12.78
Clinker	Air	225 x 113 x 75	3.727	4.228	13.44
15%	Water	225 x 113 x 75	3.609	4.130	14.44
Clinker	Air	225 x 113 x 75	3.544	4.045	14.14