EXPERIMENTAL STUDY OF PROPERTIES FOR SAND BRICK WITH PALM OIL CLINKER AS A PARTIAL REPLACEMENT FOR FINE AGGREGATE WITH RATIO 7.5%, 12.5% AND 17.5%

NUR AFIFAH ADILAH BINTI YAAKOB

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

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NUR AFIFAH ADILAH BINTI YAAKOB

Project submitted in fulfillment of the requirements
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ABSTRAK

Penyelidikan telah menginovasikan penghasilan bata pasir dengan penggunaan bahan buangan yang banyak terbuang sebagai pengganti agregat dengan menggunakan klinker minyak kelapa sawit (POC).Di dalam laporan ini membentangkan hasil ujian makmal yang dijalankan secara fizikal keatas batu pasir yang dihasilkan bagi mengetahui sifat-sifat bata pasir tersebut yang mengunakan bahan dari sisa-sisa pepejal klinker minyak kelapa sawit (POC). POC adalah hasil sampingan industri kelapa sawit dan penggunaannya dalam penghasilan batu pasir. Dengan mengunaka Sisa-sisa pepejal ini tidak juga hanya menyelesaikan masalah dalam melupuskan tetapi juga membantu memulihara sumber semula jadi. POC telah digunakan sebagai bahan gantian untuk agregat halus. Nisbah POC yang telah digunakan adalah 7.5%, 12.5% dan 17.5% dengan menggunakan dua kaedah pengawetan iaitu udara dan air pada empat umur yang berbeza iaitu 3, 7, 14 dan 28 hari telah disediakan. Ujian kekuatan mampatan dan kekuatan lenturan dilakukan pada 3,7,14 dan 28 hari. Manakala untuk ujian ketumpatan dan penyerapan air akan diuji pada hari yang ke 28. Hasil daripada ujian makmal yang telah dilakukan ke atas bata pasir, ia menunjukkan keputusan bahawa nisbah terbaik pengunaan POC adalah 12.5% untuk proses pengawetan kedua-dua udara dan air yang meningkatkan kedua-dua kekuatan mampatan dan kekuatan lenturan pada prestasi bata. Ketumpatan dan penyerapan air bata meningkat sedikit apabila meningkatkan nisbah POC. Kajian ini juga dijangka menawarkan beberapa panduan dan arahan untuk kerja-kerja penyelidikan yang akan datang mengenai penggabungan POC

ABSTRACT

Research has diverged from the production of sand brick to the utilization of abundantly available waste materials as aggregate replacement by using palm oil clinker (POC). This report presents experimental results on properties of sand brick made of palm oil clinker (POC). POC is a by-product of palm oil industry and its utilization in sand brick production not only solves the problem of disposing this solid waste but also helps to conserve natural resources. POC were incorporated as a replacement material for fines aggregate. The ratios of POC that have been used are 7.5%, 12.5% and 17.5% by using two method of curing which are air and water curing at four different age of curing which are 3, 7, 14 and 28 days have been prepared. The compressive strength test and flexural strength test was conducted at 3,7,14 and 28 days. Whereas, for density and water absorption would be test at 28 days. The results shows that the best ratio of POC is 12.5% for both air and water which enhances both compressive strength and flexural strength performance of the brick. The density and water absorption of the brick increases slightly when increasing the ratio of POC. This study is also expected to offer some guides and directions for upcoming research works on the incorporation of POC.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials.
JKR	Jabatan Kerja Raya
MS	Malaysian Standard

CHAPTER 1

INTRODUCTION

1.1 Introduction / Research Background

Palm Oil Clinker (POC) which is obtained as a final by-product from the incineration process of oil palm shell and mesocarp fibre. It usually landfilled in the plantation areas. The POC is obtained in large chunks from the mill. (Hashim Abdul Razak, Jegathish Kanadasan, 2014). In developing countries where abundant agricultural and industrial wastes are discharged these wastes can be used as potential material or replacement material in the construction industry. The use of waste materials is a potential alternative in the construction industry. Waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications. (M.A.Mannan,C.Ganapathy , 2003). In order to achieve an environmentally friendly brick, several studies are on-going on the utilization of waste materials to produce green brick.

According to ISWA journal, Economic development and prosperity are accompanied by the generation of large amounts of wastes that must be re-used in some way or disposed in landfills The generation of wastes can be reduced to some extent by improved design of products. (Nickolas J. Themelis et al). The properties of POC make them useful for a variety of construction application. So it clearly, the different substitution materials will have different effects on the properties of the cement due to their chemical, physical and mineralogical characteristics . It has been an interesting topic for research due to environmental and technical reasons (Nickolas J. Themelis et al).

1.2 Problem Statement

In order to know whether the palm oil clinker was suitable to use in sand bricks, its lightweight properties allows for its utilization as an aggregate POC have their possible contributory factors were assessed. POC were incorporated as a replacement material for aggregates and their engineering characteristics were ascertained. But, there were some problem related with waste of palm oil clinker.

Palm oil factories generate various types of waste, which include, oil palm clinker. Improper management of these wastes could lead to environmental pollution. In 2013, 5.23 million hectares of oil palm were planted, which was 3% higher than in 2012. In July 2014, there were 440 fresh fruit bunch (FFB) mills in Malaysia, of which 247 mills were located in Peninsular Malaysia and the rest in Sabah and Sarawak. Utilization of POC in the construction industry could be a step in the right direction to substitute the depleting natural aggregates as well as providing proper waste management in the agricultural industry. (Jegathish Kanadasan , Auni Filzah Ahmad Fauzi , Hashim Abdul Razak , Paramananthan Selliah , Vijaya Subramaniam and Sumiani Yusoff , 2015)

The industrial sector generates a high amount of waste due to the continuous development it is undergoing. Often, these wastes are dumped off to sites, and they become hazardous. (Fuad Abutaha, 2018)

There were many good reasons to view palm oil clinker as a resource, rather than a waste. When it replaces raw materials, recycling palm oil clinker conserves natural resources and saves energy. In many cases, products made with palm oil clinker perform better than products made without it.

1.3 Objectives

The main objective of this research are the following:

I. To identify the compressive strength of 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 analyse the density of sand brick with palm oil clinker as a partial replacement for fine aggregate.
IV. To develop the water absorption of sand brick with palm oil clinker as a partial replacement for fine aggregate.

1.4 Scope of Study

In my research were focuses on compressive strength, density, flexural strength and water absorption which is related to aims of research. There are some of limitation in order to conduct this experiment:

I. Size of brick design (250 mm X 113mm X 75mm)
II. Size of aggregate for fines
III. Size of mould
IV. Curing (3,7, 14 and 28 day)
V. Experiment and testing will be conduct at Concrete Lab (FKASA)
VI. Palm oil clinker generate from palm oil shell burning which is at Lepar Hilir Palm Oil Mill Factory, Gambang, Pahang.

1.5 Significant of Research

The purpose of this experiment for produce the great sand brick which is used palm oil clinker as partial replacement that can be used across many regions of the globe within construction material sectors. Technically, address to save natural resources and energy (Craig Heidrich et al April, 2013). This material can contribute significant environmental and economic benefits. Advantage using these materials presents significant opportunities to advance sustainable materials, reduces green-house effect and global warming (Krishnamoorthy, 2000; Naik and Tyson, 2000).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Researchers have introduced industrial waste materials into brick as aggregate to preserve the natural resources and to find a safe method of depositing these waste materials instead of dumping them into the landfills. Examples of these waste materials are paper mill, crumb rubber and palm oil clinker. (Bashar S.Mohammeda, W.L.Foo and M.Abdullahi, 2014)

The respective literature represents a variety of investigations in the field of POC applications in constriction, although its practical use is occasional. Therefore, a rational utilization of POC waste is still relevant to the construction materials production. To conclude that, palm oil clinker to be the preferred choice in the construction which is widely used in the world.

High quality of sand brick were plays an important role to ensure quality and long life of the brick still depends on the quality. The research aims to give an assessment of the possible addition of ash waste to the mixture compositions intended for the production of bottom brick. Multipressure tests were still being carried out to ensure the bottom ash is able to bear the burden. (2013, M A Semenovykh)

The objective of current research work was to determine the effect of using Palm Oil Clinker (POC) as partial replacement. Towards this, the compressive and flexural strength properties of sand bricks. Then were then compare with ratio of proportion POC in percent. The material chosen were carefully studied with respect to their properties such as moisture content, specific gravity, bulk density and chemical composition.

2.2 Material Properties of Palm Oil Clinker

The burning process of oil palm fiber produces palm oil clinker (POC), which is obtained in large chunks ranging between 100 and 400 mm before being crushed into aggregates with the required sizes. Physically the inner portions of POC are highly porous, which significantly contributes towards the lightweight nature. In order to know the potential of sand brick which compositions containing POC, studying properties of POC in term of physical and chemical properties. (Jegathish Kanadasan 1, Auni Filzah Ahmad Fauzi 1, Hashim Abdul Razak , Paramananthan Selliah , Vijaya Subramaniam and Sumiani Yusoff , 2015)

2.2.1 Physical Properties of POC

The physical properties of all the aggregates used are presented in Table 2.1. Based on its physical properties, POC falls within the criteria for structural lightweight aggregate. (Fuad Abutaha , HashimAbdul Razak and Jegathish Kanadasan, 2016)

Table 2.1 Physical characteristics of the POC Fines aggregates

Properties	**Aggregate**			
	Sand	**Granite Coarse**	**POC Fine**	**POC Coarse**
Aggregate size (mm)	<5	5-14	<5	5-14
Specific gravity	2.6	2.65	2.15	1.73
Water absorption (%)	0.39	0.58	10 ± 5	3 ± 2
Moisture content (%)	0.08	0.28	0.5 ± 0.25	1 ± 0.5
Aggregate crushing value (%)	-	17.93	-	56.44
Aggregate crushing value (Ten per cent fines)	-	-	-	16.99
Bulk Density (kg/m^3)	1361	1294	811	732

Source: Fuad Abutaha et al. (2016)

2.2.2 Chemical Properties of POC

Study the chemical composition variation of POCP from different geographical conditions and locations of Malaysia. They reported that the variation in the chemical composition of POCP resulted from the incineration ratio of fiber and shell, burning temperature as well as the soil type where the tree of palm oil was grown.

Table 2.2 Chemical composition of POCP compared to OPC

Chemical composition (%)	OPC	POCP
SiO_2	22.14	60.29
Al_2O_3	3.84	5.83
Fe_2O_3	2.98	4.71
$SiO_2 + Al_2O_3 + Fe_2O_3$	28.96	70.83
CaO	65.21	3.26
MgO	1.54	3.76
SO_3	3.22	0.11
K_2O	0.012	7.79
P_2O_5	0.012	3.10
TiO_2	0.002	0.13
Specific surface area (m^2/kg)	339	418

Source: Abdul Razak Hussein et al. (2018)

It can be seen from Table 2.2 that POCP is majorly composed of silica (SiO_2). This could affect the blending properties between cement and POCP significantly to produce different fresh, hardened and microstructure properties. (Fuad Abu taha Hashim, Abdul Razak Hussein, Adebayo Ibrahim and Haider Hamad Ghayeb, 2018)

2.3 Mechanical Properties of POC

POC is available in the form of solid lightweight material in varying sizes between 20 and 150 mm. Typically, POC is obtained in a large chunk and it is porous in nature with a sharp and rough broken edges, and often flaky with an irregular shape. (Fuad Abu taha, Hashim Abdul Razak, Hussein Adebayo Ibrahim and Haider HamadGhayeb, 2018). POC is a blackish coloured solid waste material. It is considered stable and non-biodegradable under normal environmental condition. (Mohammad Razaul Karim, Huzaifa Hashim ,Hashim Abdul Razak and Sumiani Yusoff, 2017)

2.4 Problem of Palm Oil Clinker

Palm oil clinker (POC) is the most substantial waste material discarded from palm oil mills in Malaysia for use in concrete construction (Mohammad Razaul Karim, Huzaifa Hashim and Hashim Abdul Razak, 2016)

Palm oil mills produce large amount (equivalent to around 70% of raw material) of solid waste by products in the form of fibers, nutshells, and empty fruit bunches. The nutshells and fibers are used extensively as biomass fuel, replacing fossil fuels such as petroleum in generating electricity. Combustion in a steam boiler produces approximately 5% of POC. This waste is left in open land that can lead to serious pollution in the environment. (Mohammad Razaul Karim, Huzaifa Hashim ,Hashim Abdul Razak and Sumiani Yusoff, 2017)

2.5 Material Used

Sand brick may be defined as mixture of water, cement or binder, sand and aggregate, where water and cement or binder from the paste and the aggregate forms the inert filler.

2.5.1 Cement

For this experimental program, Ordinary Portland cement (ASTM: Type-I) was used as the binder materials in the concrete which has the specific gravity of 3.14 g/cm^{3}and fineness of 3510 cm^2/g. This cement was collected from the Malaysian local market. The 7 and 28-day compressive strength of the cement was 34.2 and 45.9 MPa, respectively. (Md. NazmulHudaa, Mohd Zamin BinJumata and A.B.M. SaifulIslamb, 2016)

Another researcher also used Ordinary Portland Cement (OPC) in the study. The physical properties of cement were determined by laboratory tests and are reported in Table2.3 (Job Thomas, , Nassif Nazeer Thaickavil, and P.M. Wilson, 2018)

Table 2.3 Physical properties of Portland cement.

SI No.		Magnitude
1	Specific gravity	3.15
2	Standard consistency (%)	31.5
3	Initial setting time (min)	130
4	Final setting time (min)	279
5	Compressive strength- 28 days (MPa)	59

Source: Job Thomas et al. (2018)

2.5.2 Palm Oil Clinker

The collected POC was crushed with a crushing machine and sieved to produce aggregates similar to other types of aggregates, such as sand and granite, for the purpose of this research. Fig. 1 shows the coarse and fine POC that are incorporated in this study. (Fuad Abutaha , HashimAbdul Razak and Jegathish Kanadasan, 2016)

Figure 2.1 POC collected from the palm oil mill

Source: Fuad Abutaha et al. (2016)

2.5.3 Water

The water used in this study is from tap water which free from impurities. The usage of tap water is an alternative of controlling the quantity of water since its most practical solution and it is accordance to BS EN 1008 (2002). (Wan Ibrahim M. H 2015). The function of Portable tap water was used for mixing cement-lime mortar; the w/c or w/cm ratio was maintained to achieve minimum consistency of mortar according to ASTM C270-14 (ASTM C270-14, 2014). (Ramappa RameshNayaka, U. JohnsonAlengaramMohd ZaminJumaat, Sumiani BintiYusoff and Mohammed FouadAlnahhal, 2018)

2.5.4 Sand

Fine aggregate- manufacturing sand (M-sand). M-sand was collected from the local quarry dust industry of Malaysia. The physical properties of M-sand are shown in Table 24. (S.M. AlamgirKabir, U. JohnsonAlengaram, Mohd ZaminJumaat, SumianiYusoff, AfiaSharmin, Iftekhair Ibnu lBashar, 2017)

Table 2.4 Physical properties of sand as fine aggregates

Properties	Materials				
	M- sand	**POC < 9 mm**	**POC < 14mm**	**Crushed OPS**	**Crushed granite**
Size	<5 mm to 300 μm	5 to 9 mm	9 to 14 mm	5 to 9 mm	9 mm
Specific gravity (SSD)	2.78	1.76	1.68	1.3	2.67
24 h Water absorption (%)	5.6	6.08	5.56	24.3	0.95
Compacted bulk density (kg/m^3)	-	801	813	638	1472

Source: Mohd ZaminJumaat et al. (2017)

2.6 Application of POC

The use of waste material in the construction industry has gained significant attention lately due to its capability to produce almost equivalent performance compared to conventional materials. This increases the industrial awareness to channel by-products for use in another industry. Such a scenario produces a 'win-win' situation for both industries in that it eases the waste management issues for the processing industry, while simultaneously reducing the dependency of the construction industry on the diminishing natural resources for raw materials. (Jegathish Kanadasana, Hashim AbdulRazak and VijaySubramaniam, 2018)

POC as aggregate to produce lightweight brick. The advantages of lightweight brick have been identified by several researchers which include reduction in building cost, ease of construction, thermal and acoustic insulation, fire resistance, reduction in building weight, and as a mean of disposal of waste. (Bashar S.Mohammeda, W.L.Foo and M.Abdullahi, 2014)

2.7 Casting and Curing

Concrete cube of 100 mm x 100 mm x 100 mm sizes were cast to determine the compressive strength, water absorption, density and pulse velocity. The specimen were demoulded after 24 ± 1 h of adding water to concrete mixture and were water cured at room temperature up to a specified age of the test. The casting and curing of samples were performed in accordance with the specification of BS 12390-02. (Hasan M. Tantawi and Emhaidy S. Gharaibeh, 2006)

2.8 Production of Brick

The bricks used to be in the form of sun-dried mud blocks. Since then, a lot of modifications have been done in the composition of bricks and in brick making procedures. As a result, in today's world, brick is considered as one of the most sought after materials used in the construction of various civil engineering structures. Now-a-days, bricks are mostly made of clay and sand mixed in suitable proportion, to which binder is added. Many-a-time, the bricks are also made up earth blocks stabilized with different materials. The stabilized block is then pressed to a suitable shape and size that can be either fired or sun-dried. However, much variation is observed in the properties of bricks and especially in its compressive strength, depending upon the composition of bricks and the manufacturing procedures. (Anant L.Murmu and A.Patel, 2018)

2.9 Testing

The testing including, compressive strength, flexural strengths, density and water absorption of the sustainable lightweight concrete were obtained and analysed.

POC coarse aggregates decreased the compressive strength and density of the concrete, while increasing its porosity and coefficient of permeability. However, the reduced strength can be acceptable for other applications such as pedestrian trials and walkways. (Hussein Adebayo Ibrahim, Hashim Abdul Razak and Fuad Abu taha, 2017)

2.9.1 Compressive Strength

Compressive strength test were conducted in accordance with BS: EN 12390-3. The test was carried out at 3, 7, 28 and 56 days of age. Cubes specimen of size 100 mm × 100 mm × 100 mm were prepared for each mix. After 24 h, the specimens were de-moulded and cured until days of testing. Water cured samples were allowed to attain saturated surface dry condition (SSD) prior to tests. The strength value reported is an average of three samples. (Hussein Adebayo Ibrahim, Hashim Abdul Razak and Fuad Abu taha, 2017)

2.9.2 Flexural Strength

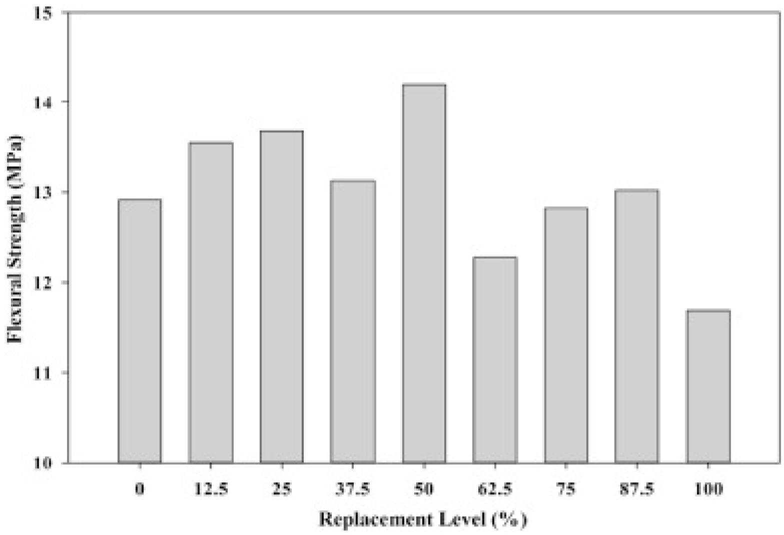

Figure 2.2 Relationship between POC replacement and flexural strength.

Source: Fuad Abutaha et al. (2016)

As observed from the figure 2.2, generally, an increase in the POC fine replacement level reduces the flexural strength beyond 50% replacement level. However, significant improvements in the flexural strength were recorded for POC 12.5, POC 25, POC 37.5 and POC 50 which were higher than control specimens by 4.9%, 5.9%, 1.6% and 9.9%, respectively. This is again highly affected by the good interlocking rate between POC fine and cement matrix. (Jegathish Kanadasan, Hashim Abdul Razak and Vijaya Subramaniamc, 2018)

2.9.3 Density

Four types of densities, namely fresh, demoulded density after 1-day, saturated surface dry, and oven-dry samples were measured for all mixtures as shown in Table 25.

Table 2.5 Physical properties of sand as fine aggregates

Mix No.	Density (kg/m^3)			
	Fresh	Demoulded (after 1 day)	Saturated surface day (28 day)	Oven dry
MPOC00	2095.39	2076.57	2109.80	1896.84
MPOC05	2085.44	2065.07	2101.66	1893.35
MPOC10	2100.00	2083.56	2129.76	1915.07
MPOC15	2120.63	2100.62	2154.16	1944.58
MPOC20	1959.30	1936.42	2014.71	1828.16

Source: N.H. Ramli Sulong et al. (2017).

Based on the oven dry density, the control POC (mix MPOC00) concrete was about 21% lighter than normal weight concrete considering its oven dry density 2400 kg/m^3. (Rasel Ahmmad, U. Johnson Alengaram, Mohd Zamin Jumaat, N.H. Ramli Sulong, Moruf O.Yusuf and Muhammad Abdur Rehman, 2017,)

2.9.4 Water Absorption

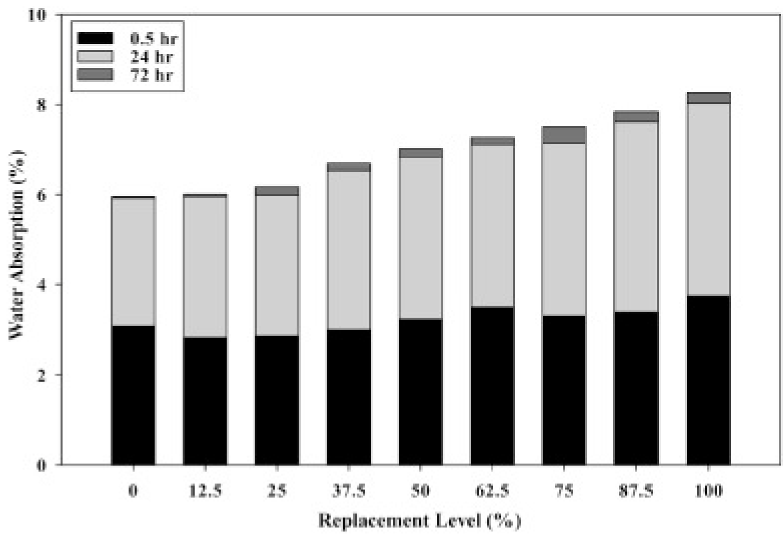

Figure 2.3 Relationship between POC replacement and water absorption.

Source: Rasel Ahmmad et al. (2017)

Fig. 2.3 shows the test was conducted based on BS 1881-122 (1983). Generally, increasing the POC fine replacement level produced higher water absorption properties. For example, the water absorption values for POC 0, POC 25, POC 50, POC75 and POC 100 were 5.9%, 6.2%, 7.0%, 7.5% and 8.3%, respectively. (Jegathish Kanadasan, Hashim Abdul Razak and Vijaya Subramaniamc, 2018)

2.10 Sustainability of POC Material

One of the current global trends is focused on recovery of usable materials from waste as well as utilization of waste as raw materials whenever feasible in construction. This can be done by exploring the means to put waste into beneficial alternative use. Examples of waste materials that has been incorporated into construction include palm oil clinker (POC). (Hussein Adebayo Ibrahim and Hashim Abdul Razak, 2016)

Based on the availability of agro-waste materials, sustainable construction materials are evaluated for their physical, mechanical properties, methods of production and environmental impact. The application of agro-waste for sustainable construction materials provides a solution which offers reduction in natural resource use as well as energy. (Mangesh V.Madurwar, Rahul V.Ralegaonkar and Sachin A.Mandavganeb, 2013)

In this way, for a large number of applications in the civil and structural engineering sector, concrete can be considered an environmentally friendly and sustainable construction material, which can contribute to a better quality of life for all mankind. (Payam Shafigh, Hilmi Bin Mahmuda Mohd Zamin Bin Jumaat, Rasel Ahmmad and Syamsul Bahria, 2014,)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter clearly defines my research methods used which is by experimental in order to conduct my study. In this chapter also, I would explains how the necessary data and information to address the research objectives and data collected, presented and analysed from conducting the testing at FKASA Concrete Laboratory UMP. The flow of work done from start to finish studies were done.

Figure 3.1 UMP FKASA Concrete Laboratory.

Current situations in the production of sand bricks, there were various blended cement and alternative material have been used or added to the normal brick. Thus, the comparison will be made between control samples and sand brick with different ratio (in percent) of Palm Oil Clinker, POC. All the parameter, equipment, apparatus, material and principle of testing would follow the standard.

3.2 Research Design

Master plan and the flow of work which indicates the strategies for conducting the search were shown in figure below:

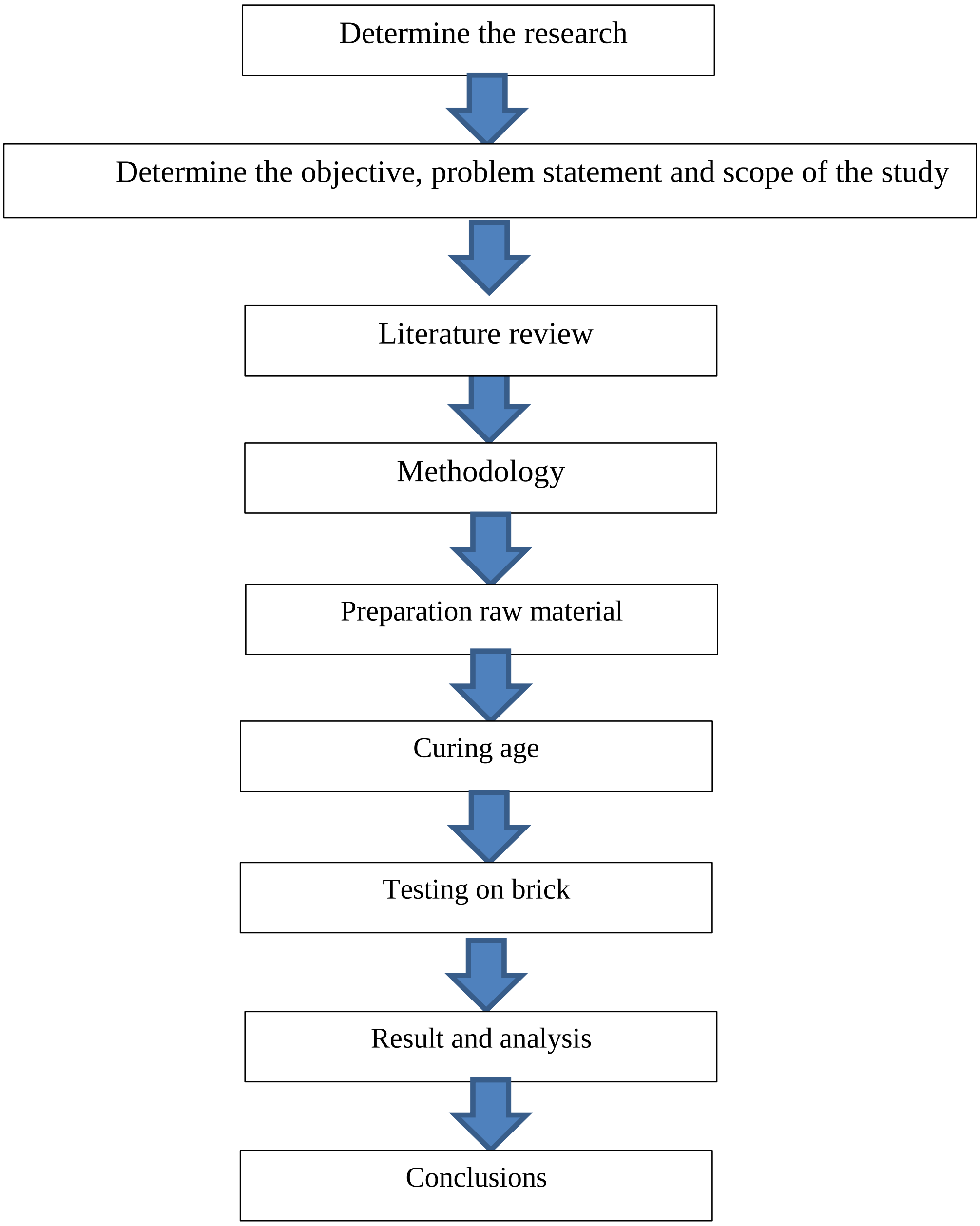

Figure 3.1 Flow chart of Final Year Project

3.3 Raw Material Preparation

The raw material preparation stage of Sand Bricks design. Basic substance in mixture which is sand, water, Palm Oil Clinker, and Ordinary Portland Cement (Brand of Orang Kuat). On my research, the brick would make in process of mechanization. Today technological and mechanical advancement has helped to have a more complete knowledge of the raw material and its properties, and better control of firing, improvement in the kiln designs, all have contributed to the advancement of brick quality and has made contemporary bricks more efficient and has improved the overall quality of the products.

Rate mixing materials of palm oil clinker as partial replacement is based on a predetermined ratio which were 7.5%, 12.5% and 17.5%.

3.3.1 Palm Oil Clinker

The POC was taken from the Lepar Hilir Palm Oil Mill Factory. The by-product that is collected from inside the boiler is called clinker or boiler stone. The clinker looks like a porous stone which is grey in colour. All the clinkers are prepared to be crushed into required size. Clinker size below 4.75mm is used as fine aggregate. The POC particles were sieved by using pan size passing 4.75 mm BS 410 Sieve.

Figure 3.3 Palm Oil Clinker

3.3.2 Sand

Sand are taken from FKASA Concrete Laboratory of Faculty Civil Engineering. Sand is a loose, fragmented, naturally-occurring material consisting of very small particles of decomposed rocks, corals, or shells. Sand is used to provide bulk, strength, and other properties to construction materials. That sand is dried in order to remove the moisture content of sand which is the trapped water content between the sand particles can cause the density to vary substantially. The maximum sand passing the same gradation size with coal bottom ash which is passing 4.8 mm mesh BS Sieve Percentage by mass passing BS 410 sieve. Aggregate specification under Clause 2.2, JKR Specification of Building Works 2005. Fulfill the requirement of 100% passing through the sieve shaker.

Table 3.1 Standard for Sieve Size

Sieve size (BS 410)	Percentage by mass passing BS 410 sieve			
	Overall limits	Additional limits for grading		
		C	* M	F
10.0 mm	100	-	-	-
5.0 mm	80 to 100	-	-	-
2.36 mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18 mm	30 to 100	30 to 90	45 to 100	70 to 100
600 μm	15 to 100	15 to 45	25 to 80	55 to 100
300 μm	5 to 70	5 to 40	5 to 48	5 to 70
150 μm	0 to 15#	-	-	-

Increase to 20% for crushed rock fines, except when they are used for heavy-duty floors.
* For prescribed mix only Grading Limit M is applicable. See also clause 2.2.3(b).
NOTE: Individual sands may comply with the requirements of more than one grading. Alternatively some sands which satisfy the overall limits but may not fall within any one of the additional limit C, M or F may also be used provided that the supplier can satisfy the S.O that such materials can produce concrete of the required quality.

Source: JKR Standard Specification for Building Works in Clause 2.2. (2005).

3.3.3 Water

Clean water is used at Concrete laboratory. That clean water is an almost non-existent entity. Its quality should be assured in the same way as any other raw material or ingredient. Quality control of water as raw material in sand brick's design. Water is the most important and least expensive ingredient of concrete. It distributes the cement evenly. It lubricates the mix. The quantity of water is the most important parameter and is controlled by the w/c ratio.

As the quantity of water in a mix goes up, the following effects are notices: the strength decreases, durability decreases, workability increases, cohesion decreases and the economy may increase at the expense of quality and reliability. Clean water is used in the study for both mixing and curing.

Figure 3.4 Source of clean water get from pipe of Concrete Laboratory

3.3.4 Cement

Ordinary Portland cement (OPC), is grey in colour. The cement used is Brand of Orang Kuat, because of its fine nature, good particle size distribution, optimal phase composition, imparts the properties of higher strength to the structures and the chemical and physical lab properties.

The standard ratio of cement and sand to be used in cement sand brick is 1:6 which is based on JKR Specifications Standard for Building Works 2005 in Clause 3.3.3 under Composition.

According to this Standard also, cement sand brick should follow MS 27 in order to produce a good cement sand brick.

Figure 3.5 Ordinary Portland Cement (Brand Of Orang Kuat)

Based on JKR Specification, it state that mechanical mixer is capable:

- One (1) bag of cement = 50kg of cement shall be taken as 0.035 cube

Size of sand brick

225 x 113 x 75 mm

Total volume for one brick

0.225 x 0.113 x 0.075

= 0.001907 m^3

Ratio for sand brick 1:6

Cement = 1 /7 x 0.001907 = 0.0002724 m^3

Sand = 6/7 x 0.001907 = 0.001635 m^3

Total cement and sand used:

1 m^3 = 2406.53 kg

Cement = 0.0002724 m^3 = 0.66 kg

Sand = 0.001635 m^3 = 3.93 kg

3.4 Preparation of Specimen

The sand brick structures will designed are follow standard procedure in order to obtain the sand brick properties based on Malaysian Standard and the gradation parameters with the requirement from JKR specification.

3.4.1 No. of Specimens

Table 3.2 Total unit of specimen for one ratio

Testing	**Type of Curing**	**3 days**	**7 days**	**14 days**	**28 days**	**total**
Compressive Strength	**Air**	3	3	3	3	12
	water	3	3	3	3	12
Flexural Strength	**Air**	3	3	3	3	12
	water	3	3	3	3	12
Density& Water Absorption	**Air**				3	3
	water				3	3
	TOTAL					54

From the Table 3.2, it shows the total unit of sand brick would be produce for one ratio which including four types of testing and age of curing days. Number of Standard or normal brick are 54 unit would be produce for all total curing of the day that state in grant. For the partial replacement of Palm Oil Clinker for each percent (%) also would be produce 60 unit. So, the overall total number of specimens are 216 unit.

3.4.2 Size of Specimens

The standard nominal size used for cement sand brick according to Standard Specifications for Building Works 2005 are 225 mm length, 113 mm width and 75 mm height.

Table 3.3 Dimension of Brick

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

3.5 Mixture Process

The Palm Oil Clinker is sundried in two days and stored in a dry place. The ratio of POC is 7.5%, 12.5% and 15% are prepared to mixture the proportions of cement and sand. Each mixture proportion contains 10 bricks of sample for testing 3, 7, 14, and 28 days. Sample for 0% of CBS are used as the control sample. The design of the mixture are measured to be mixed to produce a mixture of sand brick. It is important to ensure get the result and strength of brick. Table below shows the mix design for each ingredient in the production of sand brick.

Table 3.4 Ratio of Mix Design Sand Brick

Mixture	Ratio of Mixture	
	Sand	Palm Oil Clinker (%)
0	100	0
1	92.5	7.5
2	87.5	12.5
3	85	15.0

3.6 Curing Process

3.6.1 Air Curing

Figure 3.6 All the specimens for air curing would place at rack

3.6.2 Water Curing

Provide adequate circulation of water and space for between the cubes, and between the cubes and the side of the curing tank. Curing is in a mist room, there are sufficient space between cubes to ensure that all surfaces of the cubes are moist at all times.

Figure 3.7 All the specimens for water curing will place at curing tank

Based on JKR Specifications in Clause 4.4 and 4.5 it state that each sample batch shall be tested for the 28-day compressive strength for designed mix. But for this research, it follow grant that state for curing day are 3, 7, 14 and 28 days

Table 3.5 Type of curing process

Curing	**proportion**	**3 days**	**7 days**	**14 days**	**28 days**
	Standard	3	3	3	3
	7.5%	3	3	3	3
water curing	12.5%	3	3	3	3
	17.5%	3	3	3	3
	Standard	3	3	3	3
	7.5%	3	3	3	3
Air curing	12.5%	3	3	3	3
	17.5%	3	3	3	3

Table 3.5 shows the types of curing process for each of sand brick with four different age of curing days.

3.7 Laboratory Test

In order to determine the properties of sand brick, it shall undergo quality tests to achieve my objective of research in chapter one (1). These testing will follow the Standard Specifications of ASTM.

3.7.1 Compressive Strength Test

The compressive strength test known as compressive test was used to measure the performance of the brick sample compared to standard sand brick. The brick considered strong if they can resist the crushing load better than the standard through maximum load achieved. The size of sample which is complying with ASTM C67-03a is 225mm X 113mm X 75mm was tested on 3, 7, 14 and 28 days curing age. The sample was test immediately after the removal of sample from curing tank. The sample was put into a compressive testing machine with thick plates placed above and below each sample to distribute load equally.

The main objective of this testing is to determine the compressive strength of sand brick. Based on Malaysian Standard (MS27), the minimum permissible average compressive strength is about 5.2 N/mm2 per 3 samples.

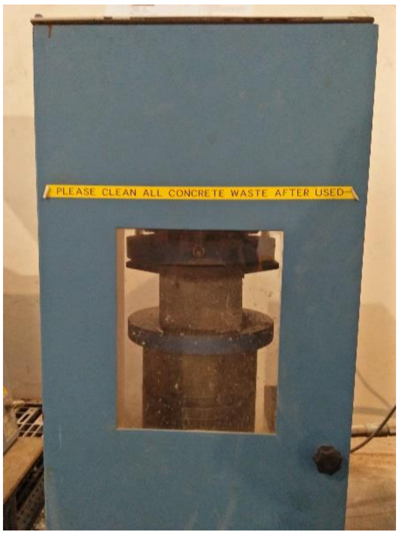

Figure 3.8 Compressive Strength Test Machine

3.7.1.1 Procedures

The testing procedures based on ASTM C 67.

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 (vi) was repeated on other sample for control sample, 7.5%, 12.5% and 17.5% bottom ash at 3, 7, 14 and 28 days for water curing and air curing.

3.7.2 Heading 3Flexural Strength Test

Flexural test evaluates the tensile strength of sand brick indirectly. It tests the ability of sand brick to withstand failure in bending. The results of flexural test on sand brick expressed as a modulus of rupture which denotes as (MR) in MPa or psi. The flexural strength is theoretically derived from the elastic beam theory, where stress-strain relation is assumed to be linear. Therefore, modulus of rupture is commonly presenting an overestimate value of brick tensile strength. The flexural test on sand brick can be conducted using the center-point loading test (ASTM C293).

The objective of this testing is to determine the flexural strength for sand brick.

Figure 3.9 Flexural Strength Test Machine

3.7.2.1 Procedures

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 0.10mm using leather shims (6.4mm thick and 25 to 50mm long) and it should extend the full width of the specimen.

VIII. Capping or grinding should be considered to remove gaps in excess of 0.38mm.

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 a rate that constantly increase the extreme fiber stress between 125 and 175 psi/min (0.86 and 1.21 MPa/min) until rupture occurs.

3.7.3 Density Test

This test method to determine of density, percent absorption and percent voids in sand brick. Testing procedures based in ASTM 04.02 C 642-97 (page 338) which is Standard Test Method for Density Absorption and Voids in Hardened.

3.7.3.1 Procedures

Oven-Dry Mass

I. The mass of the portions is determined.

II. Dry the specimens in an oven at a temperature of 100-110˚C for not less than 24-hr.

III. After removing each specimen from the oven, cool in dry air (preferably in a desiccator) 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-hr and again determine the mass.

VI. If the third value checks the second, consider the specimen dry.

VII. In case of any doubt, redry the specimen for 24-hr 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-hr 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.

Figure 3.10 oven-dry process on brick

3.7.4 Water Absorption Test

This test method used for determining the relative water absorption properties over time of sand brick. This is because the samples are made under laboratory conditions. The test was conducted at FKASA concrete laboratory. There are 5 samples of bricks for each ratio required for this test. Meanwhile, this specimen need to dry for a 3 days, 7 days, 14 days and 28 days. According to ASTM Standard C 140 -03 there are two main procedures of absorption testing :

3.7.4.1 Procedures

Saturation

I. Immerse the test specimens in water at a temperature of 15.6 °C - 26.7°C for 24 hours.

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 to drain 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)

Drying

I. Dry all specimens in a ventilated at 100°C to 115°C for not less than 24 h and until two successive weighings 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, from this test the water absorbed can be obtained between the weights recorded. The quality of brick are determined by the percentages of water absorbed. If the less water absorbed the brick can be classified as good quality brick.

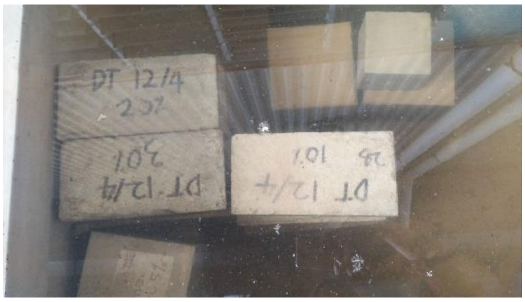

Figure 3.11 Immersed sand brick in water tank

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Chapter 4 discuss about the results of laboratory test that consist of control sample and sample with different ratio. In this laboratory test, the total units of sand brick produce are 240 units. The ratios of palm oil clinker, POC that have been used are 7.5%, 12.5% and 17.5% by using two method of curing which are air and water curing at four different age of curing which are 3, 7, 14 and 28 days. From the results of laboratory test conducted, compressive strength and flexural strength, at every age of days curing will be determined but for water absorption and density will be test at 28 days of curing. Lastly, this part also shows the comparison between control sample and the other three different ratios.

4.2 Sand Brick Test

In order to achieve the objectives of these research study, this part deal with four test conducted which are compressive strength, flexural strength, water absorption and density test that complied with American Society for Testing and Materials, ASTM Standard procedure for concrete work. Besides, for the different age of days curing, JKR Standard for Building Work 2005 and Malaysia Standard (MS) were referred.

4.2.1 Compression Strength Test

. Compression strength test were conducted using Compression Machine for brick size of samples in order to get the maximum load of compression strength by using this following equation:

$$C = \frac{W}{A} \qquad 4.1$$

Where:

C= Compressive strength of the sample (N/mm^2 or MPa)

W= Maximum load indicated by testing machine (N)

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

Table 4.1 Compressive Strength for Air Curing

Days	**Compressive Strength (N/mm²)**			
	Control Sample	**7.5% POC**	**12.5% POC**	**17.5% POC**
3	5.31	5.533	6.240	5.304
7	4.64	5.909	6.631	6.252
14	6.853	6.637	7.297	6.736
28	8.845	7.812	8.936	7.264

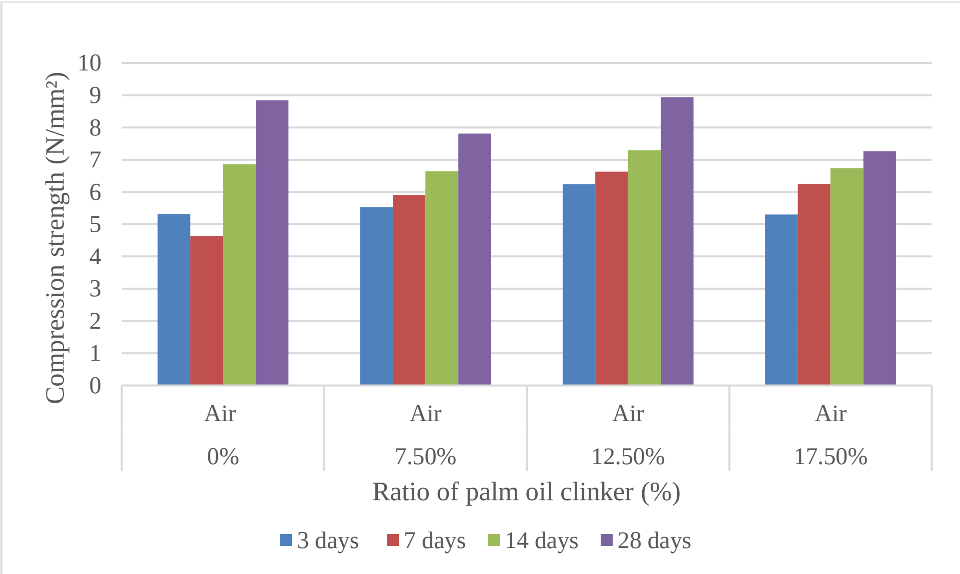

Figure 4.1 Graph of Compressive Strength for air curing of POC

The bar chart shows the air curing for compression strength against ratio of palm oil clinker. At 28 days, the highest result is 8.845 N/mm² for 12.5% ratio compare to the other samples. It can be seen that at 14, 7 and 3 days, the highest is 7.297 N/mm², 6.631 N/mm² and 6.24 N/mm² respectively for 12.5%.

The ratio of palm oil clinker for 17.5% relatively low for all age of curing. It notice that, at 0% of POC which is at 7 days of curing age, 0.67 drop from 5.31N/mm² to 4.64N/mm². So, it can be concluded that the compression strength test result for air curing at 0%, 7.5% and 12.5% increase steadily.

Table 4.2: Compressive Strength for Water Curing

Days	**Compressive Strength (N/mm²)**			
	Control Sample (0% POC)	**7.5% POC**	**12.5% POC**	**17.5% POC**
3	4.500	4.975	5.148	5.121
7	5.490	5.792	6.327	5.932
14	5.940	6.813	7.275	6.345
28	8.469	6.890	8.579	6.630

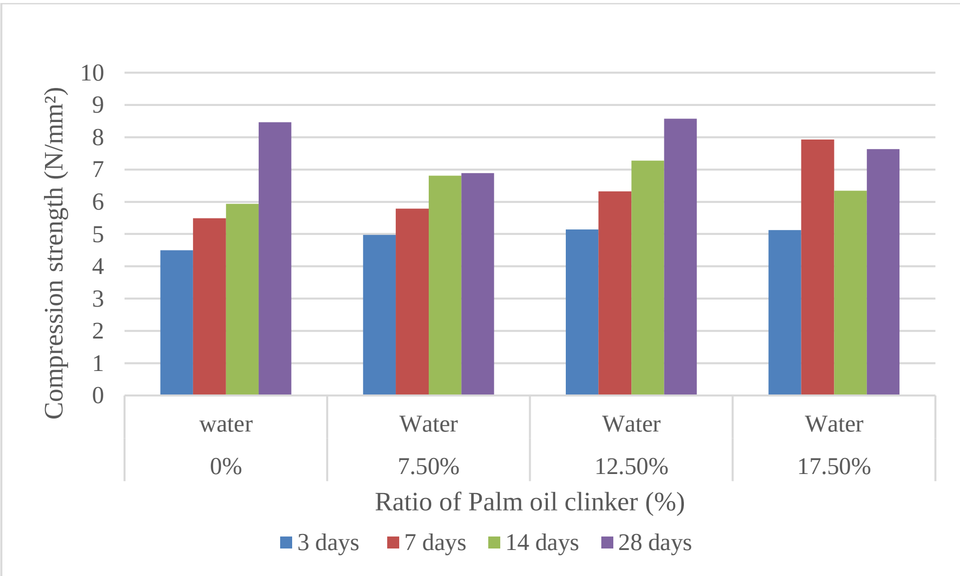

Figure 4.2 Graph of Compressive Strength for air curing of POC

From the compression strength test results for water curing with four different curing age, it shows the highest compression strength is 8.579 N/mm² which is at 28 days with ratio 12.5% of palm oil clinker. While the lowest compression strength is 4.50 N/mm² which is 3 days curing age on 0% ratio of POC.

At first glance at the chart, it is noticeable that, it increase gradually from all the three ratio with days of curing except for ratio 17.5%. Next, the graph fluctuated at ratio 17.5% of POC. Besides that, at ratio 7.5% of POC, graph increase gradually whereas from 14 days to 28 days the increment is only by 0.077 N/mm².

Table 4.3 Compressive Strength for Air and Water Curing

Ratio of palm oil clinker	Type of curing	3 days	7 days	14 days	28 days
Control sample	Air	5.31	4.64	6.853	8.845
	water	4.50	5.49	5.940	8.469
7.5%	Air	5.533	5.909	6.637	7.812
	Water	4.975	5.792	6.813	6.890
12.5%	Air	6.24	6.631	7.297	8.936
	Water	5.148	6.327	7.275	8.579
17.5%	Air	5.304	6.852	6.736	7.264
	Water	5.121	5.932	6.345	6.630

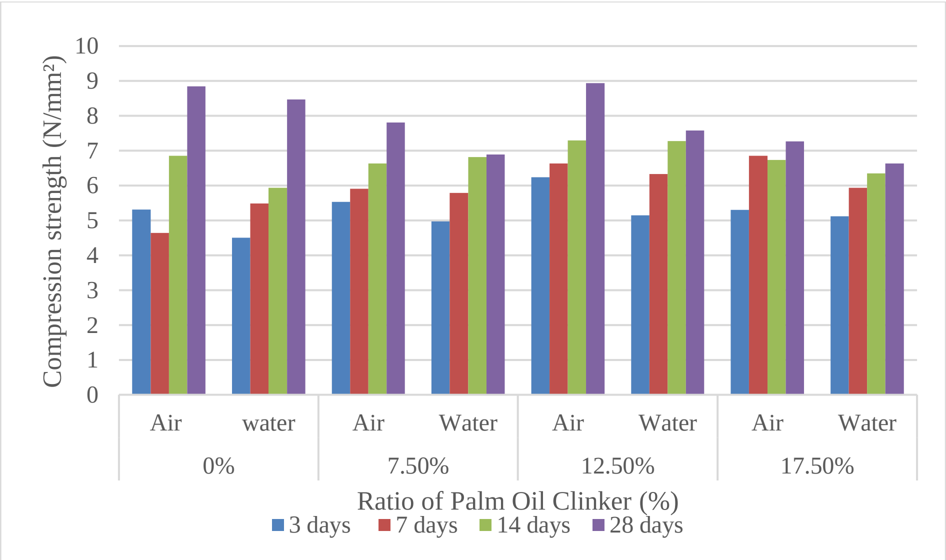

Figure 4.3 Graph of Compressive Strength for air and water curing of POC

The bar chart illustrates the air and water curing for compression strength test result against ratio of palm oil clinker. From the graph, it shows air curing led to a rise compare to water curing for all ratio which is 0%, 7.5%, 12.5% and 17.5%.

For the control samples, it is clearly shows that increased trends for all age of day curing on water curing whereas for air curing it shows slightly drop at 7 days age of curing. Besides that, result for ratio 12.5% is higher than ratio7.5% of POC on both air and water.

Overall, the best of compression strength results is ratio 12.5% of POC for both air and water curing which is at 28 days.

4.2.2 Flexural Strength Test

The flexural test on sand brick can be conducted using the center-point loading of flexural machine test (ASTM C293) for brick or cube size of sample at concrete. In order to get the maximum load of flexural strength by using this following equation:

Table 4.4 Flexural Strength for Air Curing

Days	Flexural Strength (N/mm^2)			
	Control Sample	**7.5% POC**	**12.5% POC**	**17.5% POC**
3	0.159	0.179	0.186	0.151
7	0.170	0.187	0.199	0.180
14	0.179	0.195	0.210	0.183
28	0.209	0.196	0.218	0.185

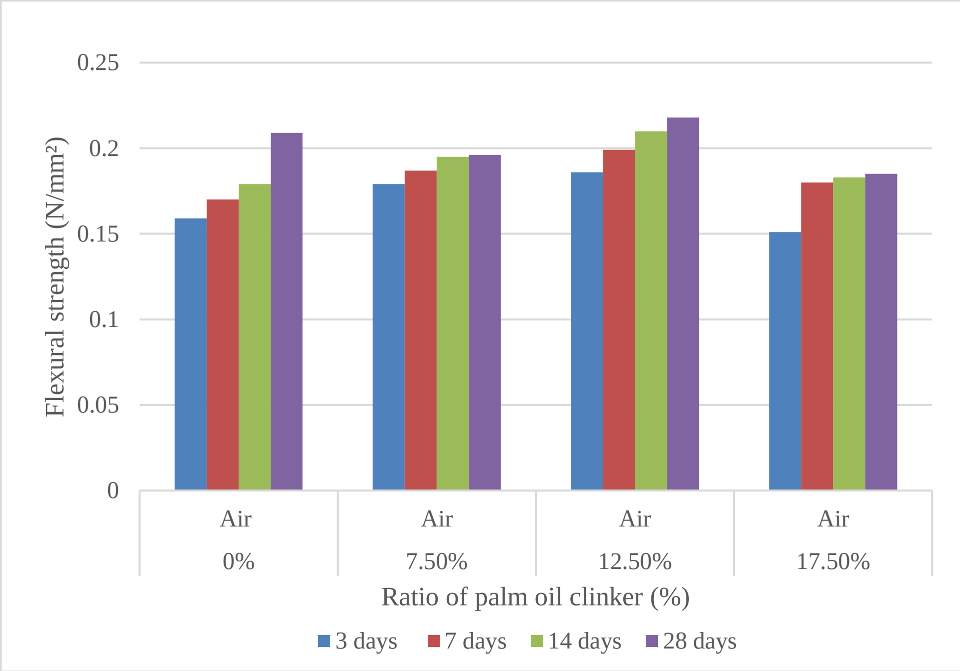

Figure 4.4 Graph of Flexural Strength for air curing of POC

The bar chart 4.4 shows the air curing for flexural strength against ratio of palm oil clinker. At 28 days, the highest result is 0.218 N/mm² for 12.5% ratio compare to the other samples.

It can be seen that at 14, 7 and 3 days, the highest is 0.210 N/mm², 0.199 N/mm² and 0.186 N/mm² respectively for 12.5%. The ratio of palm oil clinker for 17.5% relatively low for all age of curing days.

Table 4.5 Flexural Strength for Water Curing

	Flexural Strength (N/mm²)			
Days	**Control Sample**	**7.5% POC**	**12.5% POC**	**17.5% POC**
3	0.170	0.158	0.177	0.150
7	0.168	0.177	0.189	0.208
14	0.210	0.230	0.234	0.196
28	0.267	0.239	0.248	0.228

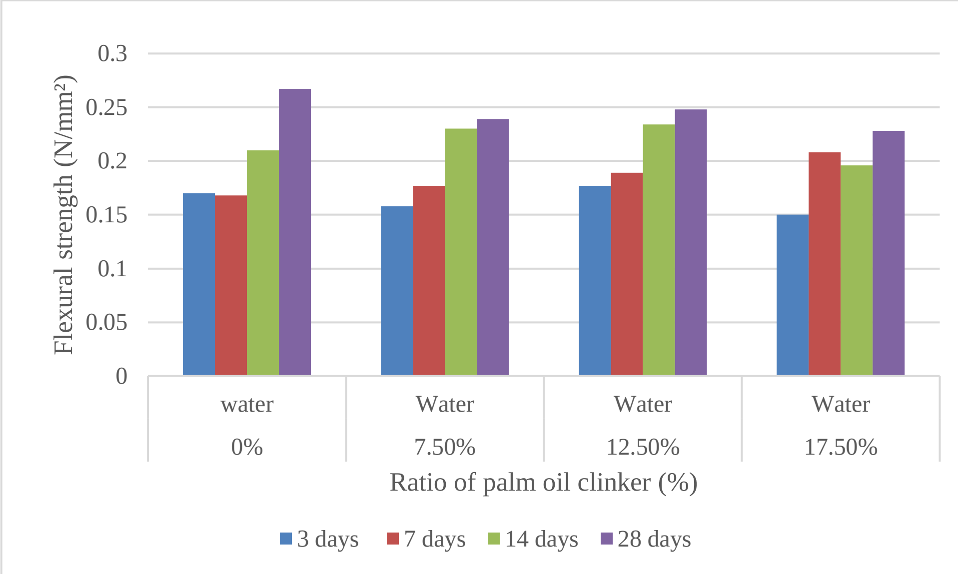

Figure 4.5 Graph of Flexural Strength for water curing of POC

According to the chart 4.5 of flexural strength test for water curing, there were highest flexural strength is 0.267 N/mm^2 which is at 28 days with ratio 0% of palm oil clinker. Flexural strength result of sand brick at 7 days which 0% is slightly drop but overall trend it shows upward from the two ratio which is 7.5% and 12.5% . Lastly, for the graph of 0% of POC, it shows increasing trend for all age of curing days except for 7 days.

Table 4.6 Flexural Strength for Air and Water Curing

Ratio of palm oil clinker	Type of curing	3 days	7 days	14 days	28 days
0%	Air	0.159	0.17	0.179	0.209
	water	0.17	0.168	0.21	0.267
7.5%	Air	0.179	0.187	0.195	0.196
	Water	0.158	0.177	0.23	0.239
12.5%	Air	0.186	0.199	0.21	0.218
	Water	0.177	0.189	0.234	0.248
17.5%	Air	0.151	0.18	0.183	0.185
	Water	0.15	0.208	0.196	0.228

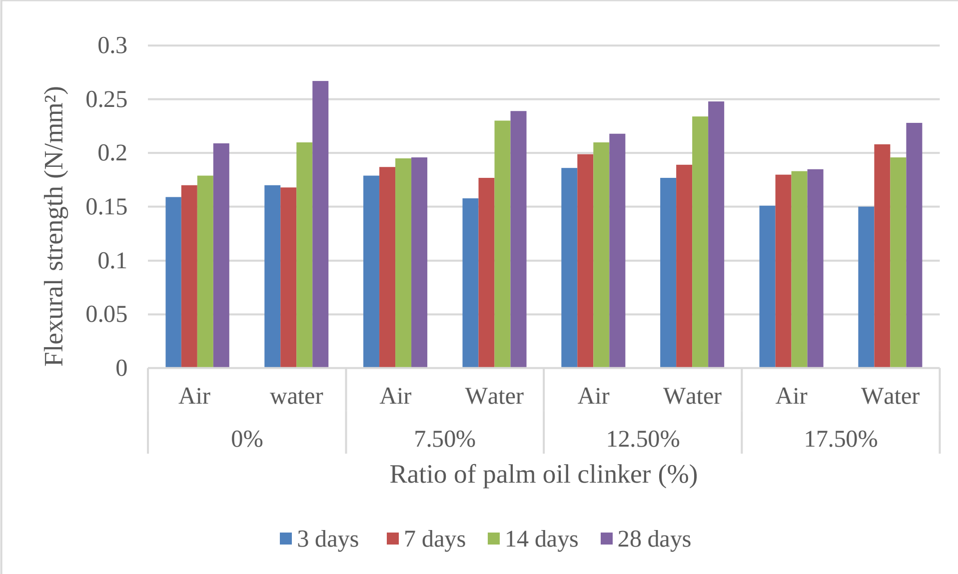

Figure 4.6 Graph of Flexural Strength for air and water curing of POC

This particular bar graph of flexural strength test against ratio of palm oil clinker shows water curing led to a rise compare to air curing for all ratio which is 0%, 7.5%, 12.5% and 17.5%.

For flexural strength test of sand brick, a gradual increase for 12.5% ratio of POC on air curing. Besides that, slightly decrease at ratio of 17.5% Another point to check out is, at 17.5%, there were constant pattern on air curing which on 7, 14 and 28 days while water curing, we can see fluctuated trend for all curing age of days. Overall, the best flexural strength test is 0% of POC on water curing.

4.2.3 Density Test

Density test were conducted on 28 days curing of the samples. Besides that, to get the results of the samples, it need to take the samples after weighted of oven-dry. So, the density can get from the formula. Formula density is:

$$\text{Density, } \rho = \frac{M}{V} \qquad 4.2$$

Where:

M = mass of the samples brick (kg)

V = dimension of bricks (Length (L) x Width (W) x Depth (D)

Table 4.7 Density Test for Air Curing

Density Test (kN/m³)	
Ratio of POC (%)	**Air Curing**
Control Samples	19.06
7.5	19.57
12.5	20.28
17.5	21.62

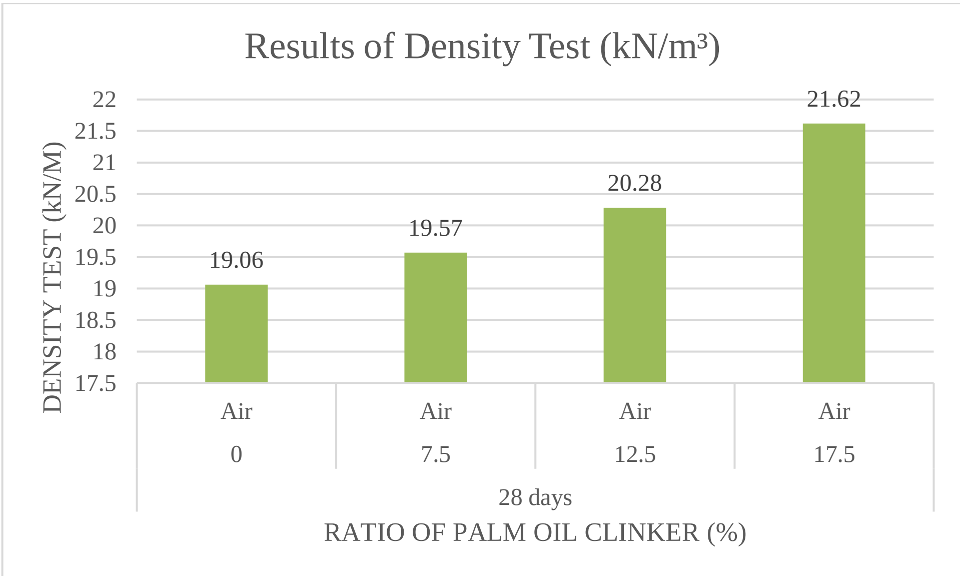

Figure 4.7 Graph of Density for air curing of POC at 28 Days of Curing Age

In table and figure 4.7 shows that the density test for air curing strength against ratio of palm oil clinker. The highest result is 21.62 kN/m³ for 17.5% ratio compare to the other samples. While the lowest density is 19.06 kN/m³ on 0% ratio which is control samples.

Table 4.8 Density Test for Water Curing at 28 Days of Curing Age

Density Test (kN/m³)	
Ratio of POC (%)	**Water Curing**
Control Samples	19.17
7.5	20.13
12.5	20.54
17.5	21.50

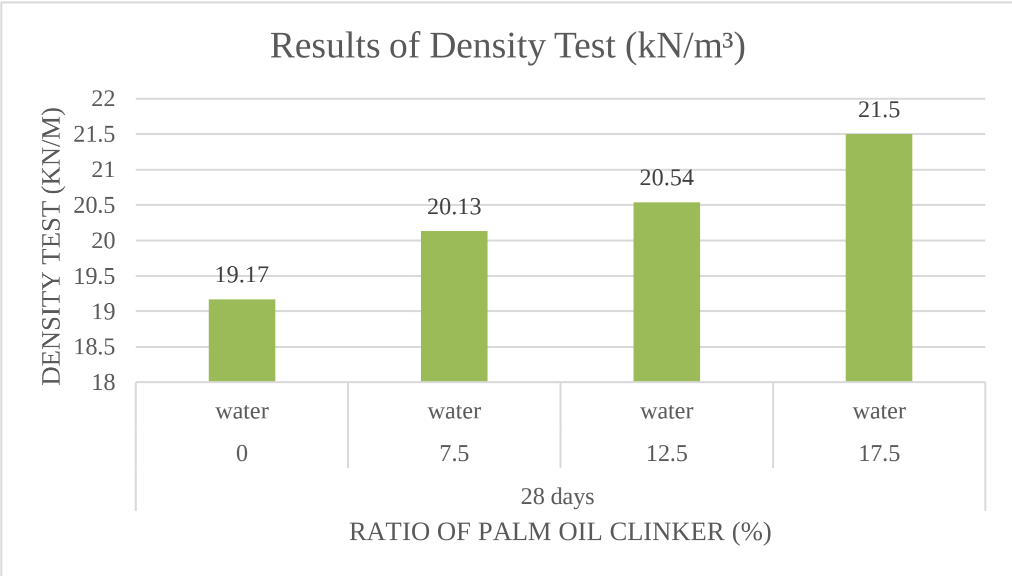

Figure 4.8 Graph of Density for water curing of POC at 28 Days of Curing Age

The bar chart 4.8 illustrates the water curing for percentage of density test result against ratio of palm oil clinker. At 28 days, the highest result is 21.50 kN/m³ for 17.5% ratio compare to the other samples. While the lowest density is 19.17 kN/m³ on 0% ratio which is control samples.

Overall trend, we can see increment pattern for density test results for all ratio of palm oil clinker which is 0%, 7.5% 12.5% and 17.5%.

Table 4.9 Density Test for Air and Water Curing at 28 Days of Curing Age

Density Test (kN/m³)		
Ratio of POC (%)	**Air Curing**	**Water Curing**
Control Samples	19.06	19.17
7.5	19.57	20.13
12.5	20.28	20.54
17.5	21.62	21.50

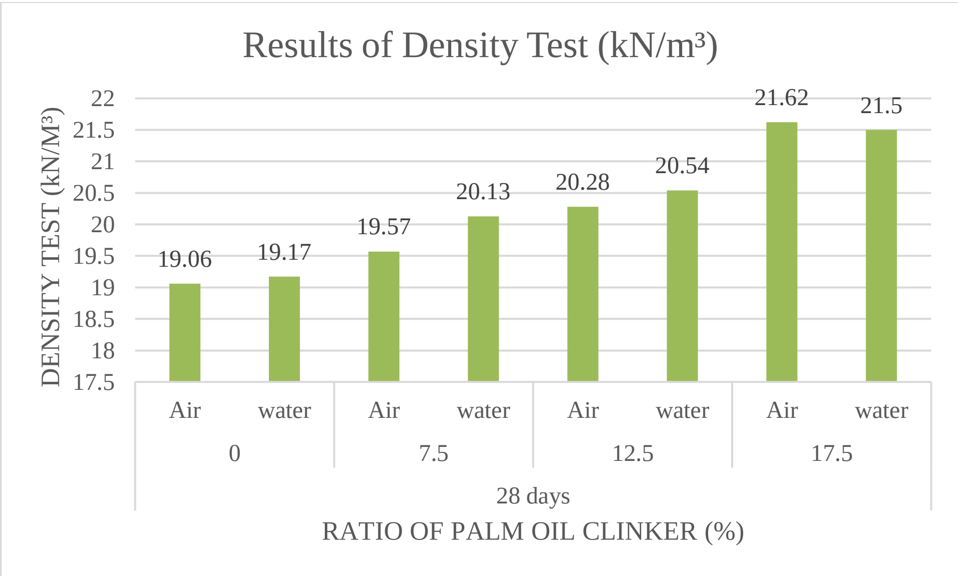

Figure 4.9 Graph of Density for air and water curing of POC at 28 Days of Curing Age

The bar chart 4.9 illustrates the air and water curing for density test result against ratio of palm oil clinker. From the graph, it shows air curing led to a rise compare to water curing for three ratio which are 7.5%, 12.5% and 17.5% except for 0% which is control samples.

For the control samples, there were shows relatively low trends compare to the ratio on both curing. However, for overall, we can see a clear upward trend chart for air and water curing which is started from 0% up to 17.5%.

4.2.4 Water Absorption Test

Water absorption test were also conducted on 28 days curing age of the samples. In order to get the results of the samples, it need to take the samples after weighted of oven-dry and immersed in water. So, the percentage of water absorption can get from the formula. Formula water absorption is

$$\text{Water absorption, } W = \frac{(W_2 - W_1)}{W_1} X100\% \qquad 4.3$$

Where:

$weight_2$= sample weight after immersed in water

$weight_1$ = sample weight after oven-dry

Table 4.10 Water Absorption Test for Air Curing at 28 Days of Curing Age

Water Absorption (%)	
Ratio of POC (%)	**Air Curing**
Control Samples	11.22
7.5	11.26
12.5	11.34
17.5	11.61

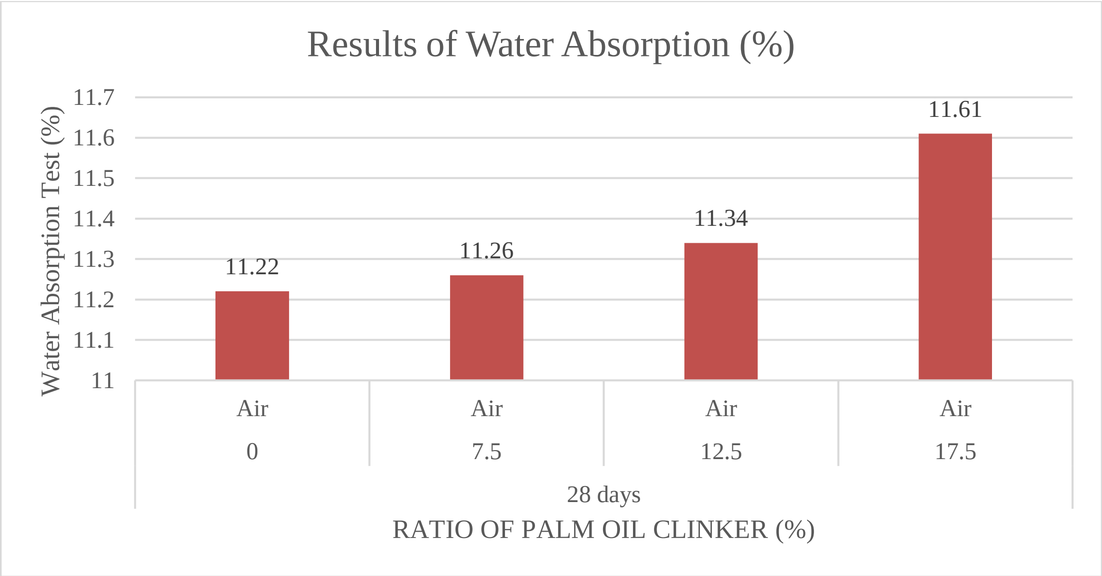

Figure 4.10 Graph of Water Absorption for air curing of POC at 28 Days of Curing Age

In table and figure 4.10 shows that the density test for air curing strength against ratio of palm oil clinker. At 28 days, the highest result is 11.61 kN/m³ for 17.5% ratio compare to the other samples. While the lowest density is 11.22 kN/m³ on 0% ratio.

So, from these graph, it indicated an increase trend for all ratio of palm oil clinker.

Table 4.11 Water Absorption Test for WaterCuring at 28 Days of Curing Age

Water Absorption (%)	
Ratio of POC (%)	**Water Curing**
Control Samples	11.88
7.5	12.03
12.5	12.30
17.5	12.47

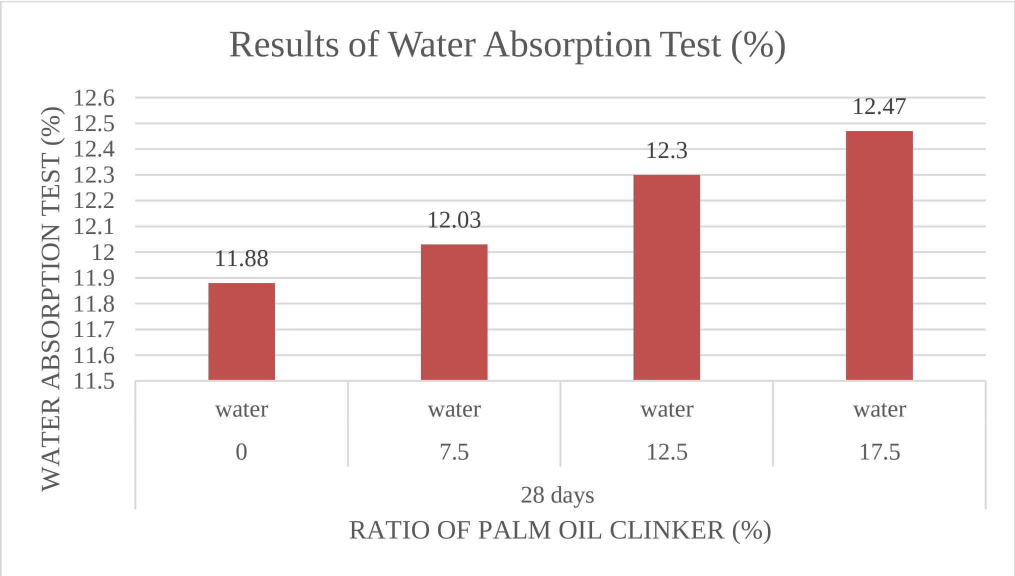

Figure 4.11 Graph of Water Absorption for water curing of POC at 28 Days of Curing Age

The bar chart 4.11 illustrates the water curing for percentage of water absorption test result against ratio of palm oil clinker. . At 28 days, the highest result is 12.47 kN/m³ for 17.5% ratio compare to the other samples. While the lowest density is 11.88 kN/m³ on 0% ratio.

Overall trend, we can see an increase trend for all ratio of palm oil clinker which is 0%, 7.5% 12.5% and 17.5%.

. **Table 4.12** Water Absorption Test for Air and WaterCuring at 28 Days of Curing Age

	Water Absorption (%)	
Ratio of POC (%)	**Air Curing**	**Water Curing**
Control Samples	11.22	11.88
7.5	11.26	12.03
12.5	11.34	12.30
17.5	11.61	12.47

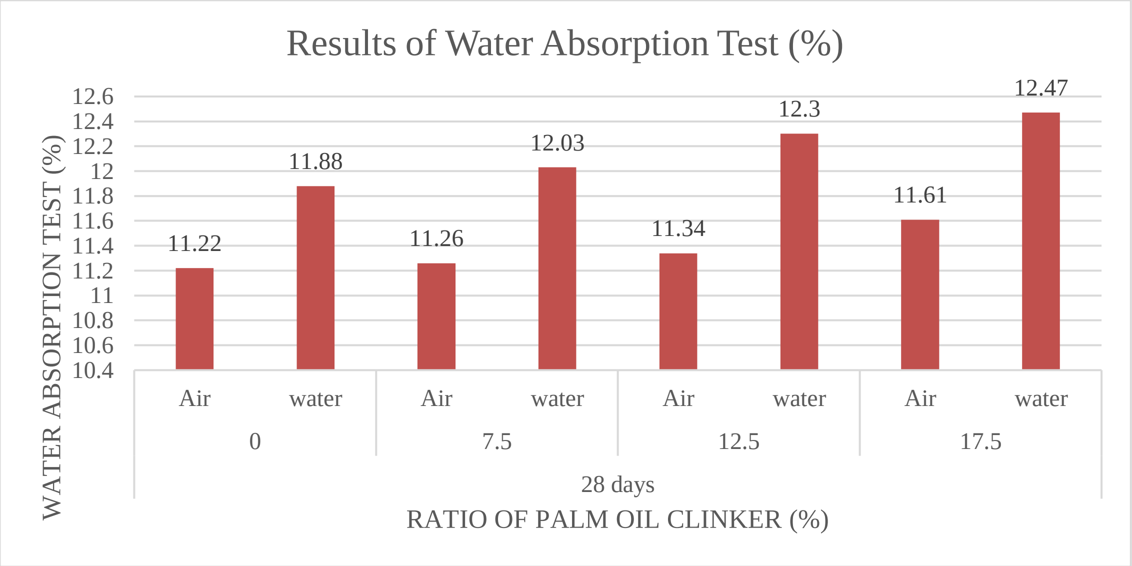

Figure 4.12 Graph of Water Absorption for air and water curing of POC at 28 Days of Curing Age

The bar chart 4.12 indicates the percentage of water absorption with four different ratio of sand brick for air and water curing at four different age of curing days.

From the graph, it shows water curing led to a rise compare to air curing for all ratio which is 0%, 7.5%, 12.5% and 17.5%.

For the control samples, there were shows relatively low trends compare to the ratio on both curing. However, for overall, we can see a clear upward trend chart of water absorption towards the increment of ratio of palm oil clinker.

4.3 Discussions

The laboratory test result data of compression strength, flexural strength, density and water absorption for 240 unit of sand bricks were analysed for two types of curing which are air and water curing on 3, 7, 14 and 28 days of curing age. From this study, there are four tests will be discussed based on the objectives of this study which are to determine compression strength, flexural strength, density and water absorption of sand brick.

The best of compression strength is 12.5% of palm oil clinker for both air and water which is at 28 days are 8.936N/mm² and 8.579 N/mm² respectively. While the best flexural strength is 12.5% ratio of POC for air curing which is at 28 days of curing age which are 0.218 N/mm² and while for water curing it shows 0% of POC is the highest data which is 0.267 N/mm² respectively. This is because, the more POC replace in brick, the strength will reduce due to difference in porosity of the POC in sand brick.

Water absorption test was conducted to determine the ability of specimen to absorb water. Figure 4.7 shows in detail the percentage of water absorption for each mixes. The best water absorption is 17.5% of POC on both air and water curing for 28 days of curing age which are 11.61% and 12.47% respectively. This happen because when a large amount of voids were observed within the internal structure of the POC aggregates, which significantly contributed to the higher water particle will be absorbed by bricks compare to control samples.

The best of density is 17.5% ratio of POC on both air and water curing for 28 days of curing age which are 21.62 kN/m³ and 21.50 kN/m³ respectively. Due to the ability of POC to fill the void inside the specimen to make the brick denser and stronger. So, as mass of specimens per unit volume increase, the density of brick increase as well.

CHAPTER 5

CONCLUSION

5.1 Introduction

In this chapter, the conclusion would be concluded by a summary from the overall of the projects. This conclusion covers all the process of project from prepares the raw materials until data analysis to achieve the objectives of the study. The results obtained in this study lead to the following conclusions. Lastly, in this chapter also would be discussed about the recommendation to improve the next project based on observation from this project.

5.2 Conclusion

From the test results presented, it can be concluded that 12.5% of palm oil clinker as a replacement of fine aggregate produces a good POC cement sand brick, exhibiting higher compressive strength and flexural strength. Overall, the objective of this study were achieved. Based on JKR Building Works 2005 stated that, the minimum permissible average compressive shall be 5.2 N/mm^2.

Thus, it shows that, the results of the compressive strength test for each replacement with fines POC at the ages of 3, 7, 14 and 28 days are the best compressive strength compare control samples. At the maximum replacement which is 12.5%, the strength achieved for both air and water curing which is at 28 days are 8.936N/mm^2 and 8.579 N/mm^2 respectively.

Besides that, flexural strength test was used in the study, hence increasing the POC substitution ratio decrease the flexural strength of sand brick. From the average of flexural strength, the limit of the replacement percentage is also 12.5% ratio of POC for both air and water curing at 28 days of curing age which are 0.218 N/mm^2 and 0.248 N/mm^2 respectively.

Starting from 17.5% replacement, it can be seen that the strength of the brick decrease with increase in percentage of POC. The value drop due to increase in porosity of the specimen. Porosity of the specimen increase due to porous structure of POC particle. This will lead to a lower strength of the specimen with increase percentage of POC inside the specimen.

According to Malaysia Standard, MS EN 1991-1-1:2010 it highlighted the limitation on density test result of sand brick which is 19-23 N/mm^3. So, from the outcome of these results of density test, it shows all the specimen meet the requirement of MS stated. The best density test is 17.5% ratio of POC on both air and water curing for 28 days of curing age which are 21.62 kN/m^3 and 21.50 kN/m^3 respectively. Fine POC gave denser mass to the bricks because it comparable with sand particles. So, the empty voids or pores within the aggregate will be fill by POC mix and it give dense density result of brick.

Besides that, the water absorption pattern increase as more POC was added as partial sand replacement. This is owing to the porous structures of the POC particles. At the same time, increase percentage of POC replacement will cause increase percentage of specimen porosity. From the result show, the highest water absorption is 17.5% ratio of POC on both air and water curing for 28 days of curing age which are 11.61% and 12.47% respectively.

There are some error during conduct the casting testing that effect certain results of age curing. This is due to systematic and random errors. Instrumental or machinery of testing which are compressive strength test machine and flexural strength test machine. Moreover, formwork of brick has a loose problem at the side or of the mould due to the continued use the same mould for the next casting.

Next, the batch of sand is different for certain duration that provided by lab assistant, so this problem make the result not uniformed or consistent.

Last but not least, the result still acceptable and can be used for the future in industry because the compressive strength, flexural strength, density and water absorption result are meet requirement based on JKR Standard.

5.3 Recommendation

Based on the studies that have been conducted which are through experimental work and test result, there are some suggestions that have been identified can be taken as an enhancement for the future study. The following suggestions were derived that can be used to reinforce data analysis, study and achieve the objectives:

i. From this study, POC is a waste material generated in large quantities in Malaysia with characteristics that make it a suitable replacement material for nature aggregates for structural application proposes.

ii. The raw materials such as sand were used which mean the sand have water content and don not know the actual moisture content of sand. As we know, the moisture content is always change, therefore, it is better in future study using dry sand which is oven-dry sand using oven machine before use the sand to mix the materials.

iii. According to this study, the size of mould for brick that have been stated in JKR Standard in Section E, Brickworks were not provided from the concrete laboratory. So that means, the student should prepare the formwork using the plywood. The dimensions of formwork were not actual or exactly uniform for all the dimensions due to saw blade of cutting machine. Then it were affected the result of testing.

iv. In carrying out the study in the future, concrete laboratory assistant need to constantly monitor the equipment and machinery. In other word, maintenance of apparatus. For example, the students need to crush the POC material using manually due to the broken of crushing machine. So that it not affect to data of results.

v. The ratios of the percentage from this study were 0%, 7.5%, 12.5% and 17.5% of palm oil clinker. In this, the ratios were used the low percentage so, the strength of brick were better compare to the control sample. Therefore, for the next study use the higher ratio such as 20%, 30% and 40% of palm oil clinker. So it can see the performance of sand brick in compressive and flexural strength test result.

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APPENDIX A

Compressive Strength for 3 days

Air Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm^2)	Maximum load (N/mm^2)	Compressive strength (N/mm^2)
0	3.915	225 x 113 x 75	25425	127700	5.02
	3.867	225 x 113 x 75	25425	128700	5.06
	3.907	225 x 113 x 75	25425	138500	5.46
	3.967	225 x 113 x 75	25425	145000	5.70
7.5	3.947	225 x 113 x 75	25425	131100	5.156
	4.070	225 x 113 x 75	25425	159500	6.273
	3.883	225 x 113 x 75	25425	142000	5.585
	3.928	225 x 113 x 75	25425	130300	5.117
12.5	3.985	225 x 113 x 75	25425	158300	6.226
	3.943	225 x 113 x 75	25425	148700	5.849
	3.935	225 x 113 x 75	25425	162200	6.380
	3.883	225 x 113 x 75	25425	165400	6.505
17.5	3.753	225 x 113 x 75	25425	142700	5.613
	3.804	225 x 113 x 75	25425	144500	5.683
	3.835	225 x 113 x 75	25425	127100	4.999

APPENDIX B

Compressive Strength for 3 days

Water Curing

Ratio (% of POC)	**Weight (kg)**	**Dimension (mm X mm X mm)**	**Area (mm^2)**	**Maximum load (N/mm^2)**	**Compressive strength (N/mm^2)**
0	4.075	225 x 113 x 75	25425	146600	4.54
	3.977	225 x 113 x 75	25425	114100	3.85
	4.164	225 x 113 x 75	25425	161000	4.72
	4.161	225 x 113 x 75	25425	152600	4.88
7.5	4.157	225 x 113 x 75	25425	131200	5.160
	4.164	225 x 113 x 75	25425	137100	5.392
	4.155	225 x 113 x 75	25425	143100	5.628
	3.692	225 x 113 x 75	25425	946000	3.721
12.5	3.849	225 x 113 x 75	25425	139200	5.475
	4.025	225 x 113 x 75	25425	136100	5.353
	4.273	225 x 113 x 75	25425	129800	5.105
17.5	3.932	225 x 113 x 75	25425	101500	3.992
	4.124	225 x 113 x 75	25425	137500	5.408
	3.958	225 x 113 x 75	25425	151600	5.963

APPENDIX C

Compressive Strength for 7 days

Air Curing

Ratio (%) of POC	**Weight (kg)**	**Dimension (mm X mm X mm)**	**Area (mm^2)**	**Maximum load (N/mm^2)**	**Compressive strength (N/mm^2)**
0	3.758	225 x 113 x 75	25425	113100	4.45
	3.634	225 x 113 x 75	25425	107100	4.21
	3.677	225 x 113 x 75	25425	108300	4.26
	3.830	225 x 113 x 75	25425	143100	5.63
7.5	3.610	225 x 113 x 75	25425	119500	4.700
	3.795	225 x 113 x 75	25425	123800	4.869
	3.524	225 x 113 x 75	25425	119000	4.680
	3.781	225 x 113 x 75	25425	121600	5.783
12.5	3.714	225 x 113 x 75	25425	184100	7.241
	3.664	225 x 113 x 75	25425	175200	6.891
	3.568	225 x 113 x 75	25425	160700	6.321
	3.639	225 x 113 x 75	25425	154400	6.071
17.5	3.997	225 x 113 x 75	25425	186900	7.351
	3.793	225 x 113 x 75	25425	200200	7.874
	3.841	225 x 113 x 75	25425	157000	6.175
	3.728	225 x 113 x 75	25425	152700	6.006

APPENDIX D

Compressive Strength for 7 days

Water Curing

Ratio (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm^2)	Maximum load (N/mm^2)	Compressive strength (N/mm^2)
0	3.988	225 x 113 x 75	25425	146600	5.77
	4.108	225 x 113 x 75	25425	114100	3.85
	4.069	225 x 113 x 75	25425	161000	6.33
	4.054	225 x 113 x 75	25425	152600	6.00
7.5	3.964	225 x 113 x 75	25425	108500	4.261
	4.102	225 x 113 x 75	25425	130900	5.140
	4.029	225 x 113 x 75	25425	118200	4.649
	3.947	225 x 113 x 75	25425	129800	5.105
612.5	3.776	225 x 113 x 75	25425	172200	6.77
	4.002	225 x 113 x 75	25425	174700	6.871
	3.874	225 x 113 x 75	25425	140000	5.506
	3.894	225 x 113 x 75	25425	156600	6.159
17.5	4.030	225 x 113 x 75	25425	211900	5.334
	3.589	225 x 113 x 75	25425	188700	5.422
	3.858	225 x 113 x 75	25425	217500	5.555
	4.074	225 x 113 x 75	25425	188600	5.418

APPENDIX E

Compressive Strength for 14 days

Air Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Compressive strength (N/mm²)
0	3.723	225 x 113 x 75	25425	181000	7.119
	3.685	225 x 113 x 75	25425	176800	6.954
	3.327	225 x 113 x 75	25425	164800	6.482
7.5	4.222	225 x 113 x 75	25425	209400	8.236
	4.281	225 x 113 x 75	25425	186900	7.351
	4.075	225 x 113 x 75	25425	112900	8.444
	3.998	225 x 113 x 75	25425	165800	6.521
12.5	4.221	225 x 113 x 75	25425	171200	6.734
	4.209	225 x 113 x 75	25425	186000	7.316
	4.235	225 x 113 x 75	25425	211600	8.323
	4.088	225 x 113 x 75	25425	173300	6.816
17.5	3.900	225 x 113 x 75	25425	170600	6.710
	3.902	225 x 113 x 75	25425	167700	6.596
	4.037	225 x 113 x 75	25425	152600	6.002
	4.193	225 x 113 x 75	25425	194400	7.634

APPENDIX F

Compressive Strength for 14 days

Water Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Compressive strength (N/mm²)
0	4.061	225 x 113 x 75	25425	177800	177.8
	3.930	225 x 113 x 75	25425	157300	157.3
	4.005	225 x 113 x 75	25425	118000	118.0
7.5	3.816	225 x 113 x 75	25425	197600	3.771
	3.939	225 x 113 x 75	25425	201100	7.910
	3.668	225 x 113 x 75	25425	153800	6.049
	3.887	225 x 113 x 75	25425	140400	5.522
12.5	3.664	225 x 113 x 75	25425	163400	7.213
	3.832	225 x 113 x 75	25425	187800	7.386
	3.780	225 x 113 x 75	25425	182700	7.225
	3.631	225 x 113 x 75	25425	142500	5.605
17.5	3.648	225 x 113 x 75	25425	133200	5.390
	3.802	225 x 113 x 75	25425	172700	6.793
	3.586	225 x 113 x 75	25425	169700	6.675
	3.844	225 x 113 x 75	25425	165700	6.517

APPENDIX F

Compressive Strength for 14 days

Water Curing

Ratio of POC (%)	**Weight (kg)**	**Dimension (mm X mm X mm)**	**Area (mm^2)**	**Maximum load (N/mm^2)**	**Compressive strength (N/mm^2)**
0	4.061	225 x 113 x 75	25425	177800	177.8
	3.930	225 x 113 x 75	25425	157300	157.3
	4.005	225 x 113 x 75	25425	118000	118.0
7.5	3.816	225 x 113 x 75	25425	197600	3.771
	3.939	225 x 113 x 75	25425	201100	7.910
	3.668	225 x 113 x 75	25425	153800	6.049
	3.887	225 x 113 x 75	25425	140400	5.522
12.5	3.664	225 x 113 x 75	25425	163400	7.213
	3.832	225 x 113 x 75	25425	187800	7.386
	3.780	225 x 113 x 75	25425	182700	7.225
	3.631	225 x 113 x 75	25425	142500	5.605
17.5	3.648	225 x 113 x 75	25425	133200	5.390
	3.802	225 x 113 x 75	25425	172700	6.793
	3.586	225 x 113 x 75	25425	169700	6.675
	3.844	225 x 113 x 75	25425	165700	6.517

APPENDIX G

Compressive Strength for 28 days

Air Curing

Ratio of POC (%)	**Weight (kg)**	**Dimension (mm X mm X mm)**	**Area (mm^2)**	**Maximum load (N/mm^2)**	**Compressive strength (N/mm^2)**
0	3.846	225 x 113 x 75	25425	228500	8.987
	3.805	225 x 113 x 75	25425	199200	7.835
	3.890	225 x 113 x 75	25425	219400	8.629
	3.954	225 x 113 x 75	25425	252400	9.927
7.5	3.661	225 x 113 x 75	25425	244500	6.617
	3.853	225 x 113 x 75	25425	267900	7.532
	3.671	225 x 113 x 75	25425	236000	6.282
12.5	3.580	225 x 113 x 75	25425	176000	6.922
	3.630	225 x 113 x 75	25425	128300	5.046
	3.680	225 x 113 x 75	25425	181000	7.119
17.5	3.567	225 x 113 x 75	25425	159300	6.265
	3.710	225 x 113 x 75	25425	238400	6.177
	3.785	225 x 113 x 75	25425	194500	6.021

APPENDIX H

Compressive Strength for 28 days

Water Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Compressive strength (N/mm²)
0	4.263	225 x 113 x 75	25425	245900	9.672
	4.292	225 x 113 x 75	25425	214100	8.421
	4.212	225 x 113 x 75	25425	192500	7.571
	4.293	225 x 113 x 75	25425	208800	8.212
7.5	4.112	225 x 113 x 75	25425	227800	8.960
	4.050	225 x 113 x 75	25425	157600	6.175
	4.080	225 x 113 x 75	25425	217000	8.535
12.5	4.351	225 x 113 x 75	25425	240100	7.443
	4.004	225 x 113 x 75	25425	167600	6.593
	3.905	225 x 113 x 75	25425	136600	6.671
17.5	4.082	225 x 113 x 75	25425	137100	6.392
	4.141	225 x 113 x 75	25425	211500	7.319
	4.026	225 x 113 x 75	25425	156900	7.171

APPENDIX I

Flexural Strength for3 days

Air Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	4.037	225 x 113 x 75	25425	4360	0.172
	3.899	225 x 113 x 75	25425	3230	0.270
	4.020	225 x 113 x 75	25425	4510	0.177
7.5	4.146	225 x 113 x 75	25425	6030	0.237
	4.029	225 x 113 x 75	25425	5250	0.206
	3.986	225 x 113 x 75	25425	3580	0.141
	3.648	225 x 113 x 75	25425	3290	0.129
12.5	3.943	225 x 113 x 75	25425	4140	0.163
	3.698	225 x 113 x 75	25425	2920	0.115
	3.587	225 x 113 x 75	25425	4110	0.162
	3.715	225 x 113 x 75	25425	3670	0.144
17.5	3.921	225 x 113 x 75	25425	3450	0.126
	3.817	225 x 113 x 75	25425	4000	0.157
	3.746	225 x 113 x 75	25425	4110	0.161
	3.888	225 x 113 x 75	25425	3790	0.149

APPENDIX J

Flexural Strength for3 days

Water Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	4.223	225 x 113 x 75	25425	4910	0.193
	4.200	225 x 113 x 75	25425	4520	0.178
	4.095	225 x 113 x 75	25425	4310	0.170
	4.073	225 x 113 x 75	25425	3590	0.142
7.5	4.016	225 x 113 x 75	25425	4420	0.174
	4.069	225 x 113 x 75	25425	4670	0.186
	3.368	225 x 113 x 75	25425	3780	0.149
	4.178	225 x 113 x 75	25425	3180	0.125
12.5	4.044	225 x 113 x 75	25425	4660	0.183
	3.932	225 x 113 x 75	25425	4030	0.159
	4.260	225 x 113 x 75	25425	5220	0.265
	4.284	225 x 113 x 75	25425	4130	0.162
17.5	3.929	225 x 113 x 75	25425	3760	0.148
	3.979	225 x 113 x 75	25425	3980	0.157
	3.924	225 x 113 x 75	25425	3840	0.151
	3.963	225 x 113 x 75	25425	3710	0.146

APPENDIX K

Flexural Strength for7 days

Air Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	3.583	225 x 113 x 75	25425	3740	0.147
	3.840	225 x 113 x 75	25425	4070	0.160
	3.913	225 x 113 x 75	25425	5150	0.203
7.5	3.763	225 x 113 x 75	25425	3550	0.140
	3.627	225 x 113 x 75	25425	4240	0.167
	3.873	225 x 113 x 75	25425	3260	0.128
12.5	3.740	225 x 113 x 75	25425	4360	0.171
	3.589	225 x 113 x 75	25425	4220	0.166
	3.690	225 x 113 x 75	25425	4120	0.162
	3.619	225 x 113 x 75	25425	3530	0.139
17.5	3.555	225 x 113 x 75	25425	4250	0.167
	3.918	225 x 113 x 75	25425	4710	0.185
	3.875	225 x 113 x 75	25425	4530	0.178
	3.872	225 x 113 x 75	25425	4790	0.188

APPENDIX L

Flexural Strength for7 days

Water Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	3.804	225 x 113 x 75	25425	3560	0.140
	3.994	225 x 113 x 75	25425	5420	0.213
	3.684	225 x 113 x 75	25425	2730	0.107
	4.077	225 x 113 x 75	25425	5320	0.209
7.5	3.934	225 x 113 x 75	25425	3300	0.130
	3.983	225 x 113 x 75	25425	3320	0.131
	3.974	225 x 113 x 75	25425	3830	0.51
	3.903	225 x 113 x 75	25425	3460	0.136
12.5	4.042	225 x 113 x 75	25425	4150	0.163
	3.868	225 x 113 x 75	25425	3850	0.151
	4.074	225 x 113 x 75	25425	5530	0.218
	3.933	225 x 113 x 75	25425	3900	0.153
17.5	4.213	225 x 113 x 75	25425	5810	0.229
	4.109	225 x 113 x 75	25425	5780	0.227
	3.511	225 x 113 x 75	25425	4190	0.165
	3.978	225 x 113 x 75	25425	5390	0.212

APPENDIX M

Flexural Strength for14 days

Air Curing

Ratio OF POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	3.646	225 x 113 x 75	25425	5240	0.206
	3.681	225 x 113 x 75	25425	4350	0.171
	3.316	225 x 113 x 75	25425	4030	0.159
7.5	4.184	225 x 113 x 75	25425	3940	0.155
	4.204	225 x 113 x 75	25425	4790	0.1884
	4.110	225 x 113 x 75	25425	4080	0.160
	4.033	225 x 113 x 75	25425	4000	0.157
12.5	3.845	225 x 113 x 75	25425	5170	0.203
	3.843	225 x 113 x 75	25425	6230	0.245
	3.922	225 x 113 x 75	25425	4660	0.183
	3.740	225 x 113 x 75	25425	5690	0.224
17.5	4.206	225 x 113 x 75	25425	4680	0.184
	4.058	225 x 113 x 75	25425	4920	0.194
	3.879	225 x 113 x 75	25425	4880	0.192
	3.993	225 x 113 x 75	25425	4160	0.164

APPENDIX N

Flexural Strength for14 days

Water Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	3.841	225 x 113 x 75	25425	5360	0.209
	4.039	225 x 113 x 75	25425	6010	0.236
	3.883	225 x 113 x 75	25425	4070	0.184
7.5	3.741	225 x 113 x 75	25425	5350	0.210
	3.777	225 x 113 x 75	25425	5820	0.229
	3.673	225 x 113 x 75	25425	6340	0.249
12.5	4.133	225 x 113 x 75	25425	5030	0.198
	4.161	225 x 113 x 75	25425	5560	0.219
	4.035	225 x 113 x 75	25425	4860	0.191
	3.979	225 x 113 x 75	25425	3900	0.153
17.5	3.668	225 x 113 x 75	25425	4230	0.166
	3.750	225 x 113 x 75	25425	6130	0.241
	3.878	225 x 113 x 75	25425	4780	0.188
	3.688	225 x 113 x 75	25425	4760	0.187

APPENDIX O

Flexural Strength for28 days

Air Curing

Ratio of POC (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
	3.942	225 x 113 x 75	25425	5070	0.199
0	3.928	225 x 113 x 75	25425	5140	0.202
	3.885	225 x 113 x 75	25425	5690	0.224
	3.798	225 x 113 x 75	25425	5020	0.197
7.5	3.782	225 x 113 x 75	25425	4500	0.177
	3.798	225 x 113 x 75	25425	5450	0.214
	3.577	225 x 113 x 75	25425	4700	0.185
12.5	3.519	225 x 113 x 75	25425	4550	0.179
	3.474	225 x 113 x 75	25425	5070	0.199
	3.692	225 x 113 x 75	25425	4660	0.183
17.5	3.773	225 x 113 x 75	25425	4680	0.184
	3.671	225 x 113 x 75	25425	4790	0.188

APPENDIX P

Flexural Strength for28 days

Water Curing

Ratio (%)	Weight (kg)	Dimension (mm X mm X mm)	Area (mm²)	Maximum load (N/mm²)	Flexural strength (N/mm²)
0	4.212	225 x 113 x 75	25425	7040	0.277
	4.339	225 x 113 x 75	25425	7010	0.276
	4.257	225 x 113 x 75	25425	6310	0.248
7.5	4.222	225 x 113 x 75	25425	6180	0.267
	3.994	225 x 113 x 75	25425	5.80	0.200
	4.196	225 x 113 x 75	25425	6030	0.237
12.5	4.092	225 x 113 x 75	25425	5610	0.221
	4.159	225 x 113 x 75	25425	5680	0.223
	4.020	225 x 113 x 75	25425	5130	0.202
17.5	4.123	225 x 113 x 75	25425	5850	0.230
	4.103	225 x 113 x 75	25425	5830	0.229
	3.975	225 x 113 x 75	25425	6540	0.257
	4.104	225 x 113 x 75	25425	5000	0.197

APPENDIX Q

Water Absorption for 28 days

Ratio of POC (%)	**Type of curing**	**Dimension (mm X mm X mm)**	**Area (mm²)**	**Weight After Ove-dry (kg)**	**Weight After Immersed (kg)**	**Water Absorption (%)**
0	Air	225 x 113 x 75	25425	3.592	3.995	11.22
	Water			3.593	4.020	11.83
7.5	Air	225 x 113 x 75	25425	3.557	3.954	11.26
	Water			3.301	3.698	12.03
12.5	Air	225 x 113 x 75	25425	3.017	3.356	11.34
	Water			3.672	4.075	12.30
17.5	Air	225 x 113 x 75	25425	2.981	3.327	11.61
	Water			3.496	3.932	12.47

APPENDIX R

Density for 28 days

Ratio of POC (%)	Type of curing	Dimension (mm X mm X mm)	Area (mm^2)	Weight After Ove-dry (kg)	Density (kg/m^3)
0	Air	225 x 113 x 75	25425	4.069	19.06
	Water			4.138	19.17
7.5	Air	225 x 113 x 75	25425	3.804	19.57
	Water			3.914	10.13
12.5	Air	225 x 113 x 75	25425	3.4165	10.28
	Water			3.992	20.54
17.5	Air	225 x 113 x 75	25425	3.814	21.62
	Water			3.795	21.50