EXPERIMENTAL STUDY OF PROPERTIES FOR SAND BRICKS WITH PALM OIL CLINKER AS PARTIAL REPLACEMENT FOR FINE AGGREGATE WITH RATIO OF 12.5% WITH RICE HUSK OF 10%, 20% AND 30%.

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.

ABSTRACT

This research conducted to utilise palm oil clinker and rice husk as partial sand replacement in brick production. Presently, waste material such as palm oil clinker and rice husk discharge to landfills due to their little application and this issue caused many type of pollution. On other hand, sand is one of the raw material used in the brick production and since the construction sector is increasing, the demand of river sand become high thus increase the exploration and depletion of river sand. Therefore, accordance with conservation efforts, this researched focused on palm oil clinker and rice husk waste as a partial fine aggregate in bricks production to reduce the pollution comes from landfilling and sand mining activity. This study focused on four mixes containing various percentages of rice husks which are 10%, 20% and 30% with same 12.5% palm oil clinker as a partial sand replacement and control sample. The ratio use for sand brick is 1:6 (1) part of cement and six (6) parts of sand accordance with MS 27. All the specimens were tested for both air and water curing in 3,7,14 and 28 days. The testing included compression test, flexural strength test, water absorption test and density test. In this research, the brick size used is 117mm width x 75mm thickness x 223mm length according to JKR specification. For the general result on strength testing, it showed that 10% to 20% replacement of fine aggregate using rice husk give the higher value than control brick in both compressive and flexural strength. Meanwhile, for water absorption, the value slightly increased with increasing rice husk. This is maybe due to the porosity of sample when rice husk increases. On overall, the brick produced using palm oil clinker and rice husk as partial sand replacement can be used for non-structural part. It also proved that air curing more effective compared to water curing process.

ABSTRAK

Kajian ini dijalankan untuk menggunakan klinker kelapa sawit dan sekam padi sebagai pengganti pasir dalam pengeluaran bata. Pada masa ini, bahan buangan seperti klinker kelapa sawit dan kelapa sawit disalurkan ke tapak pelupusan kerana kurangnya pengunaannya dan isu ini menyebabkan banyak jenis pencemaran. Selain itu, pasir adalah salah satu bahan mentah yang digunakan dalam pengeluaran batu bata dan sejak sektor pembinaan meningkat, permintaan pasir sungai menjadi tinggi sehingga meningkatkan eksplorasi dan mengurangkan pasir sungai. Oleh itu, selaras dengan usaha pemuliharaan, kajian ini menumpukan pada klinker minyak kelapa sawit dan sisa padi sawit sebagai agregat halus separa dalam pengeluaran batu bata untuk mengurangkan pencemaran yang datang dari tapak pelupusan dan perlombongan pasir. Kajian ini memberi tumpuan kepada empat campuran yang mengandungi pelbagai peratusan sekam padi iaitu 10%, 20% dan 30% dengan klinker minyak kelapa sawit yang sama iaitu 12.5% sebagai gentian pasir dan sampel kawalan. Penggunaan nisbah untuk bata pasir adalah 1: 6 (1) sebahagian daripada simen dan enam (6) bahagian pasir mengikut MS 27. Semua spesimen telah diuji untuk pengawetan udara dan air pada hari 3,7,14 dan 28 hari. Ujian ini termasuk ujian mampatan, ujian kekuatan lenturan, ujian penyerapan air dan ujian ketumpatan. Dalam kajian ini, saiz bata yang digunakan adalah lebar 117 mm x ketebalan 75mm x 223mm mengikut spesifikasi JKR. Untuk keputusan umum pada ujian kekuatan, ia menunjukkan bahawa 10% hingga 20% penggantian agregat halus menggunakan sekam padi memberikan nilai yang lebih tinggi daripada bata kawalan dalam kedua-dua kekuatan mampatan dan lenturan. Sementara itu, untuk penyerapan air, nilai itu sedikit meningkat dengan peningkatan sekam padi. Ini mungkin disebabkan porositi sampel apabila sekam padi meningkat. Secara keseluruhan, bata yang dihasilkan menggunakan klinker minyak kelapa sawit dan sekam padi sebagai pengganti pasir separa boleh digunakan untuk bahagian bukan struktur. Ia juga membuktikan bahawa pengawetan udara lebih efektif berbanding pengawetan air.

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LIST OF ABBREVIATIONS

POC	Palm Oil Clinker
RH	Rice Husk

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In recent years, palm oil clinker (POC) and rice husk which a waste material is generated in large quantities being discharged to landfills due to labelled as non-profit material. Meanwhile, construction industry have led to an increase in river sand mining and these activities raise a lot of problem including river bank erosion, river bed degradation and deterioration of a river system (Teo, Noh, Ghani, & Zakaria, 2017). Nowadays, it has been trend to focus more on utilizing solid waste and by-product to save the natural resources. Therefore, in accordance toward conservation efforts, this research focused on the clinker and rice husk which a waste materials as partial replacement for river sand in sand brick production. As a modern country, there are many areas being developed and the increment of building and house particularly increases construction materials demand especially bricks. Despite of this this matter which brings a lot of advantages toward the economy growth and produce many jobs opportunity, but there are some issues that need attention from the public as well. Brick is one of the vital materials in the construction of the buildings and river sand is the main raw materials used in the production of bricks. Furthermore, raw materials of river sand are getting depleted gradually (Abutaha & Razak, 2017). For that particular reason, this researched will focused on the clinker and rice husk obtained from the industry in Malaysia to produce the green brick and also create sustainable development. Nowadays, rice husk and clinker dumped into the landfills because of high amount production and been labelled as profitless. Thus, this green brick actually not only can reduce the consumption of the river sand but also protect the environment from the pollution caused by landfilling and prevent exploitation of area needed for waste disposal.

1.2 PROBLEM STATEMENT

The demand of the construction materials especially the bricks in the construction is increasing in Malaysia. Thus, sand mining activity also increased rapidly due to high demand of river sand because of their application in sand brick production. On other hand, high amount production of industrial waste and environmental pollution are some of the factors for obtaining new solutions for a sustainable development. Rice husk and palm oil clinker is often discarded as waste after defined useless due to their little application. Therefore, clinker and rice husk going to be recycled and used in sand brick production to reduce all these issues. Actually this by-product can be recycled and be used as a partial replacement of river sand in sand brick manufacturing which currently is seeking for alternative construction materials which are economical, environment friendly as well as provides better quality to normal sand brick.

1.3 OBJECTIVES OF STUDY

This research was conducted to achieve these objectives:

i. To determine density of brick

ii. To determine the compressive strength of brick using palm oil clinker and rice husk

iii. To determine flexural strength

iv. To find the water absorption of the sand brick

1.4 SCOPE OF STUDY

Clinker waste used in this research was taken from the Kilang Sawit Lepar Hilir and rice husk take from Kilang Beras BERNAS. Cement sand brick to be used follow the JKR standard. The experiment in the lab consists of compressive strength test and water absorption test.

Compressive strength test is used to determine the compressive strength of brick. The test using 5 specimens which placed on crushing machine and the pressure was applied till it breaks. The average result is taken as brick's compressive strength. For water absorption test, all specimens were immersed in fresh water for 24 hours. The difference weights before and after the test is defined as water absorbed by brick. The main reason of this test is to determine the quality level of the brick based on standard.

1.5 SIGNIFICANCE OF STUDY

There are many study that had carried out to improvise the quality of sand brick manufacturing as well reduce pollution come from waste material because most of rice husk and clinker dumped into landfills. For this study, palm oil clinker and rice husk were used as additional material into sand brick and it also reduces the raw material consumption which is river sand. The study is essential because the proposed material is waste product from industry in Malaysia. This will reduce the waste material at landfill as this by-product can be recycled for sand brick manufacturing purpose. Besides, it is good to create the sustainability process because use the concept of green material.

CHAPTER 2

LITERETURE REVIEW

2.1 INTRODUCTION

This research is supported with the related reading material previous research about the clinker and rice husk material which had been done as the references to describe and explain more about the characteristic and application of these materials as partial replacement in the brick manufacturing. However, there is limited research about the properties and utilization of rice husk in construction compared to rice husk ash that have been used for partial replacement in concrete making for decades. This chapter discuss about the material used as partial replacement of fine aggregate and the standard properties of brick that have been produced by the industry beside the suitable compressive strength and water absorption for safe construction.

2.2 SAND BRICK

Brick is considered as one of the most wanted after materials used in the construction of various civil engineering structures (Murmu & Patel, 2018). Basically, this material is made from the main ingredient which is river sand, cement and water. The ratio used for the mix commonly for making local cement bricks is 1:8. According to G.C.J. Lynch (1994), the brick is a walling unit which has normal size of brick in term of dimension is 337.5 mm in length, 225 mm in width and 112.5mm in height. Generally, it defined as rectangular prism of a size that can be handled conveniently with one hand is the form. The illustration below show the details

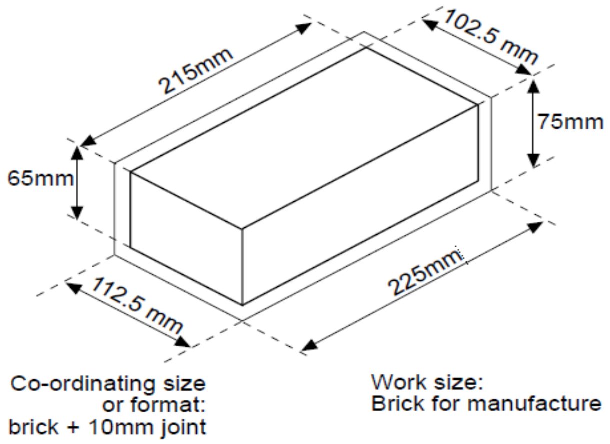


Figure 2.1: Brick of Manufacture

Source: G.C.J. Lynch (1994)

For this research, size of bricks used is according to JKR standard which is 225mm (length) x 113mm (width) x 75mm (depth).

2.3 PALM OIL CLINKER

Malaysia is agriculture based tropical country; many crops such as palm are cultivated in this region. In instance, oil palm industry in Malaysia is one of the largest producers that generates almost half of the world's total palm oil output and estimated grow even bigger as the global consumption demand increases (Hosseini & Wahid, 2014). From that industry, Malaysia generates more 18.7 million tons of crude palm oil in 2012 (Halimah et al., 2013). Figure 2.2 shows the biomass produced by different industries in Malaysia. As shown in Figure 2.2, the palm oil industry contributes around 85.5% to overall biomass produced in Malaysia which is the highest one. On other hand, there are different types of waste that generated by the palm oil processing such as palm oil clinker (POC), palm oil fuel ash (POFA), oil palm shell (OPS) and oil palm fibre (OPF). Furthermore, improper management disposal of these waste can cause environmental problems to the nature through water, air and soil pollution (Loh et al., 2013). Clinker or palm oil clinker (POC) comes through burning process of oil palm shell (OPS) and oil palm fibre. Meanwhile, most of the palm oil processing plants dispose of the clinker in them by using them as a cover for the potholes on the roads within the vicinity of the plantation area (Vijaya, Ma, Choo, & Nik, 2008).

Generally, POC is a by-product of oil shell incineration in form of a lightweight material. The POC usually comes in a large chunk and has flaky, irregular shape and porous with a rough broken surface. A lot of research done show that palm oil clinker with proper procedure has similar properties to construction raw materials such as river sand. Besides, the crushing POC has a potential to become a lightweight aggregate due to their properties (Abutaha & Razak, 2017). Meanwhile, in Malaysia, POC can be found in abundance and have little or no commercial values resulting to one of the main contributors to the pollution problem of the nation (Mohammed, Al-Ganad, & Abdullahi, 2011). However, by utilizing of this solid waste, natural resources can be preserved and there will be significant reduction in waste being discharged to the environment (Mannan & Neglo, 2010).

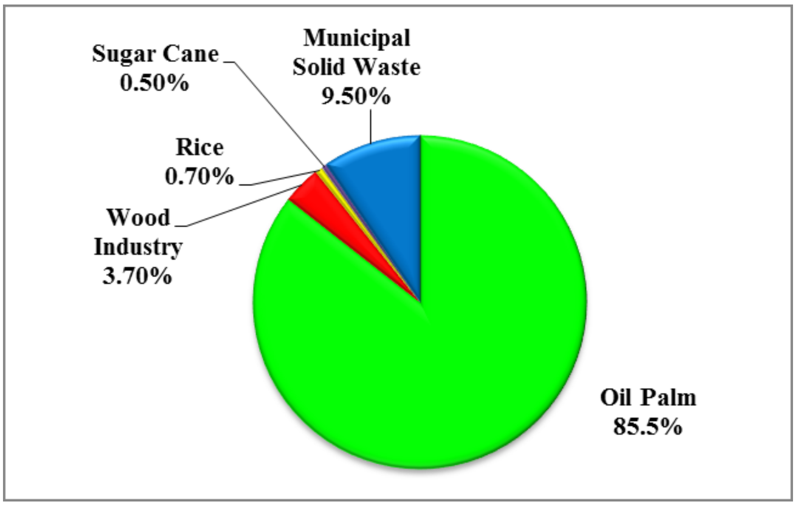


Figure 2.2: Biomass produced by different industries in Malaysia

Source: Shuit, Tan, Lee, & Kamaruddin (2009)

2.4 PROPERTIES OF CLINKER

The properties of clinker or POC as they originally comes in chunks size range in between 100 and 400mm before being crushed into aggregates with desired sizes (Kanadasan et al., 2015). Besides that, POC which grey in colour are highly porous in term of inner portions which contributes towards lightweight nature. The figure 2.3 shows a big clunks POC and figure 2.4 showed the size of POC after being crushed for certain size for fine or coarse aggregate replacement.

Figure 2.3: A large chunk of palm oil clinker (POC)

Source: Kanadasan et al., (2015)

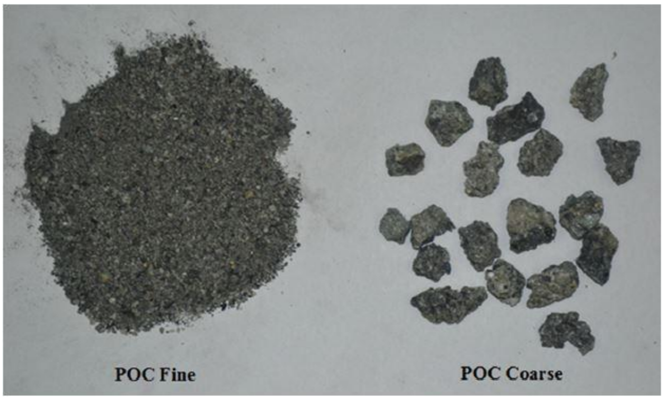


Figure 2.4: POC fine and POC coarse

Source: Kanadasan et al., (2015)

For the studies on particle size distribution between river sand and POC fine in Malaysia show similar grading features for both curves prove the suitability of POC fine as shown in Figure 2.5. The curve in figures is smooth indicate that the particle size distribution of fine POC possess ideal quality thereby enhancing the quality in term of strength. For the chemical composition of POC, it was determined by using X-ray Fluorescence (XRF) and the result shows most of the clinker in Malaysia contains silica (SiO_2) content in range between 60% and 75% as their major component (Kanadasan et al., 2015).

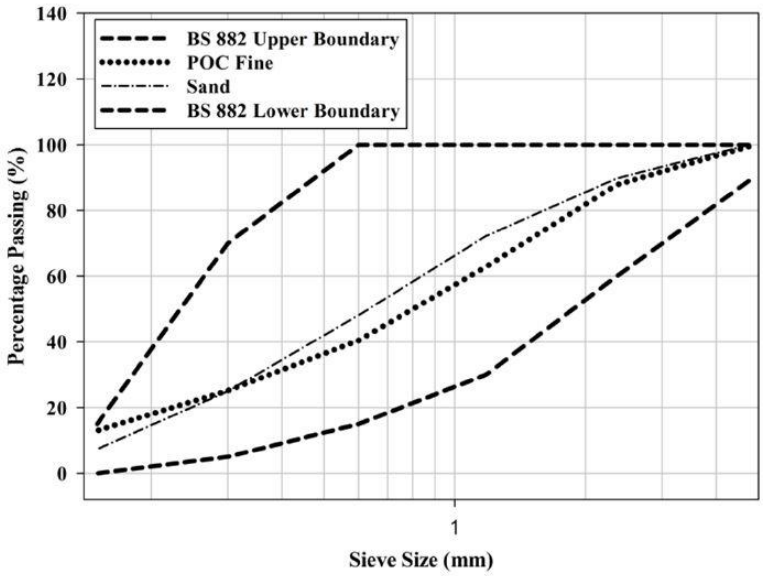


Figure 2.5: Particle size distribution for sand and POC fine
Source: Kanadasan et al. (2015)

2.5 RICE HUSK

Rice husk and rice husk ash (RHA) are the by-product from the agricultural waste rice mining industry. The rice husk ash is formed after the combustion of the rice husk which contains the chemical composition of reactive silica, SiO_2 and its physical properties are influenced by how the burning conditions take place. The size of rice husk ash is coarse and Los Angeles Abrasion Machine is used for grinding work to transform as become finer. The optimum properties can be defined by burning at 600°C to 900°C and held for 2 to 3 hours' time. The shape of the rice husk ash in form of complex shape and porous structure depend on plant origin. This material often used as a partial replacement of the cement in concrete mix. The rice husk is used in this experiment instead of the RHA. The rice husk actually light in weight, yellowish in colour, convex shape and slightly bigger than the rice grain. According to (Hwang and Chandra, 1997), rice husk contains chemical composition of cellulose 40-50 percent, lignin 25-30 percent, ash 15-20 percent and moisture 5-15 percent.

Table 2.1: Typical rice husk analysis

Property	Range
Bulk density(kg/m^3)	**96-160**
Length of husk (mm)	**2.0-5.0**
Hardness (Mohr's scale)	**5.0-6.0**
Ash (%)	**22.0-29.0**
Carbon (%)	**35.0**
Hydrogen (%)	**5.0-5.0**
Oxygen	**31.0-37.0**
Nitrogen (%)	**0.23-0.32**
Sulphur (%)	**0.04-0.08**
Moisture (%)	**8.0-9.0**

Source: Bronzeoak (2003)

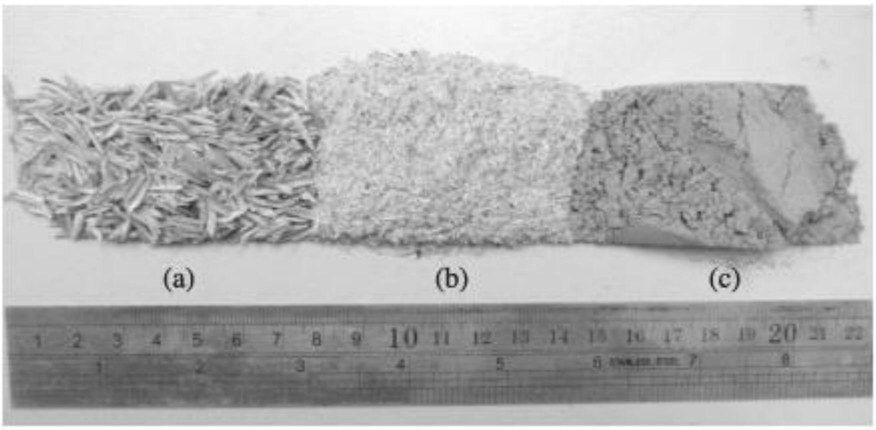


Figure 2.6: a) Rice husk, b) Burnt RHA and c) RHA after grinding

2.6 TYPES OF BRICK

The brick is the one of the building material that widely used in the construction, often mad from fired clay and secured with mortar, a bonding agent comprising of cement, sand and water. There are several types of brick that have been used for the decades that depends on the materials used for various kinds of purposes of construction project. Based on the manufacturing, bricks can be classified into two types which are sun-dried bricks and burnt bricks. Besides that, it has various types of bricks such as sand brick, clay brick, concrete brick, and facing brick. The sand brick will be used for the experimental subjected to the research.

2.6.1 Sand brick

Sand brick commonly known as calcium silicate bricks is the brick that mixed by lime, sand and water (2-3%) with no additives then followed by the chemical process during wet mixing. Next, the mix is moulded and subjected to the pressure until forming the brick using rotary table press which uses mechanical pressure. The moulded units are put into an autoclave (a steel cylinder with the closed end where heating is done by steam under pressure). The bricks are treated for 6-12 hours under steam pressure between 8-16 kg/cm^2. After that, the chemical compound which is calcium-silicate is formed when the sand and lime react chemically. The sand brick have very smooth and uniform finish in physical present as smoother finish and dense in density. Besides that, the compressive strength for this brick is about 10 N/mm^2 and very suitable for multi storied buildings. However, the sand brick made for this experiment is sand brick without presence of lime.

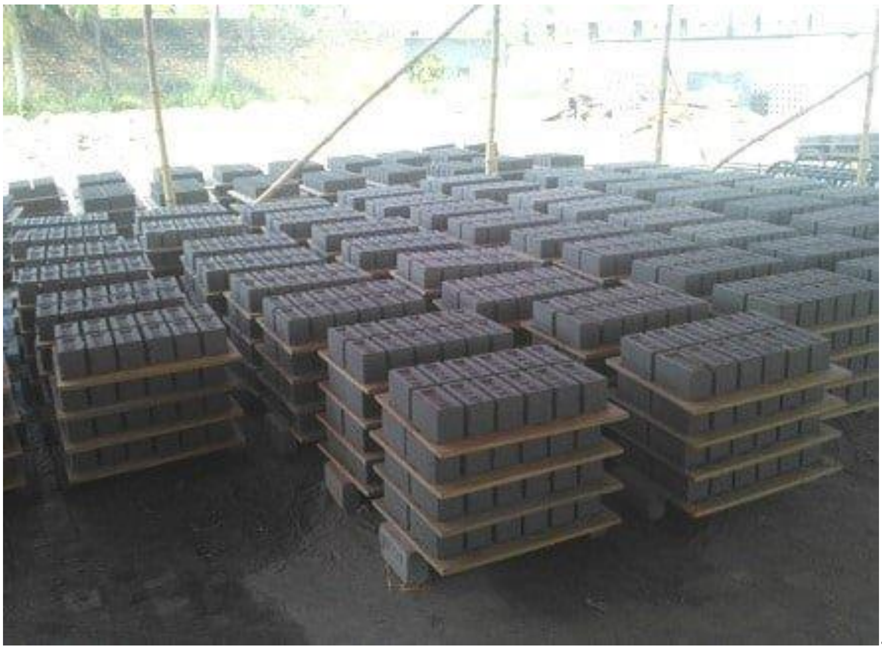


Figure 2.7: Sand Brick

2.6.2 Clay brick

Nowadays, the clay brick is the common brick that used for the house in Malaysia. Basically, the clayey soil is raw material used in the making clay brick. There are three methods to make the brick such as extruded brick, machine-moulded brick and handmade brick. For the standard size of this brick is 222mm long x 106mm wide x 73mm high with a mass of between 3.0kg and 3.5kg. This brick commonly used for the homes since it has good resistance to fire.

2.6.3 Common brick

Common brick generally made from the basic brick clay which has less make up on the colour and surface treatment. They are usually red in colour which is come from the iron content in the clay. The common brick has less compressive strength and low quality compared to facing bricks or the engineering brick. The application of this brick only applied on the internal brickwork.

2.6.4 Facing brick

The facing brick is more uniform in colour compared to the common brick and has same size with the common brick and may vary depends on the manufacturer. It also has the smoothest and highest quality appearance compared to other which more expensive compared to others. Therefore, this bricks commonly used for the external walls of building because of their looks and can be very good for the weather resistant.

2.6.5 Engineering brick

Engineering bricks which smooth red in colour are bricks manufactured extremely high temperatures, forming a dense and strong brick, allowing the brick to limit strength and water absorption. Generally, this brick have high compressive strength and low water absorption and good against to frost attack. This bricks usually used for the manholes and retaining walls because of their capability to bear such high strength of load. Besides that, there are two classes of engineering brick which is Class A or Class B where the Class A is the strongest. According to (G.C.J. Lynch, 1994) class A engineering brick must have compressive strength greater than 125 N/mm^2 and water absorption less than 4.5 percent while Class B have to achieve compressive strength greater than 75 N/mm^2 and water absorption less than 7 percent.

2.7 PROPERTIES OF BRICK

2.7.1 Density

Research made by Sutas, Mana & Pitak (2012), the brick containing rice husk has less bulk density compared to brick with addition coal bottom ash. This is because with increasing rice husk content, will increase porosity volume thus reducing the bulk density.

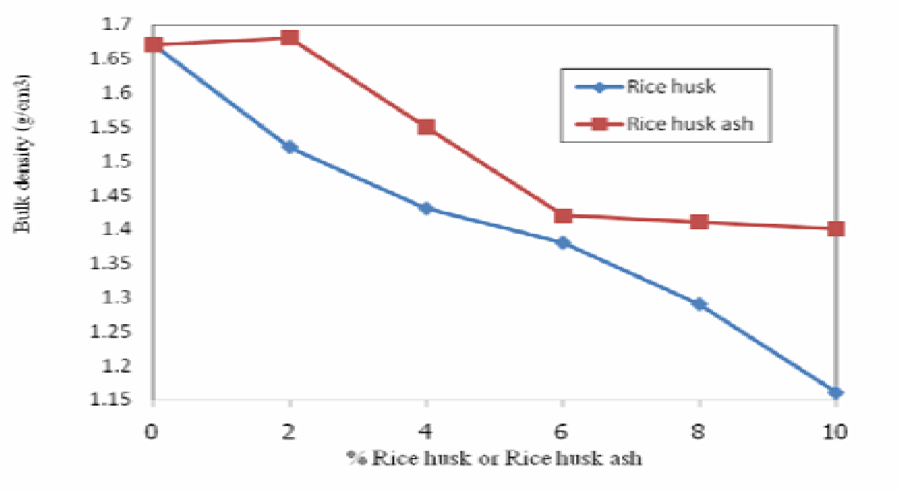


Figure 2.8: Bulk density between rice husk and rice husk ash

Source: Sutas, Mana & Pitak (2012)

2.7.2 Water absorption

The water absorption test is the test that conducted to know the amount of water absorbed under specified conditions. There are several factors that influence water absorption including type of plastic, additives used, temperature and length of exposure. Characteristic of water absorption give an effect towards durability of brick. Smith and Collis (1993) indicate that mix design and density is influenced by the absorption and indirectly related to frost resistance, soundness, and shrinkage. By the previous research, the value of water absorption was determined. The research done by Sutas, Mana & Pitak (2012) found that brick with additional rice husk increase the water absorption rate due to high porosity of the sample. This also proved by Chiang et al. (2009) that found higher rice husk addition will increase the porosity volume of the sample.

2.7.3 Compressive strength

The type compaction pressure used to form brick is the main factors that influence compressive strength of the brick which is important to sustain the load and make the construction safer. The uniformity between brick and the quality workmanship has bigger effect on the strength of brick wall structure (Ewing, Kowalsky, 2004). The compressive strength can be accessed by testing normally ten samples of bricks. According to the previous studies conducted by Shakir, Naganathan, Nasharuddin, & Mustapha (2013) the compressive strength was influenced by the age of brick. This is because the brick need longer time to reach their ultimate strength in open air condition. Figure 2.9 shows that the ideal replacement of fine aggregate using POC is about 10% to 20% as the compressive strength achieved higher compare to control specimen.

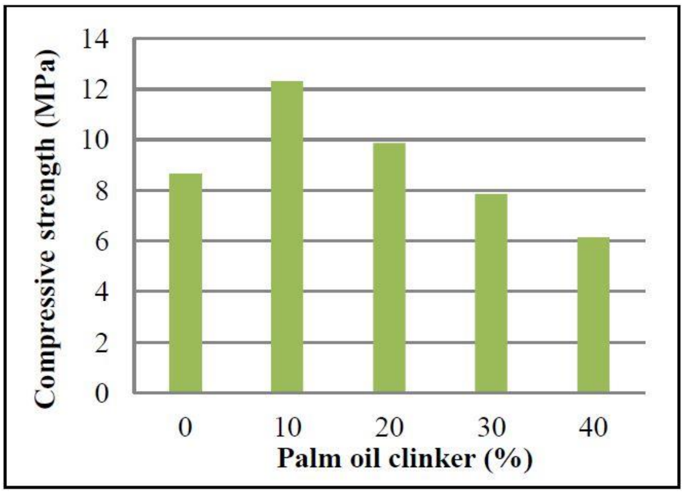


Figure 2.9: Compressive strength at 28 days age curing

Source: Ariffin (2016)

2.7.4 Flexural strength

Flexural modulus or flexural strength of a material is determined by the flexural test. Basically, the block or bricks were positioned on their flat into flexural beam apparatus. Research made by Ariffin (2016) shows the ideal replacement of fine aggregate using clinker in bricks between 10% to 20% as shown in Figure 2.10. The strength of brick is decrease with increase in percentage of POC. This is because of increment in porosity that make samples become less rigid and less dense.

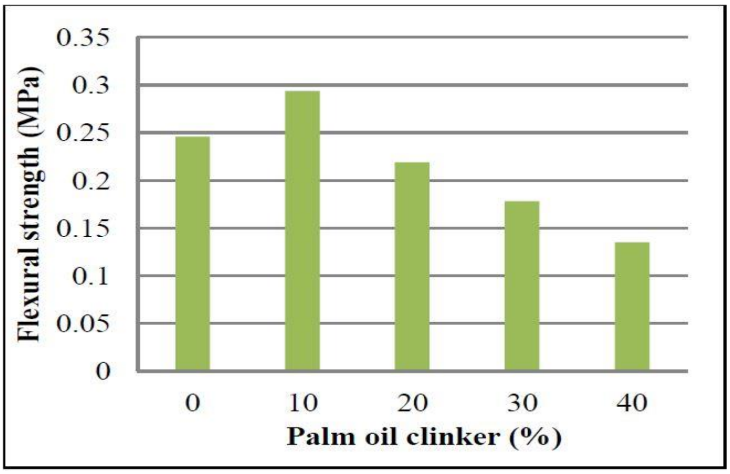


Figure 2.10: Flexural strength results up to 28days.

Source: Ariffin (2016)

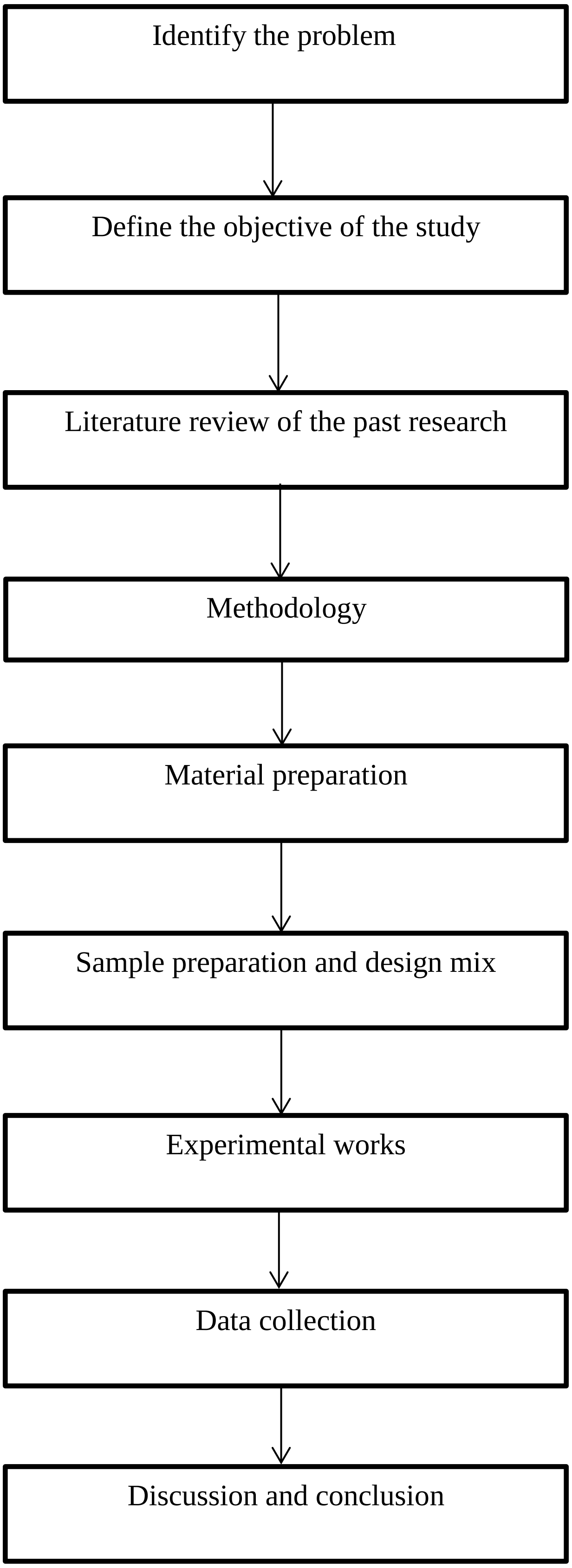
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will clarify about the research conducted and explain the study carried out. In this chapter, explanation about the materials used, the research planning and the testing conducted to find suitability of palm oil clinker as partial replacement for fine aggregates (sand) with ratio of 12.5% with rice husk of 10%, 20% and 30%. The objective of the experiment is to investigate the compressive strength and water absorption of the sand brick and compared to the standardized sand brick. This part also will give the clear point of view about the research and clearly shows how the objective of this research achieved. The experiment is following the ASTM standard which is been practiced in Malaysia. Below is a flow chart of the research methodology.

3.2 METHODOLOGY FLOW CHART



3.3 DESIGN BRICK MIX

There are few main ingredients used for the sand brick production such as Ordinary Portland Cement (OPC), fine aggregate (sand) and water. The additional materials that used are clinker and rice husk as partial replacement for the fine aggregate.

3.3.1 Cement

The type of cement used for the study is Ordinary Portland cement (Orang Kuat) that been chosen due to commonly used in construction industry. This type of cement is certified to MS EN 197-1, CEM I 42.5N / 52.5N shown in figure 3.2. There are six types of the ordinary Portland cement according to American Society for Testing and Materials (ASTM). Figure 3.2 show the type of Portland cement used which kept in an airtight container to avoid the air moisture. This cement stored in clean and dry place at Concrete Laboratory University Malaysia Pahang (UMP).

Figure 3.2: Ordinary Portland Cement (OPC)

3.3.2 Palm oil clinker (POC)

Palm oil clinker used for the experiment is from the Kilang Sawit Lepar Hilir located at Pahang. First, clinker is clean thoroughly to remove any dust on the surface of clinker and ensured clean from any debris. After that, clinker was crushed using crushing machine and then need to be sieved using sieve size 4.75mm before can be used to make the particle size smaller. This is because any particle size larger than 4.75mm could affect the result of testing.

3.3.3 Rice husk

The rice husk used got from the “Kilang Beras BERNAS” located at Kuala Rompin, Pahang which is one of the agricultural industry. The rice husk is not the ash type that usually used for the concrete therefore it does not have pozzalanicity properties. The dust need to removed first using manual sieving before rice husk is dried out in the oven. The precaution is to make sure the rice husk does not change in colour to brown during in the oven.

3.3.4 Water

Water is essential because it is the key ingredient in sand brick to make it binds together with certain reaction. The water must clean and free from any substance that harmful to the brick properties. In this study, the water used is ordinary clean tap water comes from Concrete Laboratory of University Malaysia Pahang.

Figure 3.3: Tap water

3.3.5 Fine aggregates

The fine aggregate that been used throughout this study was river sand that being provided by the civil engineering faculty laboratory. The sand used was clean up from any dirt on surface of sand. The sand then sieved through the 4.75 mm sieve size, and the passing sand is the one that used for the design brick mix. In order to protect the sand from getting wet due to excessive moisture condition, the sand was air-dried then was kept in the container.

Figure 3.4: Fine aggregate

3.4 PARAMETER USED FOR TESTING

3.4.1 Machine prepared sample

i. Sieve shaker machine (4.75 mm sieve size)

ii. Mixer machine – mix the material

iii. Weight- Weighed material and sample

Figure 3.5: Sieve shaker machine

Figure 3.6: 4.75mm sieve size and pan

3.5 DIMENSION ANALYSIS

There are 8 samples of the sand brick that were tested in the compressive strength test and flexural strength test for standard, constant replacement of fine aggregate by 12.5% of palm oil clinker with rice husk of 10%, 20%, and 30% respectively. The ratio used for the sand brick is 1:6 (1) part of cement to six (6) parts of sand accordance with MS 27. The samples were tested at 3, 7, 14 and 28 days curing age. The total samples used for this study is 128 samples including the control sample (one type of curing). According to MS 27, the dimension of the brick shall 225mm in length, 113mm in width, and 75mm in depth.

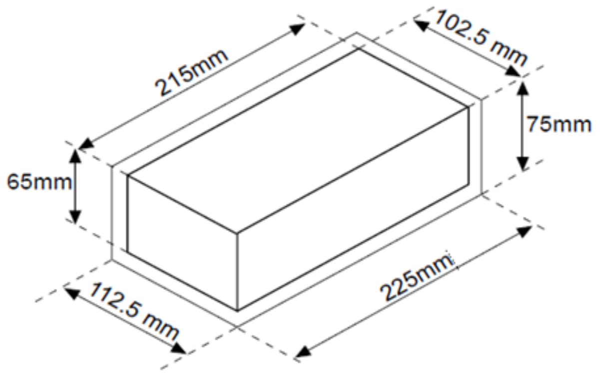


Figure 3.7: Dimension of brick

3.5.1 List prepared sample

Table 3.1: Total no of sample for compressive test (one curing method)

Days	**3**	**7**	**14**	**28**	**Total**
A1, Control	8	8	8	8	**32**
12.5% clinker					
A2, 10% rice husk	8	8	8	8	**32**
A3, 20% rice husk	8	8	8	8	**32**
A4, 30% rice husk	8	8	8	8	**32**
Total	**32**	**32**	**32**	**32**	**128**

Before the sample undergoes the compressive strength test, the samples first were tested through water curing and air curing process for the 3, 4, 7 and 28 days respectively. The objective of the curing process is the determination of the weight and dimension of sand brick before and after curing process. Therefore, the water absorption was recorded as a reading compared to the standard sand brick. From there, the volume of water absorption was known through calculation.

3.5.2 Analysis of the sample

The ratio of rice husk is 0%, 10%, 20%, and 30% with constant ratio of 12.5% palm oil clinker as fine aggregates replacement was prepared to bind together with proportions of cement and sand for testing of 3,7,14 and 28 days curing age. The control sand brick was used as reference or standard sand brick.

Table 3.2: Ratio of Mix Design Sand Brick

Mixture	**Ratio of Mixture**			
	Cement (kg)	**Sand (kg)**	**Clinker (kg)**	**Rice husk (kg)**
A1- Control	0.312	2.040	**-**	**-**
12.5% clinker				
A2- 10% rice husk	0.312	1.581	0.202	0.015
A3- 20% rice husk	0.312	1.377	0.202	0.031
A4- 30% rice husk	0.312	1.173	0.202	0.046

3.6 PROCEDURE OF WORK

3.6.1 Mould

Dimension of the mould for this testing is according to the standard brick which is 225 mm x 113mm x 75mm. The mould is very important and need to be carefully formed. The mould was created using the plywood that being provided by University Malaysia Pahang. The formwork using plywood is cheap and simple compared to other mould creation.

3.6.1.1 The procedure of forming the mould

The sheet plywood used for this casting work is 11 sheet plywood size (225mm in width and 113mm in height) and sheet plywood size (75mm in width and 113mm in height). The entire sheet of plywood will give the total of 24 sand brick sample.

Procedure:

i. The plywood was marked following the standard dimension.

ii. The saw machine was used to cut the marking dimension on plywood.

iii. The plywood was merged into the form of rectangular shape using mortise method.

3.6.1.2 The preparation of the material

Material preparation is important to make the casting work easier. The material used was sand, cement, clinker and rice husk. First, the clinker was washed thoroughly and dried out to remove moisture content. Then clinker and sand separately were sieved through 4.75 sieve size and the passing one was used for the fine aggregates in mix design. In making sample according to different proportion, all the materials such as cement, sand, clinker and rice husk were weighed based on table 3.2.

3.6.1.3 Process of work

The control sample was casted first then follows with the ratio of 10%, 20%, and 30% of rice husk at constant ratio of palm oil clinker which is 12.5%.

Procedure

i. The plywood first was sprayed by the oil to avoid stripping the forms after pouring the brick mixed.

ii. Then the proportion of each mixture is gotten into mixer machine up to 10 minutes.

iii. After the brick mixed is ready, mix was poured into the mould prepared before. The rod was used to compress the mix.

iv. The surface of the mould was covered by the wet sacks and the sample was left overnight.

v. After the 24hours or one night, the mould was opened ready for the testing. The dimension and weight of each sample were weighed before curing process take place.

Figure 3.8: Water curing tank

Figure 3.9: Air curing place

vi. After the period of 3, 7, 14 and 28 days, the sample was weighed again before next testing.

vii. Step (i) to (iv) was repeated by using the other sample of different proportions.

Table 3.3: Curing test sample

Type of test	**Mix proportion**		**3 days**	**7 days**	**14 days**	**28 days**
Water curing	A1, Control		8	8	8	8
	Constant 12.5% of clinker	A2, 10% of rice husk	8	8	8	8
		A3, 20% of rice husk	8	8	8	8
		A4, 30% of rice husk	8	8	8	8
Air curing	A1, Control		8	8	8	8
	Constant 12.5% of clinker	A2, 10% of rice husk	8	8	8	8
		A3, 20% of rice husk	8	8	8	8
		A4, 30% of rice husk	8	8	8	8

3.7 TESTING FOR SAND BRICK

3.7.1 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 needed 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:

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

vi. 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.

vii. 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 was determined by the percentages of water absorbed. If the less water absorbed by the brick, it can be classified as good quality brick.

3.7.2 Density test

3.7.2.1 Objective

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

3.7.2.2 Procedure

1. *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.

    X. Designate this last value A.

3.7.3 Compressive strength test

3.7.3.1 General

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.

Figure 3.8: Compressive tesing machine

3.7.3.2 Objective

The main objective of this testing is to determine the compressive strength of sand brick.

3.7.3.3 No of sample used

Total no of sample used for this testing is 128 samples (for one curing method only).

Table 3.3: No of sample used

Days	**3**	**7**	**14**	**28**	**Total**
A1, Control sample	8	8	8	8	**32**
12.5% clinker					
A2, 10% rice husk	8	8	8	8	**32**
A3, 20% rice husk	8	8	8	8	**32**
A4, 30% rice husk	8	8	8	8	**32**
Total	**32**	**32**	**32**	**32**	**128**

3.7.3.4 Procedure

The testing procedure 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, 10%, 20% and 30% rice husk at 3, 7, 14 and 28 days for water curing and air curing.

3.7.3.5 Calculation

Calculation of compressive strength for each sample as below:

$$C = W / A \qquad 1.0$$

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)

3.7.4 Flexural strength test

3.7.4.1 General

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).

Figure 3.9: Flexural strength testing machine

3.7.4.2 Objective

To determine the flexural strength and modulus of rupture for sand brick

3.7.4.3 Procedure

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.

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 and at center to calculate average depth and height.

3.7.4.4 Calculation

Calculate the modulus of rupture as follows:

$$R = \frac{3PL}{2bd^2}$$

Where:

R = modulus of rupture, psi, or MPa,

P = maximum applied load indicated by the testing machine, lbf, or N,

L = span length, in., or mm,

b = average width of specimen, at the fracture, in., or mm,

d = average depth of specimen, at the fracture, in., or mm.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the data obtained from compressive, flexural, density and water absorption test are presented. The influence of the clinker and rice husk on physical and compressive properties of the sand brick can be seen in this chapter. Besides, this chapter will determine the optimum proportion of rice husk based on laboratory test conducted. The experiment done through 128 samples of sand brick which including control sample and different proportion of 10%, 20%, 30% rice husk respectively with same 12.5% of clinker. The compressive and flexural has been done by testing 4 sample from each type of curing with different age curing which is 3 days, 7days, 14 days and 28days respectively. Besides, density and water absorption is tested after 28days age curing for both air and water curing. Furthermore, all data along the experiment are symbolized by graph and table.

4.2 Compressive strength test

The compression strength of sand brick is the most common performance evaluation used by the engineer. The compressive strength is calculated from the failure load divided by the cross sectional area that resisting the load. The test is accordance to ASTM C 67. Furthermore, three different proportion of sand brick with size 225mm X 113mm X 75mm test at 3, 7, 14 and 28 days. The main purpose is to achieve acceptable compressive strength of sand brick according to JKR standard which is 5.20 Mpa.

Table 4.1 and figure 4.1 summarize all the data in form of table and graph that show average compressive strength over along 28 days for both air and water curing. In general, it was found that a 28 days brick from air curing achieved 8.850 Mpa which is higher than water curing recorded only 8.470 Mpa. Meanwhile, there are decrement trend of compressive strength from 3 days to 7 days air curing which from 5.310 Mpa to 4.640 Mpa compared to other compressive strength that goes up with the days for both type of curing. Other than that, all the compressive strength of air curing much higher than water curing in different age curing except for 7 days.

Table 4.1 : Average compressive strength for control sample

Age curing	**Compressive strength (Mpa)**	
	Air curing	**Water curing**
3	5.310	4.500
7	4.640	5.490
14	6.850	5.940
28	8.850	8.470

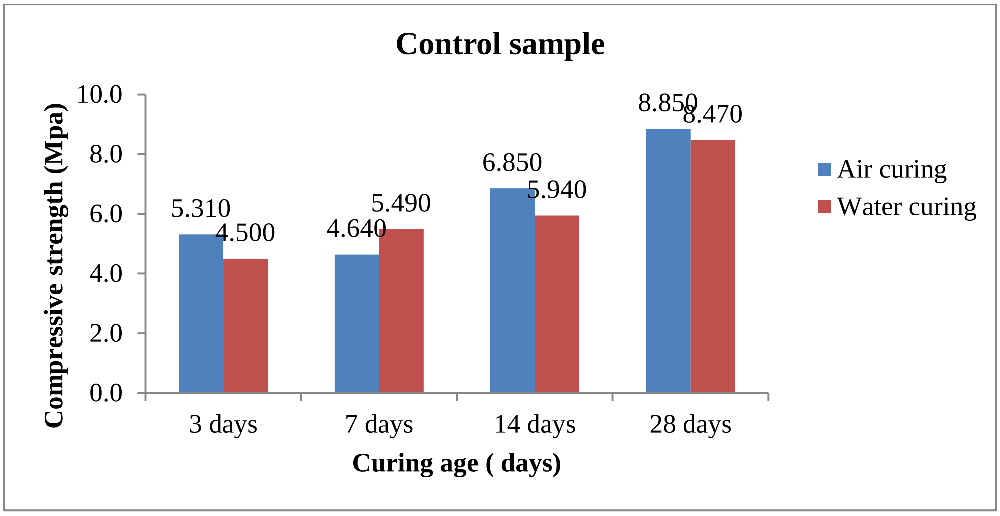


Figure 4.1: Average Compressive strength over along 28days for control sample

4.2.1 Average Compressive Strength for all proportion for air curing

Figure 4.2 summarize the compressive strength for air curing over the 28 days period. The result outcome shows that sand brick with 20% rice husk replacement of sand achieved the optimum strength that slightly higher than 10% rice husk. It was found that a 28 days sand brick (20% percentage of replacement) obtained 9.315 Mpa compared to the control sand brick with recorded only 8.85 Mpa. Besides, at 28 days, sand brick with 10% rice husk replacement recorded almost the same optimum value which is 9.312 Mpa. Meanwhile, 30% rice husk replacement achieved only 7.368 Mpa at maximum 28 days, lower than control sand rick and other ratio. The trend of all early compressive strength recorded significantly lesser strength compared to 28 days-sand brick. Furthermore, the result explains the effectiveness of rice husk and clinker in strength contribution of sand brick at certain proportions.

Table 4.2 : Average compressive strength for all proportion air curing

Days	**Air curing**			
Rice husk	**0 %**	**10%**	**20%**	**30%**
3	5.310	2.740	4.725	3.804
7	4.640	6.963	6.488	6.276
14	6.850	7.479	8.873	6.359
28	8.850	9.312	9.315	7.368

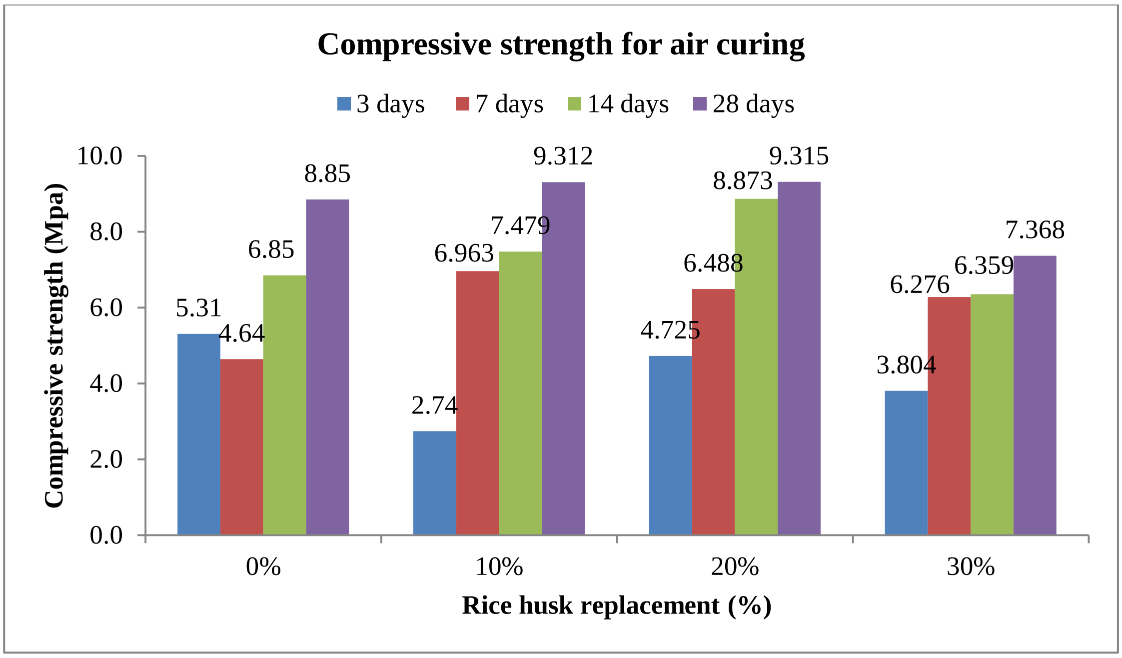


Figure 4.2: Average Compressive strength over along 28 days for air curing

4.2.2 Average Compressive Strength for all proportion for water curing

Result of 28-days compressive strength for all proportion of rice husk is much lower than control sand brick that has 8.47Mpa compressive strength. In terms of best replacement, 10% rice husk show the best result as 28-days water curing obtained 8.127 Mpa which higher than other ratio. As comparison with the days, the different pattern observed where higher the percentage of rice husk, the compressive strength goes down. Other than that, for all the proportion, the compressive strength increases with days.

Table 4.3 : Average compressive strength for all proportion air curing

Age curing	**Water curing**			
Rice husk	**0%**	**10%**	**20%**	**30%**
3	4.5	3.975	5.356	3.633
7	5.49	6.654	6.522	5.248
14	5.94	7.05	6.673	6.095
28	8.47	8.127	8.026	6.179

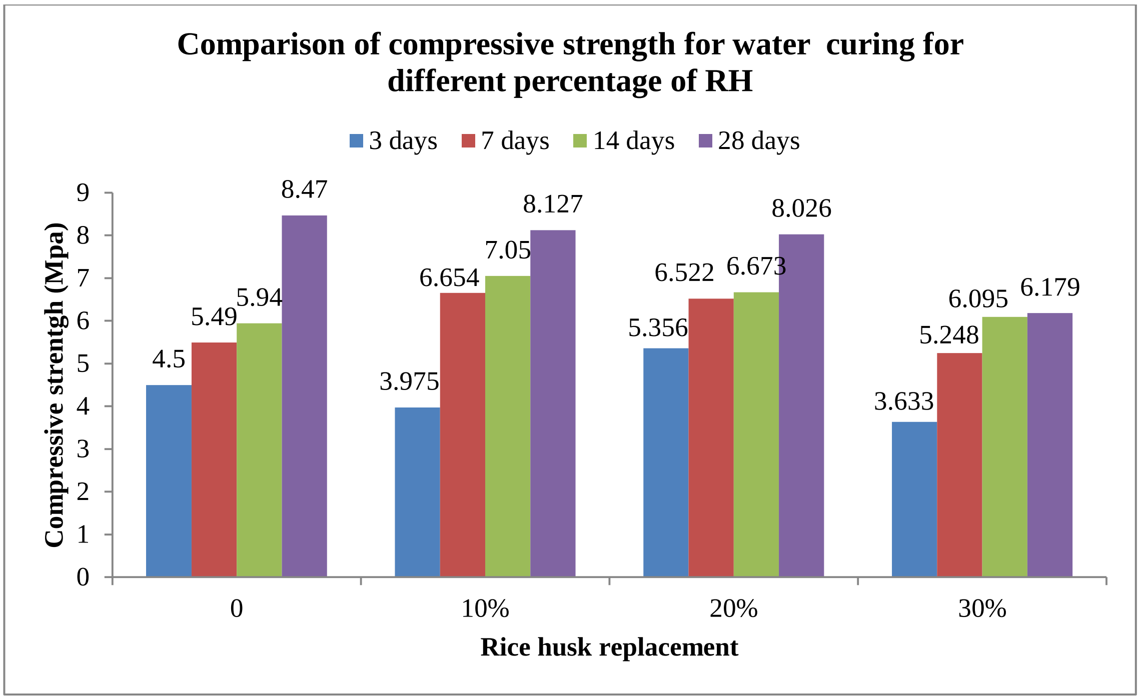


Figure 4.3: Average Compressive strength over along 28 days for water curing

4.2.3 Average Compressive Strength for all proportion for both air and water curing

The figure 4.4 shows the combination of the average compressive strength over along 28 days for both air and water curing. The result of this experiment shows that the most optimum value of compressive strength was recorded at 28 days of air curing (20% of replacement air curing) which achieved 9.315 Mpa compared to second highest value, 9.312 Mpa (10% of replacement air curing). Meanwhile, the lowest value of compressive strength after 28 days curing age was recorded with only 6.179 Mpa (30% of replacement water curing). Other than that, after 28 days age curing, all the sand brick through air curing achieved higher compressive strength compared to water curing in all proportion. This result shows that the more effective type of curing is air curing. For early strength with same 3 days of curing in all proportion, 20% of replacement water curing obtained the highest value which is 5.356 Mpa.

Table 4.4 : Average compressive strength for all proportion air and water curing

Age curing	**Air curing**				**Water curing**			
Rice husk	**0 %**	**10%**	**20%**	**30%**	**0 %**	**10%**	**20%**	**30%**
3	5.310	2.740	4.725	3.804	4.500	3.975	5.356	3.633
7	4.640	6.963	6.488	6.276	5.490	6.654	6.522	5.248
14	6.850	7.479	8.873	6.359	5.940	7.050	6.673	6.095
28	8.850	9.312	9.315	7.368	8.470	8.127	8.026	6.179

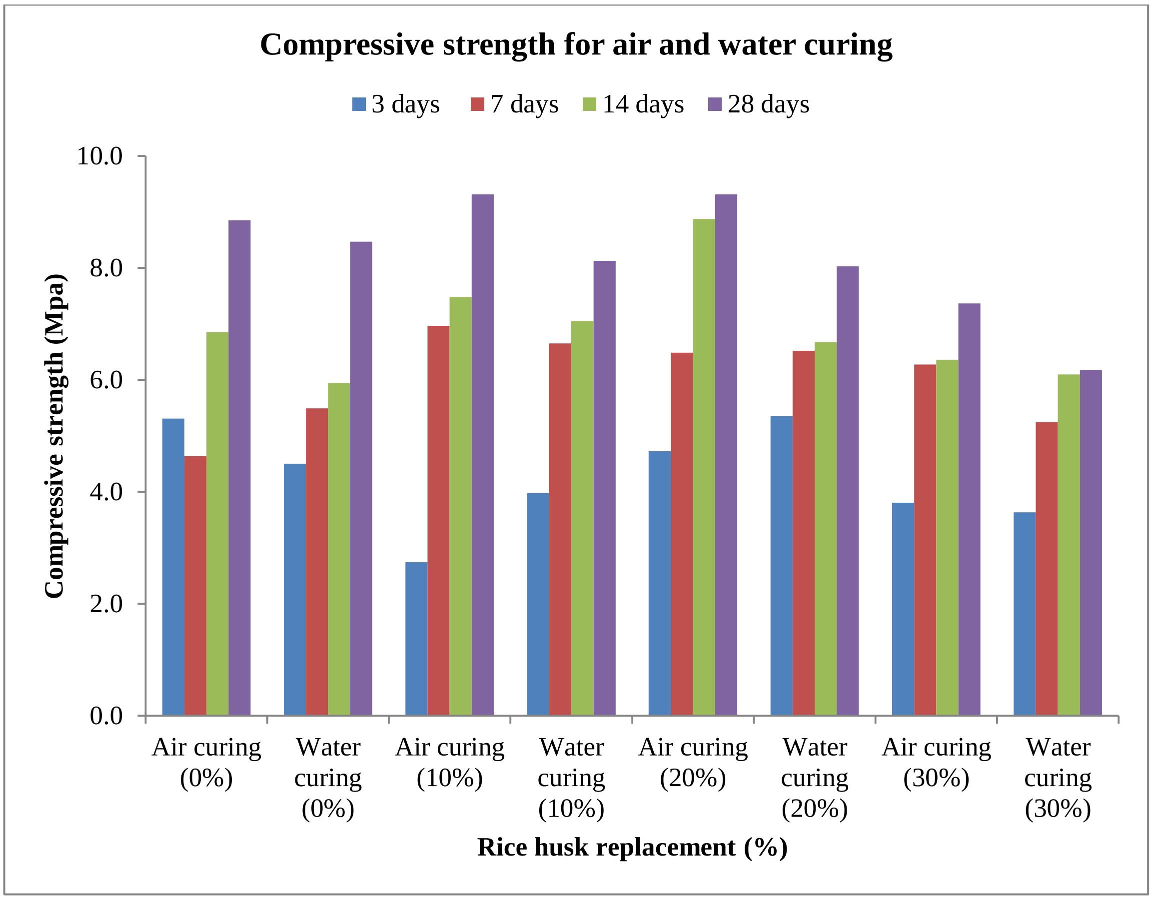


Figure 4.4: Average Compressive strength over along 28 days for air and water curing

4.3 FLEXURAL STRENGTH

4.3.1 Average flexural strength for all proportion air curing bricks

This test is the standard method of destructive test determining strength of sand brick resisting the point load using the flexural machine test. Figure 4.4 illustrated the average flexural strength of sand brick over along 28 undergoes air curing process. During 3 days, the flexural strength of control bricks was recorded 0.159 Mpa, and then increased to 0.170 Mpa at 7 days. The value went up continuously until 0.209 Mpa after 28 days curing. Furthermore, in general, bricks incorporating 20% rice husk has most optimum flexural strength after 28 days age curing which was recorded 0.254 Mpa higher than control sample recorded only 0.209 Mpa. In addition, bricks having 20% rice husk has higher flexural strength at all different days compared to others. Besides that, 10% of replacement achieved second highest flexural strength recorded 0.222 Mpa after 28 days. Other than that, bricks having 30% rice husk has lower flexural strength at all different days compared to the control sand brick. The graph also showed the flexural strength is increase with days of curing.

Table 4.5 : Average flexural strength for all proportion air curing

Age curing	**Air curing**			
Rice husk	**0%**	**10%**	**20%**	**30%**
3	0.159	0.125	0.176	0.130
7	0.17	0.175	0.176	0.141
14	0.179	0.208	0.240	0.169
28	0.209	0.222	0.254	0.173

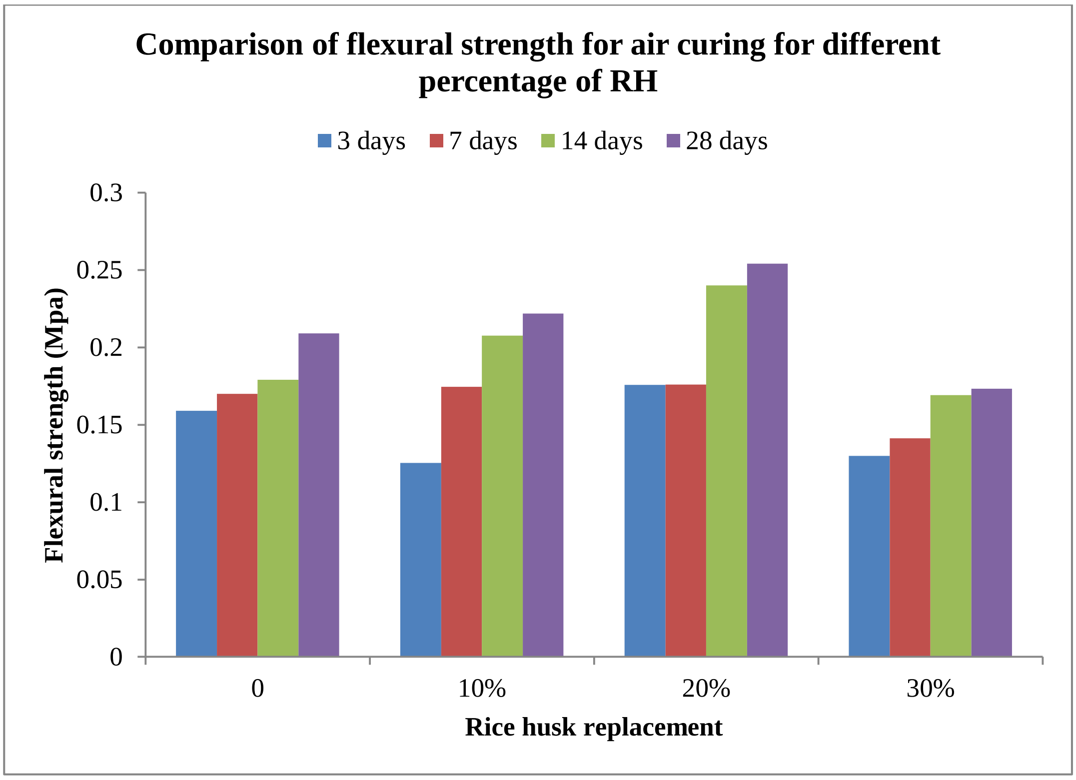


Figure 4.5: Average Flexural strength over along 28 days for air curing

4.3.2 Average flexural strength for all proportion water curing

The figure 4.6 showed the relationship of rice husk replacement and flexural strength for air curing type. For control sand brick, it indicated that the flexural strength slightly decreased from 0.17 Mpa (3 days) to 0.170 Mpa (7 days) and suddenly increased to 0.21 Mpa (14 days) and went to highest flexural strength compared to other which is 0.267 Mpa at 28 days. Furthermore, among bricks incorporating rice husk, bricks having 10% rice husk has the highest flexural strength that was recorded 0.242 Mpa at 28 days but lower than control sand brick. Furthermore, bricks having 30% rice husk, all the flexural strength in different period days recorded lower value than other bricks.

Table 4.6 : Average flexural strength for all proportion water curing

Age curing	Water curing			
Rice husk	**0%**	**10%**	**20%**	**30%**
3	0.170	0.156	0.146	0.128
7	0.168	0.173	0.170	0.137
14	0.120	0.194	0.210	0.173
28	0.267	0.242	0.236	0.188

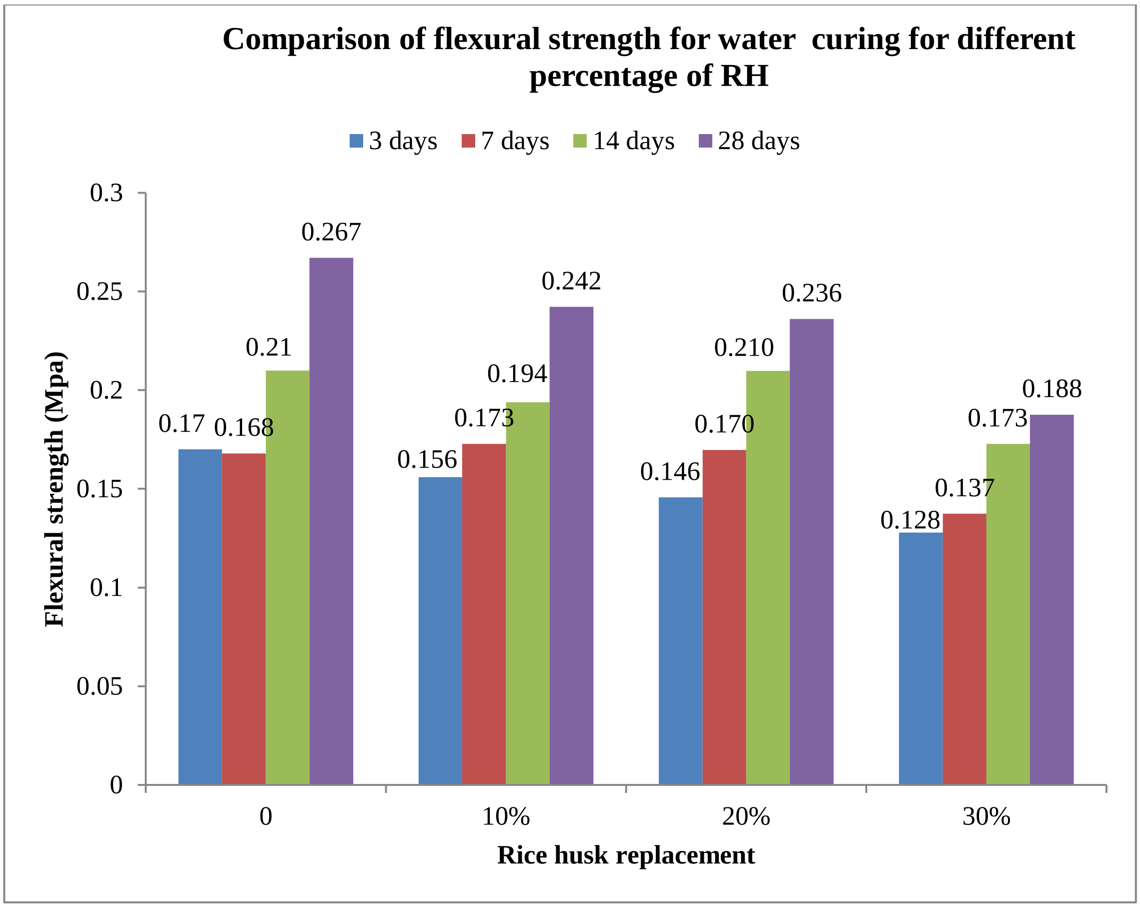


Figure 4.6: Average Flexural strength over along 28 days for water curing

4.3.3 Average flexural strength for all proportion for both air and water curing

Figure 4.7 showed control brick undergoes water curing has the highest flexural strength recorded with 0.267 Mpa at 28 days. Meanwhile, among the bricks incorporating rice husk, bricks with 20% rice husk air curing has highest flexural strength at 28 days was recorded 0.254 Mpa. Furthermore, the graph showed the water curing process has higher flexural strength value compared to air curing except for the brick having 20% rice husk. In addition, the flexural strength increased with the days.

Table 4.7 : Average flexural strength for all proportion both air and water curing

Age curing	Air curing				Water curing			
Rice husk	0 %	10%	20%	30%	0 %	10%	20%	30%
3	0.159	0.125	0.176	0.143	0.170	0.156	0.146	0.128
7	0.170	0.175	0.176	0.141	0.168	0.173	0.170	0.137
14	0.179	0.208	0.240	0.169	0.210	0.194	0.210	0.173
28	0.209	0.222	0.254	0.173	0.267	0.242	0.236	0.188

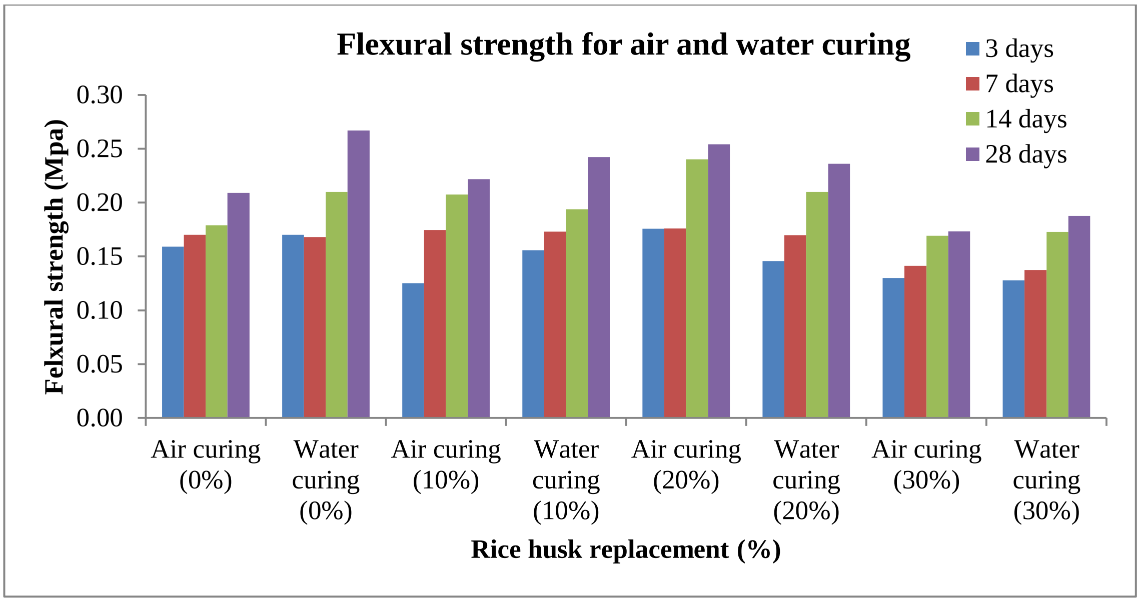


Figure 4.7: Average Flexural strength over along 28 days for both air and water curing

4.4 WATER ABSORPTION TEST

4.4.1 Water absorption at 28 days air curing

The water absorption has been tested on all types of proportion that were used in this research. The durability of the bricks is determined by water absorption. Figure 4.8 illustrated the water absorption of the sand brick with various percentages of rice husks. From the graph obtained, it showed that 10% of replacement is the best since it does not absorb too much water; only 11.02% which is lower than control sand brick recorded 11.22%. Meanwhile, sand brick with 30% rice husk showed the highest water absorption which is 14.75% because high content of the rice husk present make the sand brick more porous. In general, water absorption increased with the decrease in content of rice husk.

Table 4.6 : Water absorption at 28 days air curing

Age curing	**Air curing**			
Rice husk	**0%**	**10%**	**20%**	**30%**
28	11.22	11.02	12.59	14.75

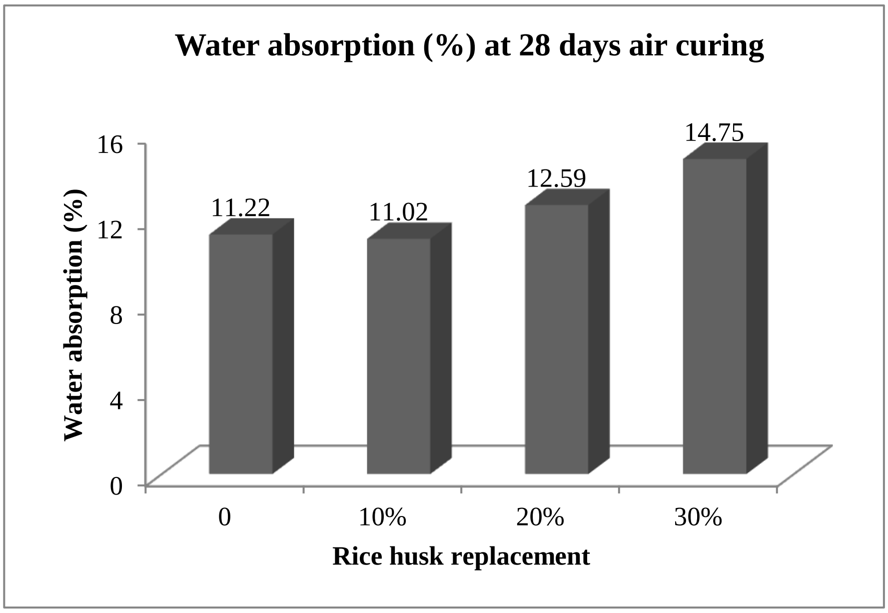


Figure 4.8: Water absorption at 28 days air curing

4.4.2 Water absorption at 28 days water curing

Figure 4.9 indicates that the lowest percentage of water absorption is 11.58% (10% of replacement) which is lower than the control sand brick recorded 11.88%. Besides, the highest percentage of water absorption is 14.92% (30% of replacement). The relationship of the graph shows as the rice husk increase, the percentage water absorption increase too.

Table 4.9 : Water absorption at 28 days water curing

Age curing		**Water curing**		
Rice husk	**0%**	**10%**	**20%**	**30%**
28	11.88	11.58	13.63	14.92

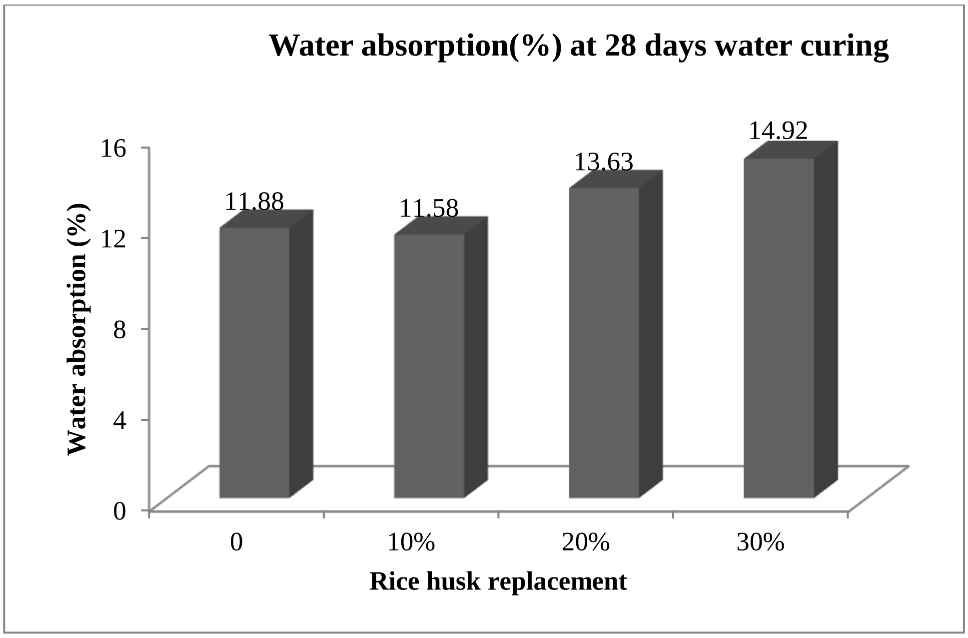


Figure 4.9: Water absorption at 28 days water curing

4.4.3 Water absorption at 28 days for both air and water curing

The figure 4.10 showed the water absorption at 28 days for all proportion both air and water curing. The results indicates 30% replacement water curing has the highest percentage water absorption which is 14.92% compared to others. In contrast, the best percentage of water absorption was recorded as 11.02 % (10% of replacement), the lowest value among the others. In general, all type proportion of sand brick that undergoes air curing achieved lower water absorption percentage compared to the water curing process.

Table 4.10 : Water absorption at 28 days air and water curing

Age curing	**Air curing**				**Water curing**			
Rice husk	**0 %**	**10%**	**20%**	**30%**	**0 %**	**10%**	**20%**	**30%**
28	11.22	11.02	12.59	14.75	11.88	11.58	13.63	14.92

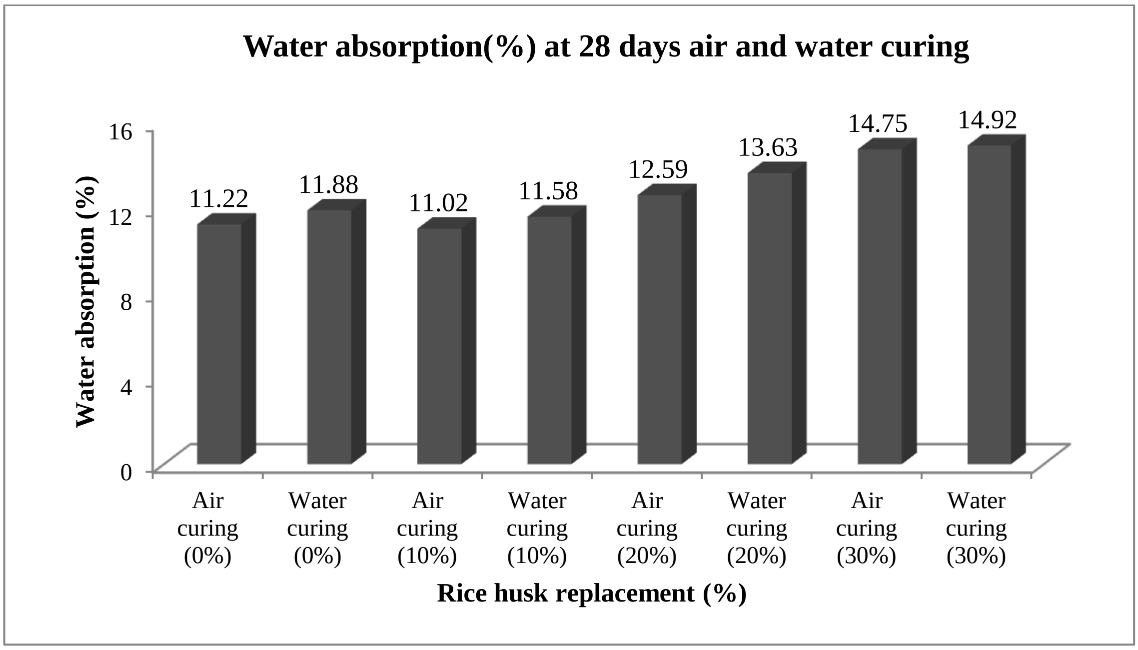


Figure 4.10: Water absorption at 28 days air and water curing

4.5 DENSITY

4.5.1 Density at 28 day air curing

The density is basically inversely proportional to the rate of water absorption, so that means the highest density have lowest water absorption rate. Result showed sand brick without clinker and rice husk have higher density value (19.06 kN/m^3) as compared to the bricks having clinker and rice husk. Decrease in the density was observed with increase in rice husk content. Minimum density was observed for bricks having 30% of rice husk (16.42 kN/m^3) which lower than brick having only 10% of rice husk was recorded 17.57 kN/m^3.

Table 4.11 : Density at 28 days air curing

Age curing	**Water curing**			
Rice husk	**0%**	**10%**	**20%**	**30%**
28	19.06	17.57	17.47	16.42

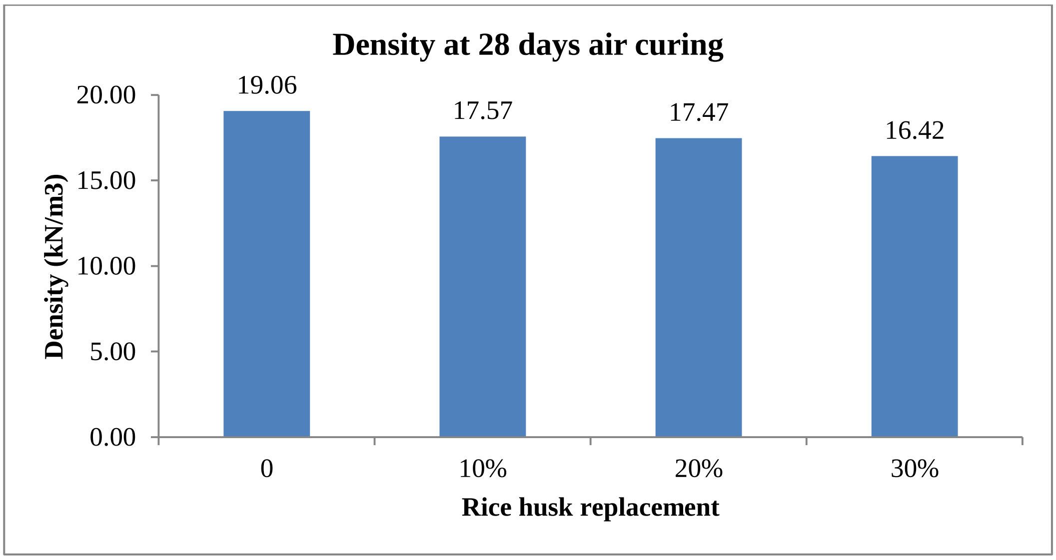


Figure 4.11: Density at 28 days air curing

4.5.2 Density at 28 days water curing

Figure 4.12 showed the result of density after 28 days water curing in all proportion. In general, increment of the density was influenced by the content of rice husk. It indicates that the highest density which is 19.17 kN/m^3 was recorded at control bricks while the lowest density at 30% of replacement which is 15.37 kN/m^3 only. In term of rice husk content, the more percentage of rice husk, the lower the density.

Table 4.12 : Density at 28 days water curing

Age curing	**Water curing**			
Rice husk	**0%**	**10%**	**20%**	**30%**
28	19.17	17.09	16.99	15.37

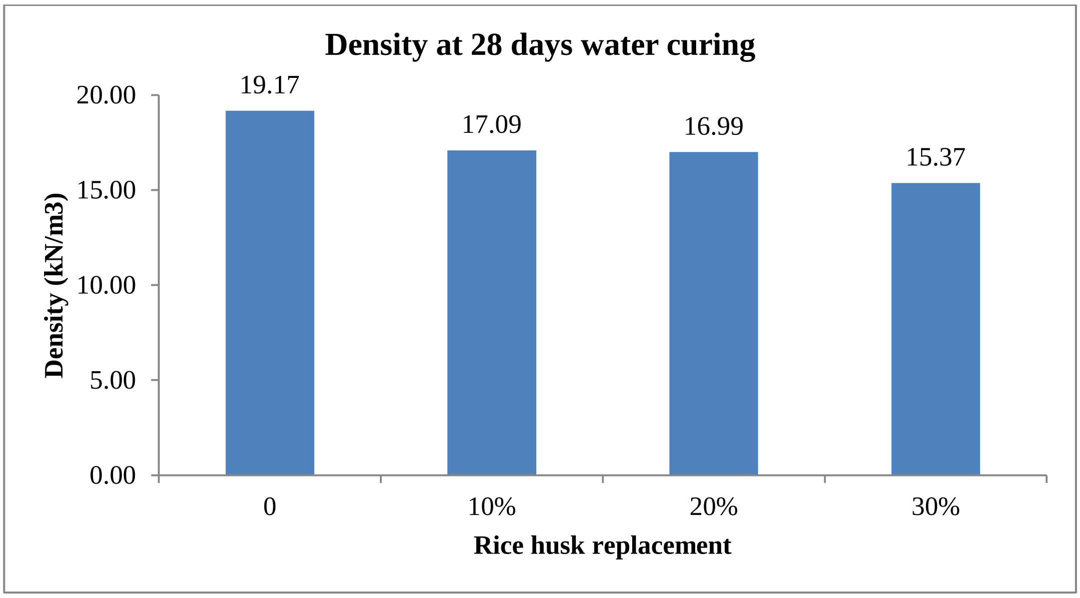


Figure 4.12: Density at 28 days water curing

4.5.3 Combination of density at 28 days for air and water curing

Figure 4.12 showed the result of density at 28 days air and water curing. Result depict that the bricks undergoes air curing had higher density than water curing. For example the density of air curing brick having 20% rice husk was 17.47 kN/m^3 higher than density of water curing brick having 20% rice husk that only recorded 16.99 kN/m^3. Increase in density was observed with decrease in rice husk content. For instance, among the three bricks having rice husk content, the highest value of density was recorded at bricks having only 10% rice husk which is 19.17 kN/m^3 compared to bricks having 30% rice husk recorded only 15.37 kN/m^3.

Table 4.13 : Density at 28 days air and water curing

Age curing	**Air curing**				**Water curing**			
Rice husk	**0 %**	**10%**	**20%**	**30%**	**0 %**	**10%**	**20%**	**30%**
28	19.06	17.57	17.47	16.42	19.17	17.09	16.99	15.37

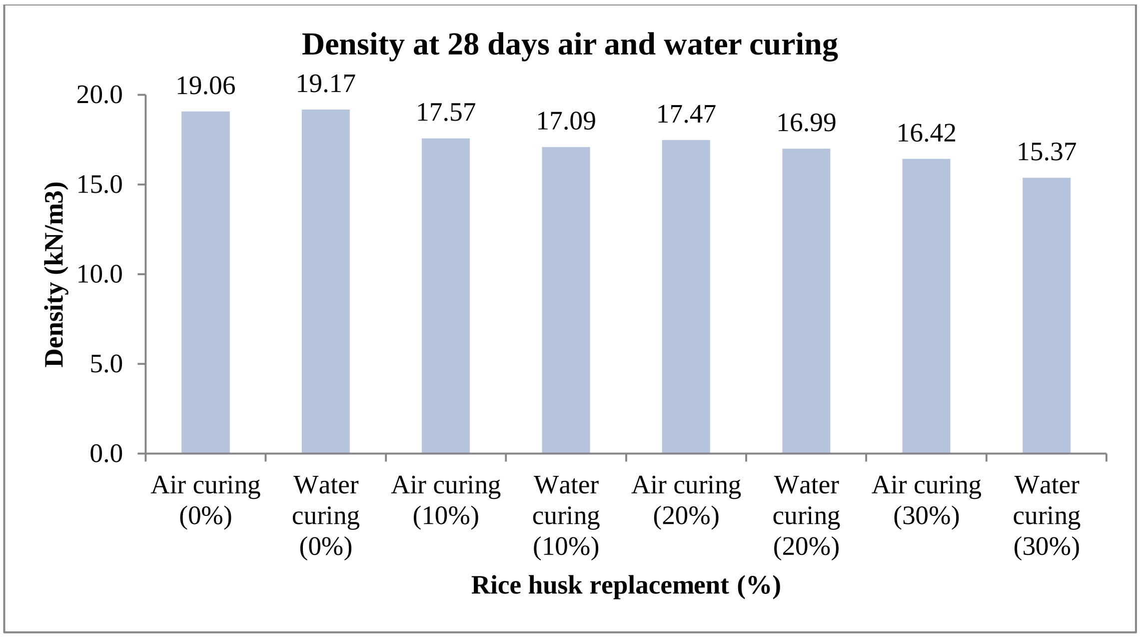


Figure 4.13: Density at 28 days air and water curing

4.6 Discussion

From the result above, the outcome from all the testing had been discussed for all four type of proportion which is A1 (control sample), A2, A3 and A4. In general, all the proportion through both air and water curing at 28 days passed the JKR standard specification which is 5.20 Mpa. Furthermore, in air curing process, the entire sample incorporating clinker and rice husk achieved higher than control sand brick as the highest one is 9.315 (type A3). However, in water curing process, control sand brick exhibit higher than other mixes which recorded 8.470 Mpa. For the flexural strength, the optimum proportion at 28 days is control sample recorded 0.267 Mpa undergoes water curing. For the air curing, proportion A3 achieved highest compressive strength recorded 0.254 Mpa. Besides, the water absorption test proved that water curing has higher water absorption rate than air curing. In other hand, brick from type A2 has the lowest water absorption rate that recorded 11.02. For the density test, all the control sand brick (air and water curing) exhibit higher value compared to other mixes.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this final chapter, the conclusions were drawn to point out the objectives and outcomes of this research. In addition, there are a few recommendations were added to study of clinker and rice husk as partial replacement of sand in brick production for future study.

5.2 Conclusion

This study is conducted to seeking the new alternative for replacement of fine aggregate in brick manufacturing. Objective from experimental study of properties for sand bricks with clinker as partial replacement for fine aggregate with ratio of 12.5% with rice husk of 10%, 20% and 30% had been achieved through several testing in laboratory and can be drawn:

i. In general, compressive strength for all of the palm oil clinker and rice husk sand brick mixes was in the range between 6.179 and 9.312 Mpa at 28 days curing age which pass JKR specification. Therefore it safe to say that all proportion is suitable for non-structural application.

ii. Furthermore, type A3 brick containing mixes 12.5% oil palm clinker with 20% rice husk achieved the optimum compressive strength while type A2 brick containing mixes 12.5 palm oil clinker with 10% rice husk has second highest compressive strength. At 28 days of air curing, type A3 sand brick achieved 9.315 Mpa, higher than control sand brick that was recorded only 8.85 Mpa.

iii. However, in term of flexural strength, all the mixes sand brick through water curing process slightly lower than control brick as the control brick recorded 0.267 Mpa. Type A2 sand brick incorporating 12.5% clinker with 10% rice husk recorded (0.242 Mpa) which best among the other mixes.

iv. In air curing process, flexural strength of type A2 and A3 achieved higher value which is 0.222 Mpa and 0.254 Mpa respectively compared to control sample (0.209 Mpa). For water curing process, all the samples achieved lower flexural strength compared to control sample (0.267 Mpa).

v. On other hand, the sand brick subjected to the water absorption test proved that type A2 sand brick (air curing) has the best proportion since it does not absorb too much water recorded only 11.02% water absorption. The water absorption increase as the rice husk increase due to the behaviours of rice husk tends to absorb water.

vi. Lastly, for the density test, all the control brick (both air and water curing) exhibit higher value compared to other mixes. Meanwhile, the results also proved that air curing process produce better sand brick compared to water curing process in overall aspect.

vii. Thus, by using the palm oil clinker and rice husk produce better strength sand brick compared to normal one. Also, this approach offers an environmentally friendly solution to the ongoing problems of solid waste material and sand river mining activity.

5.3 RECOMMENDATION

Based on the result obtained through this research, the following assumptions were made for the further study on palm oil clinker and rice husk as partial replacement in sand bricks. There are:

i. From the result of compressive strength and flexural strength, it recommended to investigate the percentage used of rice husk only in range 10% to 20% since it produce satisfactory strength.

ii. It is also recommended to use smaller size of palm oil clinker and rice husk, for example using the one that passing 3.5mm to replace river sand for better result.

iii. Besides, it is better to use air curing process only as the experiment proved the air curing process produce better result almost on all testing than water curing process.

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APPENDIX A

Compressive Strength Result at 3 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	3.915	Sample 1	225 x 113 x 75	127.7	5.02	**5.31**
	3.867	Sample 2	225 x 113 x 75	128.7	5.06	
	3.907	Sample 3	225 x 113 x 75	138.5	5.46	
	3.967	Sample 4	225 x 113 x 75	145.0	5.70	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.792	Sample 1	225 x 113 x 75	69.4	2.730	**2.740**
	3.715	Sample 2	225 x 113 x 75	63.4	2.494	
	3.628	Sample 3	225 x 113 x 75	70.6	2.777	
	3.72	Sample 4	225 x 113 x 75	75.3	2.962	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.629	Sample 1	225 x 113 x 75	119.7	4.708	**4.725**
	3.502	Sample 2	225 x 113 x 75	118.5	4.661	
	3.6	Sample 3	225 x 113 x 75	120	4.720	
	3.576	Sample 4	225 x 113 x 75	122.3	4.810	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.352	Sample 1	225 x 113 x 75	95.4	3.752	**3.804**
	3.387	Sample 2	225 x 113 x 75	93.8	3.689	
	3.365	Sample 3	225 x 113 x 75	100.5	3.953	
	3.37	Sample 4	225 x 113 x 75	97.2	3.823	

APPENDIX B

Compressive Strength Result at 3 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	4.075	Sample 1	225 x 113 x 75	146.6	4.54	**4.50**
	3.977	Sample 2	225 x 113 x 75	114.1	3.85	
	4.164	Sample 3	225 x 113 x 75	161.0	4.72	
	4.161	Sample 4	225 x 113 x 75	152.6	4.88	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.823	Sample 1	225 x 113 x 75	90.2	3.548	**3.975**
	4.011	Sample 2	225 x 113 x 75	108	4.248	
	3.922	Sample 3	225 x 113 x 75	102.5	4.031	
	3.826	Sample 4	225 x 113 x 75	103.6	4.075	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.639	Sample 1	225 x 113 x 75	145.4	5.719	**5.356**
	3.776	Sample 2	225 x 113 x 75	130.3	5.125	
	3.955	Sample 3	225 x 113 x 75	135.2	5.318	
	3.848	Sample 4	225 x 113 x 75	133.8	5.263	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.539	Sample 1	225 x 113 x 75	105.4	4.146	**3.633**
	3.513	Sample 2	225 x 113 x 75	80.2	3.154	
	3.52	Sample 3	225 x 113 x 75	88.3	3.473	
	3.546	Sample 4	225 x 113 x 75	95.6	3.760	

APPENDIX C

Compressive Strength Result at 7 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	3.758	Sample 1	225 x 113 x 75	113.1	4.45	**4.64**
	3.634	Sample 2	225 x 113 x 75	102.1	4.21	
	3.677	Sample 3	225 x 113 x 75	108.3	4.26	
	3.830	Sample 4	225 x 113 x 75	143.1	5.63	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.73	Sample 1	225 x 113 x 75	140.5	5.526	**6.963**
	3.613	Sample 2	225 x 113 x 75	179.1	7.044	
	3.815	Sample 3	225 x 113 x 75	185.4	7.292	
	3.701	Sample 4	225 x 113 x 75	203.1	7.988	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.386	Sample 1	225 x 113 x 75	169.9	6.682	**6.488**
	3.604	Sample 2	225 x 113 x 75	149.1	5.864	
	3.838	Sample 3	225 x 113 x 75	170	6.686	
	3.779	Sample 4	225 x 113 x 75	170.8	6.718	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.371	Sample 1	225 x 113 x 75	162.7	6.399	**6.276**
	3.304	Sample 2	225 x 113 x 75	156.3	6.147	
	3.438	Sample 3	225 x 113 x 75	165.7	6.517	
	3.421	Sample 4	225 x 113 x 75	153.6	6.041	

APPENDIX D

Compressive Strength Result at 7 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	3.968	Sample 1	225 x 113 x 75	146.6	5.77	**5.49**
	4.108	Sample 2	225 x 113 x 75	114.1	3.85	
	4.069	Sample 3	225 x 113 x 75	161.0	6.33	
	4.054	Sample 4	225 x 113 x 75	152.6	6.00	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.954	Sample 1	225 x 113 x 75	155.4	6.112	**6.654**
	3.955	Sample 2	225 x 113 x 75	177.5	6.981	
	3.783	Sample 3	225 x 113 x 75	164.1	6.454	
	4.043	Sample 4	225 x 113 x 75	179.7	7.068	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	4.091	Sample 1	225 x 113 x 75	173.5	6.824	**6.522**
	3.959	Sample 2	225 x 113 x 75	152.9	6.014	
	3.746	Sample 3	225 x 113 x 75	172.6	6.789	
	3.752	Sample 4	225 x 113 x 75	164.3	6.462	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.473	Sample 1	225 x 113 x 75	121.6	4.783	**5.248**
	3.558	Sample 2	225 x 113 x 75	130.3	5.125	
	3.528	Sample 3	225 x 113 x 75	156.6	6.159	
	3.465	Sample 4	225 x 113 x 75	125.2	4.924	

APPENDIX E

Compressive Strength Result at 14 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	3.728	Sample 1	225 x 113 x 75	181.0	7.12	
	3.685	Sample 2	225 x 113 x 75	176.8	6.95	**6.85**
	3.727	Sample 3	225 x 113 x 75	164.8	6.48	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.688	Sample 1	225 x 113 x 75	157.7	6.203	**7.479**
	3.76	Sample 2	225 x 113 x 75	243.2	9.565	
	3.561	Sample 3	225 x 113 x 75	192.2	7.559	
	3.607	Sample 4	225 x 113 x 75	167.5	6.588	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.562	Sample 1	225 x 113 x 75	215.5	8.476	**8.873**
	3.675	Sample 2	225 x 113 x 75	234.5	9.223	
	3.655	Sample 3	225 x 113 x 75	220.3	8.665	
	3.642	Sample 4	225 x 113 x 75	232.1	9.129	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.276	Sample 1	225 x 113 x 75	178.9	7.036	**6.359**
	3.177	Sample 2	225 x 113 x 75	194.7	7.658	
	3.313	Sample 3	225 x 113 x 75	92.9	3.654	
	3.186	Sample 4	225 x 113 x 75	180.2	7.088	

APPENDIX F

Compressive Strength Result at 14 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	4.061	Sample 1	225 x 113 x 75	177.8	7.00	**5.94**
	3.920	Sample 2	225 x 113 x 75	157.3	6.19	
	4.005	Sample 3	225 x 113 x 75	118.0	4.64	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.746	Sample 1	225 x 113 x 75	173.3	6.816	**7.050**
	3.884	Sample 2	225 x 113 x 75	201.5	7.925	
	3.836	Sample 3	225 x 113 x 75	157.8	6.206	
	3.74	Sample 4	225 x 113 x 75	184.4	7.253	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.857	Sample 1	225 x 113 x 75	176.8	6.954	**6.673**
	3.824	Sample 2	225 x 113 x 75	209.6	8.244	
	3.81	Sample 3	225 x 113 x 75	154.3	6.069	
	3.837	Sample 4	225 x 113 x 75	137.9	5.424	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.51	Sample 1	225 x 113 x 75	163.9	6.446	**6.095**
	3.689	Sample 2	225 x 113 x 75	192.9	7.587	
	3.689	Sample 3	225 x 113 x 75	163	6.411	
	3.697	Sample 4	225 x 113 x 75	100.1	3.937	

APPENDIX G

Compressive Strength Result at 28 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	3.846	Sample 1	225 x 113 x 75	228.5	8.99	**8.85**
	3.805	Sample 2	225 x 113 x 75	199.2	7.84	
	3.890	Sample 3	225 x 113 x 75	219.4	8.61	
	3.954	Sample 4	225 x 113 x 75	252.4	8.99	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.579	Sample 1	225 x 113 x 75	248.3	9.766	**9.312**
	3.54	Sample 2	225 x 113 x 75	230.5	9.066	
	3.367	Sample 3	225 x 113 x 75	229.6	9.030	
	3.601	Sample 4	225 x 113 x 75	238.6	9.384	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.559	Sample 1	225 x 113 x 75	247.2	9.723	**9.315**
	3.624	Sample 2	225 x 113 x 75	261	10.265	
	3.458	Sample 3	225 x 113 x 75	194.9	7.666	
	3.523	Sample 4	225 x 113 x 75	244.2	9.605	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.078	Sample 1	225 x 113 x 75	141.9	5.5811	**7.368**
	3.166	Sample 2	225 x 113 x 75	203.7	8.0118	
	3.316	Sample 3	225 x 113 x 75	202.2	7.9528	
	3.23	Sample 4	225 x 113 x 75	201.5	7.9253	

APPENDIX H

Compressive Strength Result at 28 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
Control sample	4.263	Sample 1	225 x 113 x 75	245.9	9.67	**8.47**
	4.292	Sample 2	225 x 113 x 75	214.1	8.42	
	4.212	Sample 3	225 x 113 x 75	192.5	7.57	
	4.293	Sample 4	225 x 113 x 75	208.8	8.21	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.964	Sample 1	225 x 113 x 75	197.4	7.764	**8.127**
	3.947	Sample 2	225 x 113 x 75	221.5	8.712	
	3.747	Sample 3	225 x 113 x 75	189.5	7.453	
	3.856	Sample 4	225 x 113 x 75	218.1	8.578	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.786	Sample 1	225 x 113 x 75	224.5	8.830	**8.026**
	3.794	Sample 2	225 x 113 x 75	188.2	7.402	
	3.721	Sample 3	225 x 113 x 75	183.9	7.233	
	3.775	Sample 4	225 x 113 x 75	219.6	8.637	

Ratio	Weight (kg)	Samples	Dimension (mm)	Maximum load (kN)	Compressive strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.558	Sample 1	225 x 113 x 75	156.3	6.147	**6.179**
	3.498	Sample 2	225 x 113 x 75	152.7	6.006	
	3.454	Sample 3	225 x 113 x 75	154.1	6.061	
	3.521	Sample 4	225 x 113 x 75	165.3	6.501	

APPENDIX I

Flexural Strength Result at 3 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	4.037	Sample 1	225 x 113 x 75	4.36	0.171	**0.158**
	3.899	Sample 2	225 x 113 x 75	3.23	0.127	
	4.020	Sample 3	225 x 113 x 75	4.51	0.177	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.715	Sample 1	225 x 113 x 75	2.54	0.100	**0.125**
	3.924	Sample 2	225 x 113 x 75	3.24	0.127	
	3.825	Sample 3	225 x 113 x 75	3.50	0.138	
	3.721	Sample 4	225 x 113 x 75	3.46	0.136	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.656	Sample 1	225 x 113 x 75	3.47	0.136	**0.176**
	3.801	Sample 2	225 x 113 x 75	4.95	0.195	
	3.625	Sample 3	225 x 113 x 75	4.65	0.183	
	3.533	Sample 4	225 x 113 x 75	4.80	0.189	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.247	Sample 1	225 x 113 x 75	3.11	0.122	**0.130**
	3.3	Sample 2	225 x 113 x 75	4.02	0.158	
	3.205	Sample 3	225 x 113 x 75	3.20	0.126	
	3.311	Sample 4	225 x 113 x 75	2.88	0.113	

APPENDIX J

Flexural Strength Result at 3 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	4.223	Sample 1	225 x 113 x 75	4.91	0.193	**0.170**
	4.200	Sample 2	225 x 113 x 75	4.52	0.178	
	4.095	Sample 3	225 x 113 x 75	4.31	0.170	
	4.073	Sample 4	225 x 113 x 75	3.59	0.141	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.916	Sample 1	225 x 113 x 75	4.20	0.165	**0.156**
	3.819	Sample 2	225 x 113 x 75	3.65	0.144	
	3.886	Sample 3	225 x 113 x 75	4.10	0.161	
	3.823	Sample 4	225 x 113 x 75	3.90	0.153	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.943	Sample 1	225 x 113 x 75	3.41	0.134	**0.146**
	3.919	Sample 2	225 x 113 x 75	3.85	0.151	
	3.903	Sample 3	225 x 113 x 75	3.75	0.147	
	3.922	Sample 4	225 x 113 x 75	3.80	0.149	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.627	Sample 1	225 x 113 x 75	3.30	0.130	**0.128**
	3.412	Sample 2	225 x 113 x 75	3.29	0.129	
	3.502	Sample 3	225 x 113 x 75	3.25	0.128	
	3.506	Sample 4	225 x 113 x 75	3.16	0.124	

APPENDIX K

Flexural Strength Result at 7 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	3.583	Sample 1	225 x 113 x 75	3.74	0.147	**0.170**
	3.840	Sample 2	225 x 113 x 75	4.07	0.160	
	3.913	Sample 3	225 x 113 x 75	5.15	0.203	
	3.663	Sample 4	225 x 113 x 75	-	-	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.728	Sample 1	225 x 113 x 75	4.76	0.187	**0.175**
	3.522	Sample 2	225 x 113 x 75	4.42	0.174	
	3.598	Sample 3	225 x 113 x 75	4.21	0.166	
	3.432	Sample 4	225 x 113 x 75	4.36	0.171	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.613	Sample 1	225 x 113 x 75	4.05	0.159	**0.176**
	3.516	Sample 2	225 x 113 x 75	4.67	0.184	
	3.723	Sample 3	225 x 113 x 75	5.27	0.207	
	3.479	Sample 4	225 x 113 x 75	3.91	0.154	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.495	Sample 1	225 x 113 x 75	4.49	0.177	**0.141**
	3.329	Sample 2	225 x 113 x 75	3.97	0.156	
	3.262	Sample 3	225 x 113 x 75	2.79	0.110	
	3.208	Sample 4	225 x 113 x 75	3.12	0.123	

APPENDIX L

Flexural Strength Result at 7 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	3.804	Sample 1	225 x 113 x 75	3.56	0.140	**0.168**
	3.994	Sample 2	225 x 113 x 75	5.42	0.213	
	3.684	Sample 3	225 x 113 x 75	2.73	0.107	
	4.077	Sample 4	225 x 113 x 75	5.32	0.209	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.779	Sample 1	225 x 113 x 75	3.92	0.154	**0.173**
	4.145	Sample 2	225 x 113 x 75	4.87	0.192	
	3.982	Sample 3	225 x 113 x 75	4.14	0.163	
	3.995	Sample 4	225 x 113 x 75	4.65	0.183	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.825	Sample 1	225 x 113 x 75	3.94	0.155	**0.170**
	3.755	Sample 2	225 x 113 x 75	4.23	0.166	
	3.786	Sample 3	225 x 113 x 75	4.53	0.178	
	3.652	Sample 4	225 x 113 x 75	4.56	0.179	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.405	Sample 1	225 x 113 x 75	3.75	0.147	**0.137**
	3.462	Sample 2	225 x 113 x 75	3.86	0.152	
	3.598	Sample 3	225 x 113 x 75	2.96	0.116	
	3.466	Sample 4	225 x 113 x 75	3.40	0.134	

APPENDIX M

Flexural Strength Result at 14 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	3.646	Sample 1	225 x 113 x 75	5.24	0.206	**0.179**
	3.681	Sample 2	225 x 113 x 75	4.35	0.171	
	3.316	Sample 3	225 x 113 x 75	4.03	0.159	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.707	Sample 1	225 x 113 x 75	5.25	0.206	**0.208**
	3.586	Sample 2	225 x 113 x 75	4.18	0.164	
	3.636	Sample 3	225 x 113 x 75	5.02	0.197	
	3.575	Sample 4	225 x 113 x 75	6.66	0.262	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.723	Sample 1	225 x 113 x 75	6.33	0.249	**0.240**
	3.584	Sample 2	225 x 113 x 75	6.68	0.263	
	3.65	Sample 3	225 x 113 x 75	5.94	0.234	
	3.68	Sample 4	225 x 113 x 75	5.46	0.215	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.369	Sample 1	225 x 113 x 75	4.13	0.162	**0.169**
	3.114	Sample 2	225 x 113 x 75	5.15	0.203	
	2.742	Sample 3	225 x 113 x 75	3.73	0.147	
	3.33	Sample 4	225 x 113 x 75	4.190	0.165	

APPENDIX N

Flexural Strength Result at 14 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	3.841	Sample 1	225 x 113 x 75	5.30	0.209	
	4.039	Sample 2	225 x 113 x 75	6.01	0.236	**0.210**
	3.883	Sample 3	225 x 113 x 75	4.67	0.184	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.935	Sample 1	225 x 113 x 75	5.29	0.208	
	3.749	Sample 2	225 x 113 x 75	4.98	0.196	
	4.064	Sample 3	225 x 113 x 75	4.32	0.170	**0.194**
	4.057	Sample 4	225 x 113 x 75	5.13	0.202	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.719	Sample 1	225 x 113 x 75	5.17	0.203	
	3.611	Sample 2	225 x 113 x 75	5.15	0.203	
	3.904	Sample 3	225 x 113 x 75	5.59	0.220	**0.210**
	3.826	Sample 4	225 x 113 x 75	5.43	0.214	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.296	Sample 1	225 x 113 x 75	4.59	0.181	**0.173**
	3.585	Sample 2	225 x 113 x 75	4.46	0.175	
	3.463	Sample 3	225 x 113 x 75	4.00	0.157	
	3.599	Sample 4	225 x 113 x 75	4.52	0.178	

APPENDIX O

Flexural Strength Result at 28 days (Air Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	3.942	Sample 1	225 x 113 x 75	5.07	0.199	**0.267**
	3.928	Sample 2	225 x 113 x 75	5.14	0.276	
	3.885	Sample 3	225 x 113 x 75	5.69	0.248	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.452	Sample 1	225 x 113 x 75	5.47	0.215	**0.222**
	3.503	Sample 2	225 x 113 x 75	5.56	0.219	
	3.604	Sample 3	225 x 113 x 75	5.71	0.225	
	3.658	Sample 4	225 x 113 x 75	5.82	0.229	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.563	Sample 1	225 x 113 x 75	6.63	0.261	**0.254**
	3.658	Sample 2	225 x 113 x 75	6.68	0.263	
	3.658	Sample 3	225 x 113 x 75	5.94	0.234	
	3.571	Sample 4	225 x 113 x 75	6.59	0.259	

Ratio	**Weight (kg)**	**Samples**	**Dimension (mm)**	**Load applied (kN)**	**Flexural strength (Mpa)**	**Average (Mpa)**
12.5% Clinker + 30% Rice Husk	3.251	Sample 1	225 x 113 x 75	4.05	0.159	**0.173**
	3.393	Sample 2	225 x 113 x 75	5.14	0.202	
	3.298	Sample 3	225 x 113 x 75	4.04	0.159	
	3.322	Sample 4	225 x 113 x 75	4.40	0.173	

APPENDIX P

Flexural Strength Result at 28 days (Water Curing)

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
Control sample	4.212	Sample 1	225 x 113 x 75	7.04	0.277	**0.267**
	4.339	Sample 2	225 x 113 x 75	7.01	0.276	
	4.257	Sample 3	225 x 113 x 75	6.31	0.248	
	4.222	Sample 4	225 x 113 x 75	6.18	0.267	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 10% Rice Husk	3.871	Sample 1	225 x 113 x 75	5.67	0.223	**0.242**
	3.781	Sample 2	225 x 113 x 75	6.56	0.258	
	3.913	Sample 3	225 x 113 x 75	5.98	0.235	
	3.852	Sample 4	225 x 113 x 75	6.42	0.253	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 20% Rice Husk	3.752	Sample 1	225 x 113 x 75	6.19	0.243	**0.236**
	3.896	Sample 2	225 x 113 x 75	5.72	0.225	
	3.82	Sample 3	225 x 113 x 75	6.00	0.236	
	3.846	Sample 4	225 x 113 x 75	6.10	0.240	

Ratio	Weight (kg)	Samples	Dimension (mm)	Load applied (kN)	Flexural strength (Mpa)	Average (Mpa)
12.5% Clinker + 30% Rice Husk	3.452	Sample 1	225 x 113 x 75	4.54	0.179	**0.188**
	3.386	Sample 2	225 x 113 x 75	5.13	0.202	
	3.445	Sample 3	225 x 113 x 75	4.69	0.184	
	3.459	Sample 4	225 x 113 x 75	4.72	0.186	

APPENDIX Q

Water Absorption Test Result at 28 days

Ratio of clinker	Ratio of rice husk	Types of curing	Dimension (mm)	Weight after oven (kg)	Weight after immersed (kg)	Rate of water absorption (%)
0%	**0%**	Air	225 x 113 x 75	3.592	3.995	**11.22**
0%	**0%**	Water	225 x 113 x 75	3.593	4.020	**11.88**
12.5%	**10%**	Air	225 x 113 x 75	3.512	3.899	**11.02**
	10%	Water	225 x 113 x 75	3.384	3.776	**11.58**
	20%	Air	225 x 113 x 75	3.367	3.791	**12.59**
	20%	Water	225 x 113 x 75	3.258	3.702	**13.63**
	30%	Air	225 x 113 x 75	3.140	3.603	**14.75**
	30%	Water	225 x 113 x 75	3.124	3.590	**14.92**

APPENDIX R

Water Absorption Test Result at 28 days

Ratio of clinker	Ratio of rice husk	Types of curing	Dimension (mm)	Weight after oven (kg)	Density (kN/m^3)
0%	**0%**	Air	225 x 113 x 75	3.705	**19.06**
0%	**0%**	Water	225 x 113 x 75	3.727	**19.17**
12.5%	**10%**	Air	225 x 113 x 75	3.416	**17.57**
	10%	Water	225 x 113 x 75	3.322	**17.09**
	20%	Air	225 x 113 x 75	3.396	**17.47**
	20%	Water	225 x 113 x 75	3.303	**16.99**
	30%	Air	225 x 113 x 75	3.191	**16.42**
	30%	Water	225 x 113 x 75	2.988	**15.37**