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

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By the name of Allah, Most Gracious, Most Merciful.

On the completion of this thesis, Experimental Study of Properties for Sand Bricks with Palm Oil Clinker as a Partial Replacement for Fine Aggregate with Ratio of 10% with Rice Husk of 10%, 20% and 30%. I would like to present my highest gratitude to Allah S.W.T for His love and mercy. Praise and peace be upon Prophet Muhammad S.A.W, his family, and his companions.

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ABSTRAK

Pada masa kini industri pembinaan seperti industri bahan terus meningkat dengan ketara di pasaran domestik dan juga pasaran global disebabkan oleh peningkatan penduduk di Malaysia setiap tahun. Batu bata telah wujud selama berabad-abad dan ia merupakan salah satu komponen penting dalam industri bahan binaan yang mendapat permintaan tinggi dan memerlukan lebih banyak penggunaan pasir dalam proses membuat bata. Selain itu, terdapat isu-isu yang berkaitan dengan bahan buangan seperti klinker kelapa sawit dan sekam padi yang telah dibuang di tapak pelupusan tanpa digunakan. Oleh itu, kajian eksperimen ini dijalankan di makmal konkrit di Universiti Malaysia Pahang untuk menentukan keberkesanan pengeluaran bata pasir yang berdasarkan penggunaan klinker minyak kelapa sawit dan sekam padi. Bata kawalan dibuat daripada campuran simen, pasir dan air. Sementara itu untuk bata alternatif, peratusan pasir digantikan dengan klinker minyak kelapa sawit sebanyak 10% dengan sekam padi sebanyak 10%, 20%, dan 30%. Saiz bata pasir yang dihasilkan adalah berdasarkan Spesifikasi Standard JKR untuk Bangunan Kerja (2005) iaitu 225 mm X 113 mm X 75 mm. Kajian ini adalah penting untuk menganalisis potensi klinker sawit dan sekam padi sebagai pengganti separa agregat halus dalam pengeluaran bata pasir. Selain itu, penyelidikan ini lebih memberi tumpuan kepada bahan mesra alam yang dapat menyumbang ke arah kelestarian bahan hijau. Hal ini demikian dengan menggunakan bahan ini sebagai pengganti agregat halus boleh membantu pengurangan bahan buangan. Berdasarkan kajian ini, ujian yang terlibat adalah ujian ketumpatan, ujian penyerapan air, ujian kekuatan mampatan dan ujian kekuatan lenturan. Kajian eksperimen dijalankan selama 3 hari, 7 hari, 14 hari dan 28 hari selepas menjalani proses pengawetan air dan udara. Oleh itu, hasil ujian yang diperoleh daripada bata alternatif dibandingkan dengan bata kawalan. Setelah mempertimbangkan hasil dan perbincangan semua tujuan utama dicapai.Kesimpulannya kajian ini dapat diringkaskan bahawa klinker minyak kelapa sawit dan sekam padi adalah salah satu bahan sisa yang sesuai untuk menjadi pengganti separa agregat halus dalam pengeluaran bata pasir. Penggantian 10% C + 10% RH disarankan sebagai nisbah terbaik dalam meningkatkan kekuatan dan ketumpatan batu pasir berbanding penggantian 20% dan 30% RH.

ABSTRACT

Nowadays construction industry such as material industry continues to emerge significantly in the domestic as well as global market due to increase the population in Malaysia. The brick has been around for centuries and it is the one of the most important component in construction material industry that have highly demand and required more consumption of sand in brick making process. Besides that, there are issues related to waste material such as palm oil clinker and rice husk that have being dumped in landfills without being used.Thus, this experimental study are carry out in concrete laboratory at University of Malaysia Pahang to determine the effectiveness of sand brick production that based on utilization of palm oil clinker and rice husk. The control brick are made from mixture of cement, sand and water. Meanwhile for alternative brick the percentages of sand are replaced by 10% palm oil clinker with rice husk of 10%, 20%, and 30%. The size of the sand brick produced are based on JKR Standard Specifications for Building Works (2005) which is 225 mm X 113 mm X 75 mm. This study is important to analyze the potential of palm oil clinker and rice husk as partial replacement for fine aggregate in sand brick production. Furthermore, this research more focusing on eco-friendly material that can contribute towards sustainability green material. This is because by using this material as replacement of fine aggregate can help reduction of waste. From this research, the test that involved are density test, water absorption test, compressive strength test and flexural strength test.This experimental studies were conducted for 3 days, 7 days, 14 days and 28 days after undergone water and air curing process. Hence, the result testing obtained from alternative brick are compared with control brick. After considering result and discussion all the main objectives are achieved. Therefore, from this research it can summarize that palm oil clinker and rice husk is one of waste material that suitable to be as partial replacement for fine aggregate in sand brick production. The replacement of 10% C + 10% RH is recommended as the best ratio in increases the strength and density of sand bricks compared to replacement of 20% and 30% RH.

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LIST OF SYMBOLS

M	Mass
V	Volume
N	Maximum load at failure (N)
F	Load at a given point on the load deflection curve (N)
L	Support Span (mm)
B	Width of sand brick (mm)
d	Depth or thickness of tested brick (mm)

LIST OF ABBREVIATIONS

JKR	Jabatan Kerja Raya
ASTM	American Society for Testing and Materials
RH	Rice husk
C	Clinker
BS	British Standard
CIDB	Construction Industry Development Board

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The construction field is a vital and productive field of the Malaysia economy. As a developing country, Malaysia has realized the crucial role of the construction field is not only in economic growth but also important in improving the quality of life and living standard of Malaysian community. Nowadays Malaysian construction industry such as material industry continues to emerge significantly in the domestic as well as global market due to increases the population every year. According to the Statistics Department, Malaysia it projected that the Malaysia's population will grow to 38.6 million in 2040. The population increase may be caused to increase the demand in many industry production.

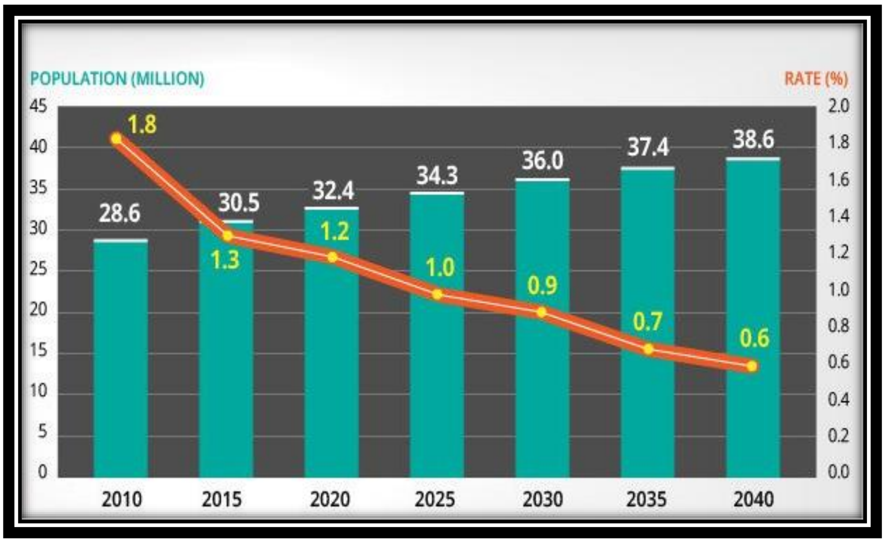

Figure 1.0 Population projection and annual population growth rate in Malaysia

Sources: (Department of Statistics, Malaysia, 2014)

Table 1 Estimated demand for major construction material in Malaysia

Construction Material	Unit	Material Quantity
Steel reinforcement	tonne	1.5 million
Ready mixed concrete	m^2	19.1 million
Plywood	piece	49.5 million
Bricks	pallet	12.8 million
Paint	5 litre	12.7 million
Sand (finishes)	tonne	25.5 million
Glass	m^2	28.4 million
Cement (finishes)	tonne	2.6 million

Sources: (CIDB Malaysia, 2018)

Table 1 represent the 8 types of materials such as steel reinforcement, ready mixed concrete, plywood, bricks, paints, sand, glass and cement that has emerged as the main construction material that have highly demand and most frequently required for any project. From the demand, the materials such as bricks and sand is highly get attention to increase research in order to develop another alternative to create more advantages toward construction material industry.

The brick has been around for centuries and it is the one of the most important component in construction material industry that contributes to high cost. It is widely used in various constructions such as wall, pole, floors, stairs and street. Bricks are define as a building material in the form of rectangle and made of major raw material types such as clay, sand, and cement. Usually brick size are based local standards which is normal dimensions is about 215mm x 102.5mm x 65mm which if mixed with a mortar layer size of 10mm (Polytechnic Module, 2012). An interesting thing about bricks is dimension and size has not changed. Generally, there are two types of bricks produced and used in local construction of houses and building which are clay brick and sand brick.

However, in this study sand brick are selected to be main subject. Sand bricks are made from a mixture of sand, cement, and water. In addition, in this research palm oil clinker and rice husk will be replace fine aggregate in the mixture of sand brick.Palm oil clinker is a by-product waste produced from burning of palm oil fibre and palm oil shell inside the boiler under high temperatures. Generally these wastes are being dumped near the palm oil mill thus resulting environmental pollution (Arunima, 2016). Meanwhile rice husk is an agriculture waste material abundantly available in rice-producing countries. The utilization of palm oil clinker and rice husk as partial replacement for sand in sand brick production can be one of option to reduce the amount of products that should be disposed in landfills and possibly eliminate the environmental impacts.

1.2 Problem Statement

In the 21st century, the introduction of sustainable development in the construction industry as well building materials has received considerable attention. The world is increasingly aware of that brick production costs are rising due to high demand, lack of resources non-renewable natural and high energy cost. In addition, for production sand bricks required the more usage of sand as it is one of the main ingredient in the mixture. Based on (Ali, 2017) it said that the raw sand in Malaysia is increasing from year 2014 which is about 29,862,000 tonnes to 34,341,300 tonnes on 2015 respectively. This increment shows that the demand of sand is quite high as well as the mining activities also increasing that may lead to the serious environmental problem such as channel degradation and erosion, head cutting, increased turbidity, stream bank erosion and sedimentation of riffle area. Besides, according to (Gabir, 2017) it state that there is a shortage of sand due to high demands for construction material even it is not the level of panic.

Meanwhile according to (Abutaha, 2016), Malaysia is the second largest material palm oil producing country that generates palm oil clinker as waste which projected to grow because increasing demand for consumption of palm oil. This material is dump at the landfill without any utilization and estimated around 2.6 million tons of solid waste was produced annually by the palm oil industry. Besides, (Habeeb & Mahmud, 2010) revealed that rice husk is an agricultural residue that accounts for 20% of the 649.7 million tons of rice produced annually worldwide without being used. Hence, to overcome the issues related with the disposal waste material in landfill without any utilization the efforts can make by utilize this material as partial replacement in sand brick production. Thus, the use of renewable waste material not only will be help to resolve waste collection problems but also give value added in term of cost, quality and productivity to sand brick.

In short, the further research should be conduct to investigate the potential of palm oil clinker and rice husk as partial replacement for sand and compared to control sand brick. Thus, this research will depend on laboratory test to study the properties of sand brick by using this waste material. Therefore, all processes of experiments should conduct towards samples of sand brick in the concrete laboratory.

1.3 Objective of Study

The objectives of this study are:

a) To determine the density of sand brick with different percentages of palm oil clinker and rice husk

b) To determine the compressive strength of sand brick with different percentages of palm oil clinker and rice husk

c) To determine the flexural strength of sand brick with different percentages of palm oil clinker and rice husk

d) To determine the water absorption of sand brick with different percentages of palm oil clinker and rice husk

1.4 Scope of Study

This experimental study will carry out in Concrete Laboratory at University of Malaysia Pahang to determine the effectiveness of sand brick production that based on utilization of palm oil clinker and rice husk. The control sand brick are made from mixture of cement, sand and water. Meanwhile for alternative sand brick the percentages of sand will replace by 10% palm oil clinker with rice husk of 10%, 20%, and 30%. The size of the sand brick will produce are based on JKR Standard Specifications for Building Works (2005) which is 225 mm X 113 mm X 75 mm. From this research, the test that involve are density test, water absorption test, compressive strength test and flexural strength test.This experimental studies will conducted for 3 days, 7 days, 14 days and 28 days after undergoes water and air curing process. Hence, the result testing obtains from alternative sand brick will compared with control sand brick.

(a) The density test

The main objective of this testing is to determine the density of sand bricks. The standard used for this experiment is ASTM C 642-97.

(b) The compressive strength test

According to standard ASTM C67-03a, the aim of this experiment is to determine the compressive strength of sand bricks.

(c) The flexural strength test

The testing objective is to determine the flexural strength for sand bricks. This experiment is referring the standard ASTM C293.

(d) The absorption test

The standard used for this experiment are based on ASTM standard C1 403-18.The objective is to determine the water absorption of sand bricks.

1.5 Significant of Study

This study is important to analyze the optimum ratio of palm oil clinker and rice husk that suitable to use as partial replacement for fine aggregate that contribute the good results in sand brick production. There are different proportions of waste material used to replace the fine aggregate in sand brick. Furthermore, this research more focusing on eco-friendly material that can contribute towards sustainability green material. This is because by using this material as replacement of fine aggregate can reduce the consumption of sand in sand brick production. On the other hand, the benefits gain from this research are reduction in amount of products that must be disposed in landfills and environmental problem.Four types of laboratory tests is conducted such as density test, compressive strength test, flexural strength test and water absorption test to achieve the aim of the research.

In summary, this study is useful towards other researchers in order to upgrade and create more innovative material in construction industry. There are many information and data related to sand brick production and utilization of waste material that will gained from this research. On top of that, the new researchers can learn from this research to get valuable experience and made as guide in order to avoid repeat the same mistake. This research also can save time, energy and money of other researchers because no need to them to repeat the same research. Besides that, the results obtained from the experimental study can used to compare with the existing results based on previous research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Along with the increasing demand for construction materials, the prices of materials in the market are also rise rapidly and there are some issue related to waste disposal material without being used. Thus, to overcome the problems faced by this industry, almost in all countries in the world the various research are made that aimed at reducing the cost of material and improving the quality in term of strength and durability of the construction material. There are many information and data from the past research that could be make as references in sequence to make new improvement to the construction materials. As we know, every construction industry totally depends on cement and the aggregates whether it is coarse or fine for the making of material. Hence, this research wants to investigate something new in order to reducing the use of fine aggregate and encouraging reuse of waste material that can contribute toward reduction of environmental problem.

In the view of this, this research have started finding for replacement material that acceptable in producing sand bricks so that the pure resources can maintained to the next generation (Sani, 2012). In this research, the fine aggregates are the main ingredients that used in sand brick production. Consequently, according to (Muthusamy & Ali, 2017) it can be seen that waste material such as palm oil clinker can be used as partial replacement that will be replaced the fine aggregate and based on (Kartini & Ernida, 2012) research stated that rice husk has potential to develop in sand brick production. There are many advantages when used this materials as partial replacement material such as solves the disposal problem of waste material and depleting the use of natural resources.

In sum, this chapter will focus about the potential of palm oil clinker and rice husk to be as partial replacement in sand brick making. Besides that, the classification of brick that always involved in construction, the material that required in sand brick production and detail about properties in term of density, water absorption, compressive strength and flexural strength will investigate in this research. All the information given obtained based on previous research.

2.2 Types of Brick

In the construction sector, bricks are one of the oldest and most famous materials that used in building. Generally, brick are strong, long- lasting and rigid material that moulded by blocks of tampered clay to get appropriate shapes and sizes at certain conditions. Brick is widely used in building because they are easy to handle and found in shape of rectangular. According to (Abdullah, 2017) the brick properties can be describes as it have a constant size and texture, flat surface, fixed shape and have an average weight in range 2.3 kg to a brick 3.3 kg and rate of absorption does not exceed 15% of its own weight. To achieve the goal of this research, it is crucial to know and understanding the types of bricks first. In this section, this research will be discover the types of bricks used which is relies on their quality, strength and process of making for different criteria. On the basic of use commonly brick have classified into the following that is sand brick, clay brick, common brick and facing brick.

2.2.1 Sand Brick

The main component of sand brick are sand, cement and water that widely produced and required less maintenance. Based on JKR Standard Specifications for Building Works (2005) the appropriate size of sand brick is as below:

Table 2. 1 Nominal size of sand brick

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

Sources: JKR Standard Specifications for Building Works (2005)

2.2.2 Clay Brick

One of the oldest and most durable construction techniques used by humankind is clay brick (Fernandes, Lourenço, & Castro, 2010). Clay brick is made of selected clays that moulded or cut into shape and fired in ovens. Based on (The Brick Industry Association, 2007) clay bricks is form from natural material on the earth and then have fired through a kiln at up to 2000 degrees. The advantages of clay bricks is consist of natural materials that has been utilize for centuries and have superior thermal mass qualities.

2.2.3 Common Brick

Common bricks are usual used for internal brickwork such as filling, support and in walls and are not suitable for use in underground. This type of brick does not have a specific package on the surface and commonly applied for the walls of the restrictions that will be cover with a layer of plaster where the appearance of the surface is no important (Salleh, 2012). Even this brick function as internal brickwork the common bricks also have disadvantages that is low of quality. Other than that, brick compression strength is lower than facing bricks and engineering bricks.

2.2.4 Facing Brick

In the UK country, facing bricks is the one of the brick that has been in high demand and has become a popular over the years, especially in the housing market. Since this type of brick has a high aesthetic value in terms of texture and appearance this brick becomes an option for use the external building wall (Salleh, 2012). Besides, this brick have ability to withstand the hot weather temperature. This brick are available in several types such as soft mud and extruded as it produced from different manufacturing technique.

2.2.5 Engineering Brick

The engineering brick have more benefit on physical characteristics in aspect of strength and water absorption compared to the appearance. This is because this brick have high strength and low in water absorption. Besides, (Ismail, 2013) state that this brick have high density and well fired. These brick usually can be used in earthworks, manholes, sewers, retaining walls and moisture proof courses.

2.3 Material

2.3.1 Cement

Generally, cement refer to the material manufacture from limestone and clay that is available in powder form. Cement is the most essential material in building construction. According to (Mugabi, 2010) the ability of cement to hold the structure have made it as one of the common component that needed in construction compared to other component. That means, the function of cement is to bind the sand and other aggregate together and then fill void in between them to form a compact mass. There are four main compounds in cement that are Tricalcium Silicate (C3S), Dicalcium Silicate (C2S), Tricalcium Aluminate (c3A) and Tetracalcium Alumina Ferrite (C4AH). Meanwhile, there are 5 main types of cement which are Portland cement, Portland composite cement, blast furnace cement, pozzolanic cement and composite cement.(BS EN 197-1-2000).Hence according to (JKR Standard Specifications for Building Works, 2005) for the brick work Ordinary Portland Cement are used. Portland cement is a fine powder presenting agglomerating, agglutinating, or binding properties that when under water, hardens and no longer decomposes when exposed to water again (Acchar, 2016). There are several product of Ordinary Portland Cement such as Castle, Dragon, Orang Kuat and Wallceem. From the other research it can seen that among product Portland Cement Cap Orang Kuat is the most quality products that could use in brick making compared to other products.

2.3.2 Sand

Sand is a genuinely existing granular material consists of finely divided rock and mineral particles. The most typical element of sand is silica (Emley, 1917). Based on (Mohd, 2015) research it state that usually sand passed 4.75 mm sieve and contains only so much coarser as it allowed by specification. Meanwhile by referring (JKR Standard Specifications for Building Works, 2015) it said that maximum size sand shall pass through is a 4.8 mm mesh BS sieve for brickwork. Sand is an important material for the construction material such as brick making because it gives strength, bulk and other properties. The finest modulus of sand should be 1.2 to 1.5 and silt content should not be more than 4% for the production of brick. In addition, sand applied for brickwork should free from dirty and coatings of clay and silt.

2.3.3 Water

For production of sand brick, it required some amount of water to mix and stick together with aggregates. This is because water is the material that has ability to giving true mixing. Besides that, the water used must clear from any impurities, alkali and acid. The characteristic of water is colourless, tasteless and odourless. For examples, tap water and river water. The volume of water that use for the making of brick depends on weight of fine aggregates in the mixture. The reduction amount of water actually can contribute positive effects towards increasing strength and workability of sand brick. It also increases durability and resistance to weathering. Meanwhile the excessive use of water make the mixture easily collapse and decreasing concrete drying shrinkage and possible for cracking. However, no testing procedure detected to determine the properties of water.

2.3.4 Palm Oil Clinker

Palm oil clinker is obtained as a by-product waste produced from burning of palm oil fibre and palm oil shell inside the boiler under high temperatures. Referring to (Onoja, 2018) the biomass waste from oil palm industry in Malaysia is expected to increase from 80 million tonnes in 2010 to 85 until 110 million tonnes by 2020.The rising the production of palm oil clinker without being used made it dumped abundantly in landfill that finally effect the our surrounding environment. This materials made up of calcium silicate, tricalcium aluminate and calcium aluminoferrite. In addition, palm oil clinker has irregular shape, porous structure and much lighter. Palm oil clinker is suitable to replace the function of sand in concrete production because there are similarity of the particle size distribution and the grading features of sand and palm oil clinker. The basic material test results showed that the properties of palm oil clinker used is similar to that of natural sand and can be used as a replacement material for natural sand (Arunima, 2016).

Table 2.2 Physical properties of sand

Property	**Value**
Fineness modulus`	3.15
Specific gravity	2.61
Sieve analysis	Zone of aggregate –Zone I

Sources: (Arunima, 2016)

Table 2.3 Physical properties of palm oil clinker

Property	**Value**
Fineness modulus`	2.59
Specific gravity	2.75
Sieve analyis	Zone of aggregate—Zone II

Sources: (Arunima, 2016)

Besides, crushed palm oil clinker can represent as lightweight aggregate that can be potentially applied in concrete production (Abutaha, 2017). (Razak,2016) stated that palm oil clinker is the low cost and environmental friendly aggregate that can be as alternative to replace normal aggregate for future use. On the other hand, (Kanadazan, 2015) said that palm oil clinker is lighter in nature, it can be used for the production of lightweight concrete that can give benefit in reduction of environmental pollution.

Therefore, based on Sujendran (2014) study it reveal that the palm oil clinker has potential to be as the coarse and fine aggregate replacement. According to British Standard, the aggregate that passes through 20 mm sieve classified as coarse aggregate meanwhile the aggregate that passes through 5 mm sieve categories as fine aggregate. Therefore to produce fine powder like sand this material need to ground to be fine first and can be utilized in production of lightweight brick.

2.3.5 Rice Husk

Paddy field is one of the main contributors to the economy in Malaysia and it can produce a material that called as rice husk. Rice husk is the outermost layer of protection encasing a rice grain. The ash contains above 90% silica with a highly porous, lightweight and specific surface area (Chiang, 2009).The production of rice husk continuously rise up from years to years that lead to increasing of waste disposal problems. Meanwhile the past research state that rice husk has ability to substitute aggregate to produce lightweight insulating concrete resulting in reduction of compressive strength and density of material (Salas, 1986). Beside that the research recognized that the utilization of rice husk material can contribute to production of lightweight brick. The use of raw rice husk in clay brick was found to increase porosity, water absorption and acceptable compressive strength in fired brick (Traore, 2018).

2.3 Properties of Brick

These sections cover the experimental properties in term of density, water absorption, compressive strength and flexural strength based on the past research.

2.3.1 Density

Density is very important parameter as low density material can reduce the load that is subjected to the ground. According to (Sutas, 2012) research it state that density value dropped with increase the amount of rice husk used because the larger the rice husk content cause the higher porosity and shorter the past among particles for gas diffusion. The addition of 2% rice hush resulted the higher density of 1.68 g/cm^3 and density tends to decrease when addition up to 20% of rice husk. (Ahmad, 2015) said that that the density decreased with the increase the ratio of rice husk in rice husk cement mortar because rice husk itself have lower density and present of porosity compared to other particle. The result observed that density values for rice husk mortar are between 2128.77 kg/m^3 to 1615.21 kg/m^3. The larger the rice husk organic matter content, the greater the porosity and shorter the path among particles for gas diffusion. Therefore, a higher rice husk addition ratio increases the open pore volume and decreases the bulk density of sintered specimens (Chiang, 2009).

2.3.2 Water Absorption Rate

Based on (Sutas, 2012) it revealed that the addition more of rice husk in specimen increase the water absorption rate due to high porosity. The addition of 2% of rice husk resulted the higher water absorption rate which is about 15.20%. According to (Ahmad, 2015) it state that when 10% and 20% rice husk applied in cement mortar the water absorption rate continues to increases and the water absorption rate for 20% of rice husk is four times higher than control brick. This is because consumption of rice husk in brick specimen absorb a lot of water content. Meanwhile, according to (Muthusamy, 2017) it recognized that the specimen absorbed more water when palm oil clinker are added as partial replacement for sand. The increasing the replacement of palm oil clinker increased the porosity of brick specimen and finally lead to increase the water absorption rate.

2.3.3 Compressive Strength

Referring (Sutas, 2012) it mention that the compressive strength lower with increase the amount of rice husk due to high porosity and low density. The compressive strength of 2% rice husk by weight resulted the strength about 6.20 MPa. In addition, from (Ahmad, 2015) it can observed that the compressive strength for 28 days curing of the rice husk cement gives the minimum compressive strength which are 2.04 N/mm^2, 2.46 N/mm^2 and 2.67 N/mm^2. Besides, the present of rice husk in cement mortar resulted significant depletion of compressive strength compared to control brick. On the other hand, optimum level of replacement of palm oil clinker was found to be 20% and the results were better than that of control mix. The replacement of palm oil clinker for fine aggregate beyond 20% in concrete made the strength of concrete decrease (Sreelekshmi, 2016).

2.3.4 Flexural Strength

(Muthusamy, 2017) study recorded that the flexural strength increases when 10% of palm oil clinker replaced in brick specimen. This is because the presence of palm oil clinker that help to fill the void in the brick specimen and lastly make it stronger but from this study it can seen that the strength decrease with increase the percentage of palm oil clinker up to 20% limit of replacement of palm oil. The highest flexural strength is when replacement of 10% palm oil clinker in brick specimen. From the test results presented, it can be concluded that 10% of pulverized palm oil clinker replacement produces a good POC cement sand brick exhibiting higher compressive strength and flexural strength owing to the filler effect of the fine palm oil clinker which filled the void inside the brick. Thus, it shows that palm oil clinker is suitable to be used as a partial sand replacement in POC cement sand brick.

CHAPTER 3

METHODOLOGY

3.1 Introduction

A research methodology is an organize strategy for conducting research. In this chapter the sequence of operations from beginning until the end of process of sand brick are emphasized in order to accomplish the goal of research. The method used in this research involved the laboratory work and experimental test. This research was conducted in the concrete laboratory at University of Malaysia Pahang. Control brick that made up of raw materials such as cement, sand and water are compared with new alternative brick that use the waste material as partial replacement for sand. Therefore, the research began with process of preparation of formwork and material. There are variety of testing carried out in the research to discover the capability and performance of palm oil clinker with rice husk as partial replacement which are density test, water absorption test, compressive strength and flexural strength. Hence, based on the results given in the laboratory test the physical characteristics of sand brick in term of density, water absorption, compressive strength and flexural strength can be determined.

3.2 Work Flow of Research

To ensure that research procedures run smoothly the research design must be prepare in advance. The work flow of research consist are set of processes that have accomplished from beginning until the end of the research. Simultaneously, by having this visual flow charts it can shows the sequence and step by step of progress of work study of sand bricks in the effective way to communicate all the process involved clearly.

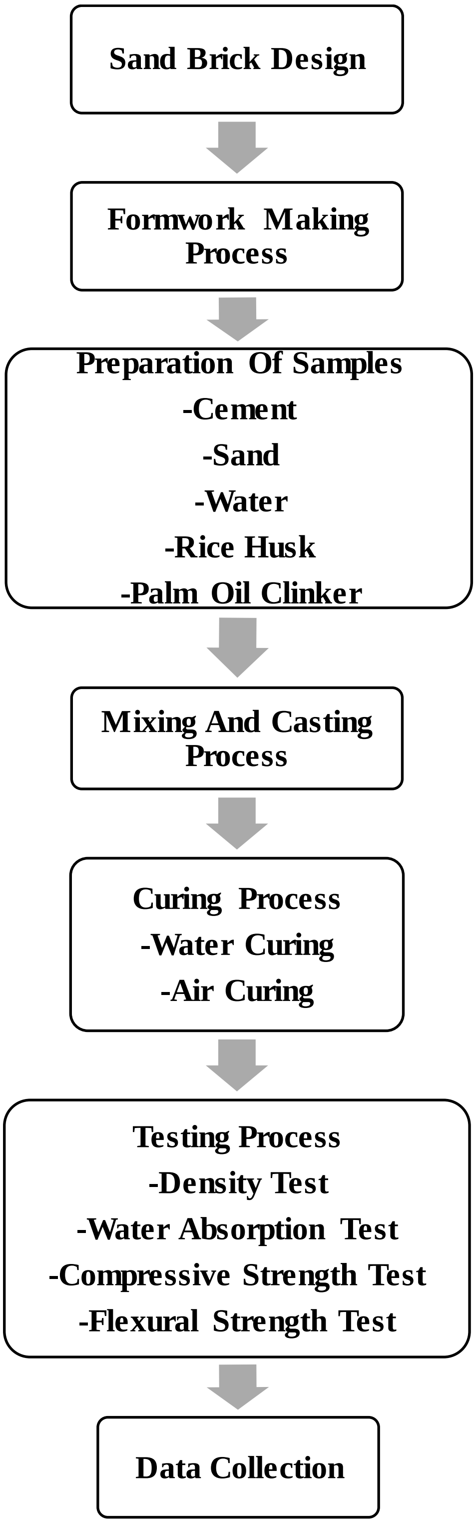

Figure 3.1 Flowchart of research

3.3 Sand Brick Design

Based on JKR Standard Specifications for Building Works (2005), it stated that all cement sand bricks shall comply with MS 27.Cement sand bricks shall be of a nominal size as given below:

Table 3.1 Size of cement sand bricks

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

Therefore by referring the Standard Specification for Building Works (2005), the dimension of one unit of sand brick to produce are decided as shown in figure below.

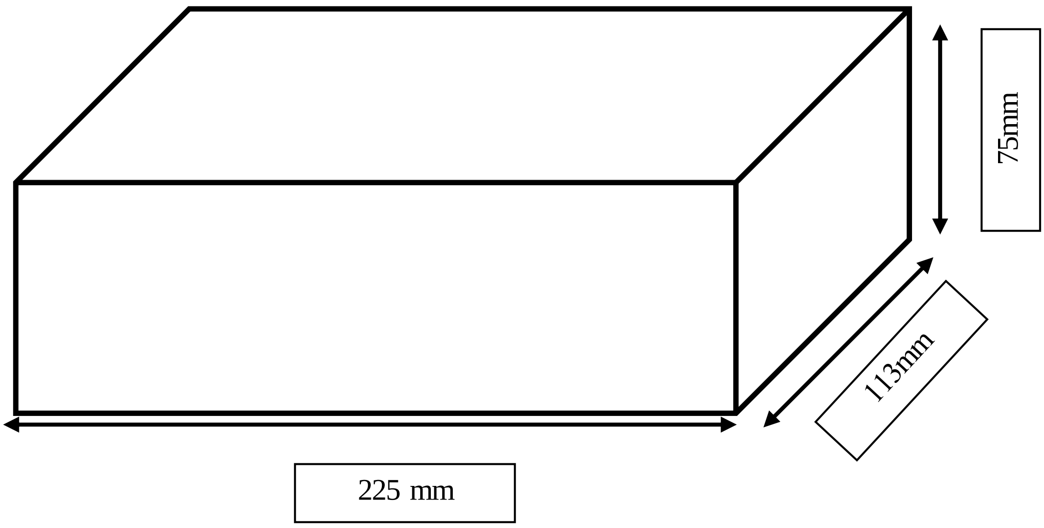

Figure 3.2 Dimension of sand bricks

Ratio mix design is the most important steps that must conducted to design the amount of percentages mixture needed for the brick making. Four types mixture was prepared that is one mixture for control sand brick meanwhile three samples for alternative sand brick. Control sand brick, mixture 0 was prepared without involving any replacement of material. However, for the alternatives sand brick, the mixture involve the replacement of 10% of palm oil clinker with 10%, 20% and 30% of rice husk that will replace the fine aggregate. The location of sample preparation is in the concrete laboratory of University Malaysia Pahang. Each samples that design used for a 3 days, 7 days, 14 days and 28 days. Table below show the mix design required for each material in the production of sand brick.

Table 3.2 Ratio of mix design required for the production of sand brick

Mixture	**Ratio of Mixture**		
	Sand (%)	**Palm Oil Clinker (%)**	**Rice Husk (%)**
0	100	0	0
1	80	10	10
2	70	10	20
3	60	10	30

3.4 Selection and Preparation of Material

3.4.1 Sand

Sand that also known as fine aggregate is mixed with cement and water to be used in production of sand brick. The type of sand used is river sand that already available at laboratory concrete of FKASA. Before the process of mixing, the sand are undergone sun dry process to make sure the wet sand is dried to eliminate moisture content. Besides that, sand is made sure clean and free from any organic matter and impurities. Lastly, sieve analysis is performed so that only particles that passing through the 4.75 mm above are retained because according to standard JKR the maximum size sand shall pass through a 4.8 mm mesh BS sieve. In addition, sieve analysis is conducted to determine the particle size distribution of fine aggregate. During the process of sieve analysis the bigger size of sieve are placed on top of smaller and in order from top to bottom. After that, sand are sieved using sieve shaker manually for 10 minutes long.

Figure 3.3 River sand

Figure 3.4 Sieve analysis process

3.4.2 Cement

According to JKR Standard Specifications for Building Works (2005) the Ordinary Portland Cement shall be used in the brick work. Thus, in order to create the better quality of sand brick this research used better quality cement product that is Portland Cement Cap Orang Kuat. Cap Orang Kuat product is a high strength Portland cement that specially formulated for early remoulding, handling and used. Usually, for a one bag of this cement contain 50 kg of weight that been purchased at YTL Cement. However unlike sand no process needed for the preparation of cement, the cement just weighted according on the amount required to produce sand bricks.

Figure 3.5 Portland Cement Cap Orang Kuat

3.4.3 Water

Without the presence amount of water all mixture cannot blend together with cement to undergo hydration processes that lead to hardening of cement. The potable water is the water that can use to mix with aggregates in the production of material. However to avoid any failure that can affect the structure of brick this research used tap water. This is because tap water can guarantee the clean water that free from any contamination. However in order to get the quality product of sand brick avoid using too much water because it will decreases the strength of brick and too little water cannot made the aggregate mix together.

Figure 3.6 Tap water

3.4.4 Palm Oil Clinker

Palm oil clinker is waste material produced from burning of palm oil shell and palm oil shell inside the boiler under conditional temperature. This material is one alternative to replaced sand in the sand brick production. In this study, the palm oil clinker that are used are produced from palm factory of Lepar Hilir, Gambang, Kuantan. The percentages of the palm oil clinker that used in this mixture for all the samples of sand brick are 10%. As palm oil clinker functioning as fine aggregate off course the process needed also the same. So, the first steps is the palm oil clinker are dried first to remove moisture content. After that palm oil clinker need to ground to be fine and then performed the sieve analysis that passes through 4.75 mm.

Figure 3.7 Palm oil clinker

3.4.5 Rice Husk

Rice husk is easily collected which is from the waste of rice milling process. It consist of high silica content and normally a small amount of rice husk can applied in brick making process to replace the function of fine aggregate. To perform this research, this material collected at rice mill at Padiberas Nasional Berhad, Kuala Rompin. Meanwhile, the proportion of rice husk that was use are 10%, 20% and 30% and mixed with other materials. The process that needs to do before can utilize this material are firstly removed the dusk and separate unneeded part of rice husk by using filter. After that, dried the rice husk using the oven and avoid using high temperature to prevent the texture of rice husk from changing colour. The dry process causes weight of rice husk to be lighter than before. The special about the utilization of rice husk in this study is it no need to ground to be fine or burned so no energy required.

Figure 3.8 Filtration of rice husk

3.4.6 Preparation of All Material

Table 3.3 The amount of material used for sand brick production

Ratio / Material	0% C + 0% RH	10% C + 10% RH	10% C + 20% RH	10% C + 30% RH
Sand (kg)	51.000	40.796	35.697	30.597
Cement (kg)	7.800	7.800	7.800	7.800
Water (kg)	8.000	8.000	8.000	8.000
Clinker (kg)	0	4.045	4.045	4.045
Rice Husk (kg)	0	0.384	0.768	1.152

Table above show the total amount of sand, cement, water, palm oil clinker and rice husk that have been prepared for 4 different types of ratio for sand brick. According to JKR Standard Specifications for Building Works (2005) the ratio used for production of sand brick is 1:6. That means that sand and cement shall be mixed in the ratio of six parts of sand to one part of cement. The main ingredients for control brick, 0% C + 0% RH are cement, sand and water. Meanwhile, palm oil clinker and rice husk are function as partial replacement to replace the role of sand for production of other alternative brick for different ratio which are 10% C + 10% RH, 10% C + 20% RH and 10% C + 10% RH.

3.5 Formwork Making Process

Formwork is temporary forms required for forming the sand bricks. For this research formwork are made by using plywood. Plywood is known as a structural material consisting of sheets of wood glued together with the grains of adjacent layers arranged at right angles or at a wide angle. The process of making formwork is conducted as following:

Figure 3.9 The plywood are marked according to the dimension of sand brick

Figure 3.10 The marked plywood were cutting using band saw machine

Figure 3.11 The formwork after the piece of plywood installed together

3.6 Mixing and Casting Process

Figure 3.12 All weighted material mixed together into the mixer

Figure 3.13 The formwork are painted using oil

Figure 3.14 Process compaction of brick samples

Figure 3.15 Brick samples after finishing process

3.7 Curing Process

Curing is compulsory process in increasing moisture content of sand bricks while maintaining a good temperature for hydration for a certain period. In addition, the process of curing increases the strength of samples within time and help to improve the durability of sand brick. Curing process started after all the samples removed from formwork after completion casting process within 24 hours. For compressive and flexural strength test, the samples have been cure for 3 days, 7 days, 14 days and 28 days. Meanwhile, for density and water absorption test the samples undergone curing process for 28 days. However, the 28 days of curing is the ideal time for the sand brick to keep wet continuously to develop full strength. There are two method of curing involved before the samples proceed with testing which are water curing and air curing. The method of curing are performed as below:

Figure 3.16 Water curing process

Figure 3.17 Air curing process

3.8 Testing Process

There are 4 testing process that conducted in this research which is density test, water absorption test, compressive strength test and flexural strength test.

3.8.1 Density Test

Density is an important parameter that indicates the weight of sand bricks. Therefore, the aim of this test is to determine the density of sand bricks. The procedure of this testing is based on ASTM 04.02 C 642-97 which is Standard Test Method for Density, Absorption and Voids in Hardened Concrete. For determination of density of sand bricks, the test conducted as the following procedure:

i. The brick samples are marked as samples number 1 for water curing and number 2 for air curing.
ii. Then, the samples are dried in an oven at a temperature of 121^0 C for not less than 24 hours for constant mass.
iii. After 24 hours, the samples are removed from oven by using hand gloves.
iv. The bricks cooled at room temperature and its weight, W is recorded. Then the mass, M are determined.
v. The dimensions of the samples is measured accurately and the volume are calculated
vi. The density is calculated based on this formula:

$$\text{Density (kN/m}^3\text{)} = \frac{Mass(M)}{Volume(V)}$$

3.8.2 Water Absorption Test

Water absorption test is one of method for determining the potential of sand bricks in water absorption. That means the proportion of water absorbed by bricks can be determined. According to ASTM Standard C 140-03 the procedures of absorption test are conducted as following:

i. The specimens are marked as samples number 1 for water curing and number 2 for air curing.
ii. Then, the samples are dried in an oven at a temperature of 121^0 C for not less than 24 hours until it achieved constant mass.

iii. After 24 hours, the samples are removed from oven by using hand gloves. Cool the samples for a while in room temperature and dry weight, W_d are recorded.

iv. Next, the specimens are immersed in water tank for not less than 24 hours.

v. After the specimen are removed from tank, the immersed weight, W_i is recorded.

vi. The percentage of water absorption is calculated based on this formula:

$$\text{Percentage of water absorption (\%)} = \left[\frac{\text{Immersed Weight} - \text{Dry Weight}}{\text{Dry Weight}}\right] \times 100$$

3.8.3 Compressive Strength Test

The compressive strength test used to measure the performance of the brick samples in term of strength. The brick considered strong if they can resist the crushing load better than the standard through maximum load achieved. The samples of brick selected for compressive strength have the dimensions 225 mm X 113 mm x 75 mm. The procedures of compressive strength test complying with ASTM C67-03a are as following:

i. The dimension and weight of each sand brick were measured.

ii. The bearing faces of upper and lower bearing plates and also the brick were wiped until cleaned.

iii. Ensure that the upper and lower plain surfaces were positioned properly when the sand brick was placed at the centre of bearing plate.

iv. Without shock the loads were continuously being applied until the sand brick failed.

v. The maximum loads carried by the sand brick during test were recorded.

vi. The compressive strength of the sand brick was calculated by using this formula:

$$\text{Compressive Strength (N/mm}^2\text{)} = \frac{\text{Maximum Load at Failure (N)}}{Average\ area\ of\ bed\ face (mm^2)}$$

Figure 3.18 Sand brick condition after undergone compressive strength test

3.8.4 Flexural 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 flexural strength is theoretically derived from the elastic beam theory, where stress-strain relation is assumed to be linear. The flexural test on sand brick can be conducted using the third point loading test (ASTM C293).The main objective is to determine the flexural strength and modulus of rupture for sand brick. The procedure of this testing is shown below:

i. The weight and dimension of the sand brick were measured
ii. The location of support and loading points were indicated at sand brick surface.
iii. The sand brick were positioned so that the tension face corresponds to the top or bottom of the sand brick.
iv. To eliminated any gap in excess of 0.10 mm between the sand brick and the load applying cap it used plate on the brick contact surface.
v. The sand brick were loaded continuously without any disturbance until rupture occurs.
vi. The maximum load carried by the specimen during testing was recorded.
vii. Finally, the cross sections of the tested sand brick were measured at each end and at center to calculate average depth and height.

viii. The flexural strength test of sand brick is calculated as following :

$$\text{Flexural Strength (N/mm}^2) = \frac{3FL}{(2bd^2)}$$

Figure 3.19 Flexural strength test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presenting and describing results of the research based on the experimental conducted in the concrete laboratory. After completing all the testing process the data are recorded, calculated and interpreted based on main objective of the study which is to determine the density, water absorption, compressive strength and flexural strength of sand bricks. The properties of sand bricks were investigated by using ratio of 10% of palm oil clinker with 10%, 20% and 30% of rice husk as partial replacement for fine aggregate. Final results for each testing are tabulated in the form of tables and graphs to represent the data clearly. Finally, the discussions have been made based on the results gathered and compared with the control standard.

4.2 Density Test

Sand brick samples that have four types of ratio that are 0% C + 0% RH, 10% C + 10% RH, 10% C + 20% RH and 10% C + 30% RH have been through two different of curing process that is water curing and air curing for 28 days. Based on procedure of density test for sand bricks after curing process the weight of samples with dimensions of 255 mm x 113 mm x 75mm which have been dried in the oven at 121° C for 24 hours have been recorded.

After that, the density results have presented as shown below and comparison of density have been make based on four different ratio of clinker with rice husk replacement for water curing, air curing and both curing.

4.2.1 Comparison of Density of Sand Bricks for Water Curing

Table 4.1 The density of sand bricks for water curing

Ratio	Density (kN/m^3)
0% C + 0% RH	19.17
10% C + 10% RH	17.61
10% C + 20% RH	16.99
10% C + 30% RH	16.79

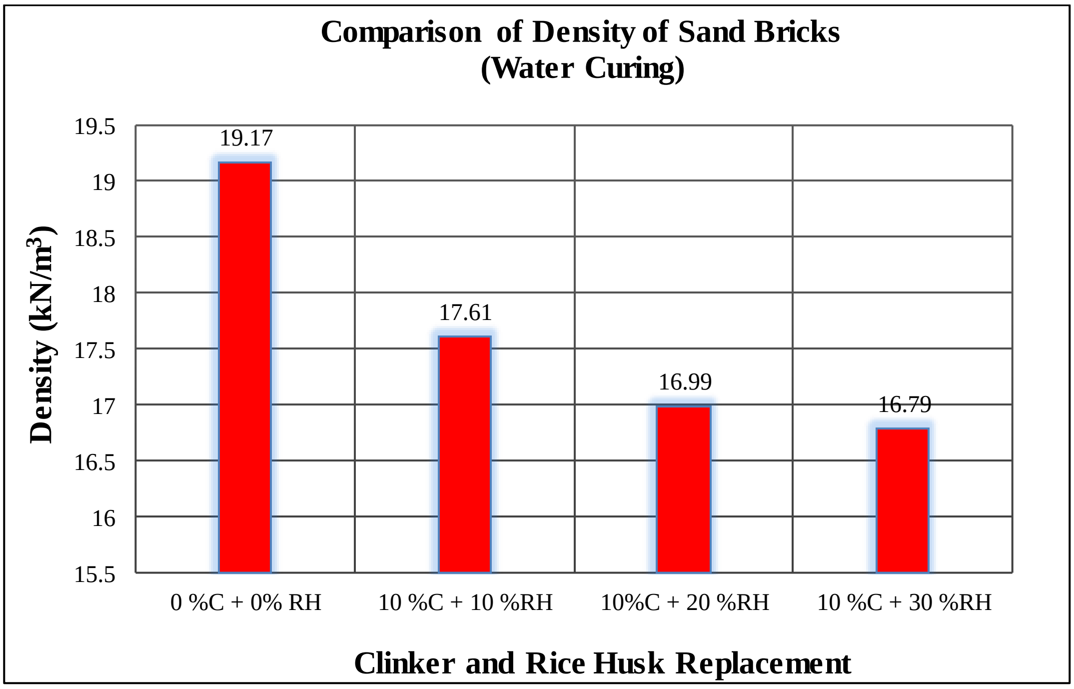

Figure 4.1 Comparison of density of sand bricks for water curing

The table and bar chart above indicates the result of density for sand bricks with different percentages of clinker and rice husk replacement for water curing which are 0% C + 0% RH, 10% C + 10% RH ,10% C + 20% RH and 10% C + 30% RH .From the chart above, the density of sand bricks of 0% C + 0% RH is 19.17 $kN/m^{3,}$ 10% C + 10% RH is 17.61 kN/m^3, 10% C +20% RH is 16.99 kN/m^3 and 10% C + 30% RH is 16.79 kN/m^3.So, the highest density is samples from 0% C +0% RH with 19.17 kN/m^3 whereas the lowest density is the samples 10% C + 30% RH with 16.17 kN/m^3.Based on the data represented it reveals that the value of density for water curing decreased continuously with the increased the amount of rice husk used in mixture of sand bricks.

4.2.2 Comparison of Density of Sand Bricks for Air Curing

Table 4.2 The density of sand bricks for air curing

Ratio	Density (kN/m^3)
0% C + 0% RH	19.06
10% C + 10% RH	19.22
10% C + 20% RH	16.80
10% C + 30% RH	16.14

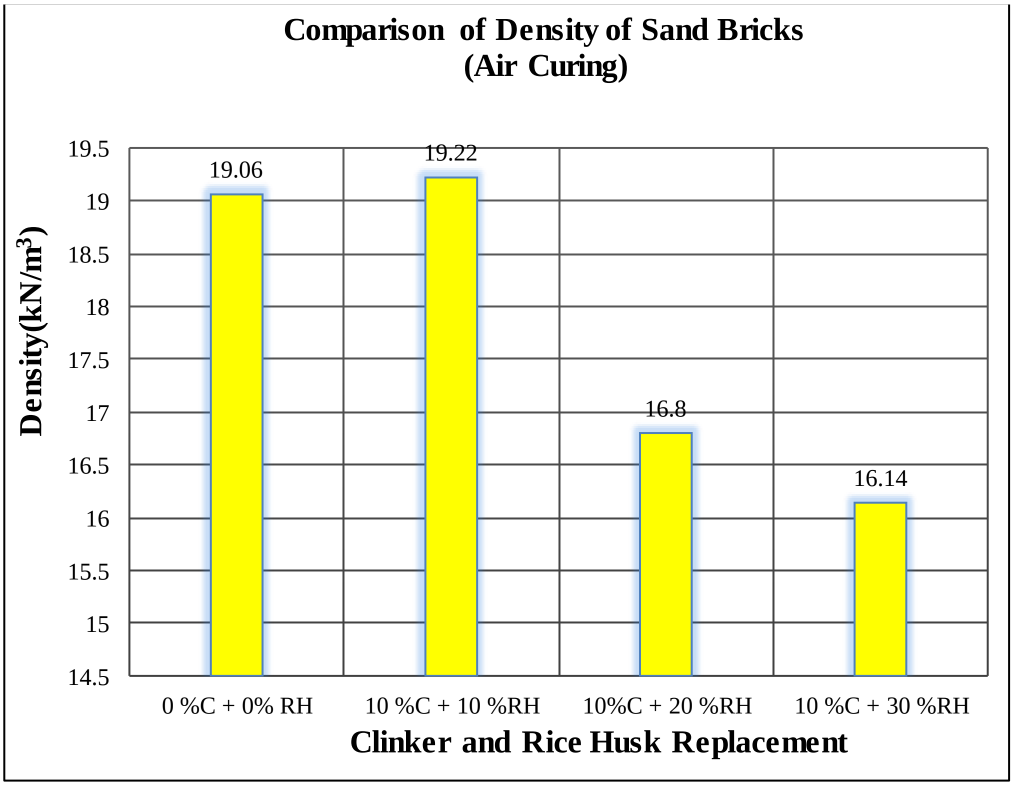

Figure 4.2 The comparison of density of sand bricks for air curing

The table and bar chart above demonstrate the value of density for sand bricks with different percentages of clinker and rice husk replacement for air curing which are 0% C + 0% RH, 10% C + 10% RH ,10% C + 20% RH and 10% C + 30% RH .From the chart above, the density of sand bricks of 0% C + 0% RH is 19.06 kN/m^3, 10% C + 10% RH is 19.22 kN/m^3, 10% C +20% RH is 16.80 kN/m^3 and 10% C + 30% RH is 16.14 kN/m^3.Therefore, the maximum density is samples from 10% C +10% RH with 19.22 kN/m^3 while the lowest density is the samples 10% C + 30% RH with 16.14 kN/m^3. Finally, it can concluded that density of sand bricks increased up to replacement of 10% C + 10% RH but suddenly dropped to 16.8 kN/m^3 and 16.14 kN/m^3 when replacement of rice husk increased.

4.2.3 Discussion of Density Test

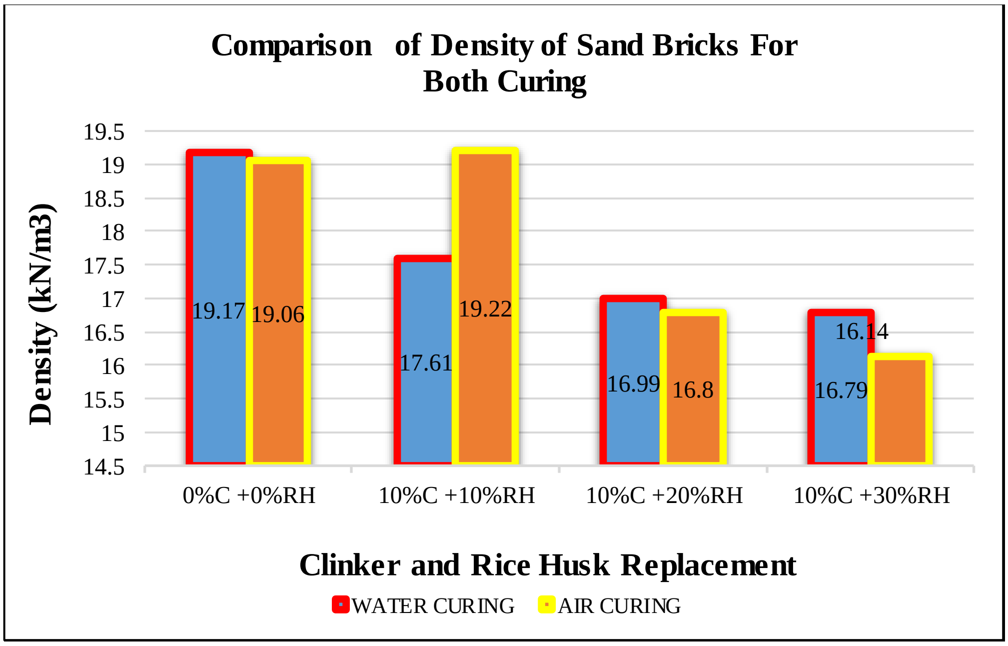

Figure 4.3 The comparison of density of sand bricks for water and air curing

Therefore according to previous data analysis comparison is made for both curing. The most results appear that the density of sand bricks is highest when going through the water curing process but only for ratio of 10% C + 10% RH get the lower result compared to air curing. Besides that, all density values except 10% C + 10% RH dropped continuously with increased percentages of rice husk that replaced the sand. The highest density for water curing is 0% C + 0% RH (19.17 kN/m^3) and for air curing is 10% C + 10% RH (19.22 kN/m^3). Whereas, the lowest density is 10% C + 30% RH same for both curing which is 16.79 kN/m^3 for water curing and 16.14 kN/m^3 for air curing.

Density is a crucial parameter that indicates the weight of the sand bricks. Referring data analysis for these samples it can conclude that sand bricks samples without any replacement of rice husk has highest density compared to with rice husk. The result reveals that density reduces with increase rice husk quantity. That means that the higher the content of rice husk and the lower the amount of fine aggregate used, the higher the porosity and finally reduce the density of sand bricks.

4.3 Water Absorption Test

After the specimen experienced process of water and air curing for 28 days, the specimen that have four different ratio which are 0% C + 0% RH, 10% C + 10% RH, 10% C + 20% RH and 10% C + 30% are tested for water absorption to determine the amount of water absorbed in the sand bricks. For this test, the weight of dried specimen and also the weight of immersed specimen after removed it from tank for 24 hours were recorded. Hence, the results of water absorption rate are expressed in formula below:

$$\text{Water absorption rate (\%)} = \left[\frac{\text{Immersed Weight} - \text{Dry Weight}}{\text{Dry Weight}}\right] \times 100$$

Next, the percentages of water absorption calculated for each specimen were represented in form of table and bar chart. The discussion from results obtained are made according to comparison of four ratio involved in this testing for water and air curing process.

4.3.1 Comparison of Water Absorption Rate of Sand Bricks for Water Curing

Table 4.3 The percentage of water absorption for water curing

Ratio	**Water Absorption Rate (%)**
0% C + 0% RH	11.88
10% C + 10% RH	10.51
10% C + 20% RH	7.92
10% C + 30% RH	8.97

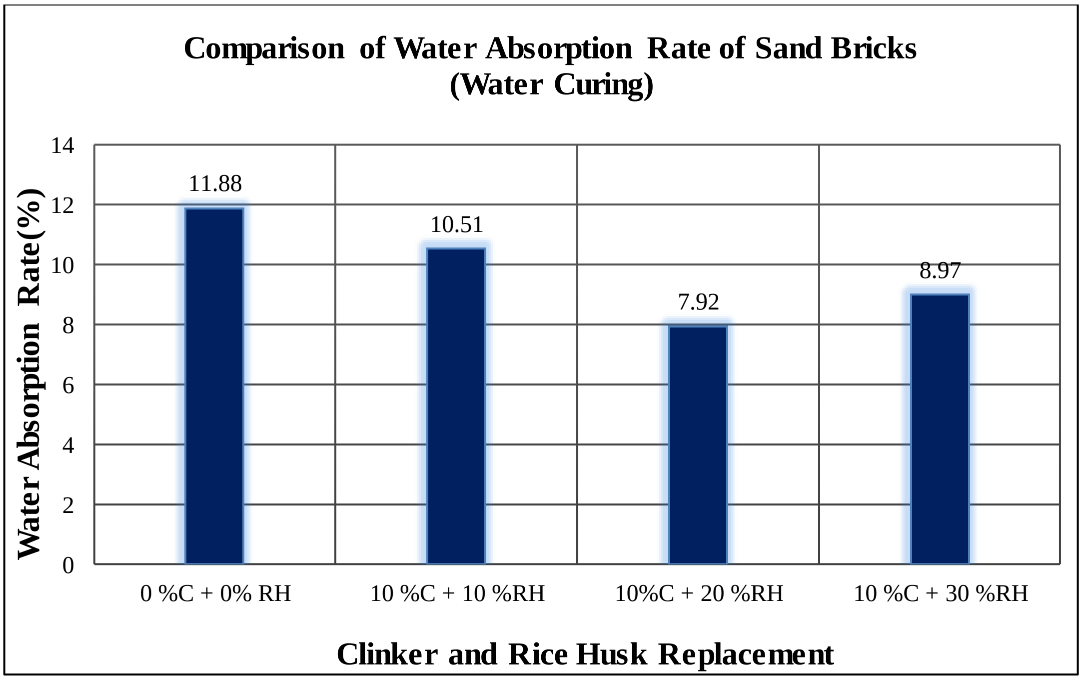

Figure 4. 4 The comparison of water absorption of sand bricks for water curing

The above chart shows water absorption rate for variation percentages of clinker and rice husk replacement for water curing. According to the bar graph the first column is control samples followed by 10% C + 10% RH, 10% C + 20% RH and the last column is 10% C + 30% RH. The water absorption rate of sand bricks for control sample is 11.88%, 10% C + 10% RH is 10.51%, 10% C +20% RH is 7.92% and 10% C + 30% RH is 8.97%. Thus, the control sample have maximum water absorption rate which is 11.88% meanwhile 10% C + 20% RH have minimum percentage of water absorption rate which is 7.92%.In conclusion, the trend of graph indicates that when the amount of rice husk replaced for the fine aggregate increased up to 20% the water absorption rate decreased but increased back when 30% RH are used.

4.3.2 Comparison of Water Absorption Rate of Sand Bricks for Air Curing

Table 4.4 The percentage of water absorption for air curing

Ratio	Water Absorption Rate (%)
0% C + 0% RH	11.22
10% C + 10% RH	8.45
10% C + 20% RH	11.66
10% C + 30% RH	12.55

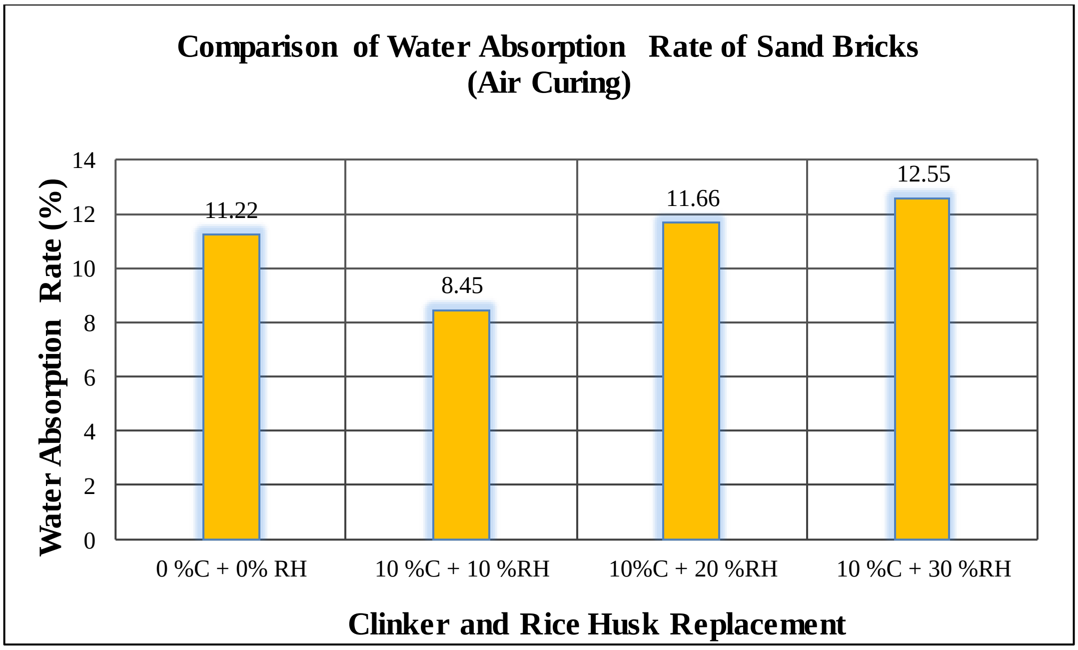

Figure 4.5 The comparison of water absorption of sand bricks for air curing

The result of water absorption rate for variation percentages clinker and rice husk replacement for air curing are shown in table and bar chart above. According to the bar graph the first column is control samples followed by 10% C + 10% RH, 10% C + 20% RH and the last column is 10% C + 30% RH. The water absorption rate of sand bricks for control sample is 11.22%, 10% C + 10% RH is 8.45 %, 10% C +20% RH is 11.66% and 10% C + 30% RH is 12.55%. Therefore, the best water absorption rate was 10% C + 30% RH which is 12.55% meanwhile the lowest water absorption rate was 10% C + 10% RH which is 8.45%. In general, the water absorption rate for air curing process from 11.22% suddenly decreased to 8.45% when replacement of 10% C + 10% RH was used but when the amount of rice husk increased up to 30% the water absorption rate rise significantly.

4.3.3 Discussion of Water Absorption Rate

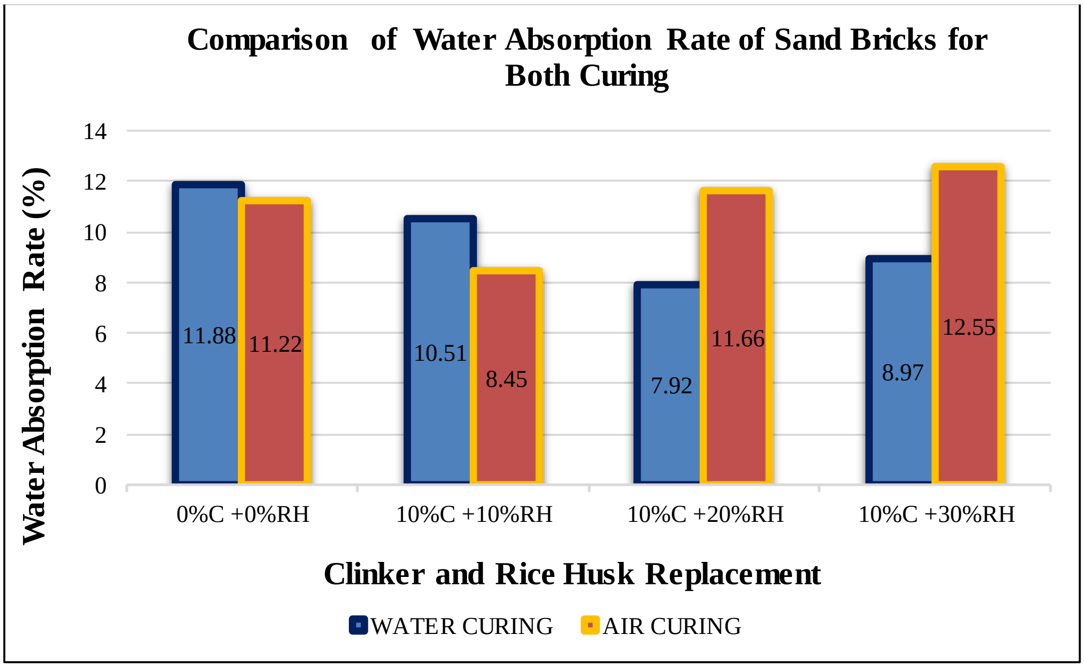

Figure 4.6 The comparison of water absorption of sand bricks for both curing

The best result of water absorption rate for water curing is control samples, 11.88% and for air curing is 10%C + 10% RH, 12.55%. Meanwhile, the lowest water absorption rate for water curing is 10%C + 20% RH, 7.29% and for air curing is 10%C + 10% RH, 8.45%.

Generally, it can seen that when rice husk applied in sand bricks the water absorption rate will become higher. In addition, the usage of raw rice husk in the mixture absorbed a lot of water. Lastly from this study it can sum up that the replacement more of clinker with rice husk improved the effect of water absorption in sand bricks.

4.4 Compressive Strength Test

Compressive strength test is one of the important test on bricks that implemented to determine the load carrying capacity of bricks under compression. This test is carried out after curing process for 3 days, 7 days, 14 days and 28 days. All samples with dimensions of 255 mm x 113 mm are tested by using compressive test machine in order to get the maximum load at failure. The values of maximum load taken are applied in compressive strength formula below:

$$\text{Compressive Strength (N/mm}^2\text{)} = \frac{\text{Maximum Load at Failure (N)}}{Average\ area\ of\ bed\ face(mm^2)}$$

After that, the compressive strength results have presented as shown below and comparison of strength have been made based on four different ratio of clinker with rice husk replacement for water curing, air curing and both curing.

4.4.1 Comparison of Compressive Strength of Sand Bricks for Water Curing

Table 4. 5 The compressive strength of sand bricks for water curing

Ratio/Day	0% C + 0% RH	10% C + 10% RH	10% C + 20% RH	10% C + 30% RH
3 days	4.50	2.21	4.02	4.13
7 days	5.49	6.15	5.37	4.68
14 days	5.94	6.60	6.70	6.42
28 days	8.47	7.72	6.99	6.62

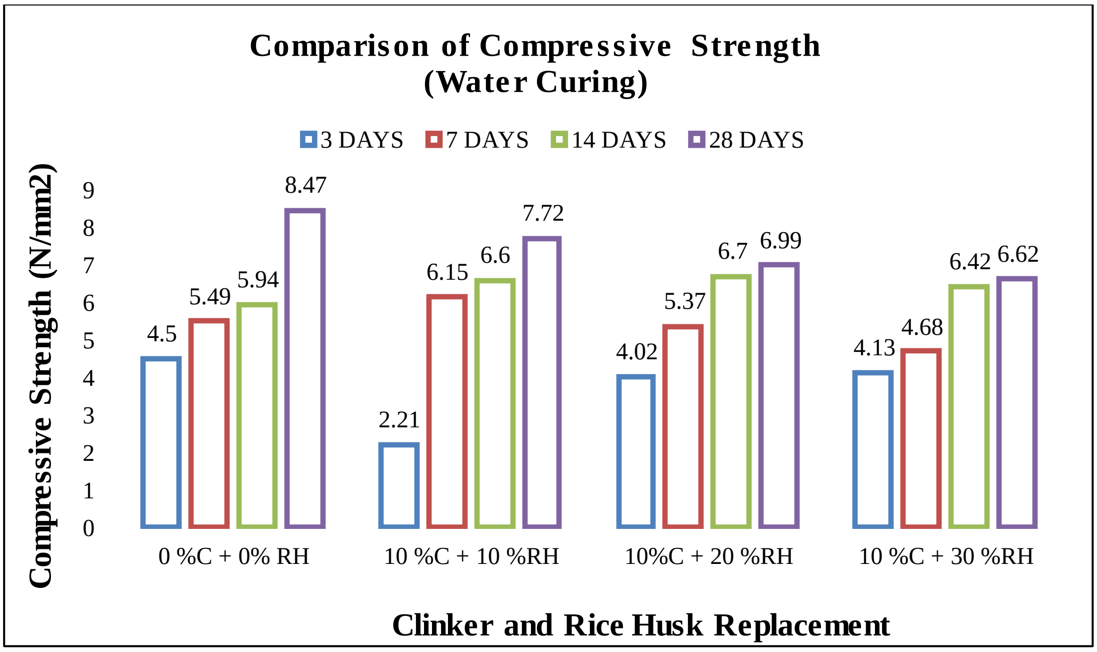

Figure 4.7 The comparison of compressive strength of sand bricks for water curing

The data above illustrate the compressive strength of sand bricks for water curing at 3 days, 7 days, 14 days and 28 days. The comparisons were made based on four different types of ratio that is 0% C + 0% RH, 10% C + 10% RH, 10% C + 20% RH and 10% C + 30 % RH.

The compressive strength of control samples at 3 days, 7 days, 14 days and 28 days are 4. 50 N/mm², 5.49 N/mm², 5.94 N/mm² and 8.47 N/mm² respectively.Meanwhile, the results for compressive strength of 10% C + 10% RH at 3 days, 7 days, 14 days and 28 days are 2.21 N/mm², 6.15 N/mm², 6.60 N/mm² and 7.72 N/mm² respectively.Besides that, the compressive strength of 10% C + 20% RH at 3 days, 7 days, 14 days and 28 days are 4.02 N/mm², 5.37 N/mm², 6.70 N/mm² and 6.99 N/mm² respectively. For 10% C + 30% RH, the result of compressive strength at 3 days, 7 days, 14 days and 28 days revealed that the strength are 4.13 N/mm², 4.68 N/mm², 6.42 N/mm² and 6.62 N/mm² respectively.

4.4.2 Comparison of Compressive Strength of Sand Bricks for Air Curing

Table 4.6 The compressive strength of sand bricks for air curing

Ratio/Day	0% C + 0% RH	10% C + 10% RH	10% C + 20% RH	10% C + 30% RH
3 days	5.31	4.82	4.98	2.89
7 days	4.64	6.09	5.98	5.48
14 days	6.85	8.67	7.86	6.82
28 days	8.85	9.48	9.05	7.7

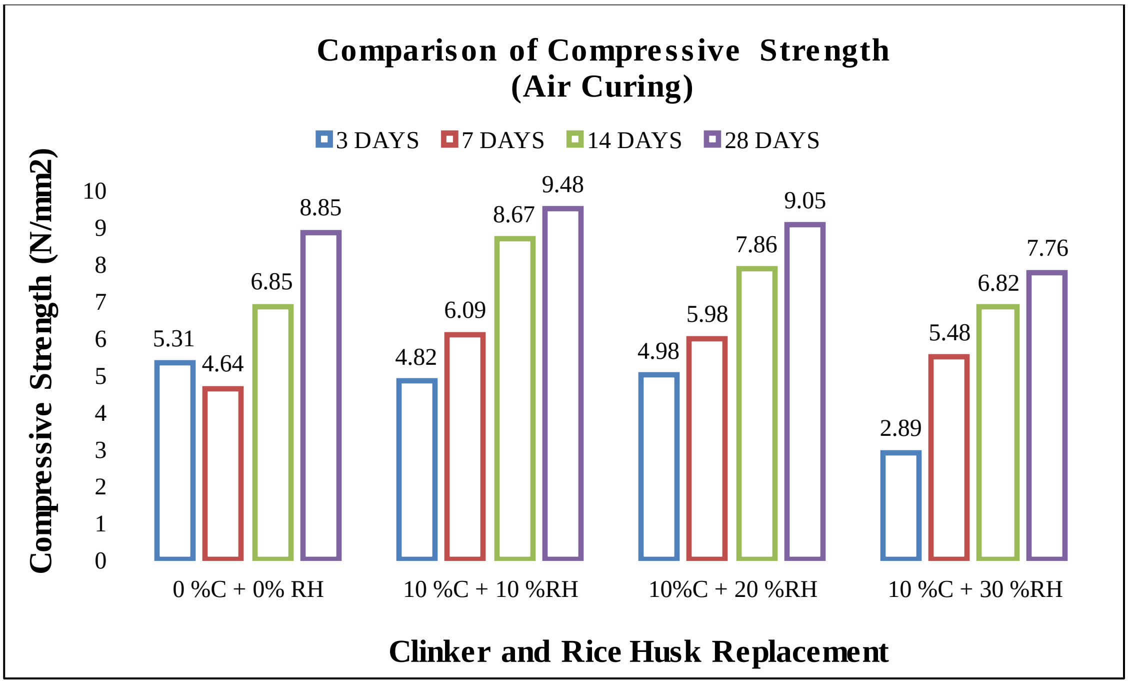

Figure 4.8 The comparison of compressive strength on of sand bricks for air curing

The data above represent the compressive strength of sand bricks for air curing at 3 days, 7 days, 14 days and 28 days. The comparisons were made based on four different types of ratio that is 0% C + 0% RH, 10% C +10% RH, 10% C + 20% RH and 10% C +30 % RH.

The compressive strength of control samples at 3 days, 7 days, 14 days and 28 days are 5.31 N/mm², 4.64 N/mm², 6.85 N/mm² and 8.85 N/mm² respectively. Meanwhile, the results for compressive strength of 10% C + 10% RH at 3 days, 7 days, 14 days and 28 days are 4.82 N/mm², 6.09 N/mm², 8.67 N/mm² and 9.48 N/mm² respectively. Besides, the compressive strength of 10% C + 20% RH at 3 days, 7 days, 14 days and 28 days are 4.98 N/mm², 5.98 N/mm², 7.86 N/mm² and 9.05 N/mm² respectively. For 10% C + 30% RH, the result of compressive strength at 3 days, 7 days, 14 days and 28 days revealed that the strength are 2.89 N/mm², 5.48 N/mm², 6.82 N/mm² and 7.76 N/mm² respectively.

4.4.3 Discussion of Compressive Strength

According the result collected mostly the compressive strength of rice husk dropped when the replacement of clinker with rice husk increased. The compressive strength be affected by the porosity and density. When the samples have higher porosity and lower density the strength declined. The entire ratio have the highest compressive strength at 28 days for both curing process compared to others curing period because at 28 days the sample have achieved the fully strength. The maximum strength for compressive strength is air curing process which is 10%C + 10% RH with 9.48 N/mm² meanwhile the minimum strength is water curing process that is 10%C + 10% RH with 2.21 N/mm².In sum, air curing process is the suggested curing process in order to gain the maximum strength for sand bricks.

4.5 Flexural Strength Test

Flexural strength test is compulsory test on sand bricks to determine the flexural strength of sand bricks. This test is carried out after curing process for 3 days, 7 days, 14 days and 28 days. All samples with dimensions of 255 mm x 113mm are tested according to method of the third point loading. Based on this testing, the value of maximum load were recorded and applied in formula of flexural strength below:

$$\text{Flexural Strength (N/mm}^2\text{)} = \frac{3FL}{(2bd^2)}$$

Next, the flexural strength results have demonstrate as shown below and comparison of strength have been made based on four different ratio of clinker with rice husk replacement for water curing, air curing and both curing.

4.5.1 Comparison of Flexural Strength of Sand Bricks for Water Curing

Table 4.7 The flexural strength of sand bricks for water curing

Ratio/Day	0% C + 0% RH	10% C + 10% RH	10% C + 20% RH	10% C + 30% RH
3 days	1.70	1.11	0.99	1.11
7 days	1.68	1.79	1.65	1.47
14 days	2.10	2.09	1.92	1.61
28 days	2.67	2.30	2.11	2.08

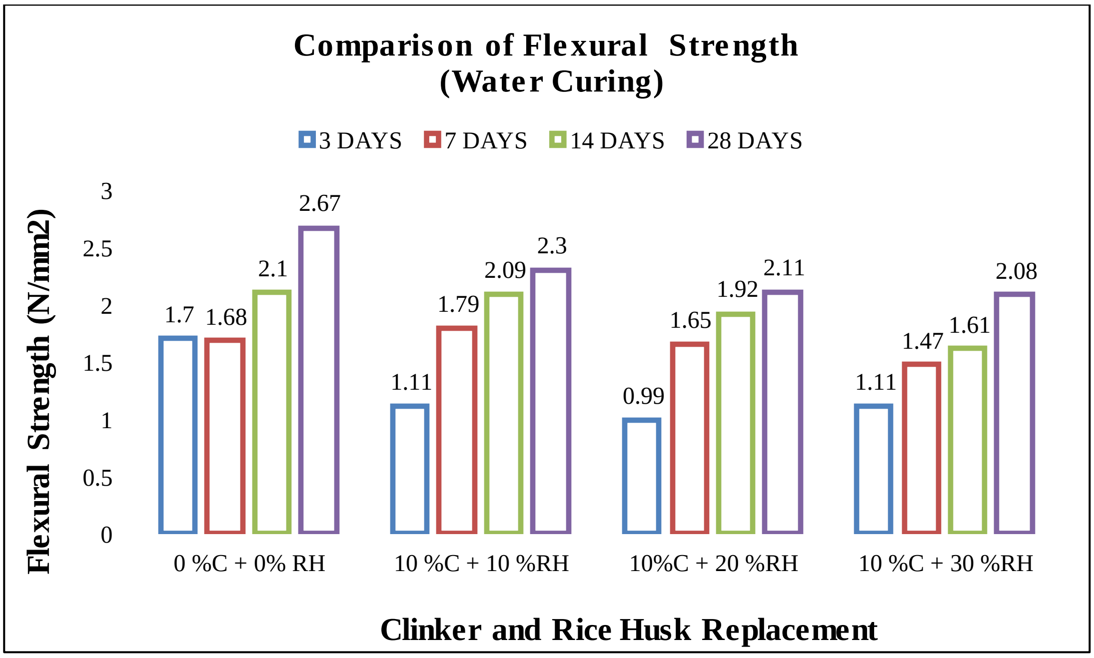

Figure 4. 9 The comparison of flexural strength of sand bricks for water curing

The bar chart illustrates the flexural strength of sand bricks for water curing at 3 days, 7 days, 14 days and 28 days. There are four types of ratio that is 0% C + 0% RH, 10% C + 10% RH, 10% C + 20% RH and 10% C + 30 % RH and comparison were made based on it.

The flexural strength of control samples at 3 days, 7 days, 14 days and 28 days are 1.70N/mm²,1.68 N/mm², 2.10 N/mm² and 2.67 N/mm² respectively. Meanwhile, the results for flexural strength of 10% C + 10% RH at 3 days, 7 days, 14 days and 28 days are 1.11 N/mm², 1.79 N/mm², 2.09 N/mm² and 2.30 N/mm² respectively. Besides that, the flexural strength of 10% C + 20% RH at 3 days, 7 days, 14 days and 28 days are 0.99 N/mm², 1.65 N/mm², 1.92 N/mm² and 2.11 N/mm² respectively. For 10% C + 30% RH, the result of flexural strength at 3 days, 7 days, 14 days and 28 days revealed that the strength are 1.11 N/mm², 1.47 N/mm², 1.61 N/mm² and 2.08 N/mm² respectively.

4.5.2 Comparison of Flexural Strength of Sand Bricks for Air Curing

Table 4. 8 The flexural strength of sand bricks for air curing

Ratio/Day	0% C + 0% RH	10% C + 10% RH	10% C + 20%RH	10% C + 30% RH
3 days	1.59	1.27	1.12	0.90
7 days	1.70	1.60	1.47	1.11
14 days	1.79	2.21	1.88	1.57
28 days	2.09	2.31	1.95	1.73

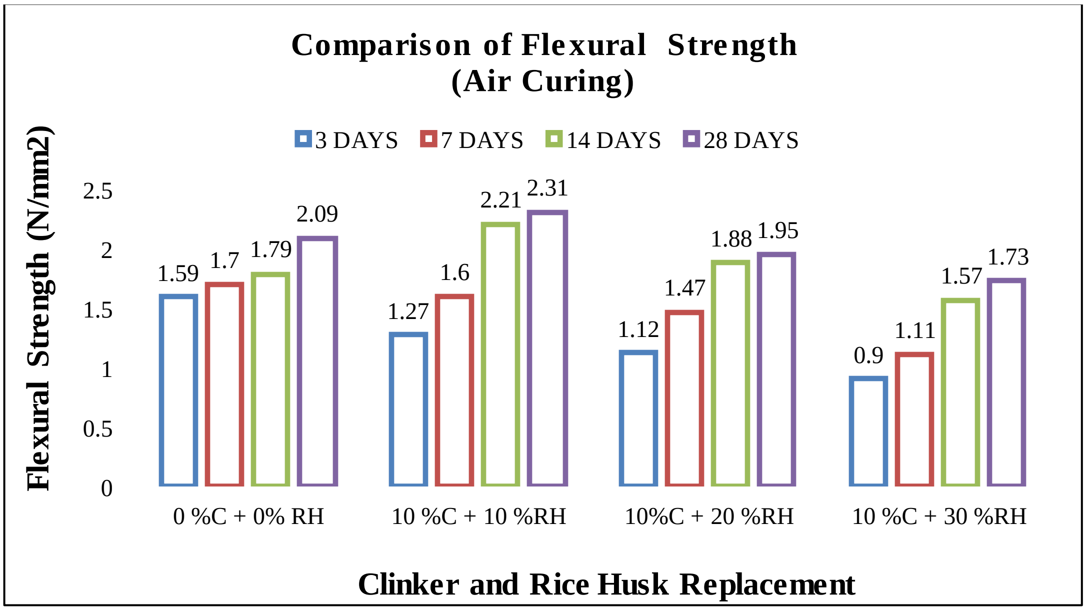

Figure 4. 10 The comparison of flexural strength of sand bricks for air curing

The chart indicates the flexural strength of sand bricks for air curing at 3 days, 7 days, 14 days and 28 days. The comparisons were made based on four different types of ratio that are 0% C + 0% RH, 10% C + 10% RH, 10% C + 20% RH and 10% C + 30 % RH.

The flexural strength of control samples at 3 days, 7 days, 14 days and 28 days are 1.59 N/mm², 1.70 N/mm², 1.79 N/mm² and 2.09 N/mm² respectively. Meanwhile, the results for flexural strength of 10% C + 10% RH at 3 days, 7 days, 14 days and 28 days are 1.27 N/mm², 1.60 N/mm², 2.21 N/mm² and 2.31 N/mm² respectively. Besides that, the flexural strength of 10% C + 20% RH at 3 days, 7 days, 14 days and 28 days are 1.12 N/mm², 1.47 N/mm², 1.88 N/mm² and 1.95 N/mm² respectively. For 10% C + 30% RH, the result of flexural strength at 3 days, 7 days, 14 days and 28 days state that the strength are 0.90 N/mm², 1.11 N/mm², 1.57 N/mm² and 1.73 N/mm² respectively.

4.5.3 Discussion of Flexural Strength

In conclusion, normally this chart depicts that the flexural strength of all ratio growth with increased the period of curing process. This means that when samples undergone 28 days curing process it have highest flexural strength compared to other days. However while the amount of rice husk increased in sand brick production, the quality of flexural strength mostly dropped. This is because the samples have lower density. The peak flexural strength is 0%C + 0% RH that experienced water curing process, 2.67 N/mm² meanwhile the lowest strength is air curing for 10%C + 30% RH which is 0.90 N/mm².

CHAPTER 5

CONCLUSION

5.1 Introduction

In this section conclusion of the entire research are made based on the main objective of the study which are to determine density, water absorption, compressive strength and flexural strength of sand brick samples for ratio 10% clinker with 10%, 20% and 30 % rice husk. These experimental studies were conducted for 3 days, 7 days, 14 days and 28 days after undergone water and air curing process. Besides that, the recommendations of this study also will be discussed according to analysis of previous result collected for future works.

5.2 Conclusions

After considering result and discussion recorded all the main objectives are achieved. Therefore, from this research it can summarize that:

i. Clinker and rice husk is one of waste material that suitable to be as a partial replacement for fine aggregate in sand brick production.

ii. For density test, replacement of 10% clinker with 10%, 20%, 30% rice husk revealed that the higher the percentage of rice husk the higher the porosity and finally lower the density of sand bricks.

iii. For water absorption test, replacement of 10% clinker with 10%, 20% and 30% rice husk stated that when the amount of rice husk increase in the mixture it will absorbed a lot of water and lastly made the water absorption rate higher.

iv. For compressive and flexural strength test, replacement of 10% clinker with 10%, 20% and 30% rice husk shown that strength will decrease with increase the percentage of rice husk applied in sand brick composition because it have high porosity and low density.

v. The replacement of 10% C + 10% RH is recommended as the best ratio in increases the strength and density of sand bricks compared to replacement of 20% and 30% RH.

vi. The curing period up to 28 days is the perfect days in order for sand bricks reached the fully strength.

5.3 Recommendations

The finding in this study is only applicable for experimental study of properties of palm oil clinker and rice husk as partial replacement for fine aggregate in sand brick manufacture. In order to improve this study more research needs to be done. In addition, there are some improvement that have been identify to ensure the quality of research for future work. Below there are some of recommendations for next researchers:

i. Further research on properties of sand bricks in term of water absorption, fire resistance, weather resistance and porosity.

ii. The utilization of small scale of clinker or rice husk like 1%, 2%, 3% to know how much the small amount can affect the properties of sand bricks.

iii. Use the specific size of fine aggregate such as passing 4.75 mm for all samples.

iv. Apply oven dry method instead of sun dry to ensure the wet sand have undesirable water content.

v. Try to replace clinker or rice husk with other waste materials such as shredded paper and bamboo.

vi. Take and record the dimension of samples because not all samples have uniform size.

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APPENDIX A

DENSITY TEST

Ratio	Weight After Oven,Wd	Density,kN/m³ $\frac{Mass}{Volume}$
0% C + 0% RH	3.727	19.17
10% C + 10% RH	3.423	17.61
10% C + 20% RH	3.302	16.99
10% C + 30% RH	3.264	16.79

Density of sand bricks for water curing at 28 days

Ratio	Weight After Oven,Wd	Density,kN/m³ $\frac{Mass}{Volume}$
0% C + 0 % RH	3.705	19.06
10% C + 10% RH	3.736	19.22
10% C + 20% RH	3.266	16.80
10% C + 30% RH	3.138	16.14

Density of sand bricks for air curing at 28 days

APPENDIX B

WATER ABSORPTION TEST

Water absorption rate of sand bricks for water curing at 28 days

Ratio	**Weight After Oven,Wd**	**Weight After Immersed,Wi**	**Rate Of Water Absorption,%** $[\frac{(Wi-Wd)]}{Wd}$ **X 100**
0% C + 0 % RH	3.593	4.020	11.88
10% C + 10% RH	3.577	3.953	10.51
10% C + 20% RH	3.434	3.706	7.92
10% C + 30% RH	3.368	3.670	8.97

Water absorption rate of sand bricks for air curing at 28 days

Ratio	**Weight After Oven,Wd**	**Weight After Immersed,Wi**	**Rate Of Water Absorption,%** $[\frac{(Wi-Wd)]}{Wd}$ **X 100**
0% C+ 0% RH	3.592	3.995	11.22
10% C + 10% RH	3.493	3.788	8.45
10% C + 20% RH	3.294	3.678	11.66
10% C + 30% RH	2.828	3.183	12.55

APPENDIX C

COMPRESSIVE STRENGTH TEST

Compressive Strength of sand bricks with ratio of 10% C + 10% RH at 3 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.309	3.300	3.479	3.606	3.699	3.636
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	60.5	54.2	54.0	128.0	117.0	123.1
Compressive strength (N/mm^2)	2.38	2.13	2.12	5.03	4.60	4.84
Average (N/mm^2)		2.21			4.82	

Compressive Strength of sand bricks with ratio of 10% C + 20% RH at 3 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.569	3.558	3.405	3.062	3.311	3.420
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	91.7	115.0	99.8	132.0	117.8	130.1
Compressive strength (N/mm^2)	3.61	4.52	3.93	5.19	4.63	5.12
Average (N/mm^2)		4.02			4.98	

Compressive Strength of sand bricks with ratio of 10% C + 30% RH at 3 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.746	3.631	3.466	3.102	3.334	3.173
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	119.9	98.3	96.9	73.5	73.8	72.9
Compressive strength (N/mm^2)	4.72	3.87	3.81	2.89	2.90	2.87
Average (N/mm^2)		4.13			2.89	

Compressive Strength of sand bricks with ratio of 10% C + 10% RH at 7 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	4.047	3.693	3.874	3.226	3.675	3.503
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	135.3	189.8	144.0	139.8	139.7	184.8
Compressive strength (N/mm^2)	5.32	7.47	5.66	5.50	5.49	7.27
Average (N/mm^2)		6.15			6.09	

Compressive Strength of sand bricks with ratio of 10% C + 20% RH at 7 days

Characteristics			**Water Curing**		**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.713	3.513	3.322	3.127	3.487	3.324
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	143.3	148.1	118.3	149.9	146.8	159.5
Compressive strength (N/mm^2)	5.64	5.82	4.65	5.90	5.77	6.27
Average (N/mm^2)		5.37			5.98	

Compressive Strength of sand bricks with ratio of 10% C + 30% RH at 7 days

Characteristics			**Water Curing**		**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.506	3.407	3.378	3.011	3.164	3.076
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	116.4	116.4	124.0	139.5	144.0	134.8
Compressive strength (N/mm^2)	4.58	4.58	4.88	5.49	5.66	5.30
Average (N/mm^2)		4.68			5.48	

Compressive Strength of sand bricks with ratio of 10% C + 10% RH at 14 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	4.045	4.146	4.090	3.779	3.756	3.661
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	146.2	178.5	179.1	220.7	226.3	214.7
Compressive strength (N/mm^2)	5.75	7.02	7.04	8.68	8.90	8.44
Average (N/mm^2)		6.60			8.67	

Compressive Strength of sand bricks with ratio of 10% C + 20% RH at 14 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.561	3.800	3.365	3.459	3.342	3.423
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	210.2	172.4	128.2	181.8	219.2	198.3
Compressive strength (N/mm^2)	8.27	6.78	5.04	7.15	8.62	7.80
Average (N/mm^2)		6.70			7.86	

Compressive Strength of sand bricks with ratio of 10% C + 30% RH at 14 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.571	3.480	3.583	3.286	3.172	3.087
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	150.3	171.5	167.6	198.4	167.3	154.6
Compressive strength (N/mm^2)	5.91	6.75	6.59	7.80	6.58	6.08
Average (N/mm^2)		6.42			6.82	

Compressive Strength of sand bricks with ratio of 10% C + 10% RH at 28 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.746	3.661	3.472	3.571	3.409	3.739
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	181.2	201.1	206.2	243.2	241.1	239.0
Compressive strength (N/mm^2)	7.13	7.91	8.11	9.57	9.48	9.40
Average (N/mm^2)		7.72			9.48	

Compressive Strength of sand bricks with ratio of 10% C + 20% RH at 28 days

Characteristics	**Water Curing**				**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.540	3.637	3.304	3.351	3.419	3.499
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	176.8	186.1	170.0	239.1	218.5	232.7
Compressive strength (N/mm^2)	6.95	7.32	6.69	9.40	8.59	9.15
Average (N/mm^2)		6.99			9.05	

Compressive Strength of sand bricks with ratio of 10% C + 30% RH at 28 days

Characteristics	**Water Curing**				**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	4.028	4.145	4.144	3.281	3.211	3.369
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	159.3	190.7	155.1	199.0	185.1	207.5
Compressive strength (N/mm^2)	6.27	7.50	6.10	7.83	7.28	8.16
Average (N/mm^2)		6.62			7.76	

APPENDIX D

FLEXURAL STRENGTH TEST

Flexural Strength of sand bricks with ratio of 10% C + 10% RH at 3 days

Characteristics			**Water Curing**		**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.799	3.571	3.669	3.561	3.330	3.528
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	2.73	2.65	3.08	3.79	2.96	2.98
Flexural strength (N/mm^2)	1.07	1.04	1.21	1.49	1.16	1.17
Average (N/mm^2)		1.11			1.27	

Flexural Strength of sand bricks with ratio of 10% C + 20% RH at 3 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.343	3.281	3.483	3.169	3.337	3.287
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	2.54	2.47	2.54	2.50	3.30	2.72
Flexural strength (N/mm^2)	1.00	0.98	1.00	0.98	1.30	1.07
Average (N/mm^2)		0.99			1.12	

Flexural Strength of sand bricks with ratio of 10% C + 30% RH at 3 days

Characteristics	Water Curing				Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.665	3.384	3.518	3.043	3.309	3.103
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	2.81	2.91	2.74	2.49	2.58	2.42
Flexural strength (N/mm^2)	1.11	1.14	1.08	0.98	1.01	0.95
Average (N/mm^2)		1.11			0.98	

Flexural Strength of sand bricks with ratio of 10% C + 10% RH at 7 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.727	3.491	3.622	3.661	3.533	3.499
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	4.53	4.30	4.82	4.19	4.08	3.97
Flexural strength (N/mm^2)	1.78	1.69	1.90	1.65	1.60	1.56
Average (N/mm^2)		1.79			1.60	

Flexural Strength of sand bricks with ratio of 10% C + 20% RH at 7 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.722	3.595	3.374	2.945	3.354	3.416
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	4.25	4.09	4.24	3.31	3.57	4.31
Flexural strength (N/mm^2)	1.67	1.61	1.67	1.30	1.40	1.70
Average (N/mm^2)		1.65			1.47	

Flexural Strength of sand bricks with ratio of 10% C + 30% RH at 7 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	2.940	3.244	3.137	2.519	3.097	3.171
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	0.56	3.06	2.59	3.31	2.48	2.68
Flexural strength (N/mm^2)	2.20	1.20	1.02	1.30	0.98	1.05
Average (N/mm^2)		1.47			1.11	

Flexural Strength of sand bricks with ratio of 10% C + 10% RH at 14 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	4.098	3.833	3.852	3.603	3.849	3.563
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	5.61	5.09	5.22	5.16	6.41	5.29
Flexural strength (N/mm^2)	2.21	2.00	2.05	2.03	2.52	2.08
Average (N/mm^2)		2.09			2.21	

Flexural Strength of sand bricks with ratio of 10% C + 20% RH at 14 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.729	3.779	3.573	3.545	3.513	3.544
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	5.01	4.81	4.81	5.38	5.26	3.66
Flexural strength (N/mm^2)	1.97	1.89	1.89	2.12	2.07	1.44
Average (N/mm^2)		1.92			1.88	

Flexural Strength of sand bricks with ratio of 10% C + 30% RH at 14 days

Characteristics		Water Curing			Air Curing	
Samples	1	2	3	4	5	6
Weight (kg)	3.404	3.159	3.194	2.675	2.932	3.028
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	4.28	4.11	3.90	4.07	4.32	3.57
Flexural strength (N/mm^2)	1.68	1.62	1.53	1.60	1.70	1.40
Average (N/mm^2)		1.61			1.57	

Flexural Strength of sand bricks with ratio of 10% C + 10% RH at 28 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.871	4.256	3.517	3.740	3.366	3.444
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	6.52	5.98	5.04	6.76	5.36	5.47
Flexural strength (N/mm^2)	2.56	2.35	1.98	2.66	2.11	2.15
Average (N/mm^2)		2.30			2.31	

Flexural Strength of sand bricks with ratio of 10% C + 20% RH at 28 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.540	3.635	3.687	3.322	3.219	3.253
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	5.34	5.38	5.40	5.21	4.91	4.73
Flexural strength (N/mm^2)	2.10	2.08	2.12	2.05	1.93	1.86
Average (N/mm^2)		2.11			1.94	

Flexural Strength of sand bricks with ratio of 10% C + 30% RH at 28 days

Characteristics		**Water Curing**			**Air Curing**	
Samples	1	2	3	4	5	6
Weight (kg)	3.418	3.675	3.687	2.999	3.144	3.071
Area (mm^2)	25 425	25 425	25 425	25 425	25 425	25 425
Maximum load (N)	6.02	5.04	4.77	4.77	4.10	4.32
Flexural strength (N/mm^2)	2.37	1.98	1.88	1.88	1.61	1.70
Average (N/mm^2)		2.08			1.73	