A STUDY OF OPTIMUM COCONUT SHELL (CS) RATIO IN CEMENT SAND BRICKS

NOORHAYA BINTI KASA

B.ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

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A STUDY OF OPTIMUM COCONUT SHELL (CS) RATIO IN CEMENT SAND BRICKS

NOORHAYA BINTI KASA

Thesis submitted in fulfillment of the requirements for the award of the degree of
B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources
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JANUARY 2015

SUPERVISOR'S DECLARATION

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Signature	:
Name of Supervisor	: MRS. SHARIZA BINTI MAT ARIS
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DEDICATION

Praise to Almighty Allah Subhanahu wa Ta'ala,
with His mercy and sympathy I was able to completed this thesis and also
Prophet Muhammad (Peace Be upon Him) who is light for humanity.

I would like to dedicate this thesis to my parents
Mr. Kasa Bin Husin and Mrs. Azizah Binti Saidin, who's been my greatest supporters.
Their affection, love, encouragement and prays of day and night
make me able to get such success and honor.

I also want to dedicate it to my siblings,
Mohd Nasrin Bin Kasa, Nor Azlina Binti Kasa, Noorhayati Binti Kasa and
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ABSTRACT

This thesis is an overview a study of optimum ratio of coconut shell cement sand brick (CSCSB). Cement is used as the binding material for coconut shell and sand. In this study, a standard mix used is cement: sand, which is ratio 1: 6, a coconut shells are added by using difference ratio. The mix proportions of CSCSB are cement: sand: coconut shells, ratios used are 1: 5: 1, 1: 4.5: 1.5 and 1: 3: 3. There are total of 90 CSCSB was produced in this research, with dimension of 225 mm x 113 mm x 75 mm. Air curing is selected, since CSCSB is a sensitive brick. The properties of CSCSB will be define by undergo necessary testing such as compression test at 3, 7, 14 and 28 days, density test and water absorption rate test. The value of compressive strength of CSCSB is decreasing as the ratio of coconut shell is increases. Even though a compaction is done properly during brick casting, since coconut shell are irregular shape, the void or porous space may produce during brick casting, this void or porous space may lead to a strength reduction. The density of CSCSB is decreased with increase in coconut shell. This decreased density is due to the fibrous nature of the coconut shell, where coconut shell has a low density. The water absorption rate is increased with increased of coconut shells. The water absorption rate is increase due to the porous space of CSCSB, where is water can get through the porous area in brick, since coconut shell is fibrous, thus make it easier to absorb water. From this study, the optimum ratios are obtained, where ratio 1:4.5:1.5 shows the best performance which satisfied with the standard control. The use of coconut shell in cement sand brick is an alternative to encourage environmental protection in order to minimize waste material.

ABSTRAK

Kertas kerja ini adalah gambaran keseluruhan mengenai nisbah optima tempurung kelapa di dalam bata simen. Simen digunakan sebagai bahan pengikat antara tempurung kelapa dan pasir. Di dalam ujikaji ini, simen: pasir digunakan sebagai piawai campuran, nisbah yang digunakan adalah 1: 6, tempurung kelapa ditambah berdasarkan nisbah yang berbeza. Campuran bahagian yang digunakan untuk bata simen tempurung kelapa adalah simen: pasir: tempurung kelapa, nisbah yang digunakan adalah 1: 5: 1, 1: 4.5: 1.5 and 1: 3: 3. Sembilan puluh biji bata simen tempurung kelapa dihasilkan di dalam ujikaji ini, saiz bata yang digunakan adalah 225 mm x 113 mm x 75 mm. Perapian yang dijalankan adalah perapian udara, hal ini kerana bata simen tempurung kelapa merupakan bata yang sensitif. Sifat- sifat bata simen tempurung kelapa akan ditentukan dengan menjalani ujian seperti ujian mampatan pada hari ke-tiga, ke-tujuh, ke-empat belas , dan ke-dua puluh lapan, ujian ketumpatan dan ujian kadar penyerapan air. Nilai kekuatan mampatan bata simen tempurung kelapa mulai menurun apabila nisbah tempurung kelapa meningkat. Walaubagaimanapun, proses pemadatan telah dilakukan dengan baik semasa proses pembuatan bata simen tempurung kelapa, tetapi bentuk tempurung kelapa yang tidak teratur, ruang- ruang berliang akan terhasil semasa proses pembuatan bata, ruang- ruang berliang ini boleh menyebabkan kekuatan mampatan berkurangan. Ketumpatan bata simen tempurung kelapa menurun apabila nisbah tempurung kelapa meningkat. Hal ini disebabkan tempurung kelapa yang bersifat serabut dan tempurung kelapa juga mempunyai nilai ketumpatan yang rendah. Kadar penyerapan air bata simen tempurung kelapa juga mulai meningkat apabila nisbah tempurung kelapa meningkat. Hal ini disebabkan, ruang-ruang berliang yang terhasil dalam bata simen tempurung kelapa menyebabkan air mudah masuk menerusi liang- liang tersebut, tambahan tempurung kelapa yang bersifat serabut, memudahkan air diserap masuk ke dalam bata simen tempurung kelapa .Di dalam ujikaji ini, nisbah optima telah diperolehi, dimana nisbah 1: 4.5: 1.5 menunjukkan prestasi yang terbaik yang sejajar dengan piawai kawalan. Ujikaji ini dapat membuktikan bahawa penggunaan tempurung kelapa di dalam bata simen merupakan salah satu kaedah untuk menggalakkan perlindungan alam sekitar dalam mengurangkan bahan buangan.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CS	Coconut Shells
IBS	Industrial Building System
MS	Malaysia Standard
OPC	Ordinary Portland Cement
PWD	Public Work Department

Department of Statistic, Malaysia

Ministry of Agriculture and Agro-based Industry, Malaysia

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Even though the construction industry have become more advanced in technology such as Industrialized Building System (IBS), but the usage of brick in construction is still on demand. The growths of the construction are increasing with the increased in population for people to fulfill their living needs. According to the Department of Statistic, Malaysia, the population for year 2010 is 28.6 million, and it is expected to rise by 10 million to 38.6 million in year 2040.

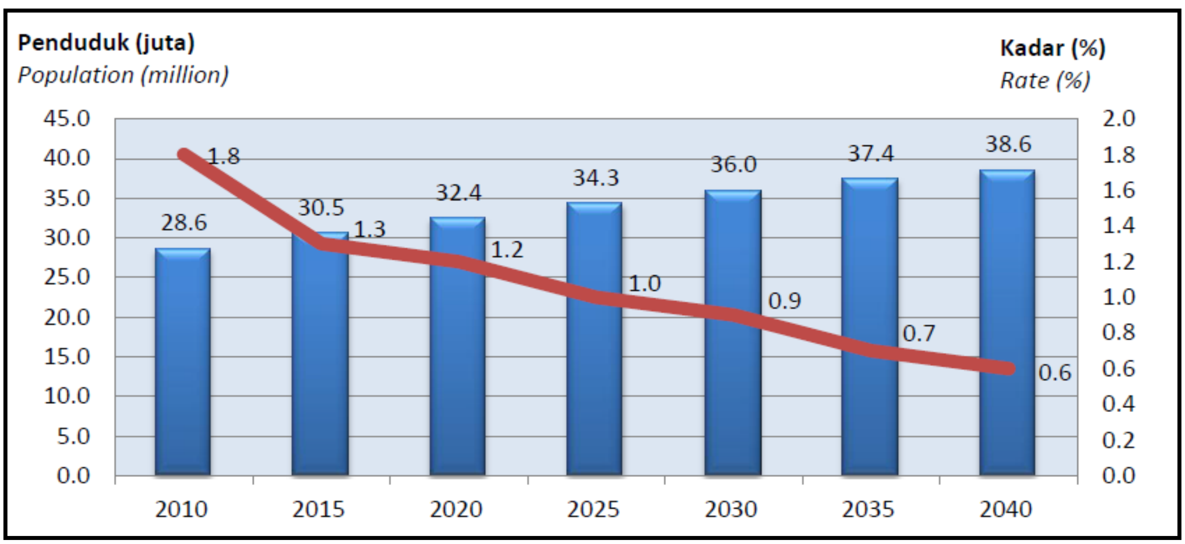


Figure 1.1: Chart of Population projection and annual population growth rate, Malaysia

Source: Department of Statistics, Malaysia

The production of bricks is about 1391 billion units in worldwide annual and it is expected that the demand of bricks will continuously rising. By using bricks, the building constructions have high compressive strength and durability in order to protect from foreign disturbance. The advantages of bricks to the structural component of a building are, brick can resist multiple resistance against heat and sound. The bricks components also act as an insulator to the certain part of building component due to the resistance. The building construction can become much easier, faster and cheaper, in term of workability. One of the most accommodating masonry units is bricks, due to its physical, chemical and mechanical properties. Bricks can be classified as one of the back boned of building construction.

Malaysia is full with natural waste materials such as agricultural and industrial waste. Those waste can be recycle into useful material, which is into renewable buildings materials. The rising in population, automatically the waste materials and the amount will increase according to the growth in population. Some of the non-decaying waste materials will remain in environment, perhaps for thousand years. The waste materials could cause a crisis, and then contributing to the environmental problems. However, to minimize or to overcome the environmental problem is by making a uses of these waste material into a potential material, and helps to maintain a good environments.

The potential of using agricultural waste in buildings construction material has been investigated by various researchers. These automatically will double the advantage, which are disposal of waste material and reduction in construction cost. Malaysia can be categories as a countries where have abundant waste material, those waste material can be used as a potential material in buildings construction. One of the abundant waste materials is a coconut shell.

5. KAWASAN-KAWASAN PENGELUAR UTAMA KELAPA MALAYSIA

NEGERI	DAERAH
Perak	- Hilir Perak
Johor	- Pontian, Batu Pahat, Muar
Selangor	- Sabak Bernam, Kuala Selangor
Sarawak	- Asa Jaya, Simunjan, Kuching
Sabah	- Pitas, Kudat, Lahad Datu, Tawau, Semporna

Sumber: DOA

Figure 1.2: The Areas of Primary Coconut Production

Source: Department of Agriculture, Malaysia

Coconut shell is a form of agricultural solid waste. After the coconut is scraped out from the shell, the shell is usually discarded as wastes. Coconut shell has surface texture which is fairly smooth on the inside and rough on the outside and it is one of the most promising agricultural wastes with its possible uses and it has a good workability. A coconut shell can be used for construction material application, it would definitely not only beneficial towards the environment, but also can be advantageous for low income families as, it can be used for the construction of low cost houses. More than ninety three countries have grown a coconut tree. South East Asia is classified as the origin of coconut. According to the Ministry of Agriculture and Agro-based Industry, Malaysia, the achievement and coconut production for year 2015 is 810 million, and it is expected to rise by 400 million to 1,210 million in year 2020.

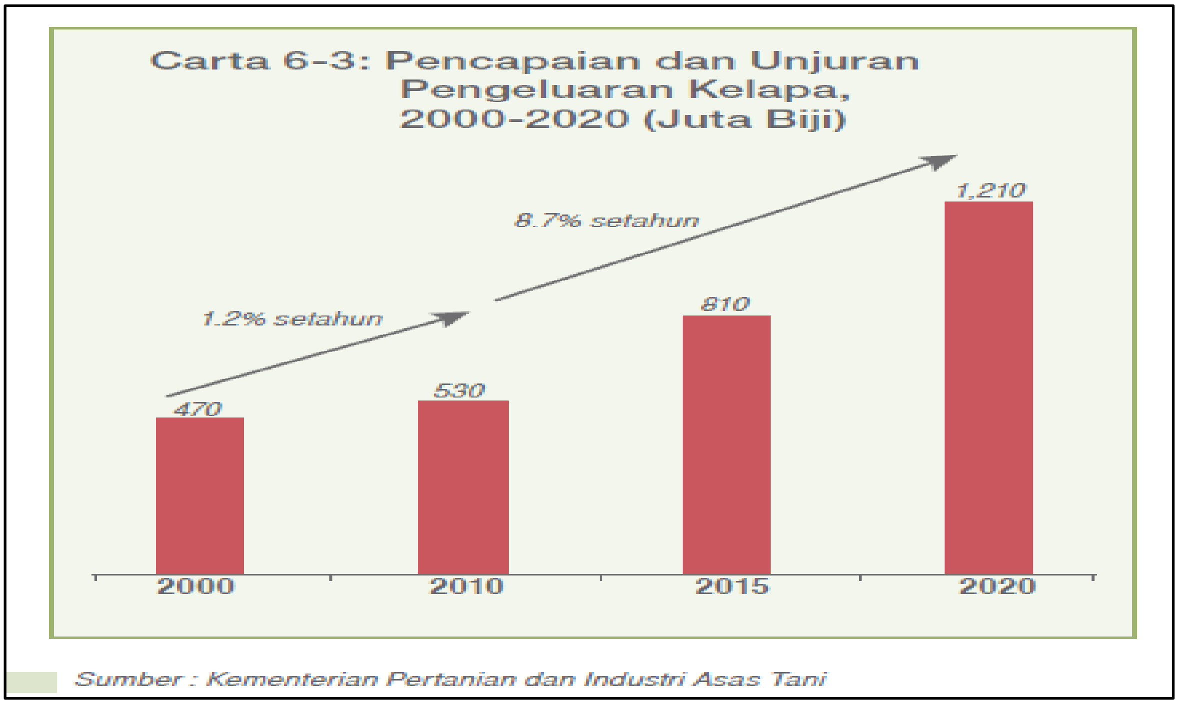


Figure 1.3: The Achievement and Rate of Coconut Production

Source: Ministry of Agriculture and Agro-based Industry, Malaysia

Green bricks an environmentally friendly alternative. Green element or environmentally refer to any product or service that is not harmful to the atmosphere or surroundings. Generally, in Malaysia, the application of green brick is not too familiar compared to the abroad country. Malaysia can be a country that practices a green brick production, it is because Malaysia is a tropical countries that have abundant of natural waste materials such as coconut shell. Coconut shell is one of the common agricultural wastes in tropical countries. Brick is the first masonry material that can be certified for environmental claims, by adding the natural waste materials into the bricks mixture, it is the allowed materials by building codes to be reused in new building application.

1.2 PROBLEM STATEMENT

Nowadays people starting to turn into green buildings, a green building come from usage of green materials. One of the green building materials is a brick, the basic brick that we have in construction is a sand brick and clay brick. But to improve the brick, which is by turning the bricks into green bricks, we can add natural waste material from agricultural waste. Green brick is an environmentally friendly, which is not harm to the atmosphere or surroundings. Green brick have an ability to be a light weight bricks, it is because by adding these waste materials will reduce the density of bricks. It is definitely a good result, because we can reduce the load of brick wall on the buildings structure. There are lots of agricultural wastes in Malaysia, one of the wastes are coconut shells. Green brick have been used in most abroad countries, such as India. These waste materials will dispose or dumping in some places if the waste was not treated properly. Dumping will required a place to dump those waste materials. Even though these waste was dispose, but it will take maybe a hundred or thousand years to dispose properly.

The waste materials will become potential materials if it was treated properly. After the coconut being scraped out from the shell, the shell was discarded as a wastes material. From these waste, it could double the advantages as the waste material are turn into potential material and disposal of waste material. One of the ways to improve the waste materials are by turn this waste into a potential materials the potential materials that can be used in building materials. By adding these agricultural wastes into brick mixture can help reduce the environmental impacts, which is by disposing these wastes into a potential building source material. In other countries, the usage of waste materials has been used widely in bricks, concrete and other. Various researchers have been investigated that, there are potential of using agricultural waste in building construction works and helps in reduces the environment problems of solid waste.

1.3 OBJECTIVE OF STUDY

The objectives of this study are:

a) The objective of this research is to investigate the optimum ratio of coconut shells in cement sand brick.

b) To determine the characteristic of cement sand brick:

    i. Density
    ii. Water absorption rate
    iii. Compressive strength

1.4 SCOPE OF STUDY

In this research, a coconut shells are used as the waste materials. Based on the objective of this research is to study the optimum percentage of coconut shells used in the green bricks. The dimensions of the brick are according to the Public Work Department (PWD) Standard Specification for Buildings Works, 2005, it stated that, all cement sand brick shall comply with MS 27. The nominal size of cement sand brick are, the length is 225 mm (± 3.2), width is 113mm (± 1.6) and depth is 75mm ± (1.6). The ratio used for the brick mixture is 1 ratio 6 (1:6) which are according to cement sand brick ratio. In this research, there are three ratio used for bricks mixture in order to determine which are the best ratio, one ratio have thirty samples each. Each ratio will undergo a testing and analysis, and based on the testing and analysis result, the best optimum percentages of coconut shells are determined.

In order to determine the best optimum ratio of coconut shell in green brick, the design properties, including density, water absorption rate, and compressive strength will be defined by undergoing necessary testing and analysis. Density test are carried out because, with the addition of waste material which are coconut shell, bricks tend to decreased in density. As the waste materials are increased, the density of brick tends to decreased. Water absorption test need to be carried out, as the coconut shell has a high water absorption. A buildings will exposed to the water such as rain, so we need to know the water absorption rate of bricks contain a coconut shell as a waste material. The compressive strength are carried out is to find out the strength of the brick, either it is comply with the standard requirement. Then, the result of a brick testing and analysis will be compared, and then the best result will be determined as it is fulfill all the entire requirement according to the Public Work Department Standard Specification for Buildings Works, 2005.

1.5 SIGNIFICANT OF STUDY

This research will be significant if the green bricks were developing successfully, as the design properties was comply with the standard requirement. This study also will give an advantage to the construction industry, which is reduction in construction costs, it is because with a little or no cost at all, these waste material can be obtained. Besides that, this study will become a helpful especially for the government, which is by turn these waste materials into a potential material, automatically the environmental issue can be solved. Since, by using these waste materials material, and at the same time these waste materials will be dispose and reduces dumping spaces and helps to maintain a clean environment.

In addition, the growth populations in Malaysia have been increasing, increasing in population, automatically the demand for the houses will also increase. If green brick can be used in building construction, it is not only benefit the environment but also helps in reduction of construction cost, automatically we can produce a low cost house for a low income family. This will become a good solution, as today lots of citizen cannot afford to buy a houses, because the price is too expensive. Malaysia should take the advantages by having an abundant of waste material such as coconut shell, and turn this waste into a potential material that will benefit the people and also the environment. Lastly, this research study will spread the knowledge about turning these waste materials into a potential material that can benefit people and helps in maintain a clean environment.

CHAPTER 2

LITERATURE REVIEW

2.1 BRICK

Brick are widely used construction and buildings material around the worlds. Brick has been used for at least 10, 000 years in a variety of a structure, including homes, private buildings and public buildings. There are varieties of brick, which are common brick, usually it is for general building work, secondly facing brick, and it is for attractive appearance or aesthetical view when it is used without rendering or plaster, and lastly engineering bricks, the bricks are more dense and strong, and it is to defined limits for absorption and strength.

There are varieties of bricks dimension, in this research the dimension of bricks are according to the Public Work Department (PWD) Standard Specification for Buildings Works (2005), it stated that, all cement sand brick shall comply with MS 27. The nominal size of cement sand brick are, the length is 225 mm (± 3.2), width is 113mm (± 1.6) and depth is 75mm ± (1.6). Bricks are produce according to the standard specific application in which the bricks will be used.

There are currently about 1391 billion units of brick are produce in a worldwide annual, and it is expected the demand of bricks will continuously rising (Mohammad Shahid Arshad, Dr. P. Y. Pawade et al., 2014). Brick are listed as the most durable of buildings materials. Brick offers sustainability advantages, which are it is made from the abundant resources on earth either sand or clay, it is also enhances a buildings efficiency, both in short term use or for long term use and lastly it is manufactured in an environmentally responsible. A key element in construction sustainability is to minimize the use of energy over a buildings usable life. Brick provides energy efficient for a building that reduces the amount of energy necessary to heat or cool the interior.

Bricks also have a good durability, so it will eliminates the need for exterior maintenance. According to the National Institute for Standard and Technology has rated the bricks masonry as having a 100-year lifespan. Brick also have a good thermal necessary to insulate buildings, which are it allows to lower level of heating. Brick have the ability to absorb heat and shield the interior from a rapid rise in temperature. The heat later released into the cooler night air. The advantages of bricks are, it does not fade or become brittle, and it requires little maintenance or repaired compared to other products.

In addition, brick provides a comfortable environment for building users and at the same time it reduces noise transmission from the exterior. Bricks are widely recognized as being both resistant to fire and to water extrusion, where is we know that the fire and water extrusion can considerably shorten the life of a buildings.

2.2 GREEN BRICK CONCEPT

Green building is the best practice of creating structure and using processes that are environmentally responsible. One of the things to produce green building materials is a green construction material. Green building materials is a composed of renewable. Green materials are environmentally responsible because impacts are considered over the life of the product. In addition, green building materials promotes conservation of using renewable resources such as agricultural waste.

Besides that, integrating green building materials into building project can help reduce the environmental impacts such as reuse, recycling and disposal of these agricultural and industry waste into potential materials and useful materials. Brick is a construction material with a rectangular shape. Brick is the best choice in order to produce green building, by making the brick as environmental friendly. Brick is a highly sustainable building materials, it has long lifecycle, minimal waste and many recycling option.

Green brick concept comes from making the brick by adding natural waste materials. In this research, the natural waste materials used are coconut shells, coconut shells is an agricultural waste. Coconut shells are agricultural wastes which are abundant waste. By adding the coconut shells into the brick will turn the coconut shells from waste material into potential material that can be used for produce green building materials.

2.3 MATERIAL

2.3.1 Cement

In the most general, cement is a binder, a substance that hardens independently, and can bind other materials together. Cement used in construction is characterized as hydraulic and non-hydraulic. The most common cement are Portland cement, it is harden due to hydration, chemical reaction that occur independently.

According to (BS 12: 1996), cement can be defined as a hydraulic binder. It is a finely ground inorganic material which, when it is mixed with water, it form a paste which sets and hardens by means of hydration reactions and processes. This hydration process results in a progressive stiffening, hardening and strength development. After hardening, the strength and stability will stay remain even underwater or when constantly exposed to wet weather.

In this research, types of cement used are Ordinary Portland Cement (OPC). OPC is the most common cement used in general construction when there is no exposure to sulphate in the soil or groundwater. OPC is a basic material and commonly used in basic mortar, concreting and grouting process (it is being used to fill the cores of concrete blocks). OPC is a gray colored powder.

The (ASTM C-150, 2005) has designated five types of Portland cement, which are Type I – V. physically and chemically, these cement types primarily difference in their content and in their fineness. In terms of performance, they are primarily difference in the rate of early hydration and their ability to resist sulfate attack. Each type has their own characteristic and the usage of the five types is depending on the applications. Table below shows their general features of the five types of Portland cement.

Table 2.3.1: General Features of the five types of Portland cement.

Types	Classification	Characteristics	Applications
Type I (Ordinary Portland Cement)	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II (Modified Portland Cement)	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions

Type III (High-early-strength Portland Cement)	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV (Low-heat Portland Cement)	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V (Sulfate-resistance Portland Cement)	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

Source: Richard T Kreh (2008)

The differences between these cement types are rather subtle. The properties of mature concretes made with all five are quite similar. Thus these five types are often described by the term Ordinary Portland Cement (OPC). Since, research is focusing on brick, so type I can be used.

2.3.2 Fine Aggregates

Fine aggregates can be classified as sand, sand can be classified as fine, coarse and gravelly. Fine sand is known as sand passing through a screen with clear opening of 1.5875 mm, it is generally used for masonry works. Gravely sand is known as sand passing through a screen with clear openings of 7.62 mm, it is generally used for plastering works. Coarse sand is known as sand passing through a screen with clear opening of 3.175 mm, it is generally used for masonry work. Sand is formed by the decomposition of sand stones due to the various effects of weather. Sand usually used as the fine aggregates in concrete and other similar mixture. For a good mix, fine aggregates need to be clean, hard, strong particles free of absorbed chemical and other fine materials that could, hardened properties and mixture proportion.

Fine aggregates can help in reducing shrinkage which occurs in setting and drying, therefore minimizing cracking, it is also provides support function to the finer by producing voids of size. Sand act as filler which contribute to the strength of mix. Fine aggregates generally consist of natural sand or crushed stone. Natural gravel or sand is usually dug from a pit, river, lake, or seabed may be used as fine aggregates, but a care should be taken and all the impurities must be removed. In this research, river sand is used. The river sand was obtained from beds of river, river sand consists of fine rounded grains. The sand source should not be too dry, there should be sufficient moisture in the sand. The volume of sand increases as the presence of moisture, it is due to the fact that moisture causes film of water around the sand particles. Inaccurate volume measurements result when sand is too dry or too wet.

2.3.3 Water

On earth surface water cover about 70% and water is the only substance that exists on earth in all three physical states of matter, including gas, liquid, and solid. Pure water is colorless, odorless and tasteless, water is the most essential in our daily life. Same goes with the brick production, without water the brick mixture cannot stick and mix together with other material. The water used is water that free from acid, alkali's and other organic material.

Water plays as an important part in the brick mixing, firstly, water will spread the cement to ensure that all fine aggregate are coated tightly. Secondly, water makes the brick mixing more easily. Lastly, water is the chemical reaction agent in cement to bind all fine aggregates in brick mixture. In this research, pipe water which is clean and can be used for drinking is used. There is no testing were conducted to the water sample.

2.3.4 Coconut shells

Coconut shells are form of agricultural solid waste, it is one of the most promising agricultural wastes, and it is one of the abundant wastes. Since waste materials can be obtained at little or at no cost. The natural waste materials are making significant contribution to the conservation of natural resources, which are leads to environmental protection by turn this waste material into potential and useful material.

According to the (Sreenivasulu Dandagala et al., 2014) a coconut shells show a wide diversity in size, weight, shape, and color. Then, the surface texture of the shells was fairly smooth in the inside and rough on the outside. Coconut shells also have a high capacity of moisture retaining and water absorbing. Based on (K. Gunasekaran et al., 2013) a coconut shells has better workability and the pore structure in coconut shells behave like a reservoir. Coconut shells represent more than 60 % of the domestic wastes, it was abundantly available agricultural waste. Based on (Mohammad Shahid Arshad, Dr. P. Y. Pawade et al., 2014) coconut is a versatile product, since it has multiple uses. Almost all the parts of a freshly grown coconut are eatable or otherwise are used in some or other manner.

According to (Parag S. Kambli et al., 2014) coconut shells have a potential for the development of new composite because of their high strength and modulus properties. There are various researcher have been investigated the use of coconut shells in civil engineering construction, the hardness of coconut shell are proven as the coconut shell also have been used in the production of activated carbon due to the it's hardness and high carbon content. According to (B. Damodhara Reddy[1], S. Aruna Jyothy[2], Fawaz Shaik[3] et al., 2014) coconut shell are considered strong and hard, it's have more resistance against crushing, impact and abrasion. The use of coconut shell in in modern construction material has gained popularity due to its lower density and good superior thermal insulation properties. The inherent economies and advantages offer by this natural waste materials have been recognize by architects, engineers, and contractors.

Based on (Salleh Z.[a,b*], Islam M. M[b], M. Y. M. Yusop[a], and M. A. Mun'aim M. Idrus[a] et al., 2013) in the recent past, the potential candidate for the development of new composites material are coconut shell, it's because of their high strength and modulus properties. Coconut shells possess a composite of high strength and it is suitable to be used in the broad range of application such as building materials.

The study of coconut shell used in the bricks is gaining an importance in terms of possible reduction of waste product in the environment and finding a suitable alternative for renewable natural waste material. In this research, a coconut shells are collected from the local vendor. The particles size of the coconut shells range from 25 mm to 30 mm.

Figure 2.3.4: Coconut Shells

Figure 2.3.5: Size of Crushed Coconut Shells (25 mm to 30 mm)

2.4 CONCLUSION

In this research, a green brick concept is used to produce Coconut Shell Cement Sand Brick (CSCSB). The cement used is Ordinary Portland Cement (OPC). OPC is the most common cement used in general construction. For the fine aggregate, river sand is used, the sand source should not be too dry, where there should be sufficient moisture in the sand. Pipe water which is clean is used, there is no testing were conducted to the water sample. Coconut shells are form of agricultural solid waste, and one of the abundant wastes. It can be concluded that, as the coconut shells increased, the compressive strength is decreased. The density will tend to decrease as increased of coconut shell, since it has a low density. Meanwhile, the water absorption rate will tends to increase as a coconut shells is increased, a coconut shells has a high water absorbing ability, where is it act like a reservoir.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this research is to study the optimum ratio of coconut shells in cement sand brick, where coconut shell is the natural waste material and it is used in cement sand brick production in this research, in order to find out how the brick properties will differ from the actual one. The motives of this chapter are to outline the research methodology of this study, explaining on the waste material, the apparatus and procedure, and design properties that will be defined by undergoing necessary testing and analysis.

This chapter is an alternative to find out the outcome of the objective of this study. This clause will ensure that the progress of this study will be conducted with efficiently, smooth and according to the framework. The benefit of this research methodology is to avoid any issues or problem that can affects the probability to find out the final result. The overall of this chapter covers from the early step on conducting the research until the final phase of the study. This will assure the research on the right track and to ensure the right order of work sequence for the whole project.

3.2 CONCEPTUAL FRAMEWORK OF RESEARCH

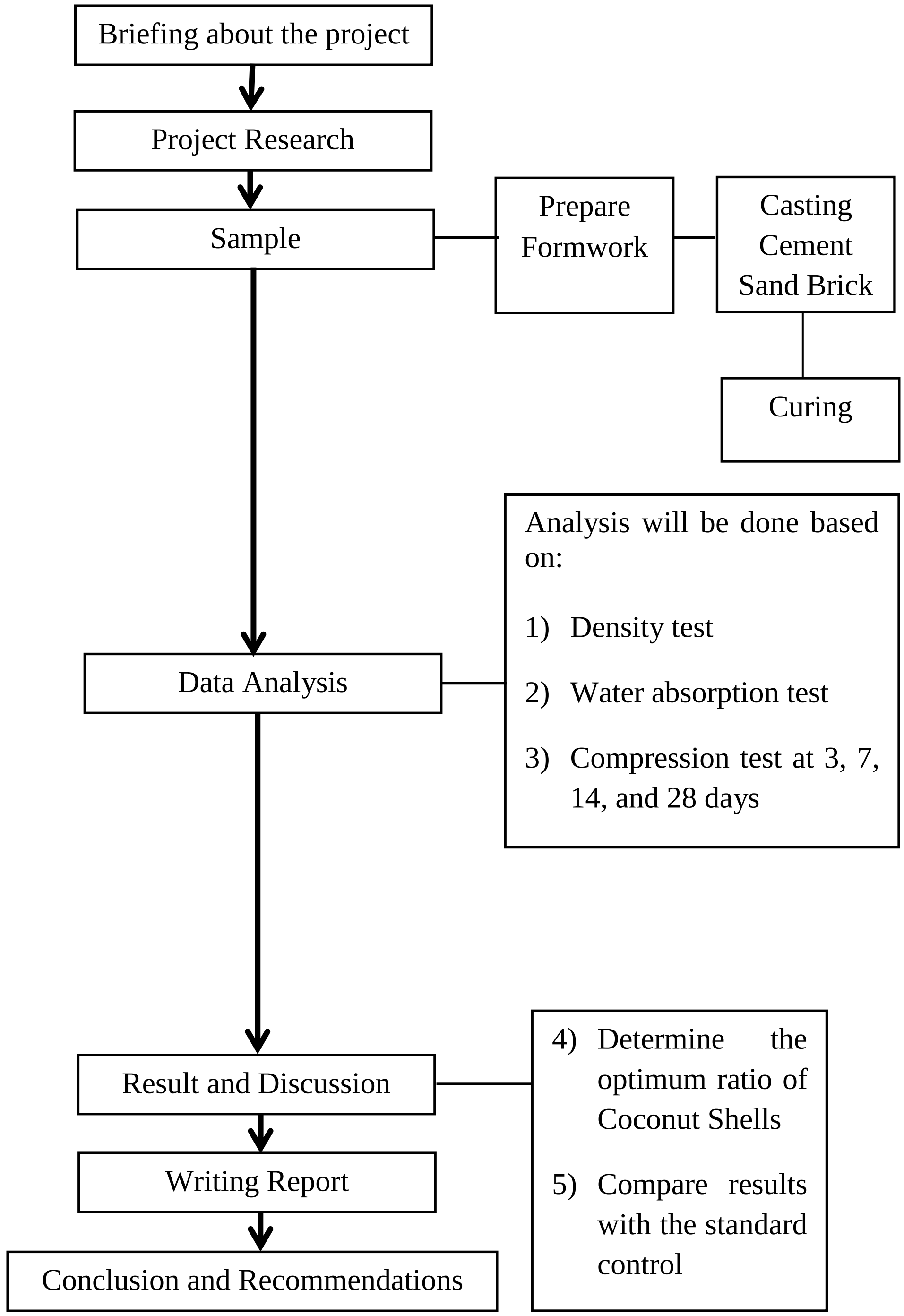


Figure 3.2: Conceptual framework of research

3.3 CEMENT SAND BRICK DESIGN

The cement sand brick are designed as shown in figure below. The design dimension of cement sand brick are according to the Public Work Department, Standard Specification for Buildings Works, 2005.

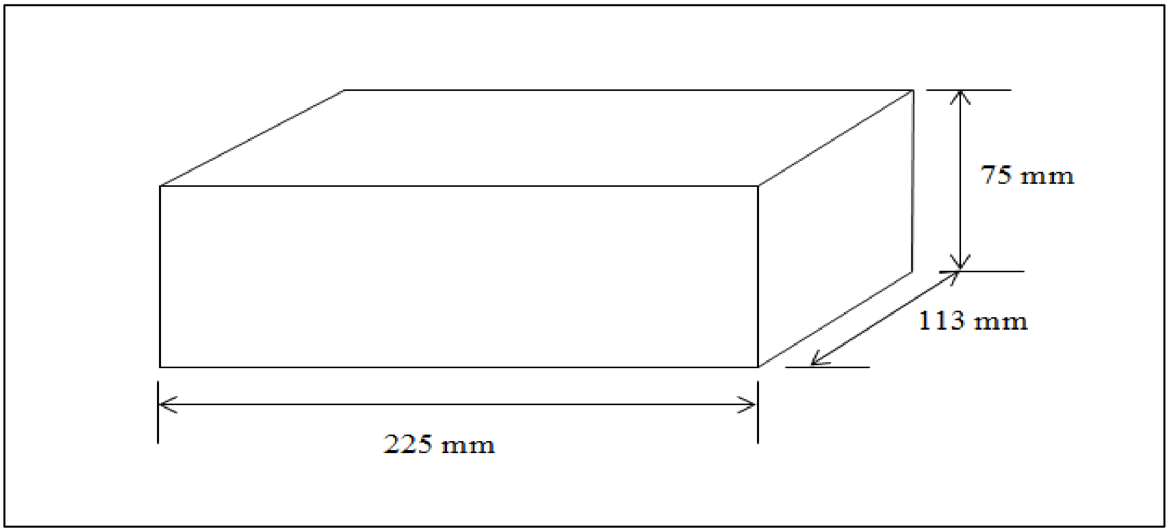


Figure 3.3: Cement Sand Brick Dimension

Height = 75 mm, Width = 113 mm, Length = 225 mm

In this research, the dimension of the sand brick based on Public Work Department, Standard Specification for Buildings Works, 2005, it stated that, all cement sand brick shall comply with Malaysia Standard 27 (MS 27). Cement sand brick shall be nominal size as given in the table below.

Table 3.4: Brick Standard Dimension

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

Source: Public Work Department

According to (Masonry skills, [6th] edition), the flow making brick including, storing the raw material, mixing the materials, molding the brick, curing the brick, storing the brick, and brick testing. According to (Ismail Demir, 2006) the samples were dried at laboratory condition (60% relative humidity) for 72 hours. Then, the samples will proceed to the curing process.

According to (ASTM C-31) satisfactory moisture environment can be created during the initial curing of the specimens. After curing process, sample will undergo necessary testing. In this research, for the standard control, ratio used for the cement brick design is 1: 6 for cement: sand. The mix will be prepared by adding three difference ratios of coconut shells, then mix will be poured into the formwork.

In this research, there are three ratios used for cement sand brick design, the ratio is cement: sand: coconut shell. The first ratio is 1: 5: 1, secondly 1: 4.5: 1.5 and last ratio is 1: 3: 3. In this study, the mold dimension for brick is 225 mm x 113 mm x 75 mm, the mold weight is 706.83 g. For one ratio, the total sample is thirty samples, so the total samples including all three ratios is 90 samples of brick. Below is the calculation of cement sand brick:

Mold dimension = 225mm x 113 mm x 75 mm
Mold weight = 706.83 g

Sand + mold = 3847.01 g
Sand = 3140.18 g = 3.140 kg

Cement + mold = 3513.81 g
Cement = 2806.98 g = 2.806 kg

Coconut shell + mold = 1596.96 g
Coconut shell = 880.13 g = 0.880 kg

Volume of Brick = 0.225 m x 0.113 m x 0.075 m =0.0019 m^3

Cement = 2.806 kg / 0.0019 m^3 = 1476.64 kg/m^3

Sand = 3.140 kg / 0.0019 m^3 = 1652.63 kg/m^3

Coconut Shell = 0.880 kg / 0.0019 m^3 = 463.16 kg/m^3

For the first ratio.

Total Sample = 30
Total Volume of Sample = (0.0019 m^3)(30) = 0.057 m^3
Ratio = cement: sand: coconut shell = 1: 5: 1
0.057 m^3 / 7 = 0.008143 m^3

Ratio	Cement	Sand	Coconut Shell
Volume	0.008143 m^3	0.04071 m^3	0.008143 m^3
Weight	12 kg	67 kg	3.80 kg
Total	14.4 kg	80.40 kg	
1 Sample			0.127 kg

The second ratio.

Total Sample = 30
Total Volume of Sample = (0.0019 m^3)(30) = 0.057 m^3
Ratio = cement: sand: coconut shell = 1: 4.5: 1.5
0.057 m^3 / 7 = 0.008143 m^3

Ratio	Cement	Sand	Coconut Shell
Volume	0.008143 m^3	0.03664 m^3	0.01221 m^3
Weight	12 kg	60 kg	5.66 kg
Total	14.4 kg	72 kg	
1 Sample			0.189 kg

<u>The third ratio.</u>

Total Sample = 30

Total Volume of Sample = (0.0019 m^3)(30) = 0.057 m^3

Ratio = cement: sand: coconut shell = 1: 3: 3

0.057 m^3 / 7 = 0.008143 m^3

Ratio	Cement	Sand	Coconut Shell
Volume	0.008143 m^3	0.024429 m^3	0.024429 m^3
Weight	12 kg	40.40 kg	11.31 kg
Total	14.4 kg	48.48 kg	
1 Sample			0.377 kg

3.4 CEMENT SAND BRICK MANUFACTURING PROCEDURE

In this research, the materials used are Ordinary Portland Cement (OPC), sand, plywood, coconut shell, and water. In this study, the first steps in brick manufacturing are by making brick formworks. The materials used for brick formwork are plywood. The thickness of plywood used for brick formwork is 12 mm, so the thickness must be taken into consideration when marking the dimension of brick on the plywood. Firstly, the plywood is marked by using marker according to the brick size, then after marking are done, the next process are cutting the plywood. Lastly, nailing process, the pieces from plywood are nailed together to form a brick formwork. The following figure below, figure 3.4, 3.5 and 3.6 shows the skecthes of the formwork.

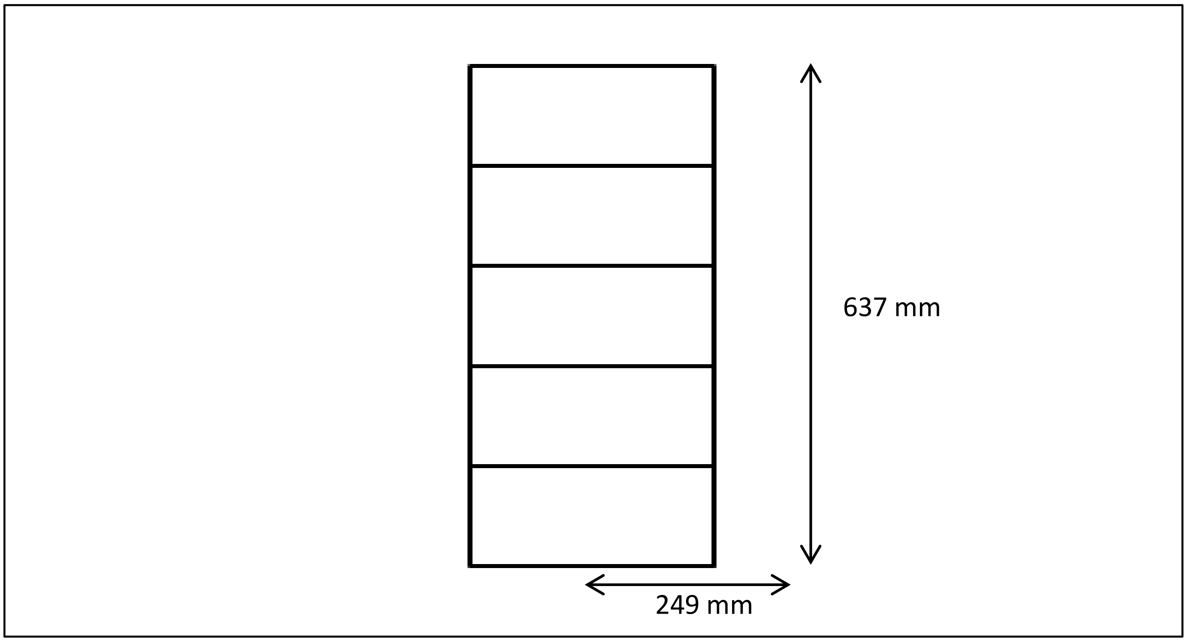


Figure 3.4: Plan view of brick formwork

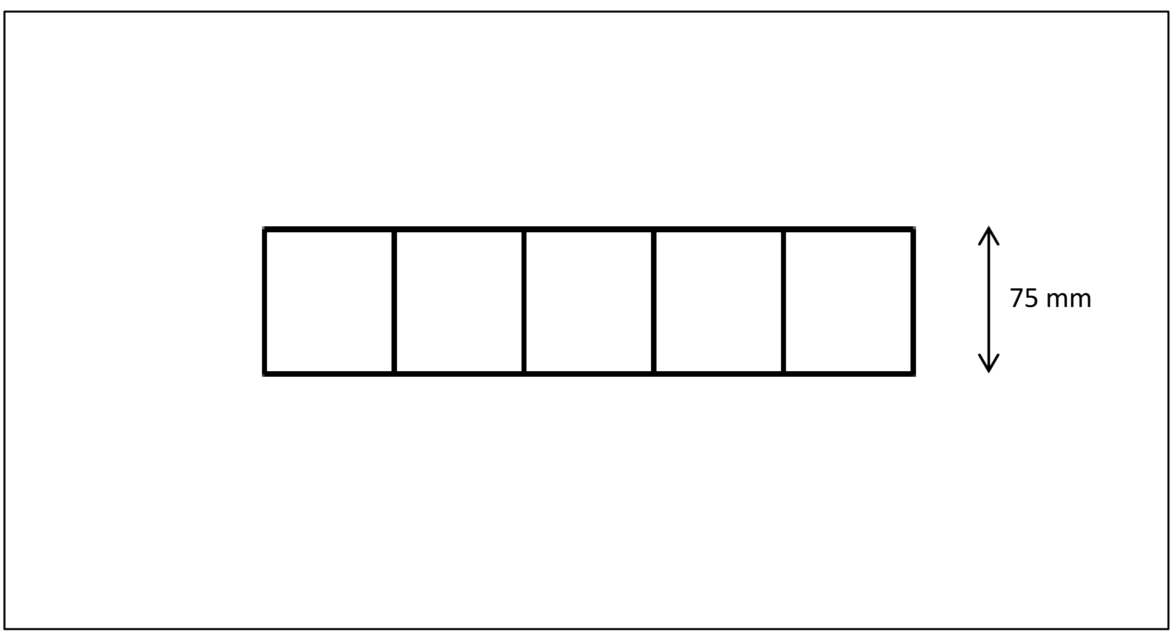


Figure 3.5: Side view of brick formwork

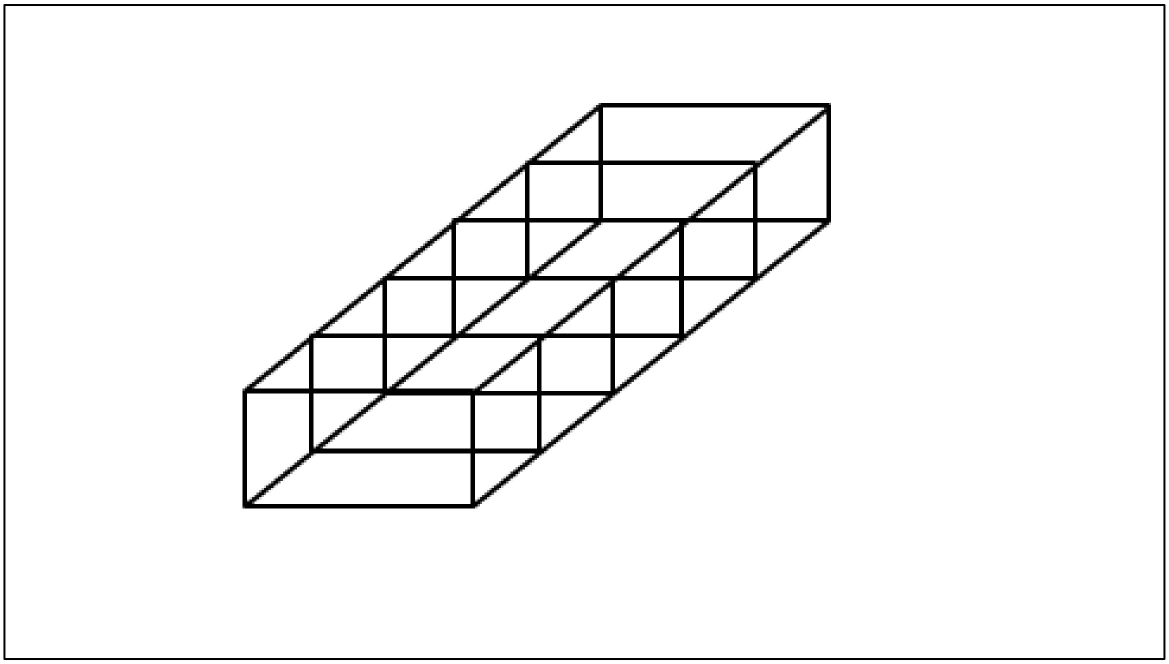


Figure 3.6: Brick formwork

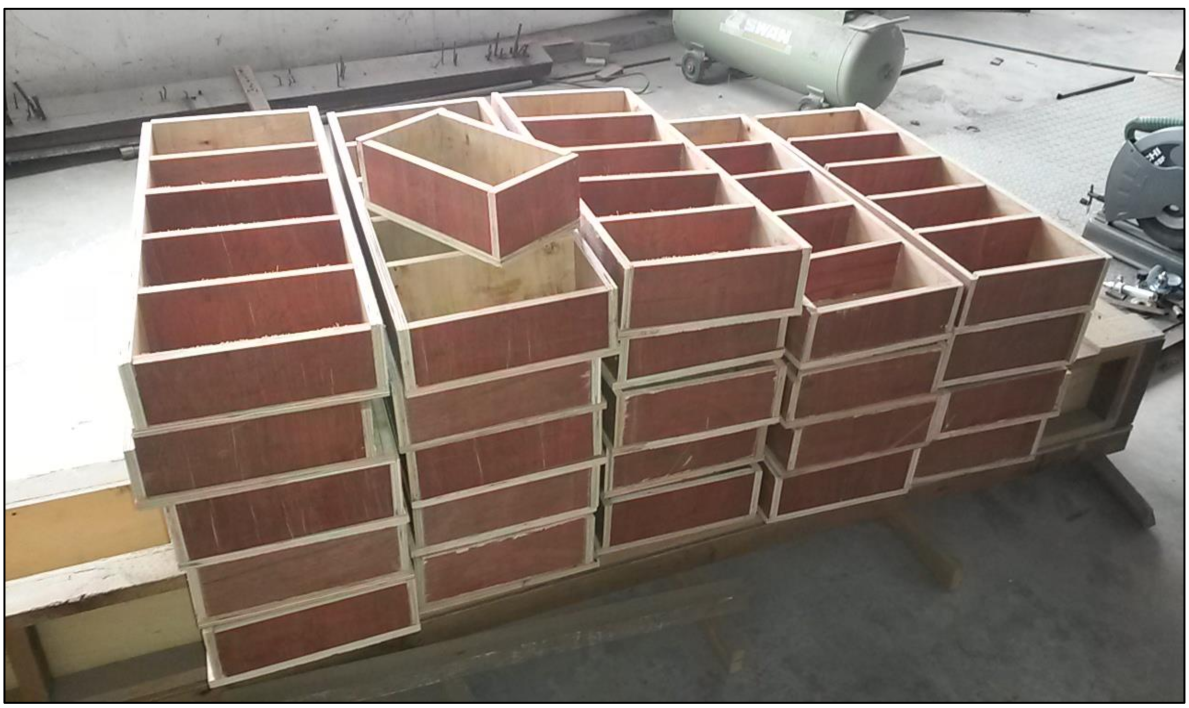


Figure 3.7: Completed bricks formwork.

The figure 3.7 above shows the completed brick formwork. Next, after the brick formwork is done, the brick manufacturing can be proceed. In brick mixing process, the material needed are Ordinary Portland Cement (OPC), sand, coconut shells, and water. Firstly, Ordinary Portland Cement, sand, coconut shell is weight according to the weight that has been calculated. Secondly, after all materials has been weight, in the tray mix Ordinary Portland cement and sand thoroughly. After cement and sand is mix thoroughly, make a hole in the center. Then, water is added into the mix and stir thoroughly until the mix is smooth.

The quantity of water is depending on the workability of the mix, where is to test the workability by take about a handful of mix and then pressed in our hand, if there is no water flow out from our hand, and then the workability is good. After that, coconut shell is added into the mixture. Next, brush the oil into the brick formwork to ease the process of removing bricks from formwork. Then, pour the mix into the formwork and compact thoroughly. Lastly, after three days the formwork can be opened and the bricks are let to be dried according to the curing time which is 3 days, 7 days, 14 days, and 28 days.

Figure 3.8: Fresh casting bricks

Figure 3.9: Bricks that has been removed from fromwork

3.5 THE PRINCIPLES OF PARAMETER USED

3.5.1 Compressive Strength

Next parameter is compressive strength. Compressive strength is one of the design properties of bricks, which can be determined by undergo a compression test. In general, the compressive strength is the capacity of material to withstand the applied loads or the maximum amount of compressive loads that material can bear before fracturing. The compressive strength was measured by using a compression testing machine. The compression test of brick is conducted by crushing them until they fail or crumble, then strength is noted, and then averages are taken. In this research, samples were cured for three, seven, fourteen, and twenty eight days, and crushed after curing process respectively to determine the compressive strength. The compression test was conducted according to the (ASTM C 39-03).

3.5.2 Density

The first parameter is the determination of density. Density or more precisely is a volumetric mass density, it can be defined as the measure of the heaviness of objects. As the percentage of waste material increased, it leads to the decrease in the density of samples, and increase in percentage of waste materials in sample reduced the strength and density of samples. In this research, the density of the sample may differ from the standard control due to the coconut shells. Density test was conducted according to ASTM C373 – 88.

3.5.3 Water Absorption Rate

Second parameter is water absorption rate. Water absorption rate test is to determine the proportion of water absorbed by bricks, it is a guide to the effects of exposure to water or humid conditions. Water absorption rate is important because, the bond between bricks and mortar is largely influenced by the capacity of bricks to absorb water. The water absorption test indicated water absorption was directly proportional to the green waste material content, it could be attributed to the high void and cellulose nature of the waste material. In addition, an increase in water absorption values is due to an increase in porous structure because of waste material added. In this research, water absorption test was conducted according to ASTM C373-88.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the results of the data are presented. All data from compressive strength, density and water absorption rate will be compared with the standard control. Then, all the differences will be discussed in order to determine the optimum ratio of cement sand brick.

4.2 COMPRESSIVE STRENGTH

The compression test is carried out at 3 days, 7 days, 14 days, and 28 days.

Table 4.2: Result of Compression Test

Compressive Strength (Mpa)				
Ratio / Days	Standard Control	1st Ratio (1: 5: 1) (CS1)	2nd Ratio (1: 4.5:1.5) (CS1.5)	3rd Ratio (1: 3: 3) (CS3)
3	7.180	5.382	4.863	3.195
7	7.364	6.979	5.542	4.826
14	7.785	7.269	6.095	5.570
28	8.330	7.932	7.213	6.357

Table 4.2 above shows a summary result of compression test including standard control, 1st ratio, 2nd ratio, and 3rd ratio.

4.2.1 Compressive Strength at Three Days

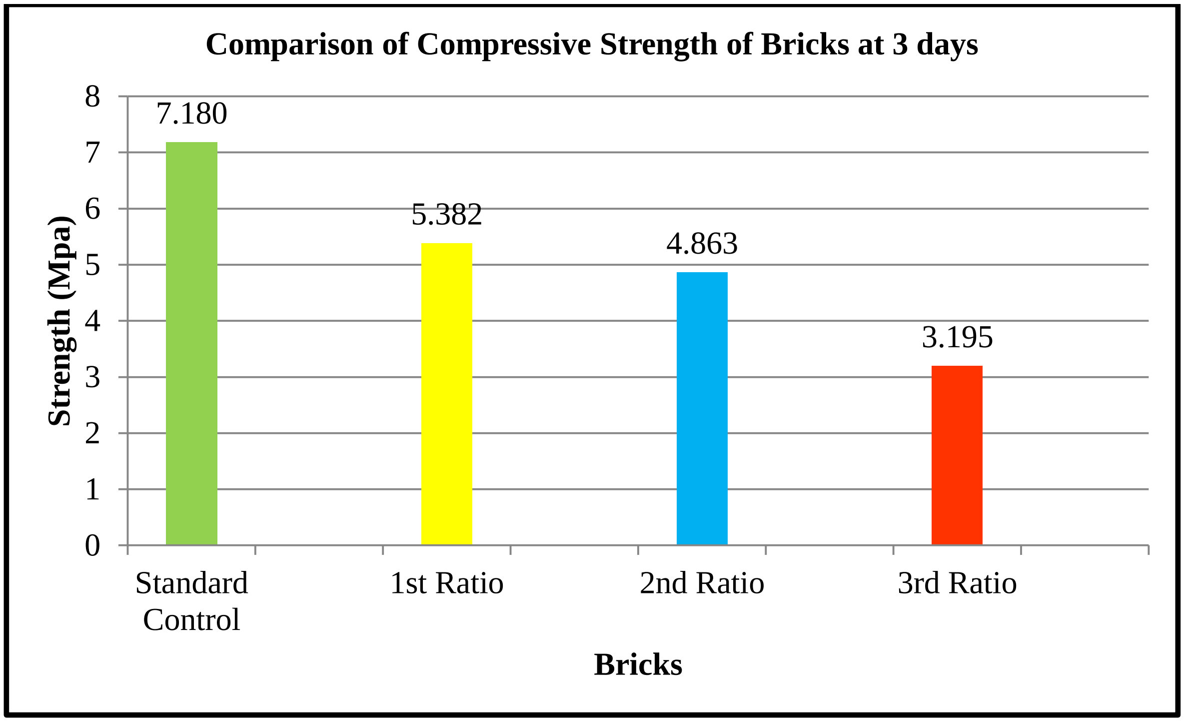


Figure 4.2.1: Compressive strength result at 3 days

From the figure 4.2.2 above, it shows the result of compressive strength at 3 days. Typically, at the age of 3 days, brick should achieve 50 % of its strength. From figure 4.3 below, the compressive strength of standard control is 7.180 Mpa. For the first ratio, the compressive strength at three days reduced to 5.382 Mpa. For the second ratio, the value of compressive strength at three days reduced to 4.863 Mpa. Lastly, the third ratio, the value of compressive strength at three days reduced to 3.195 Mpa. The result of compressive strength at three days shows that, the third ratio have the lowest strength compare to the first and second ratio. Meanwhile, the second ratio differ about 2 Mpa from the standard control.

4.2.2 Compressive Strength at Seven Days

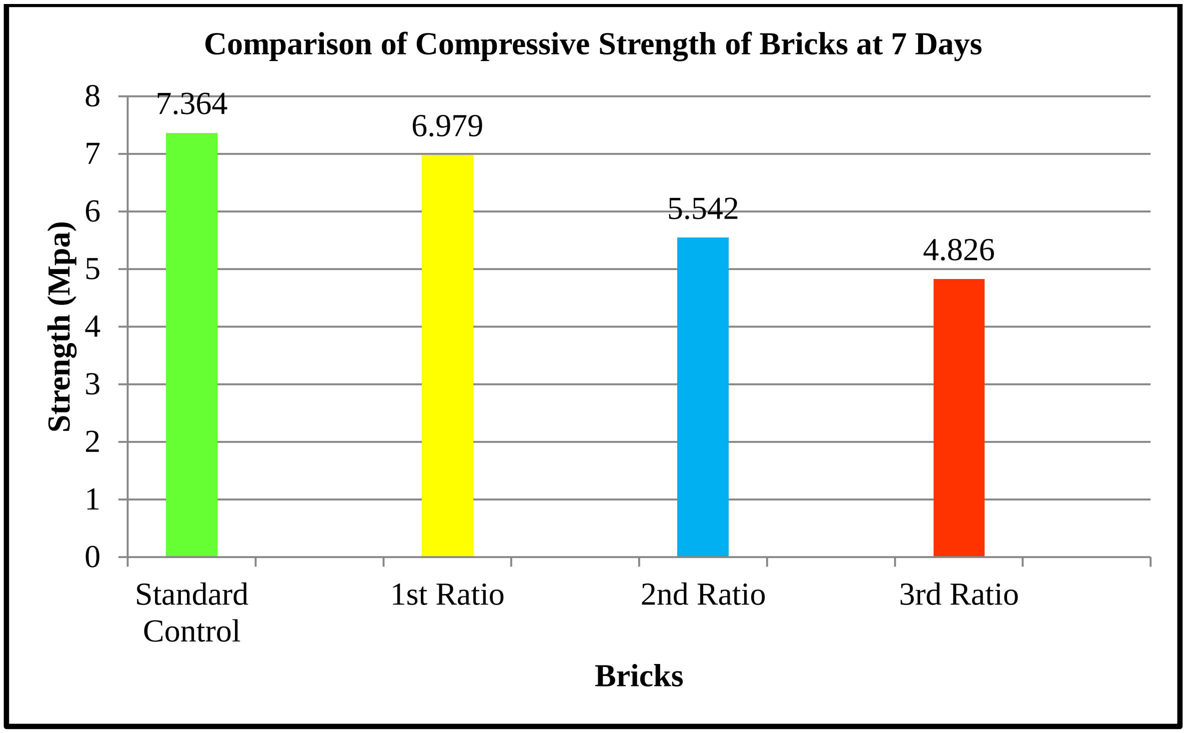


Figure 4.2.2: Compressive strength result at 7 days

The figure 4.2.3 above shows the compressive strength of brick at 7 days. Typically, at seven days, brick should achieve 75 % of its strength. From figure above, the compressive strength of standard control at seven days is 7.364 Mpa. For the first ratio, the compressive strength is 6.979 Mpa. The compressive strength of the second ratio is 5.542 Mpa, and for the third ratio is 4.826 Mpa. The compressive strength of the first ratio shows that, the strength only differ about 1 Mpa from the standard control, while the compressive strength of second ratio only differ about 2 Mpa from the standard control. Even though the value of compressive strength for the third ratio is 4.826 Mpa, but it has strength and quite high for the highest ratio of coconut shell.

4.2.3 Compressive Strength at Fourteen Days

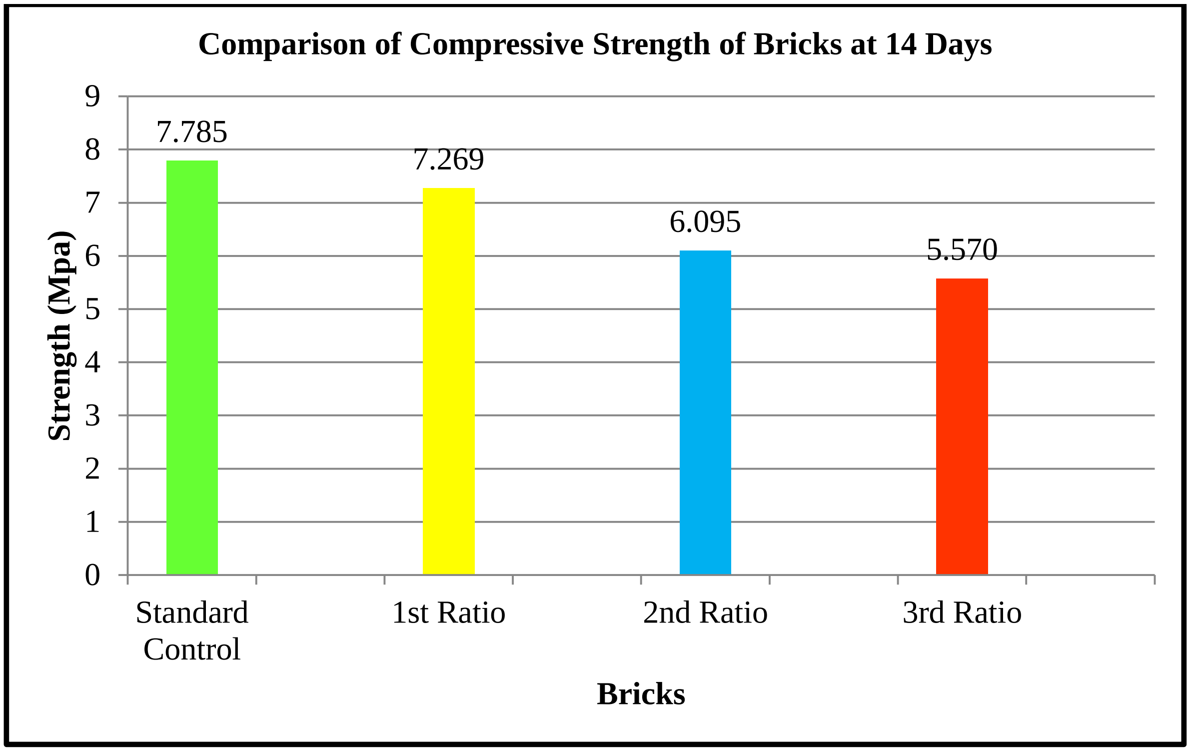


Figure 4.2.3: Compressive strength at 14 days

The figure 4.2.5 above shows the result of compressive strength of brick at 14 days. Typically, at fourteen days brick should achieve 94% to 95% of its strength. The compressive strength of the standard control at fourteen days is 7.785 Mpa. Meanwhile, the compressive strength of the first ratio is 7.269 Mpa. Then, the second ratio compressive strength is 6.095 Mpa and the third ratio is 5.570 Mpa. From the result, it shows that the value of compressive strength of standard control and the first ratio only differ about 0.5 Mpa, and the compressive strength of second and standard control differ about 1 Mpa.

4.2.4 Compressive Strength at Twenty-eight Days

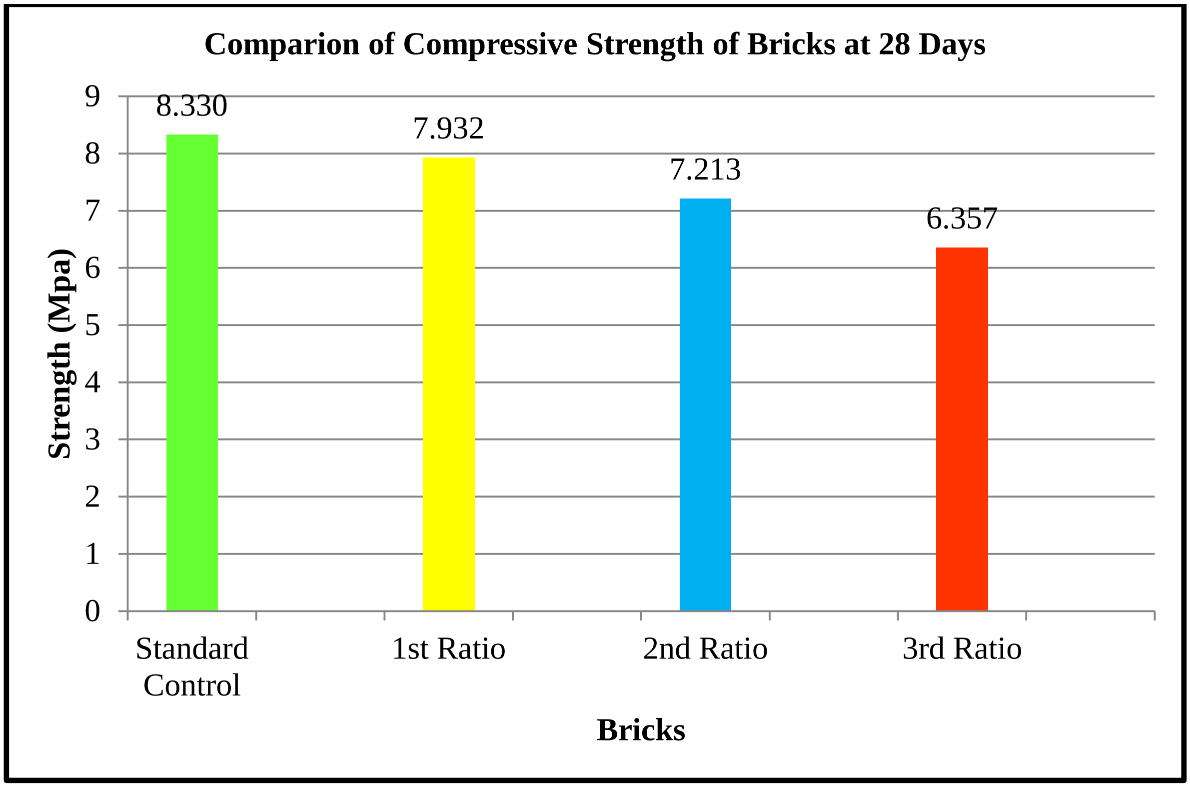
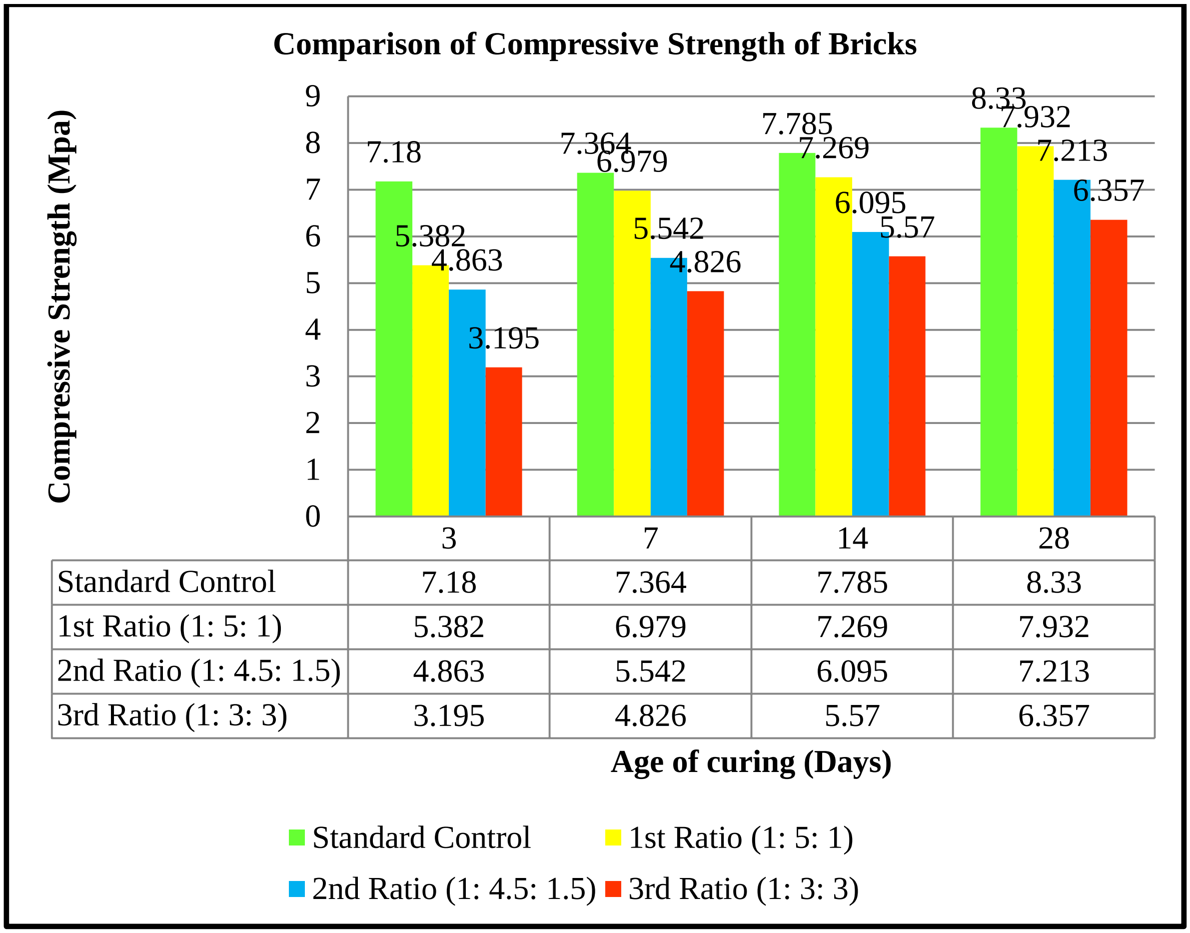


Figure 4.2.4: The compressive strength at 28 days

The figure 4.2.5 above shows the compressive strength at twenty-eight days. Typically, at twenty-eight days brick should achieve 99% to 100% of its strength. The compressive strength of standard control at twenty-eight days is 8.330 Mpa. For the first ratio, the compressive strength is 7.932 Mpa, the compressive strength of second ratio is 7.213 Mpa and the third ratio compressive strength is 6.357 Mpa. At twenty-eight days, brick gain more strength and the difference value of compressive strength of the standard control and the third ratio is only 2 Mpa. From this result, the third ratio starting to gain more strength compare to the compressive strength at three days. It is a good value, since the third ratio has the highest ratio of coconut shell.

4.2.5 Comparison of Compressive Strength of Bricks



	3	7	14	28
Standard Control	7.18	7.364	7.785	8.33
1st Ratio (1: 5: 1)	5.382	6.979	7.269	7.932
2nd Ratio (1: 4.5: 1.5)	4.863	5.542	6.095	7.213
3rd Ratio (1: 3: 3)	3.195	4.826	5.57	6.357

Figure 4.2.5: Comparison of Compressive Strength of Bricks

The figure 4.2.6 above shows the graph of the compressive strength of brick of the standard control, and the Coconut Shell Cement Sand Brick (CSCSB) for the first ratio, second ratio, and third ratio. The compressive strength of bricks does exceed 5 Mpa and above at fourteen days, it is satisfied with the Public Work Department, Standard Specification for Buildings Works, 2005, where is the compressive strength of brick should be 5.2 Mpa and above. Based on the result above, coconut shell does have strength, it is because at twenty-eight days, the difference between standard control and the others ratio is from 1 Mpa to 2 Mpa, From the compressive strength result, the value of compressive strength of CSCSB is decreasing as the ratio of coconut shell is increases, it is supported by Reddy, B.D. Jyothy, S.A. and Shaik, F. 2014, with addition of coconut shell, and the overall strength is decreased when compared with the control. Compressive strength is related to the cement content, it is due to the difficulty to determine how much mix water was absorbed by coconut shell, thus not available for reaction between coconut shells and cement, may contribute to the strength reduction.

Coconut shells exhibit high impact resistance, since CSCSB has high porosity, it will reduce the compressive strength. Porosity can be define as the CSCSB possess more porous space, this porous space will resulted a weak bond strength between CS, sand and cement. Even though a compaction is done properly during brick casting, since CS is in irregular shape, the void or porous space may produce during brick casting. Then, when CSCSB undergo a compression test, the strength will definitely drop. Another factor that may affect a compressive strength is curing process. In this research, an air curing was chosen since CSCSB is sensitive due to CS. Curing is a process where sample are protected from loss of moisture, and it is a process to increase compressive strength. Usually the heat of hydration may have reduced in water curing process, since water is available during curing process. In air curing, water is not available during curing process, a water absorbed by CS during brick casting would help the hydration process in CSCSB. This hydration will lead to the moisture loss in CSCSB, and the compressive strength will also affect. The compressive strength of CSCSB is develops in early stages, and compressive strength continues to increase with age.

Even though, the compressive strength of the brick do reduced when compared with the standard control, but the strength does passing the standard provide by Public Work Department. The compressive strength of the bricks is rising as the age of curing is increased, it is supported by Osei, D.Y. 2013, where the strength of the specimen is increased as it aged at all replacement of coconut shell. The maximum compressive strength of 8.330 Mpa is attained at 0 % of coconut shell, while the minimum strength of 6.357 Mpa is attained at the third ratio (1: 3: 3).

4.3 DENSITY

Meanwhile for density test, CSCSB undergo water curing for 7 days, since bricks consists green materials, it is more sensitive. A proper curing is done, where clean water is used. After 7 days of water curing, brick will undergo 7 days of oven dried. Then, dry weight of brick is obtained. Table 4.3 below shows the result of the density of the bricks.

Table 4.3: Result of Density of Bricks

Brick / Value	Standard Control	1st Ratio (CS1)	2nd Ratio (CS1.5)	3rd Ratio (CS3)
Density (kg/m^3)	1782.8	1612.42	1608.5	1455

4.3.1 Comparison of Density of Bricks

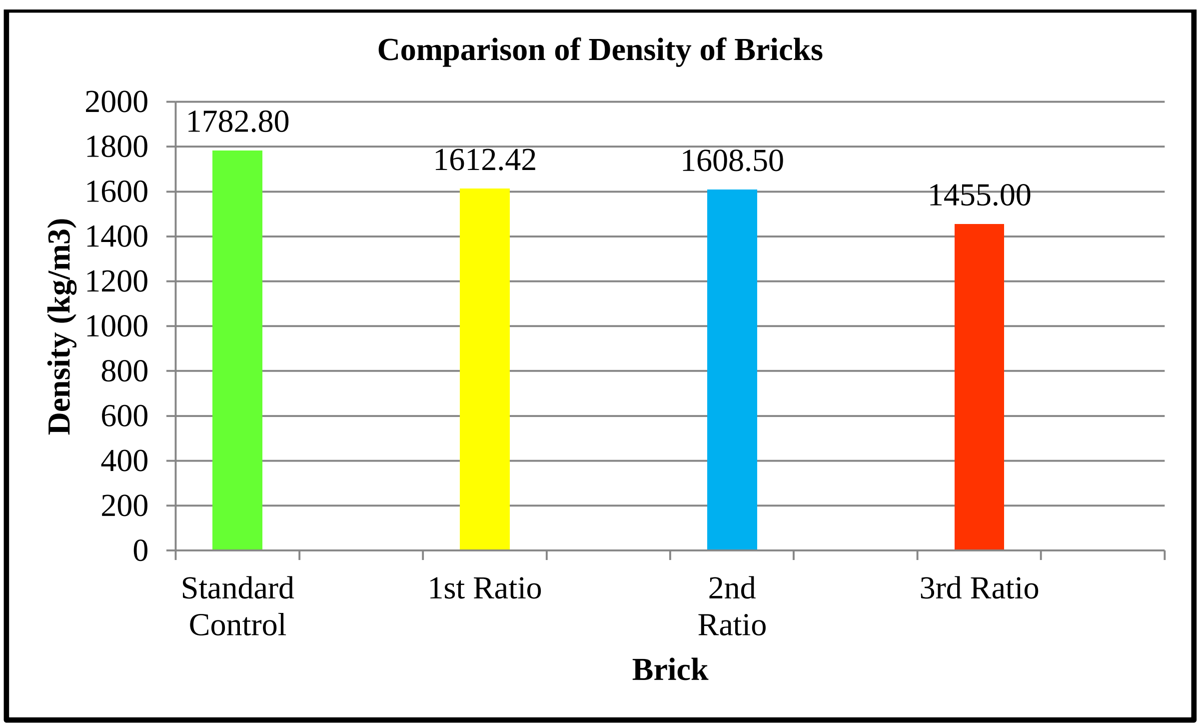


Figure 4.3.1: Comparison of Density of Brick.

Figure 4.3.2 above shows the comparison of density of bricks. From the graph above, the density of bricks of the standard control is 1782.80 kg/m^3, the first ratio (1: 5: 1) is 1612.42 kg/m^3, a second ratio (1: 4.5: 1.5) is 1608.50 kg/m^3, and the last ratio (1: 3: 3) is 1455.00 kg/m^3. The density of bricks is decreasing with the increasing of coconut shells, it is supported by Reddy, B.D. Jyothy, S.A. and Shaik, F. 2014, and the densities are decreased with increase in coconut shell. This decreased density is due to the fibrous nature of the coconut shell, where coconut shell has a low density. The density of bricks decreased to the 1455.00 kg/m^3 at the third ratio, bricks that have density below than 1500 kg/m^3 can be classified as the light weight bricks, according to the Gunasekaran, K. Kumar, P.S. and Laskhmipathy, K. 2011, the requirement of light weight can be fulfill by coconut shells.

The maximum density, 1782.80 kg/m^3 is attained at 0 % of coconut shells while the minimum density, 1455.00 kg/m^3 at the third ratio (1: 3: 3). It is seen that, the density of bricks is decreased as the coconut shells is increased thus can be categorized as a light weight and it is proven by Kambli, P.S. and Mathapati, S.R. 2014, a coconut shells is suitable as low strength-giving lightweight material.

4.4 WATER ABSORPTION RATE

Meanwhile for water absorption rate, CSCSB undergo water curing for 7 days, since bricks consists green materials, it is more sensitive during curing, so proper curing should be done where a clean water should be used. After undergo 7 days of water curing, brick will undergo 7 days of oven dried. Then, dry weight of brick is obtained. Then, after 7 days oven dried, bricks will be submerged for 24 hours, and then wet weight of brick after 24 hours is obtained. Table 4.4 below shows the result of water absorption rate of bricks.

Table 4.4: Result of Water Absorption Rate of Bricks

Brick / Value	Standard Control	1st Ratio (CS1)	2nd Ratio (CS1.5)	3rd Ratio (CS3)
Water Absorption Rate (%)	10.73	10.80	12.00	16.66

4.4.1 Comparison of Water Absorption Rate of Bricks

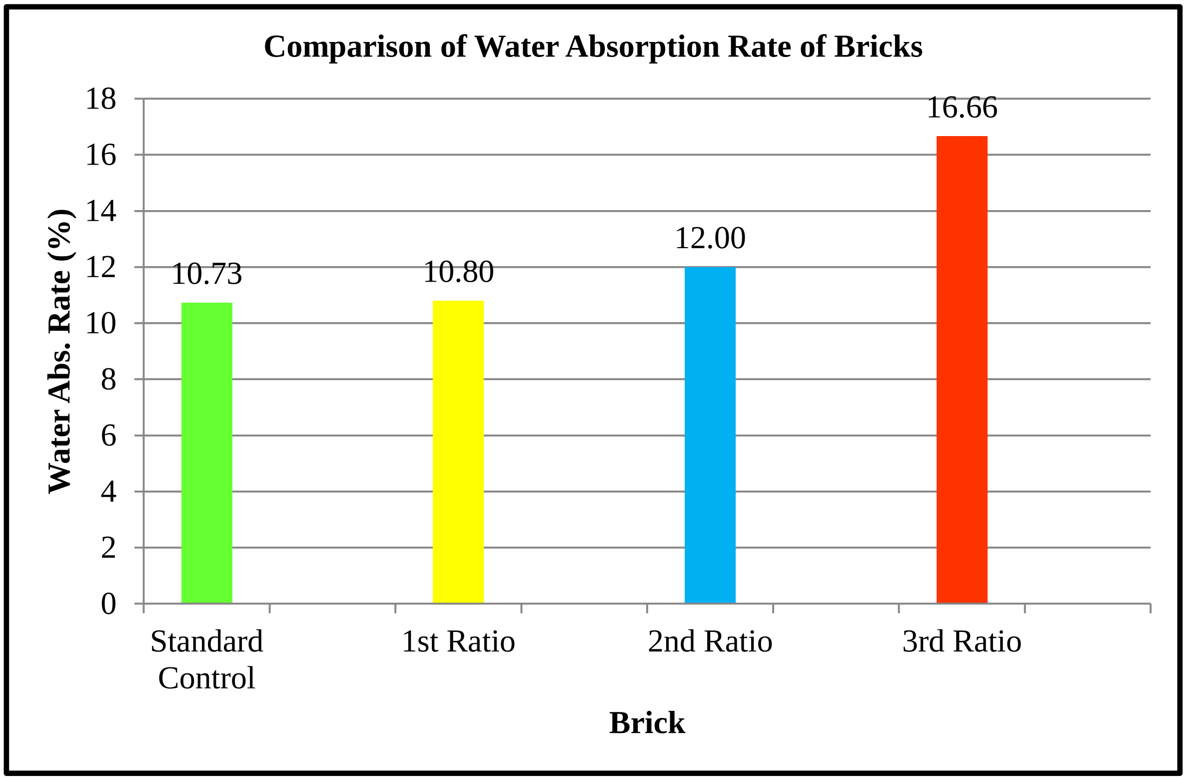


Figure 4.4.1: Comparison of Water Absorption Rate of Bricks

Figure 4.4.2 above shows the comparison of water absorption rate of bricks. From the graph above, the water absorption rate of the standard control is 10.73 %, and the CSCSB for the first ratio (1: 5: 1) is 10.80 %, the second ratio (1: 4.5: 1.5) is 12.00 %, and the third ratio is 16.66 %. From above value, the water absorption rate is increased with increased of coconut shells. The water absorption rate is increase due to the porous space of

CSCSB, where is water can get through the porous area in brick, since coconut shell is fibrous, thus make it more easier to absorb water. It is supported by Gunasekaran, K. Kumar, P.S. and Laskhmipathy, K. 2012, the pore structure in coconut shells behave like a reservoir and the water absorbed by the coconut shells during submerged is stored and the pore structures in the coconut shells acts as a reservoir. In addition, according to Arshad, M.S. and Pawade, P.Y. 2014, a coconut shells is porous and fibrous and it holds the moisture by provide a barrier for moisture to move towards the surface, it is due to the fibrous nature that provide high absorbing ability.

The maximum water absorption rate, 16.66 % is attained at the third ratio, since the third ratio has the highest ratio of coconut shells. While the minimum water absorption rate, 10.73 % is attained at 0 % of coconut shells. The water absorption rate of the first ratio suffer a little of water absorption rate since it has the smallest ratio of coconut shells. While, the second ratio increase a little bit compared to the first ratio, since the coconut shells ratio is increased.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As conclusion, all the objectives in this research is successfully completed and achieved. The characteristic of Coconut Shell Cement Sand Brick (CSCSB) including compressive strength, density and water absorption rate of all ratio where is (1:5:1), (1:4.5:1.5) and (1:3:3) were determined. Overall, the CSCSB can be classified as the green brick, since with addition of the coconut shells into the cement sand brick mixtures, and the characteristic of CSCSB is satisfied when compared it with standard control.

The strength of CSCSB do decreased with increasing of coconut shells, but still passing the standard strength provided by Public Work Department. From the first, second and third ratio, the highest compressive strength at twenty-eight days is 7.932 Mpa attained at first ratio, and the second highest compressive strength is 7.213 Mpa attained at the second ratio. Both ratio value of compressive strength does not highly differ with the standard control.

The density of CSCSB is decreased and it is an advantage since it has potential to be produced as light weight bricks. From the all ratio, the third ratios possess the lowest density, 1455 kg/m^3, compared to the first and second ratio. Meanwhile, the density of the first and second ratio is 1612.42 kg/m^3 and 1608.50 kg/m^3. In this research, the primary purposed of the study is to determine the optimum ratio of cement sand brick containing natural waste material. It is a one way to make use of the agricultural waste material automatically saves dumping spaces, since it is abundant and has a potential to be used in construction material (Osei, D.Y. 2013). A light weight bricks is not the primary purposed in this research, but with the increasing of coconut shell, the density tends to decreased.

Lastly the water absorption rate of CSCSB is increased due to the increasing of coconut shells. From all ratios, the highest water absorption rate is 16.66 %, attained at the third ratio, while the lowest water absorption rate is 10.80 %, attained at the first ratio. The water absorption rate of the second ratio is 12 %. The water absorption rate of the first and second ratio is higher a little bit compared with the standard control at 10.73 %. The value of water absorption rate from the three ratios is satisfied, generally the limit of water absorption rate is 20 %. All the three ratios does not exceed the general limit of water absorption rate. The water absorption rates of CSCSB tend to increase with the increasing of coconut shells. The third ratio has the highest of water absorption rate since it has the highest ratio of coconut shells.

As a result, the best optimum ratio from all ratios is the second ratio (1:4.5:1.5). The performance of the CSCSB of the second ratio is satisfied with the standard control. The value of compressive strength, density and water absorption rate of the CSCSB (1:4.5:1.5) is not highly differ with the standard control. The compressive strength of the CSCSB of the second ratio is also high, and differs a little with the first ratio.

It is also has a satisfied density, since the density of the second ratio is lower compared with the first ratio. Even though the third ratio possess the lowest density but the primary purposed of this research is not producing a light weight bricks. But it is an advantageous, since coconut shells have a potential to be produced as light weight bricks. In term of water absorption rate, the CSCSB of the second ratio also has a satisfied water absorption rate at 12 %. Even though it is higher than the water absorption rate of the first ratio at 10.80 %, but it is still not exceed the general limit of the water absorption rate.

5.2 RECOMMENDATION

As stated above in the conclusion, the best optimum ratio of Coconut Shell Cement Sand Bricks (CSCSB) is the second ratio (1:4.5:1.5), since the compressive strength, density and water absorption is satisfied with the standard control.

The compressive strength, density and water absorption rate of the third ratio (1:3:3) is still can be accepted, since CSCSB of the third ratio does has strength. Even though it is a little bit lower compared with the other ratios, but it is can be improved. Since a coconut shells has a potential in producing light weight bricks. To overcome the lower strength of the CSCSB that has a higher ratio of coconut shells is by adding admixture, in order to increase the strength of the CSCSB, and at the same time CSCSB can be classified as the light weight brick in future.

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APPENDIX A

Raw Data Obtained for Density

Standard Control

Sample	Dry Weight (g)
1	1760.69
2	1786.52
3	1801.19

First Ratio (CS1)

Sample	Dry Weight (g)
1	3118
2	3014
3	3103
4	3002
5	3081

Second Ratio (CS1.5)

Sample	Dry Weight (g)
1	2967.31
2	3117.28
3	3143.52
4	2938.95
5	3171.37

Third Ratio (CS3)

Sample	Dry Weight (g)
1	2700.48
2	2766.72
3	2833.48
4	2782.63
5	2738.34

APPENDIX A

Raw Data Obtained for Water Absorption Rate

Standard Control

Sample	Dry Weight (g)	Weight after Submerged for 24hr (g)
1	1753.66	1938.05
2	1747.89	1933.02
3	1731.75	1923.40

First Ratio (CS1)

Sample	Dry Weight (g)	Weight after Submerged for 24hr (g)
1	2844.90	3137.79
2	2816.30	3125.00
3	2732.65	3032.00
4	2836.21	3136.00
5	2849.50	3151.00

Second Ratio (CS1.5)

Sample	Dry Weight (g)	Weight after Submerged for 24hr (g)
1	3072.88	3405.88
2	3267.71	3601.56
3	3072.84	3553.83
4	3164.02	3502.01
5	3177.92	3522.34

Third Ratio (CS3)

Sample	Dry Weight (g)	Weight after Submerged for 24hr (g)
1	2884.25	3388.96
2	2885.49	3345.52
3	2852.19	3325.67
4	2821.49	3300.02
5	2846.24	3310.14

APPENDIX C

Raw Data Obtained for Compressive Strength

Standard Control

Sample / Days	3	7	14	28
1	7.109 Mpa	7.555 Mpa	7.769 Mpa	7.970 Mpa
2	7.723 Mpa	7.768 Mpa	7.986 Mpa	8.250 Mpa
3	6.709 Mpa	6.769 Mpa	7.601 Mpa	8.770 Mpa

First Ratio (CS1)

Sample / Days	3	7	14	28
1	5.027 Mpa	6.990 Mpa	7.280 Mpa	7.877 Mpa
2	6.43 Mpa	7.408 Mpa	7.340 Mpa	7.863 Mpa
3	5.229 Mpa	7.017 Mpa	7.257 Mpa	8.25 Mpa
4	5.164 Mpa	6.521 Mpa	7.349 Mpa	8.12 Mpa
5	5.061 Mpa	6.959 Mpa	7.119 Mpa	7.552 Mpa

Second Ratio (CS1.5)

Sample / Days	3	7	14	28
1	4.64 Mpa	5.39 Mpa	5.84 Mpa	7.085 Mpa
2	4.449 Mpa	5.63 Mpa	6.32 Mpa	7.490 Mpa
3	5.501 Mpa	5.56 Mpa	5.94 Mpa	6.650 Mpa
4	-	5.59 Mpa	6.28 Mpa	7.000 Mpa
5	-	-	-	7.841 Mpa

Third Ratio (CS3)

Sample / Days	3	7	14	28
1	3.796 Mpa	4.782 Mpa	5.47 Mpa	6.785 Mpa
2	3.079 Mpa	5.177 Mpa	5.745 Mpa	6.19 Mpa
3	3.115 Mpa	5.196 Mpa	5.873 Mpa	6.31 Mpa
4	3.087 Mpa	4.561 Mpa	5.318 Mpa	6.24 Mpa
5	2.717 Mpa	4.416 Mpa	5.446 Mpa	6.17 Mpa