A STUDY OF OPTIMUM CORN COB RATIO IN CEMENT SAND BRICK

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A STUDY OF OPTIMUM CORN COB RATIO IN CEMENT SAND BRICK

NUR HAFIZAH BINTI MOHD SHAFEE

Thesis submitted in fulfillment of the requirements for the award of the degree of
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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering.

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DEDICATION

To my beloved parents.

Mr.Mohd Shafee Seman and Mrs.Aslamiah Salleh.

Nothing in this world can compare to

your endless love, sacrifice and support from the day I was born until now.

To my brother.

Mr.Mohd Safwan Mohd Shafee.

Thanks a lot for your endless supports and helps.

To my one and only sister.

Ms.Halimaton Nadia Mohd Shafee

I adore you so much. You're such an inspiration.

To my three little baby brothers.

Mr.Mohd Zailan Mohd Shafee,

Mr.Mohd Nur Fahmi Mohd Shafee

Mr. Mohd Aliff Husaini Mohd Shafee.

Whatever you do, don't give up.

Not-to-forget, to my three-some sweet enemies.

Ms.Noorhaya Kasa.

Ms.Nurul Nadia Mohtar.

Ms.Khairunnisa Muhammad Husain.

I will cherish the moments we've shared together for the rest of my life.

Last but not least.

To myself.

Thank you for not giving up.

May Allah bless us always.

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ABSTRACT

This paper is an overview on the investigation of optimum corn cobs ratio in cement sand brick which gives the best properties of corn cob-cement sand brick (CCCSB) in terms of compressive strength, density and water absorption rate. The mix proportions cement:sand:corn cob used for this study were 1:5:1, 1:4.5:1.5 and 1:3:3. Every batching of mix proportions were measured by volume. A total of 90 CCCSB samples of size 225 mm x 113 mm x 75 mm were produced. For each mix proportion, 30 samples were prepared. There were 20 samples prepared for compression test, five samples prepared for density test and another five samples for water absorption test. The compression test results were taken at 3, 7, 14, and 28 days curing ages. The justification of choosing the optimum ratio of corn cobs inside the CCCSB were made based on the value of compressive strength, density, and water absorption rate obtained from compression test, density test and water absorption test respectively. The compressive strength of CCCSB is affected by corn cobs ratio inside it. This is due to the pozzolanic reaction which takes place after a few days inside the mixtures and increases with curing ages such that the strength of the mix proportion will increasing gradually. Meanwhile, the water absorption rate and the density are highly-related to each other which are also affected by the corn cobs ratio. The corn cob contains fibre which absorbs water excellently and is lightweight. When the corn cob ratio is high, the water absorption rate is also high as the increasing of pore spaces. This condition happened as the corn cobs will try to absorb the water and filling up the empty voids inside CCCSB. As the corn cob is considered as lightweight, the density of CCCSB will decrease as the corn cob ratio is increase. Therefore, based on the results, the optimum CC ratio in cement sand brick was ratio 1 from CCCSB mix proportion 1:5:1. This mix proportion has the highest compressive strength at 28 days which is 6.00 N/mm^2 exceeding the Public Work Department (PWD) standard of minimum permissible average compressive strength of $5.2 N/mm^2$, the highest density which is 1650.84 kg/m^3 and the lowest water absorption rate; 12.38% which falls under standard provided by ASTM C67 which is 20%.

ABSTRAK

Kertas kerja ini adalah gambaran keseluruhan mengenai ujikaji optima tongkol jagung di dalam bata simen yang akan memberi ciri-ciri bata simen-tongkol jagung yang terbaik dari segi kekuatan mampatan, ketumpatan dan kadar resapan air. Nisbah campuran simen:pasir:tongkol jagung yang digunakan untuk kajian ini adalah 1:5:1, 1:4.5:1.5, dan 1:3:3. Setiap bancuhan kadar campuran disukat melalui isipadu. Sejumlah 90 sampel bersaiz 225 mm x 113 mm x 75 mm telah dihasilkan. Bagi setiap kadar campuran, 30 sampel telah disediakan. Terdapat 20 sampel disediakan untuk ujian mampatan, lima sampel disediakan untuk ujian ketumpatan, dan lima lagi sampel disediakan untuk ujian penyerapan air. Keputusan ujian mampatan telah diambil pada 3, 7, 14 dan 28 hari mengikut umur perapian *(curing)*. Justifikasi pemilihan nisbah optima tongkol jagung di dalam bata simen dibuat berdasarkan nilai kekuatan mampatan, ketumpatan, dan kadar serapan air yang diperolehi melalui ujian mampatan, ujian ketumpatan dan ujian penyerapan air. Ujian mampatan bata simen dapat dipengaruhi oleh nisbah tongkol jagung yang berada di dalamnya. Hal ini kerana reaksi ‘pozzolanic’ yang berlaku di dalam campuran setelah beberapa hari, seiring dengan peningkatan umur perapian (*curing)* yang membuatkan kekuatan campuran meningkat. Sementara itu, kadar penyerapan air dan ketumpatan adalah sangat berkaitan antara satu sama lain yang juga dapat dipengaruhi oleh nisbah tongkol jagung yang terdapat di dalam campuran bata simen. Tongkol jagung mempunyai fiber yang meresap air dengan cemerlang dan ringan. Apabila nisbah tongkol jagung tinggi, kadar penyerapan air juga turut meningkat oleh kerana peningkatan ruang liang. Keadaan ini akan berlaku apabila tongkol jagung mencuba untuk menyerap air dan mengisi lompang kosong yang terdapat di dalam bata simen. Oleh kerana tongkol jagung tersebut adalah ringan, ketumpatan bata-simen tongkol jagung akan menurun apabila nisbah tongkol jagung meningkat. Oleh itu, berdasarkan keputusan ujian-ujian yang dilakukan, nisbah optima tongkol jagung di dalam bata simen adalah nisbah 1 daripada nisbah campuran 1:5:1. Nisbah campuran ini mempunyai kekuatan mampatan yang paling tinggi pada hari 28 iaitu 6.00 N/mm^2 melepasi standard Jabatan Kerja Raya (JKR) mengenai purata miminum kekuatan mampatan yang dibenarkan iaitu 5.2N/mm^2, ketumpatan yang paling tinggi iaitu 1650.84 kg/m^3 dan kadar penyerapan air yang paling rendah; 12.38% yang berada dibawah standard yang dibenarkan oleh ASTM C67 iaitu 20%.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	Britih Standard
BS EN	British Standard Europe Norm
CC	Corn Cob
CCCSB	Corn Cob Cement Sand Brick
DOA	Department of Agricultural of Malaysia
FAO	Food and Agriculture Organization
GBR	Green Building Rating
GGBFS	Grounf Granulated Blast Furnace Slag
MS	Malaysian Standard
PWD	Public Work Department

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In this modern world, the construction industry in Malaysia is growing hastily along with the increasing number of populations in this worldwide. In fact, according to Roskovic et al. (2005) and Shafigh et al. (2014), the world's population has been expected to surge from the present, six to nine billion by the year 2050 and by the end of century, the human's population will reach 11 billion. This will result in a significant increase in the demand for food, water, river sources, energy, common goods and services.

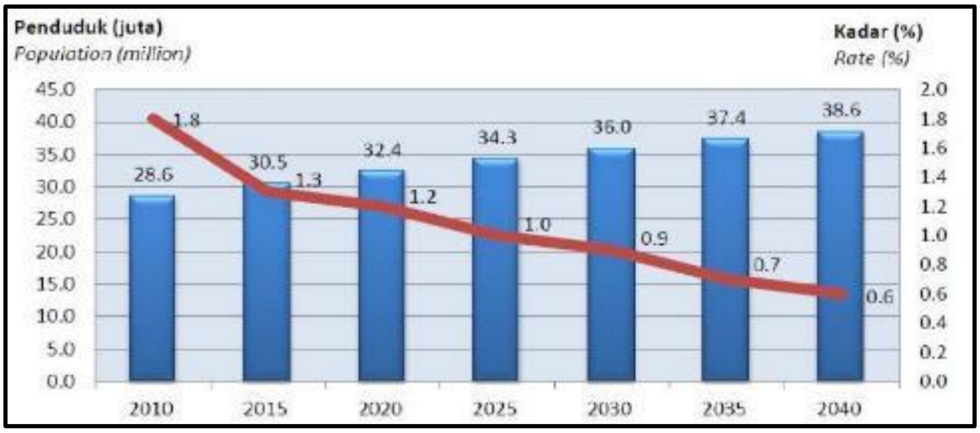

Figure 1.1: Chart of annual population growth rate in Malaysia year 2010 – 2040

Source: Department of Statistics, Malaysia

The government around the globe, especially in most developing countries such as Malaysia has been facing a crucial problem of housing demand which has increasing day by day. Hence, the growth of the industry of construction is also increasing, since the people want to fulfil their needs of living. In order to fulfil the demand of housing, the demand of materials of construction such as bricks by the constructors especially the contractors has also inflating.

Brick is one of the oldest material which is found has been used by human beings in the construction industry. In 14,000 B.C and earlier, bricks were found in the Egypt in the form of hand-moulded and sun-dried. The types of bricks are continuing to be varied in most countries and they are being used through ages because of their greater physical and engineering properties. In addition, bricks can be classified into various types and uses such as building brick or common brick, floor brick, paving brick and facing brick.

Brick is a construction material which can be categorized in term of 'masonry'. Generally, masonry is a combination of stone and brick units with mortar as their binding material. Masonry is primarily used in vertical structural elements such as building walls. High in proportion along with their height and length, let them acting to enclose or divide the area and supporting the loads from other elements.

Examples of masonry used in historical landmarks all around the world are including the Great Wall in China, the ruins of Greek and Roman, the pyramids in Egypt, the great cathedrals in Europe, the Taj Mahal in India, and many more. Hence, when shortage supplies of building materials, especially bricks happen, the construction industry will be in trouble. This is because masonry unit such as bricks still in popular use nowadays.

Figure 1.2: Masonry units used in construction site

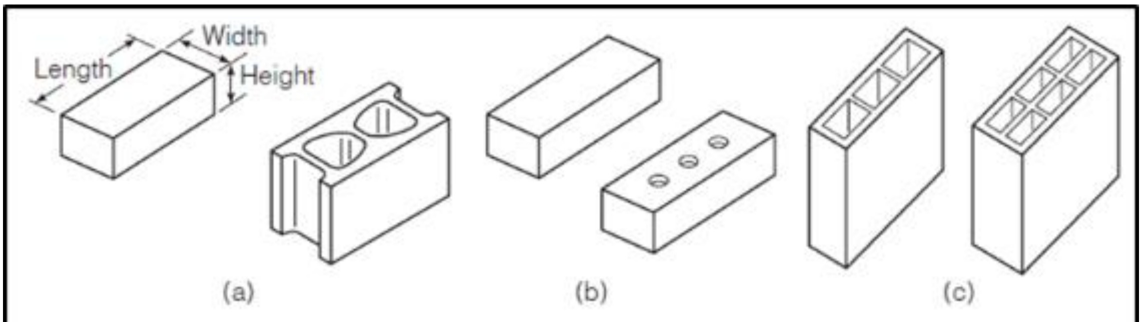

FIGURE 8.2 Examples of masonry units: (a) concrete masonry units, (b) clay bricks, and (c) structural clay tiles.

Figure 1.3: Illustration on various types of masonry units

Source : Mamlouk et al. (2011)

In the time being, the wastes produced by the Malaysian people day by day has overloaded and there are no enough areas or spaces available to dump all of these wastes. The wastes can either came from industrial or agricultural sectors. By finding out sustainable and affordable alternative, the overburdened wastes out there can be slowly eliminated. The people also has realized and becoming more concern about the issues relating with environment and demanding more practical resolutions. Table 1.1 below shows the total production of vegetables and cash crops in Malaysia in year 2013.

Table 1.1: Summary of data on vegetables and cash crops in Malaysia year 2013

Kategori Tanaman *Category of Crops*	Keluasan Bertanam *Planted area* (Ha)	Keluasan Berhasil *Harvested area* (Ha)	Pengeluaran *Production* (Mt)	Nilai Pengeluaran *Value of Production* (RM '000)	Purata Hasil Pengeluaran *Average Production* (Mt/Ha)
Sayuran *Vegetables*	67,777	65,155	1,434,200	4,773,989	22.01
Tanaman Ladang *Cash Crops*	19,269.86	18,142	237,892	640,790	13.11

Source: Department of Agriculture, Malaysia

Based on the table above, the total production of vegetables and cash crops is 1,672,092 metric tan (Mt). This number of production also means that the total wastes that will be withdrawn at some point later on. In the meantime, the research field has executed many researches on agricultural wastes for decades. They believed that the negative impacts of the disposal can be reduced by consumption of the wastes incorporation with the bricks. Moreover, in order to overcome this problem, a practical solution has been found by recycling these materials becoming into new materials or in another words, renewable materials of construction.

Therefore, many researchers have made their attempts in integrating the agricultural wastes into the production of bricks such as by using corn husk ash, corn cob ash, oil palm kernel, olive’s seed ash and many more. At the end of time, the outcome from those researches executed is the production of ‘green’ element in bricks. Green element can be defined as eco-friendly goods, services and practices which caused no harms on the environment. The following are the characteristics of green products; they are usually made from environmentally friendly materials, lessen the effect on environment, create a healthy environment, free from any harmful chemicals and compounds, and of course, have many purposes together with a longer shell life.

1.2 PROBLEM STATEMENT

Nowadays, the world's population has developing in a rapid growth. Thus, the production of wastes also increasing. Besides, since the population is increasing, the construction of buildings such as houses which are needed by human beings will also increasing. Along with this situation, the construction materials such as bricks will be highly demanded by contractors and will be produced in huge quantity by the suppliers. Generally, there are many types of bricks manufactured in the factories all around the world. The most common brick used in Malaysia is clay brick but its production is really limited since clay is hardly to get and it's quite expensive. Thus, cement sand bricks will be used to replace clay brick which is much way cheaper. The materials needed to form cement sand brick are sand, cement and water.

Besides, getting in line with the increase number of population, the vast production of wastes, either originally came from industrial or agricultural sectors are increasing day by day. These wastes should be considered to be reduced or removed completely since Malaysia doesn't have enough spaces to process them. Nonetheless, the researchers have gathered their consciences regarding this issue. Nowadays, they have executed researches on the agricultural by-product wastes such as corn husk ash, olive's seed, corn cobs, palm kernels, coconut shells, and many more into the bricks production and fortunately, they have found out some positive impacts on the bricks. Besides, if this huge production of wastes are not treated properly, they will give harms to the environment such as the emission of bad smells as they are mostly biodegradable. Besides, it is such a waste if these wastes are being ignored and thrown away as they have many potentials to be found. Hence, to reduce the risk of polluting the environment and human health, the invention of green brick is believed to be a practical solution to this problem.

It is necessary to find the best mix design of cement sand bricks. In order to produce the green element in the bricks, the corn cob wastes has been chosen. These corn cobs will be partially added into the cement sand bricks and will help the cements to bind with the sand. The standard ratio of cement and sand to be used in cement sand brick is 1:6. The manufacturing of green bricks in Malaysia has not been widened yet. This is because, the green bricks are only being established and used in the countries which produced vast crops of agriculture such as Africa, Portugal and Ghana. Hence, this research will emphasize on the optimum percentage of corn cob which will represent the best properties of green bricks.

1.3 OBJECTIVE OF STUDY

The objectives of this study are:

1. To determine the optimum percentages of corn cob used in cement sand bricks which will give the best properties.

2. To determine the characteristics of the cement sand brick with corn cob in terms of compressive strength, density, and water absorption.

1.4 SCOPE OF STUDY

Generally, this research is to comprehend the optimum percentage of corn cob used inside the green brick. The standard nominal size used for cement sand brick according to (Standard Specifications for Building Works 2005) are 225 mm length, 113 mm width and 75 mm height. Hence, in order to find out the optimum ratio of corn cobs inside the cement sand brick, ratio value of 1, 1.5 and 2 have been chosen. In other words, the ratio of cement sand brick mixture are 1:5:1, 1:4.5:1.5, and 1:4:2 (Cement:Sand:Corn Cob).

In order to obtain the characteristic of cement sand brick containing the corn cobs proportions, there are three parameters outlined for this research which are compressive strength, density and water absorption. Moreover, in order to get precise results, each ratio will have 30 samples, including 20 samples for compression test, five samples for density test and five samples for water absorption. Finally, the result of these three tests will be compared to the standard control result and the conclusion for this research will established.

1.5 SIGNIFICANT OF STUDY

This research will provide a significant attempt in order to produce the green brick element in cement sand brick by using corn cobs, wastes from corns. This will also help people to learn managing the wastes properly, neither agricultural wastes nor industrial wastes, by letting them know that certain wastes can use ‘3R’ concept; reduce, reuse and recycle again into a new product.

Besides, this study will become helpful to the government of Malaysia, especially in the construction industry since green brick is a new trend in Malaysia. As the green brick using wastes such as corn cob, the price for buying materials to produce common brick before this such as clay, cement and sand can be reduced too.

Furthermore, this study also pointing up the uses of wastes such as corn cob in order to help providing the people a healthy environment. Since the agricultural by-products being produced naturally, they are mostly biodegradable. Generally, biodegradable waste is a type of waste which can be broken down or decomposed naturally in a matter of times such as weeks or months. Primarily, this study will also help to spread the knowledge about the advantages and functions of green brick in construction industry of Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 BRICK

Brick is one of the oldest manufactured materials of building in worldwide. There are numerous types of brick, including clay brick, cement sand brick, concrete brick, sand lime brick and many more. Each types of brick have their own purposes, and also advantages and disadvantages.

As cited in (Wikipedia) webpage, brick which is generally used in masonry construction, a brick can be defined as a block or a single unit which comes from different types such as concrete material or sand and lime, clay-bearing soil, air-dried or fire-hardened. Generally, bricks will be produced in huge quantities and can be classified in many classes, materials, sizes, types and of course, vary with time period and region or area.

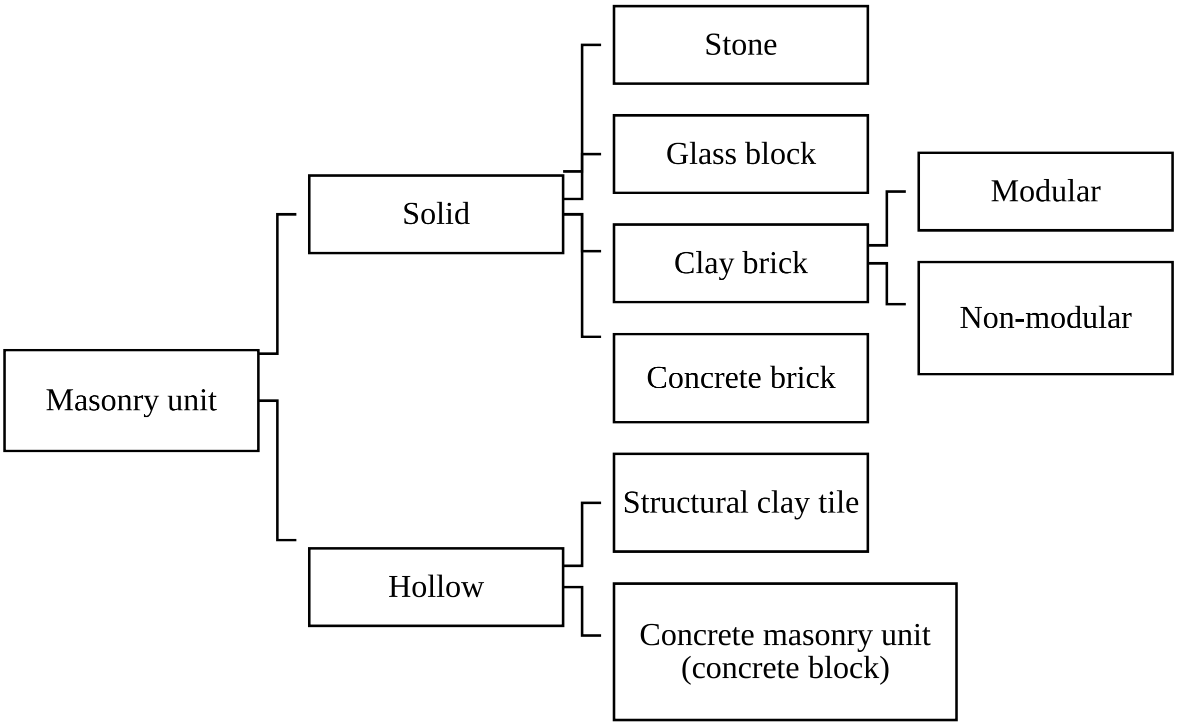

Figure 2.1: Types of masonry units

Source: Somayaji.S (2001)

Fired-bricks and non-fired bricks are commonly two basic categories of bricks which have their own purposes and advantages and disadvantages. Fired-bricks or so-called artificial stone have been used since 5000 B.C and they are the strongest and one of the longest-lasting materials of building. Meanwhile, it is a fact that air-dried bricks which also can be called as mudbricks are older in history compared to fired-bricks. They are added with additional ingredients such as straws or other mechanical binder in it.

As in construction site, the term of works related to bricks is brickwork. Brickwork is a type of work where the bricks are laid together in courses and patterns which be at variance known as bonds. Many type of mortars can be used prior to purposes of construction in order to ensure the bricks are laid together and stick together and eventually make a durable structure.

2.1.1 Cement Sand Bricks

Cement sand bricks can be categorized as concrete bricks. It is also can be known as sandcrete as the production of sandcrete is based from sand, water and cement (Ettu et al., 2013). Mamlouk et al. (2011) cited that the solid concrete units are generally called concrete bricks, whereas hollow units are known as concrete blocks, cinder blocks or hollow blocks. Generally, there are two types of concrete masonry units which are concrete building bricks and load-bearing concrete masonry units.

Cement sand bricks is in concrete building brick type. Somayaji.S (2001) defined that concrete building brick is a solid masonry unit which made from Portland cement, compatible lightweight or normal-weight aggregates, water and with or without the addition of other materials. In addition, this type of brick is completely solid, similar with the clay brick building's size and shape. Moreover, the compressive strength of this type of brick itself is considered as higher than the load-bearing masonry units. Meanwhile, Somayaji.S (2001) also defined a load-bearing concrete masonry unit as a solid or hollow masonry unit which made from water, cement, and mineral aggregates with or without the addition of other materials.

Figure 2.2: Example of cement sand brick

Source: Yue Whatt Trading Sdn. Bhd. Webpage (2015)

According to Standard Specification for Building Works (2005), cement sand brick should follow MS 27 in order to produce a good cement sand brick.

Table 2.1: Standard nominal size of cement sand brick by Public Work Department (PWD)

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

Source: Standard Specification for Building Works 2005.

In addition, as also stated in Standard Specification for Building Works 2005, the general composition of cement sand brick shall contain constant mixture sand and cement. In the ratio of six (6) parts of sand to one (1) bag of cement, the sand and cement shall be mixed together uniformly. The minimum permissible value of average compressive strength for cement sand brick shall be 5.2 N/mm^2. If the average compressive strength of bricks do not reach this value, the bricks should be rejected.

2.2 GREEN BRICK TECHNOLOGY

The rating of ‘green’ of building and infrastructure has become broadly spreading in the most recent years. In general, the current system of Green Building Rating (GBR) will evaluate the buildings’ sustainability conferring to several categories, by which the materials of construction used is one of the vital category. Carbon dioxide (CO_2) emission during the production of Portland cement is such an issue, along with the significant amount of water, aggregate, fillers and energy used for concrete production as well as waste of construction from their demolition. Thus, this has made the most important materials used in construction not as much of compatible with the environmental requirements of modern sustainability of construction industry (Shafigh et al.,2014).

Therefore, the usage of both agricultural and industrial waste components can be a revolution to produce new and more products which sustainable and environmental friendly. (Meyer.C, 2009) and (Federico & Chidiac, 2009) cited in their journal that industrial wastes such as silica fume, fly ash, recycled concrete, post-consumer glass, ground granulated blast furnace slag (GGBFS), recycled plastics and recycled tyres have been successfully used in concrete research conducted by researchers.

Also, in addition, latest studies have shown that the successful usage of agricultural solid wastes in both non-structural and structural concrete. Among the wastes used in previous researches for this purpose are such as tobacco wastes, pistachio shell, spent mushroom substrate, coconut shell, rice husk, oil palm shell or oil palm kernel and corn cob. The outcome results by using these wastes are such as energy saving, conservation of natural resources, cost reduction of construction materials, partial replacement of conventional aggregates and helps protecting the environment by lessening the disposal of wastes problem. (Shafigh et al.,2014)

Besides concrete, brick also has been revolutionized to become a part of green technology. Industrial wastes and agricultural wastes has also been used in previous researches such as waste paper inside the fire brick conducted by (Shibib, 2014), limestone dust and glass powder wastes as bricks' new material by (Turgut, 2007), adding spent coffee ground inside clay bricks by (Muñoz Velasco et al., 2015) and corn husk ash in soil bricks by (Yalley and Asiedu, 2013). Some of these wastes giving positive outcomes such as good thermal and mechanical properties in bricks research conducted by (Shibib, 2014) and reducing the sufficient amount of energy in producing brick research conducted by (Yalley and Asiedu, 2013) and so on.

2.2.1 Corn Wastes

In this research, corn cob will be used inside the cement sand brick. Raheem and Adesanya (2011) in their research stated that corn cob is a waste which comes from the agricultural waste product acquired by corn or maize. In year 2000, Food and Agriculture Organization (FAO) found that the production of corn over the whole world has reached 589 million tonnes.

On the other hand, according to statistic in year 2013 made by Department of Agricultural of Malaysia (DOA), corn or maize or its scientific name 'Zea Mays L.", has the second highest hectareage as well as the second highest production out of 10 types of other vegetables in Malaysia. Therefore, there are many corn cobs wastes have been produced in year 2013.

Table 2.2: Statistics of highest hectareage for 10 types of vegetables for the year 2013

Jenis Sayur *Types of Vegetables*	**Luas Berhasil** *Harvested area* **(Ha)**	**Pengeluaran** *Production* **(Mt)**	**Nilai Pengeluaran** *Value of Production* **(RM '000)**
Sawi *Brassica*	14,291.4	250,059.9	745,178
Jagung *Sweet Corn*	9,301.3	86,499.0	367,621
Kobis Bulat *Cabbage*	4,836.5	129,148.0	277,668
Timun *Cucumber*	4,834.1	119,857.1	299,643
Bayam *Spinach*	4,210.8	56,649.0	139,923
Cili *Chilly*	3,984.6	59,775.0	451,899
Kangkung *Water Spinach*	3,660.5	43,900.7	96,581
Ubi Kayu *Cassava*	3,651.9	62,842.8	84,838
Kacang Panjang *Long Bean*	3,551.3	53,264.7	174,176
Ubi Keledek *Sweet Potato*	2,971.0	50,747.5	96,928
Jumlah *Total*	**55,293.3**	**912,743.7**	**2,734,455**

Source: Department of Agriculture Malaysia (2013)

Department of Agriculture Malaysia (DOA, 2013) also has illustrated a pie chart diagram of the total production of 10 vegetables in Malaysia in year 2013 as follows.

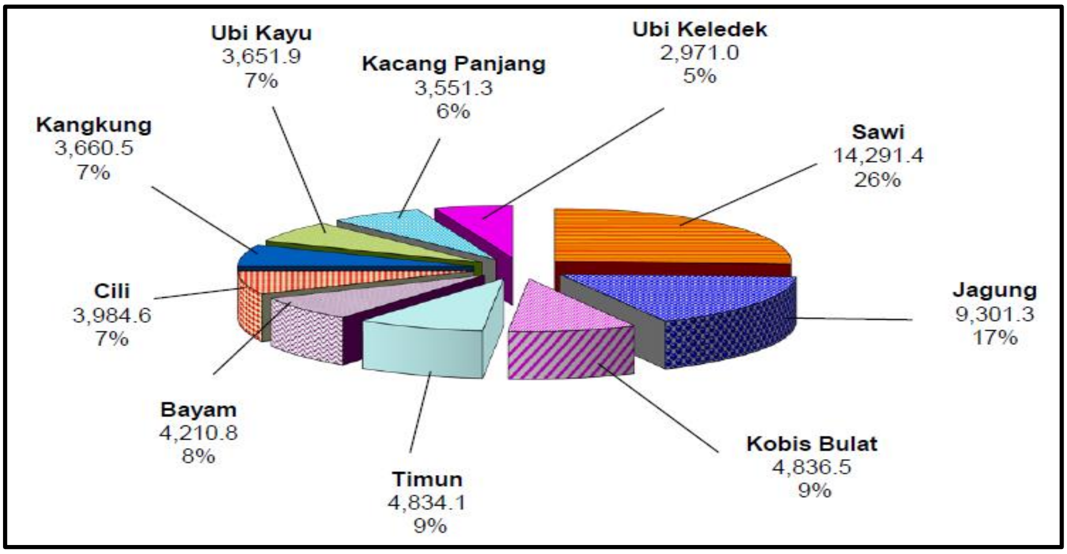

Figure 2.3: Pie chart of highest hectareage for 10 types of vegetables in year 2013

Source: Department of Agriculture Malaysia (2013)

2.3 CEMENT

According to (Somayaji, 2001), cement can be defined as any material that unites or binds; essentially like glue. In civil engineering, cement or cementitious materials always related to the ingredients in concrete, mortar and grout. Meanwhile, according to (BS EN197-1:2000), cement is a hydraulic binder; more specifically, an inorganic material which finely grounded. After it mixes with water, it will form a paste which then sets and hardens because of the hydration reactions and processes. Eventually, it will preserve stability and strength even under the water.

There are two types of cements which are commonly used in building construction; hydraulic and non-hydraulic cement. Hydraulic cement is actually the cement which turning into solid form where the water is present and resulting a material which does not degenerate in water. Meanwhile, non-hydraulic cement does not need water to transform into the solid form. There are some variations in both types of cement which are listed in table 2.3 below.

Table 2.3: Hydraulic and non-hydraulic cement

Material	**Cementitious Nature**
Portland cement	Hydraulic
Lime	Nonhydraulic
Gypsum	Nonhydraulic
Natural pozzolan	Pozzolanic or latent hydraulic
Fly ash	Pozzolanic or latent hydraulic
Silica fume	Latent hydraulic
Ground blast-furnace slag	Hydraulic or latent hydraulic

Source : Somayaji.S (2001)

In conjunctions, there are many types of Portland cement which has been designated by American Society for Testing and Materials (ASTM). Every construction project may use different type of cement, according to their own purposes of project.Each type of Portland cement has their own characteristics and applications as follows.

Table 2.4: Types of Portland cement according to ASTM C150

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

Table 2.4: Continued.

Type	Classification	Characteristics	Applications
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	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 : Somayaji.S (2001)

For this investigation, the type of cement to be used is ordinary Portland cement. Since this research focusing on the bricks which doesn't have any main priorities, Portland cement type I will be used. The cement is measured by volume batching with the aid of standard size of brick formwork.

2.4 SAND

According to (Standard Specification for Building Works 2005), the sand gradation for cement sand brick has to meet the terms with MS 29. In the context of MS 29, sand can be regarded as fine aggregate. When it is found compulsory, the fine aggregates should be washed and screened before being used. Besides, before using the sands, the sands should be graded before being analysed as designated in MS 30 and should be within the limits specified in the table 2.5 below.

Table 2.5: Grading of fine aggregate

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

Source: Standard Specifications for Building Works (2005)

After executing the sieve analysis test, the maximum size of sand should pass through the BS sieve of 4.8 mm mesh (Standard Specification for Building Works 2005). Hence, the effective size of fine aggregate for this research is the sand which successfully passing through the 4.82 mm sieve. The type of sand used for this research is river sand.

2.5 WATER

Water is one of the element of the cement sand brick. This is due to a condition where water is needed as the cement used; ordinary Portland cement which is hydraulic type. It will only become hardened and turned into solid when there is the presence of water. This process is called hydration.

Somayaji.S. (2001) cited that hydration is a continuous process under two conditions which are setting and hardening stages. Thus, according to (Standard Specification for Building Works 2005) the water used must comply with MS 28 which required the water to be clean and free from unwanted materials which will affect the properties and the results at the end of the testing.

In addition, either potable or non-potable water can be used for mixing as long as the water is clear from any contaminants. (Mamlouk et al., 2011). For this research, the water proportion to be used are based on the judgement during the mixing. Raheem,A.A (2006) in his research stated that the water will be judged as sufficient when there is no water flowing out from a quantity of caked mixture when pressing it between the palms.

2.6 CONCLUSION

As a conclusion, this research is proposing a green brick element in cement sand brick with addition of corn cob wastes into it. The nominal size of the corn cob cement sand brick (CCCSB) is 225 mm length, 113 mm width and 75 mm with three different mix proportions; 1:5:1, 1:4.5:1.5 and 1:3:3 (Cement:Sand:Corn cobs). Type of cement used is ordinary Portland cement (OPC) and clean water from pipe water will be used for mixing the CCCSB mixtures. The proportion of the water used for all mix design will judge as sufficient when there is no water flowing out from a quantity of caked mixture when pressing it between the palms. Meanwhile, the type of sand used is river sand.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this research is to study the properties of the cement sand brick being added with three different ratios of corn cob in terms of compressive strength, water absorption and density. There are three motives of this chapter which are to outline the research methodology of this study, clarify the calculations of the corn cob ratios, and explaining the parameter and testing conducted to achieve the objectives of this research.

This clause is an approach in order to ensure the research to achieve the objectives outlined earlier. It will also can assure the research to be conducted correctly according to the procedures of the testing. When the research being executed according to standard of procedure, the result outcome is highly believed to be correct and trusted. Therefore, by preparing research methodology in thesis, any issues or technical problems that can affect the final results of this research can be avoided in the future. The arrangement of this chapter will cover from the first step on executing the research until the final phase of the study. This will guarantee the exact way of the research to be leaded to and can be completed within the timeframe given.

3.2 CONCEPTUAL FRAMEWORK OF RESEARCH

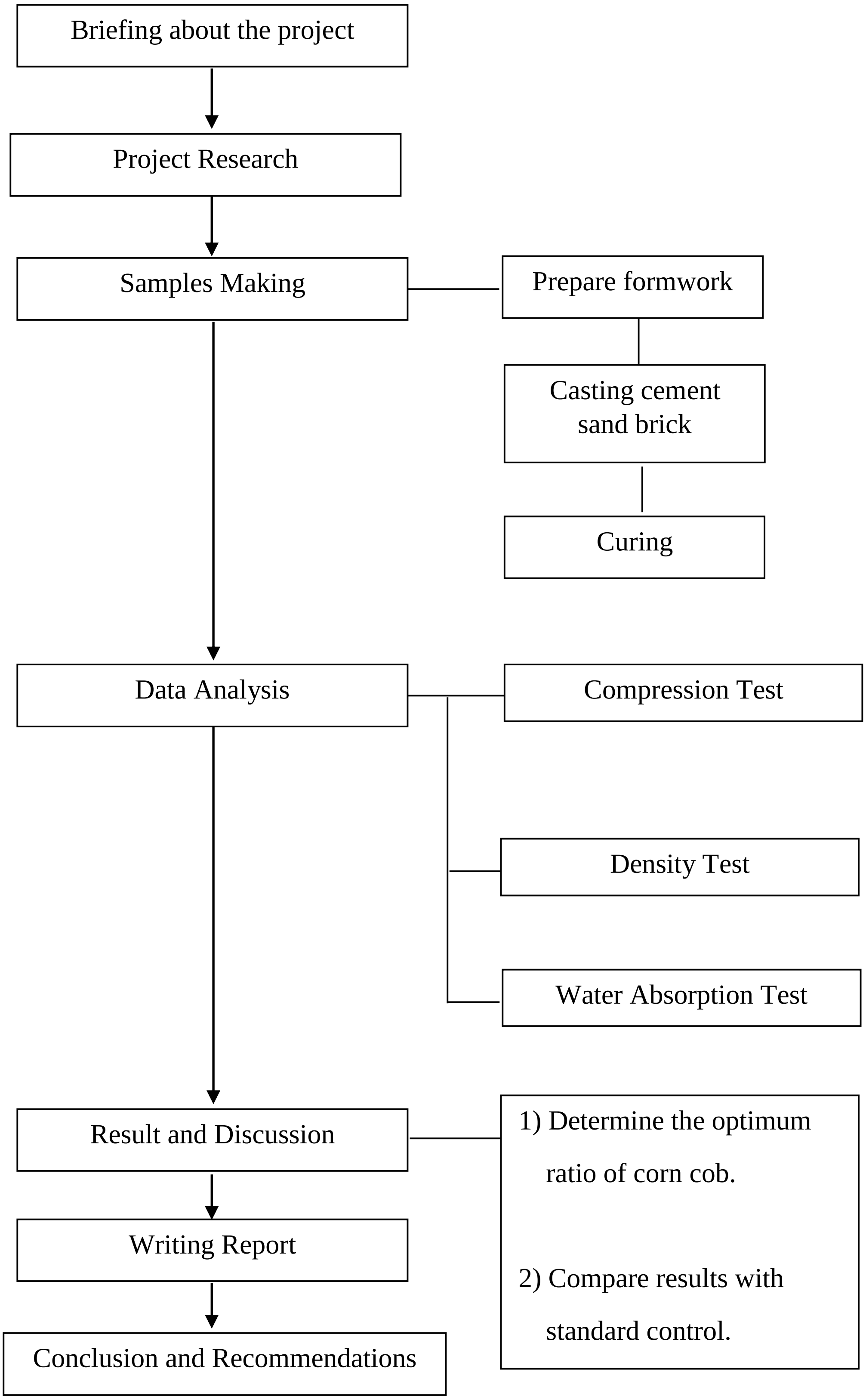

Figure 3.1: Conceptual framework of research.

3.3 BRICK DESIGN

Brick design is important since the brick is the main character in this research. The following sub-section will explain the details of the proposed cement sand brick used

3.3.1 Size of cement sand brick

Design of a cement sand brick will follow the standard nominal sizes provided by Public Work Department (PWD) in (Standard Specification for Building Works 2005).

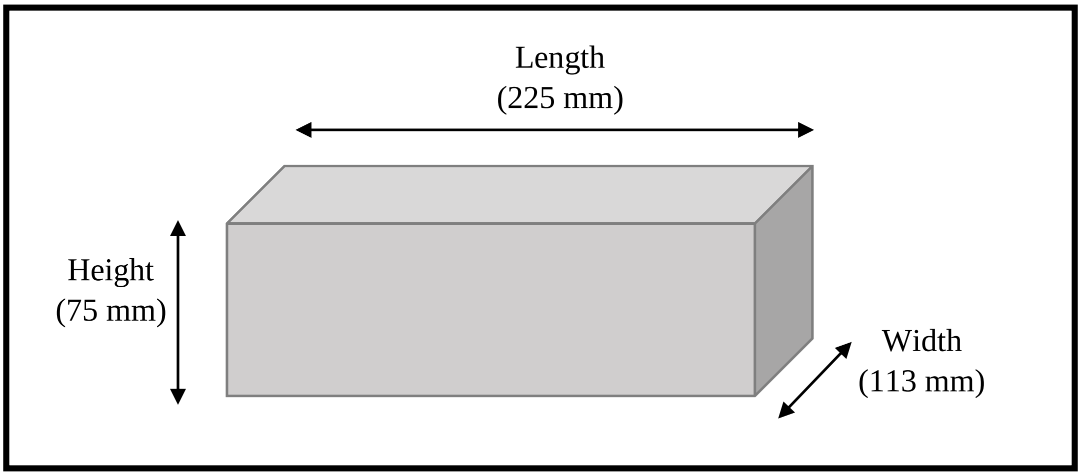

Figure 3.2: Size of a propose cement sand brick

3.3.2 Size of Formwork

In order to produce 90 samples of cement sand brick added with three ratios of corn cobs, the following size of formwork has been proposed. Formworks are made from plywood with 12 mm thickness and complying with MS 228. Each batching of cement sand bricks will use six formworks which at the end of mixing, the total of 30 samples of bricks will be obtained.

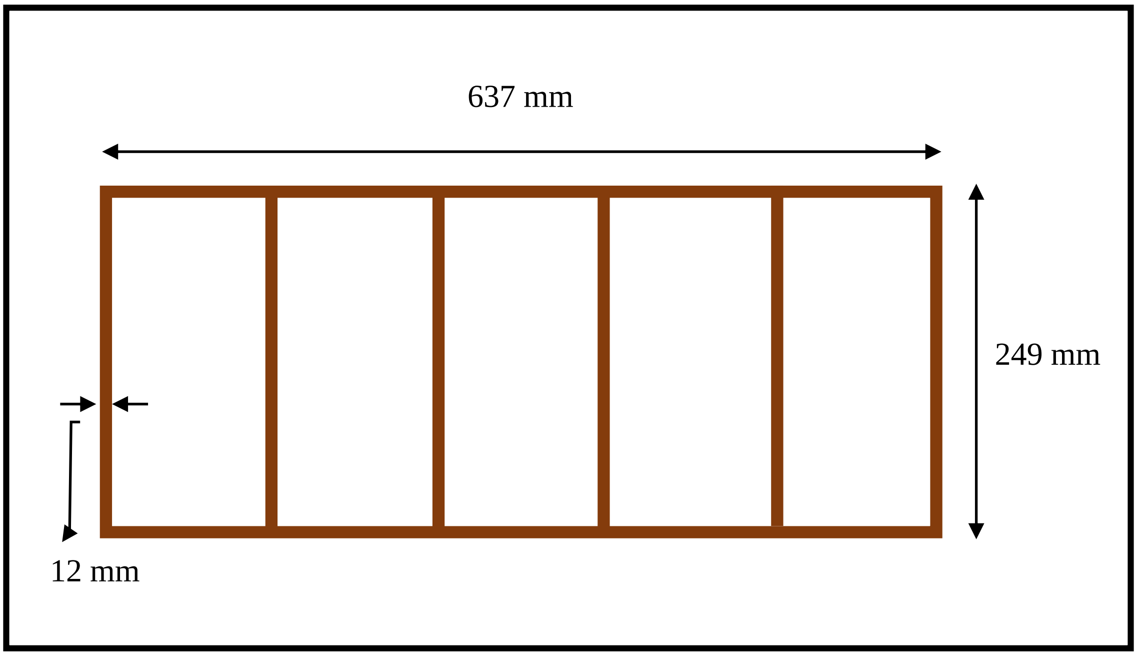

Figure 3.3: Plan layout of propose formwork

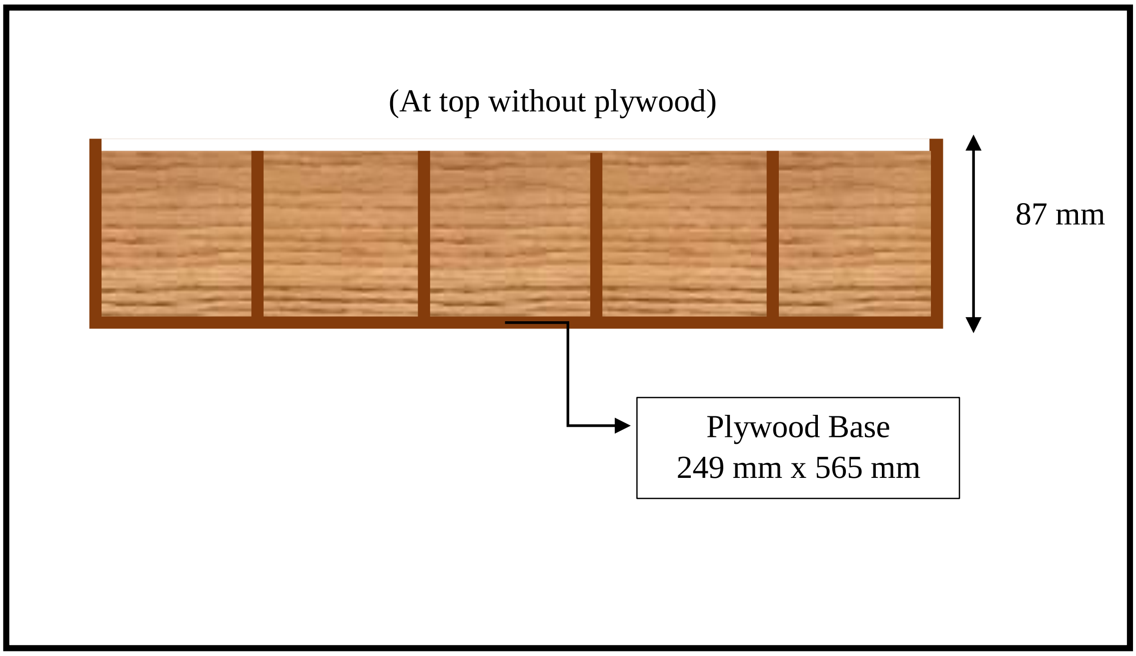

Figure 3.4: Front view of propose formwork

Figure 3.5: Finished formwork

3.4 CORN COB

Corn cobs will be obtained from a fresh corn juice seller in Kuala Berang, Terengganu. The corn cobs will only be chosen if they are in good condition and not rotten. After that, dry the corn cobs for 24 hours under the sunlight. The reason for why sunlight drying has been chosen over the oven drying because of the loss of moisture content of the corn cobs are low compare to the loss of moisture content due to oven drying. Besides, if the method of oven drying is used, the corn cobs will get rapidly burned and since the oven is already in high temperature, the corn cobs are tend to become ashes.

Since the purpose of this study is to find the optimum ratio of corn cobs in cement sand brick, thus the corn cobs themselves should be in the original shape and not in the form of ashes as to obtain the accurate results for the three testing parameters. Figure 3.6 shows the corn cob before and after the drying process.

Figure 3.6: Corn cobs after 24 hours drying under sunlight

After all the corn cobs have been dried out under the sunlight for 24 hours, the corn cobs will be cut into several parts for about 1 cm length. This is to ensure the smoothness of the cement sand brick to be casted later. Thus, the corn cobs in smaller size is chosen to be added into the cement sand brick rather than the bigger size.

Figure 3.7: Corn cob size which has been cut into 1 cm length

3.4.1 Calculation of corn cobs ratio

For this study, the mix proportions of cement: sand: corn cob used are 1:5:1, 1:4.5:1.5, and 1:3:3. The calculation of the three materials for each batches are as follows.

- Mould weigh = 706.83 g
- Mould + Sand weigh = 3847.01 g
- Sand weigh = 3140.18 g
- Mould + Cement weigh = 3513.81 g
- Cement = 2806.98 g
- Mould + Corn cob = 1041.55 g
- Corn cob = 334.72 g
- Volume of brick = 0.225 m x 0.113 mm x 0.075 mm
  = 0.0019 m^3
- For 1 m^3, (i)Cement = 2.807 kg / 0.0019 m^3
  = 1477.316 kg/m^3

  (ii)Sand = 3.141 kg / 0.0019 m^3

  = 1653.158 kg/m^3

  (iii)Corn cob = 0.335 kg / 0.0019 m^3

  = 176.316 kg/m^3
- For 30 samples of brick:

  Volume = 0.0019 m^3 x 30 samples

  = 0.057 m^3

  (1+6 = 7 ratio) = 0.057 m^3/7 ratio

  = 0.008143 m^3 per 1 ratio

(i) Cement: Sand: Corn cob (1:5:1)

Cement needed (kg) = $0.008143\ m^3 \times 1477.316\ kg/m^3 \times 1$ ratio

= 12.03 kg

Sand needed (kg) = $0.008143\ m^3 \times 1653.158\ kg/m^3 \times 5$ ratio

= 67.308 kg

Corn cob needed (kg) = $0.008143\ m^3 \times 176.316\ kg/m^3 \times 1$ ratio

= 1.435 kg

(ii) Cement: Sand: Corn cob (1:4.5:1.5)

Cement needed (kg) = $0.008143\ m^3 \times 1477.316\ kg/m^3 \times 1$ ratio

= 12.03 kg

Sand needed (kg) = $0.008143\ m^3 \times 1653.158\ kg/m^3 \times 4.5$ ratio

= 60.577 kg

Corn cob needed (kg) = $0.008143\ m^3 \times 176.316\ kg/m^3 \times 1.5$ ratio

= 2.154 kg

(iii) Cement: Sand: Corn cob (1:3:3)

Cement needed (kg) = 0.008143 m^3 x 1477.316 kg/m^3 x 1 ratio

= 12.03 kg

Sand needed (kg) = 0.008143 m^3 x 1653.158 kg/m^3 x 3 ratio

= 40.385 kg

Corn cob needed (kg) = 0.008143 m^3 x 176.316 kg/m^3 x 3 ratio

= 4.307 kg

Table 3.1: Summary of cement, sand and corn cob needed for three respective ratios

Ratio / Materials	1:5:1	1:4.5:1.5	1:3:3
Cement	12.03 kg	12.03 kg	12.03 kg
Sand	67.308 kg	60.577 kg	40.385 kg
Corn cobs	1.435 kg	2.154 kg	4.307 kg

3.5 METHODS OF BRICK CASTING

The method of casting corn cob-cement sand brick (CCCSB) used in this study is the same with the method of casting concrete. The usage of formwork is a must in order to acquire the bricks in a good shape. The initial start of this study is to prepare the formwork for CCCSB. The formwork is made from plywood with 12 mm thickness. It will be designed based on the nominal size of the brick. After executing some calculations on the formwork measurement, the proposed formwork sizes are 637 mm length, 249 mm width and 87 mm height. Six formworks will be prepared, where each formworks contain five bricks and the total bricks obtained at the end of the mixing process are 30 bricks.

Then, the cement, sand, and water will be mixed thoroughly according to the calculations of proportions which have been made. For this study, three mix designs will be used which are cement:sand:corn cob 1:5:1, 1:4.5:1.5, and 1:3:3. The water proportion will be judged as sufficient when there is no water flowing out from a quantity of caked mixture when pressing it between the palms. Thus, the workability of CCCSB is also assumed to be workable based on this finding.

After the mixing process, the mixture will be placed inside the formworks along with the corn cobs which will be placed by three layers at the center carefully. This is to avoid the corn cobs from being outside the bricks just because it will get the fungus to grow on it when the bricks are soaked inside the water. Unfortunately, when this condition happened, at the end of time, the results will be affected. Therefore, that’s why the precaution step will be taken when placing the corn cobs inside the mixture in order to ensure the results acquired at the end of the every testing are accurate.

Then, by letting them to harden for three days, the bricks will be demoulded from the formworks and the bricks will be prepared to undergo three testing which are compression test, density test and water absorption test. Type of curing used for this study is air-drying. Air-drying curing is applied since the water curing is not suitable for this research as the growth of fungus will increase on the corn cob surfaces. After the curing process, the bricks will be tested and the results will be recorded.

3.6 THE PRINCIPAL OF PARAMETER USED

For this study, three parameters which are compressive strength, density and water absorption will be find out by conducting compression test, density test and water absorption test on bricks respectively. These parameters are important because in the last part, the properties of CCCSB can be identified and the main objective, finding the optimum ratio of corn cobs inside can be acknowledged based on the results assimilated from these testing. All results will be compared with the standard control result.

3.6.1 Compressive strength

In the study of materials strength, compressive strength is the structure or material's capacity in resisting the applied loads which tend the structure or material itself to reduce size or fracture. This parameter is crucial as the compressive strength is the main key in designing a structure. In addition, the compressive strength of materials will increase at the later ages of curing. The curing ages of bricks used for this study is 3, 7, 14 and 28 days respectively. Thus, by conducting the compression test on CCCSB, the compressive strength of CCCSB can be identified and then be classified whether it has passing the standard permissible strength of the cement sand brick provided by PWD standard. This study will follow the standard procedure of ASTM C39-03 in order to attain correct and precise results.

3.6.2 Density

The density, or more specifically, can be defined as the volumetric mass density of a substance. The general formula of density is mass per unit volume. Different materials contain different density. Thus, the density of CCCSB will be different with every different mix design and of course, with the addition of different ratios of corn cobs inside them. The standard procedure of ASTM C373-88 will be followed.

3.6.3 Water absorption

Water absorption is the main factor which can affect the durability of bricks. The brick is said to be durable and more resistant towards environment when less water infiltrating the brick. The higher the water absorption, the lower the durability of the bricks. Thus, to determine the rate of water absorption of bricks, standard of procedure ASTM C67 will be used.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the results of compression test, density test, and water absorption test will be discussed. This phase is important as the discussions in here will verify whether the objectives of this study will be achieved or not.

4.2 COMPRESSION TEST RESULT

The samples compared for compression test are standard control bricks which made from cement:sand 1:6 mix design, three respective mix design of CCCSB which are cement:sand:corn cob 1:5:1 , 1:4.5:1.5, and 1:3:3. The table 4.1 below shows the overall results for compressive strength test for all brick samples.

Table 4:1: The compression test results for all samples

Mix Design / Days	Compressive Strength (N/mm^2 or MPa)			
	Standard Control (1:6)	**Mix proportion (1:5:1)**	**Mix proportion (1:4.5:1.5)**	**Mix proportions (1:3:3)**
3	7.180	2.824	2.639	0.959
7	7.364	3.363	3.108	2.260
14	7.785	5.022	4.422	4.219
28	8.330	6.000	5.085	4.953

In order to analyse the result easily, every compressive strength results of mix proportions will be compared to the standard control by days. The comparison will be illustrated in the following charts.

4.2.1 Comparison of 3 days compressive strength

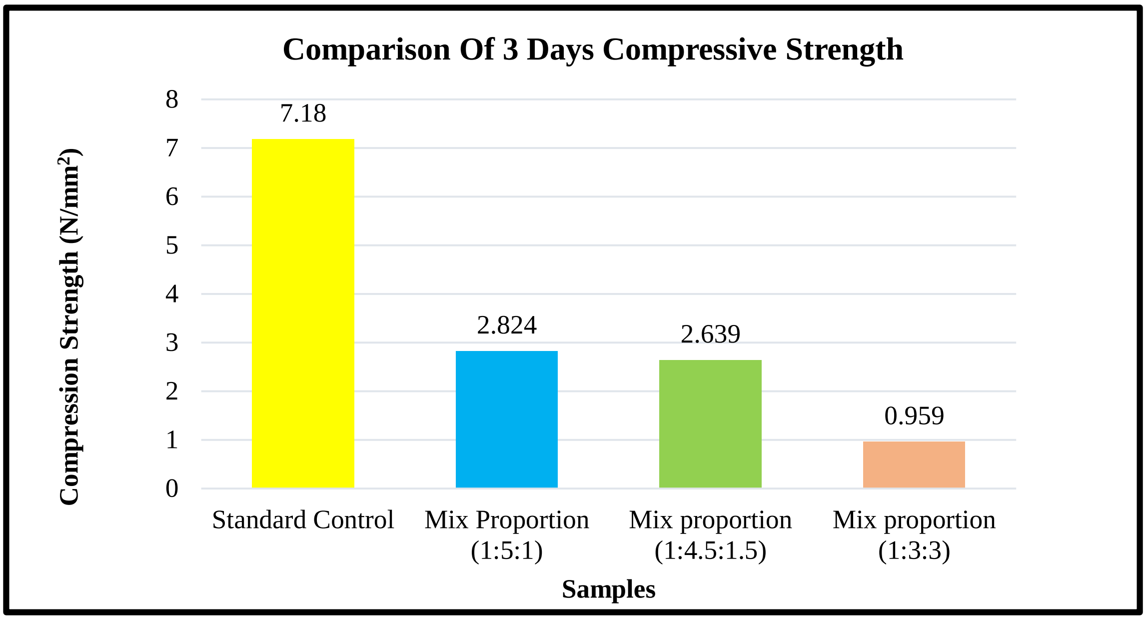

Figure 4.1: Comparison of 3 days compressive strength

Based on figure 4.1, the compressive strength of standard control is 7.18 N/mm^2, while mix proportion 1:5:1, mix proportion 1:4.5:1.5 and mix proportion 1:3:3 are 2.824 N/mm^2, 2.639 N/mm^2, and 0.959 N/mm^2 respectively. This shows that at the early ages of curing, the standard control has achieve the minimum permissible average compressive strength of cement sand brick, 5.2 N/mm^2 compare to the value of compressive strength of CCCSB at the early ages of curing which are still low.

Just like previous research by Adesanya,D.A and Raheem A.A (2009), they have proven that the compressive strength of corn cob ash-blended cement concrete is lower than the standard control at the early ages but increases significantly at later ages. The percentage of differences in value between standard control and these mix proportions are about 60 % till 87 %.

4.2.2 Comparison of 7 days compressive strength

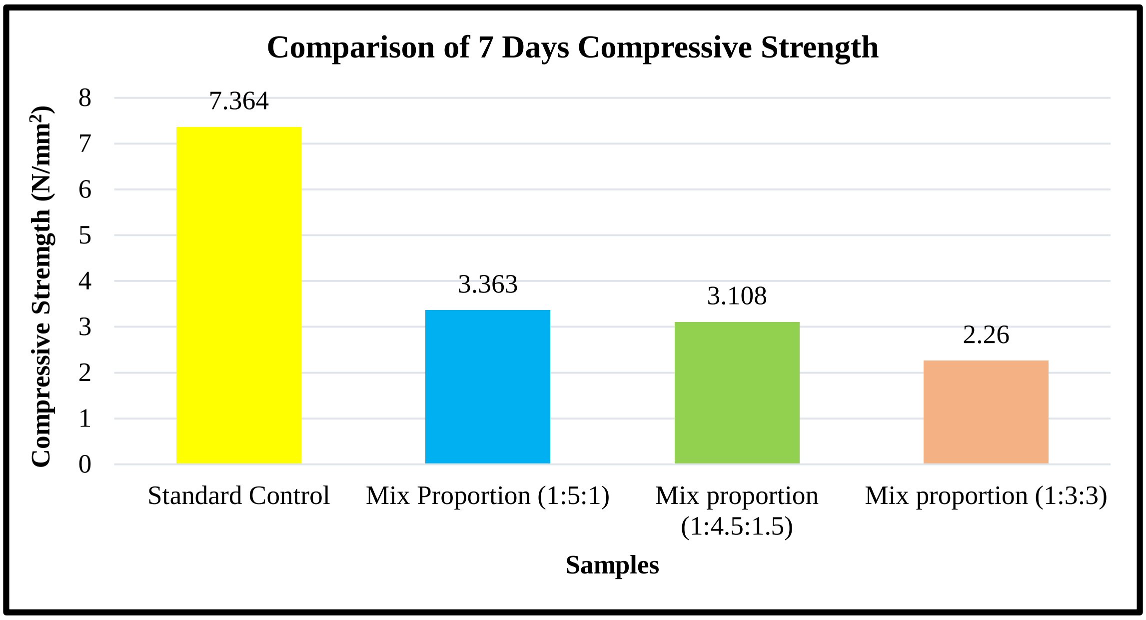

Figure 4.2: Comparison of 7 days compressive strength

From the observation of figure 4.2, the compressive strength of all samples has gradually increasing in day 7. The standard control and mix proportion 1:5:1, mix proportion 1:4.5:1.5 and mix proportion 1:3:3 samples have increased until 7.364 N/mm^2, 3.363 N/mm^2, 3.108 N/mm^2 and 2.260 N/mm^2 respectively. This shows that the addition of the corn cob ratio inside the cement sand brick will also increase the strength of the bricks and has been proven by previous researchers (Binici et.al, 2008). Besides, different ratios of corn cobs being put inside the cement sand brick will have slightly different compressive strength after curing.

4.2.3 Comparison of 14 days compressive strength

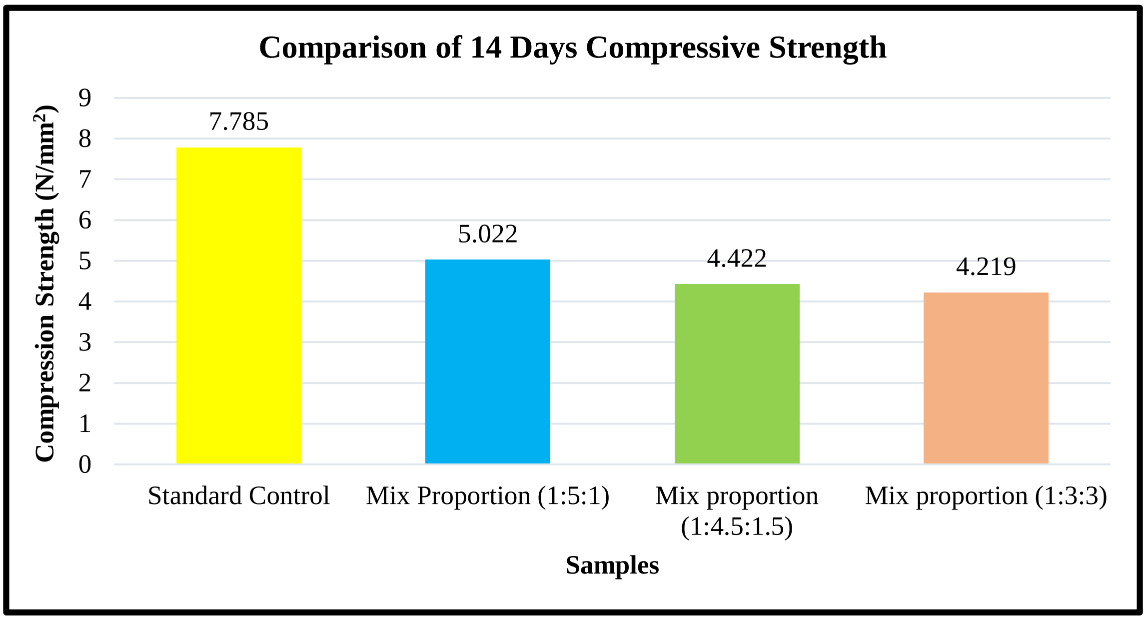

Figure 4.3: Compression of 14 days compressive strength

Based on the results in figure 4.3, the compressive strength of all samples have increasing gradually which the standard control strength has achieved 7.785 N/mm^2, the mix proportion 1:5:1 has achieved 5.022 N/mm^2, mix proportion 1:4.5:1.5 has achieved 4.422 N/mm^2 and mix proportion 1:3:3 has achieved 4.219 N/mm^2.

Therefore, in 14 days, the CCCSB mix proportion 1:5:1 has nearly achieved the permissible compressive strength of the standard cement sand brick with by difference only in 0.178 N/mm^2. In the meanwhile, for CCCSB mix proportion 1:4.5:1.5 and mix proportion 1:3:3, both have differences about 0.778 N/mm^2 and 0.981 N/mm^2. This differences show that when the ratio of corn cobs is high, the compressive strength of the CCCSB is decreasing.

4.2.4 Comparison of 28 days compressive strength

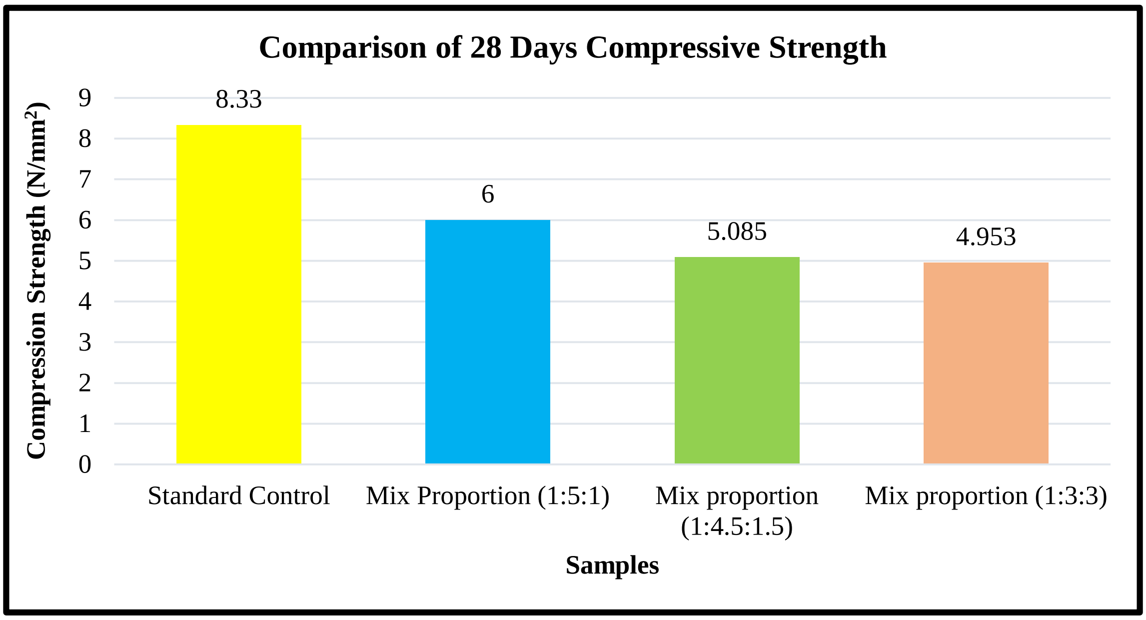

Figure 4.4: Comparison of 28 days compressive strength

Based on the figure 4.4, after the 28 days air curing, obviously the compressive strength for all standard controls and mix proportions samples are gradually increase. As the standard control and mix proportion 1:5:1 are exceeding the minimum permissible average compressive strength of cement sand brick with value of 8.330 N/mm^2 and 6.00 N/mm^2 respectively, while the mix proportion of 1:4.5:1.5 and mix proportion 1:3:3 nearly reach it with value of 5.085 N/mm^2 and 4.953 N/mm^2.

4.2.5 Comparison of standard control and different mix proportions in 3, 7, 14 and 28 days of curing ages.

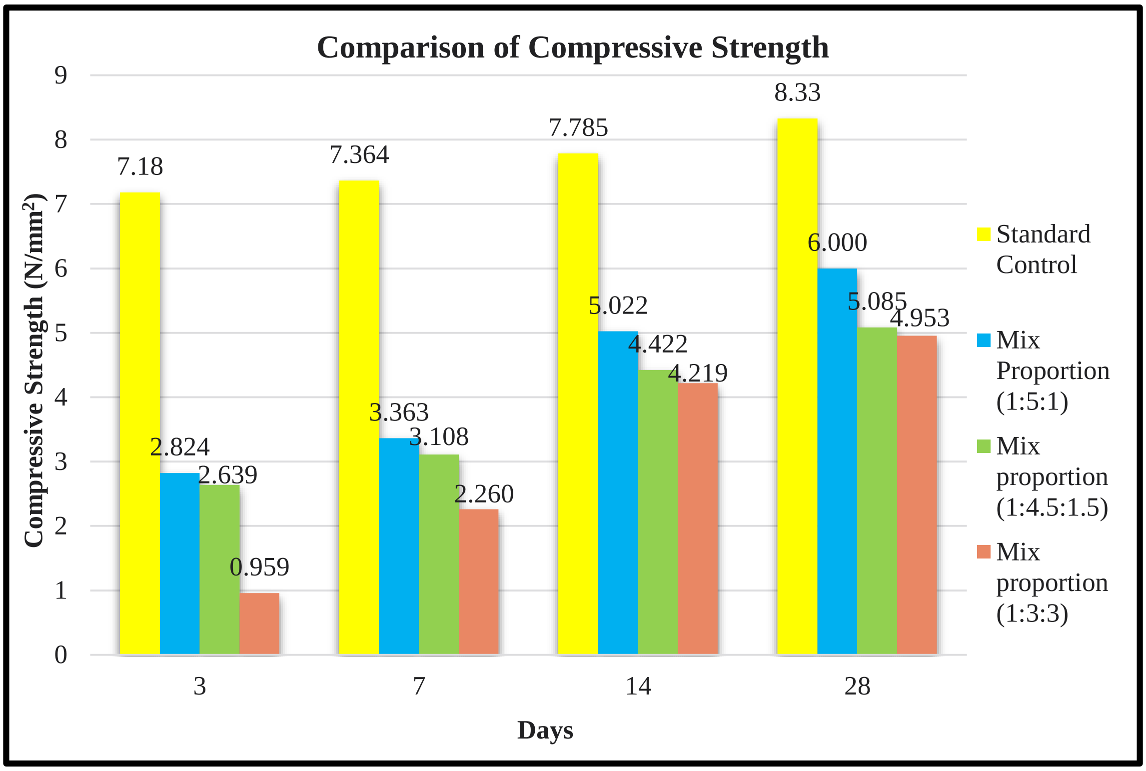

Figure 4.5: Comparison of compressive strength of all samples

Based on the figure 4.5 above, the compressive strength of CCCSB is clearly increasing with increasing of curing ages and with lower ratio of corn cobs. The standard control strength has increased gradually till the age of 28 days. However, compare to the CCCSB mix proportion of 1:5:1, 1:4.5:1.5 and 1:3:3, the strength value are very low at early ages of 3 and 7 days of hydration. The lowest compressive strength is at 3 days achieved by the CCCSB mix proportion 1:3:3 with value of 0.959 N/mm^2 while the highest compressive strength is achieved by CCCSB mix proportion 1:5:1 at 28 days which is 6.00 N/mm^2.

As proven by Ettu et. al (2013) in previous study, the low early strength could be because of the pozzolanic reaction which was not thus far significant at the hydration early ages. Moreover, the pozzolanic reaction will take place after a few days and increased with curing ages such that the strength of the mix proportion will increasing gradually by the ages of curing compare to the strength of standard control bricks.

4.3 DENSITY TEST

The density test result for standard control bricks and CCCSB bricks made from different proportions of corn cob is shown in table 4.2.

Table 4.2: The density test results for all samples

Samples	Standard Control	Mix proportion (1:5:1)	Mix proportion (1:4.5:1.5)	Mix proportion (1:3:3)
Density (kg/m^3)	1782.80	1650.84	1541.47	1404.66

Based on the table 4.2, the following charts in figure 4.6 have been created for making the result analysing process easier.

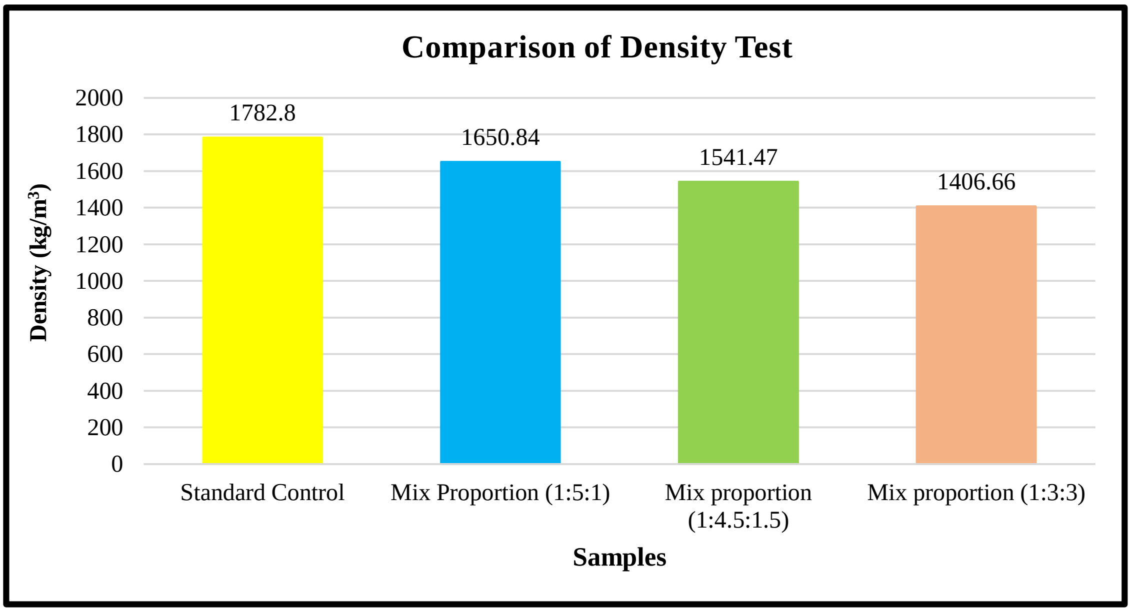

Figure 4.6: Comparison of density test of all samples

Based on the figure above, the density of the standard control is the highest which is 1782.80 kg/m^3, followed by the mix proportion 1:5:1, mix proportion 1:4.5:1.5 and mix proportion 1:3:3 which are 1650.84 kg/m^3, 1541.47 kg/m^3 and 1406.66 kg/m^3 respectively. This pattern of result has been proven by Olafusi et. al (2012) and Ganesh et. al (2015) in previous studies which are when the percentage of corn cob increase, the density of the bricks will decrease. This was due to the lightweight properties of the corn cob itself which made the CCCSB density decreased as the corn cobs ratio increased.

4.4 WATER ABSORPTION TEST

Lastly, the water absorption test result for standard control bricks and CCCSB bricks made from different proportions of corn cob is shown in table 4.3. This test is able to predict the durability of the brick, which is when the rate of water absorption is high, the brick will become less durable.

Table 4.3: The water absorption test results for all samples

Samples	**Standard Control**	**Mix Proportion (1:5:1)**	**Mix proportion (1:4.5:1.5)**	**Mix proportion (1:3:3)**
Water Absorption (%)	10.73	12.38	13.1	16.44

The chart in figure 4.7 below will ease the analysing process of the water absorption rate result.

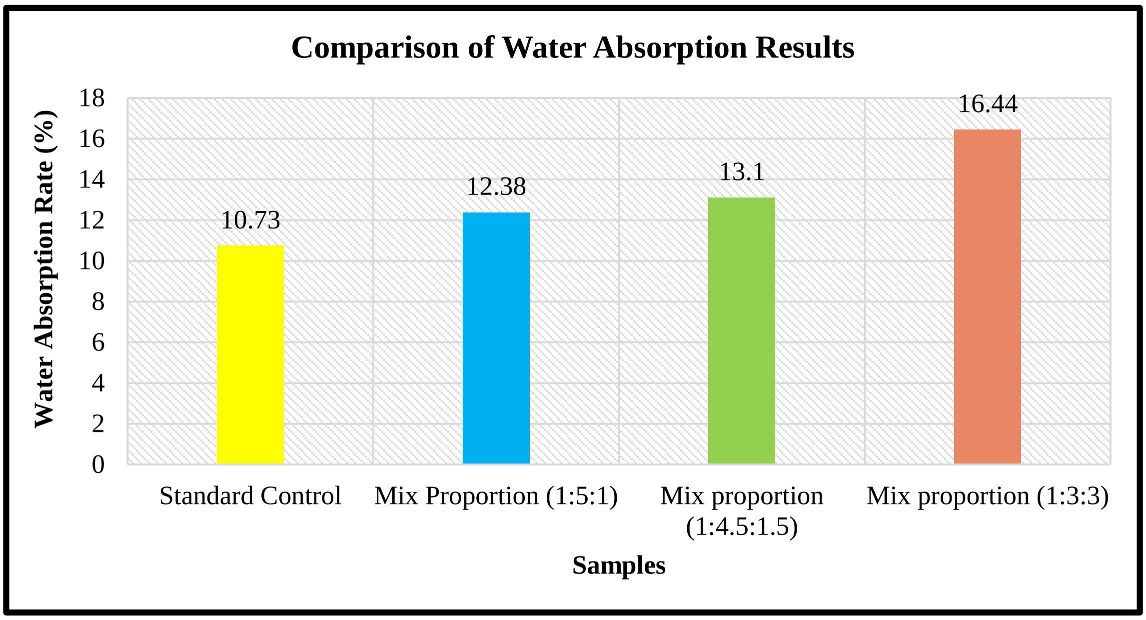

Figure 4.7: Comparison of water absorption test of all samples

Based on the observation, the lowest rate of water absorption is standard control bricks which is 10.73 %, followed by CCCSB mix proportion 1:5:1, CCCSB mix proportion 1:4.5:1.5 and CCCSB mix proportion 1:3:3 which are 12.38 %, 13.10 % and 16.44 % respectively. This means that the highest rate of water absorption is CCCSB mix proportion 1:3:3. Thus, CCCSB mix proportion 1:3:3 is the least durable compare to the other two mix proportions. According to Binici et. al (2008) proposed in previous study, the water absorption or the penetration of the water will reduced with the increased of the green material. This is due to the increasing of pore spaces of CCCSB as the corn cob is a fibre type, thereby it will absorb water and filling up the empty voids.

Hence, the relationship between water absorption and the durability of CCCSB is inversely proportional which is when the higher the rate of the water absorption, the lower the durability of the bricks and vice versa. In contrast, the relationship between the ratio of corn cobs inside the CCCSB and the water absorption rate is proportional since the higher the ratio of the corn cobs in CCCSB, the higher the rate of water absorption of CCCSB.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, the objectives in this research are well accomplished and completed. The optimum of the corn cob ratio in cement sand brick has been determined based on the comparison of results in terms of compressive strength, density and water absorption. Based on the discussion in previous chapter, the CCCSB mix proportion 1:5:1 has the highest compressive strength and density, but with the lowest water absorption rate. In the meanwhile, CCCSB mix proportion 1:4.5:1.5 has the overall average of compressive strength, density, and water absorption rate between CCCSB mix proportion 1:5:1 and CCCSB mix proportion 1:3:3. Lastly, the CCCSB mix proportion 1:3:3 can be assumed to have the lowest compressive strength and density, but with the highest water absorption rate. Therefore, the optimum ratio of corn cob used in cement sand bricks which will give the best properties among the three parameters is ratio 1 from CCCSB mix proportion 1:5:1.

This is because this mix proportion contributes the highest compressive strength at 28 days curing ages. According to PWD standard, the cement sand brick should have the minimum permissible average compressive strength of 5.2 N/mm^2. Generally, at 28 days curing ages, a concrete will achieve 100 % strength, and this theory is also applied for bricks. For that reason, this mix proportion has achieved 6.00 N/mm^2 at 28 days and has passing the minimum permissible average compressive strength provided by PWD.

Moreover, in terms of water absorption rate, it has the lowest value which is 12.38 % compare to the mix proportion 1:4.5:1.5, 13.10 % and mix proportion 1:3:3, 16.44 %. the brick is said to be durable if the water absorption rate is low. In addition, by comparing the standard provided by ASTM C67 which is the average of water absorption of the bricksamples should lower than 20 %. Obviously, the water absorption rate of mix proportion 1:5:1 is 12.38 % which is lower than 20 % and this condition has satisfied and verified the durability of the CCCSB.

However, for the density characteristic, CCCSB mix proportion 1:5:1 has the highest density which is 1650.84 kg/m^3. Unlike CCCSB mix proportion 1:4.5:1.5 and CCCSB mix proportion 1:3:3, these mix proportions have low densities which are 1514.7 kg/m^3 and 1406.66 kg/m^3 respectively. Generally, the parameter of density is actually to show the degree of porosity in a material. When the density is high, it means that the degree of porosity is low and vice versa. For this study, CCCSB mix proportion 1:5:1 possess the highest density as the ratio of corn cob is low. Thus, from here, it can be concluded that when corn cob ratio is low, the density and the degree of porosity will become high.

5.2 RECOMMENDATION

Based on the results obtained from the various tests carried out in this research, the following recommendations can be made in order to improve the accuracy and the precision of the results such as further studies should be carried out with a longer curing ages of 90 days until 120 days as to obtain the higher compressive strength of CCCSB.

In addition, the usage of admixtures also can be considered such as the use of accelerator can obtain a greater strength at early ages of curing, while with the plasticizer, high strength can be obtained both at early and later curing ages or by using the water reducing and retarder, the greater strength at later curing ages alone can be achieved (Raheem, et. al, 2010).

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APPENDIX A

Raw Data of Compression Test Results

Standard Control

Day/Sample	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

Ratio 1 (1:5:1)

Day/Sample	3	7	14	28
1	2.458	3.413	4.096	4.134
2	3.064	4.662	5.571	5.137
3	3.626	3.554	5.407	5.949
4	2.748	2.866	4.492	6.284
5	2.225	2.318	5.544	8.494

Ratio 1.5 (1:4.5:1.5)

Day/Sample	3	7	14	28
1	1.269	2.747	4.45	5.223
2	2.71	2.259	3.929	3.821
3	3.937	3.709	4.623	4.887
4	-	3.718	4.685	6.409
5	-	-	-	-

Ratio 3 (1:3:3)

Day/ Sample	3	7	14	28
1	0.583	1.367	3.790	4.87
2	0.317	0.671	4.452	5.07
3	1.314	3.647	3.926	4.918
4	1.623	2.343	4.240	-
5	-	3.271	4.685	-

APPENDIX B

Raw Data of Density Test Results

Standard Control

Sample	Oven (g)
1	1760.69
2	1786.52
3	1801.19

Ratio 1 (1:5:1)

Sample	Oven (g)
1	2720.07
2	3017.51
3	3380.28
4	3434.71
5	3187.11

Ratio 1.5 (1:4.5:1.5)

Sample	Oven (g)
1	2793.8
2	3124.59
3	2904.47
4	3062.65
5	2811.48

Ratio 3 (1:3:3)

Sample	Oven (g)
1	2639.79
2	2312.38
3	2951.26
4	2723.10
5	2766.04

APPENDIX C

Raw Data of Water Absorption Test Result

Standard Control

Sample	Oven (g)	Submerged 24hr (g)
1	1753.66	1938.05
2	1747.89	1933.02
3	1731.75	1923.40

Ratio 1 (1:5:1)

Day/Sample	Oven (g)	Submerged 24hr (g)
1	2972.17	3320.81
2	2868.97	3240.83
3	2970.13	3311.63
4	2860.57	3231.90
5	2885.32	3252.33

Ratio 1.5 (1:4.5:1.5)

Sample	Oven (g)	Submerged 24hr (g)
1	3123.89	3552.99
2	3253.54	3691.13
3	3223.88	3575.40
4	2874.81	3262.85
5	3194.96	3638.92

Ratio 3 (1:3:3)

Sample	Oven (g)	Submerged 24hr (g)
1	2680.61	3092.46
2	2325.77	2720.02
3	2406.00	2845.17
4	2846.48	3279.39