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COMPRESSIVE STRENGTH OF LIGHT WEIGHT FOAMED CONCRETE BRICKS WITH DIFFERENT SIZE OF HOLLOW UNDER DIFFERENT CURING REGIME

NUR AFIRAH BINTI KAMALRULZAMAN

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

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I hereby declare that the work in this thesis entitled Compressive Strength of Lightweight Foamed Concrete Brick with Different Size of Hollow under Different Curing Regime is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

Special Dedicated for Beloved both of my parents,
Kamalrulzaman bin Said and Rohana binti Yusof.
Your sacrifices and contribution that you gave too high values
I admire that will last a lifetime

For my respectable supervisor,
En. Mohd Arif bin Sulaiman
who always support and encouragement to pursue the ideals.

For my colleagues, Ahmad Fahimi and Marwan Hafiz who always
gives advice and struggled along to achieve our ambitions.
May our friendship is eternal.

"A Bunch of Thanks !"

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Thank you.

ABSTRACT

Lightweight foamed concrete is a unique product of construction material that has been used in the construction of the building. The usage of lightweight foamed concrete as the bricks was not widely used in Malaysia. Cost savings in using mortar for bricklaying can be reduced because mortar just pasted to the face of the hollow brick alone compared with solid brick that need to paste mortar around the face. Hollow concrete brick are slow to absorb heat and with the using of this brick is suitable for a living due to the nature of concrete that is not hot plus empty space in the brick and heat will flow to avoid the heat trapped inside it. The purpose of this study is to determine the effect of different size of the hollow to compressive strength of foamed concrete bricks and also to determine the compressive strength of hollow foamed concrete bricks under different curing regimes. In this study, the density of the lightweight foamed concrete used is 1600 kg/m^3 while the size of the brick used is 215 x 102.5 x 65 mm. Sample A represent the solid brick while Sample B, Sample C and Sample D were the bricks with hollow size 55 x 55 mm, 60 x 60 mm and 65 x 65 mm respectively. Eighty samples of bricks with different hollow sizes have prepared. Under the bed position, the compressive strength was 30 – 56% decreased with the increasing size of hollow while for stretcher was 52 – 76%. The compressive strength in both stretcher and bed position under water-curing regime was 1 – 20% higher compared to samples under air-curing regime.

ABSTRAK

Oleh sebab konkrit ringan berliang adalah produk bahan binaan unik yang telah digunakan dalam pembinaan bangunan, penggunaan konkrit ringan berliang sebagai batu bata tidak digunakan secara meluas di Malaysia. Penjimatan kos dalam menggunakan mortar untuk penyusunan bata boleh dikurangkan kerana mortar hanya ditampal ke permukaan bata berongga sahaja berbanding dengan bata yang kukuh yang perlu diletakkan mortar di seluruh permukaan. Bata konkrit berongga adalah lambat untuk menyerap haba dan dengan menggunakan batu bata ini sesuai untuk kehidupan seharian kerana sifat konkrit yang tidak panas ditambah ruang kosong di dalam bata dan akan mengalir di dalamnya untuk mengelakkan haba panas yang terperangkap. Tujuan kajian ini adalah untuk menentukan kesan saiz yang rongga bata yang berbeza untuk kekuatan mampatan bata konkrit berliang dan juga untuk menentukan kekuatan mampatan bata berongga konkrit berbusa di bawah pengawetan yang berbeza . Dalam kajian ini, ketumpatan konkrit berliang yang ringan digunakan adalah 1600 kg/m3 manakala saiz bata yang digunakan adalah 215 x 102.5 x 65 mm. Sampel A mewakili bata tanpa rongga manakala Sampel B, Sampel C dan Sampel D adalah batu bata berongga dengan saiz 55 x 55 mm, 60 x 60 mm dan 65 x 65 mm. Untuk menjalankan penyelidikan itu, lapan puluh sampel bata berongga dengan saiz rongga yang berbeza telah digunakan untuk menentukan kekuatan sampel pada kedudukan *bed* dan *stretccher* dan ujian kekuatan mampatan dijalankan. Pada kedudukan *bed* kekuatan mampatan adalah 30 - 56% menurun dengan saiz yang semakin meningkat berongga manakala bagi *stretcher* adalah 52-76 %. Kekuatan mampatan di bawah pengawetan air adalah 1 - 20% lebih tinggi berbanding dengan sampel di bawah pengawetan udara.

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LIST OF ABBREVIATIONS

ASTM	American Society for testing and Materials
BS	British Standard
LFC	Lightweight Foamed Concrete
OPC	Ordinary Portland cement
RTV	Room-Temperature Vulcanizing
SMART	Storm water Management and Road Tunnel

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In the development of construction, bricks become one of the most important materials in building in Malaysia. Clay bricks are widely used in various types of construction, particularly for forming the wall of the building. Nevertheless, the process of mining the clay is not sustainable in construction because the raw material is mined and piled in a quarry stock usually located near the factory. Shale is usually allowed to weather for about three months and this also takes quite a long time to produce the clay bricks. Therefore, there are new requirements for sustainability of materials in the construction industry which is concrete bricks is introduced in order to reduce the process of burning clay brick. Concrete brick is a combination of cement and aggregates with specific ratios of every material.

Nowadays, concrete bricks are being upgraded by using lightweight foamed concrete as the materials for produce bricks to reduce the density of concrete that will make it easy for handling and that is the reason where lightweight concrete brick is formed. Lightweight concrete is a type of concrete that have been injected using air into the composition of concrete or the finer size of aggregates are omitted when concrete is prepared. There are three categories of lightweight concrete which is concrete with no fine aggregates, lightweight aggregate concrete and the aerated concrete or basically called as foamed concrete.

Lightweight foamed concrete are usually wide-open to the multiplicity of loading condition application in engineering field and this increase the total research study of foamed concrete that can resist the compressive strength which act on the material or structure that subjected to the loading (Rahman, et al., 2010). Foamed concrete is a unique product of construction material that has been used in the construction of the building. It is made up of slurry of cement or combined with mortar or paste and performed foamed concrete will produce. This type of lightweight concrete is an innovative green technology idea to reduce the cost of conventional concrete. It has defined that foamed concrete is one of the lightweight concrete and it is referred to cellular material which is consisting of Portland cement, fine sand, water, foaming agent and compressed air (Dalton & Hanna, 2006). There are differences between foamed concrete and conventional concrete which is the aggregates in the foamed concrete was replaced by the homogenous cells created by air in the form of small bubble which utilize a stable air cell structure rather than traditional aggregate (Zaidi, et al., 2009).

Lightweight foamed concrete is lighter compared with conventional concrete and commonly the density of conventional concrete is 2300 kg/m^3 while for lightweight concrete is between 300 to 1800 kg/m^3. Foamed concrete is a possibility of lightweight concrete producing intermediate strength capabilities with excellent thermal insulation, freeze-thaw resistance, high impact resistance and good shock absorption (Rahman, et al., 2011).

1.2 PROBLEM STATEMENT

Malaysia is one of the developed countries that are full of variety of constructions. As we know, brick is the most significant materials in any construction of masonry and it is a key material to build a durable construction. In construction industry, lightweight foamed concrete has been the best commercial materials and it also can be used to produce the bricks. However, industrial parties were appeared with variety size of hollow of the bricks to achieve the minimum specification and requirement of compressive strength needed in the material. The foamed concrete has potentials as an alternative lightweight concrete to produce strength proficiency with a great compressive strength.

In order of using hollow bricks as a wall partition of the building, reinforcement can be installed in between the hollow to increase the strength of the masonry unit itself. This will strengthen the wall as well compared by using solid brick that does not have the strength of reinforcement. As for the usage of lightweight foamed concrete, it has the lowest density compared with conventional concrete and this will easier for handling the work during construction.

So, the approach of using hollow lightweight foamed concrete bricks is expected to be the one of method that can optimize the economy in construction works. Although the using of hollow foamed concrete may be reducing the workability because it may have low density but it still can be used according to the optimum size of the hollow that can restrain the load. Since the solid bricks are denser and more weight than foamed concrete bricks, the dead load on the structure is lesser and structure is subject to a lower load which leads to economic design. By comparing with the other masonry units, foamed concrete brick has the least density due to the substantial reduction in its mass and the dead load on the structure is lesser and structure is subject to lower loads which lead to a lower cost of the structure (Prakash, et al, 2013).

1.3 RESEARCH OBJECTIVES

The research objectives for this study are as follows:

(i) To determine the effect of different size of the hollow to compressive strength of foamed concrete bricks.

(ii) To determine the compressive strength of hollow foamed concrete bricks under air-dry curing and water curing.

1.4 SCOPE OF STUDY

The scope of this study is to investigate the compressive strength of the foamed concrete brick by different type of curing which is water curing and air-dry curing and to conduct the testing, 80 samples of bricks will be used with different size of the rectangular hollow include the solid brick as the manipulated variable in order to compare the strength between those samples and the effective opening of hollow that able to restrained the load given also will be determined. The size of bricks is according to BS 3921 with the standard work size of a brick is 215 x 102.5 x 65 mm as shown in Figure 1.1.

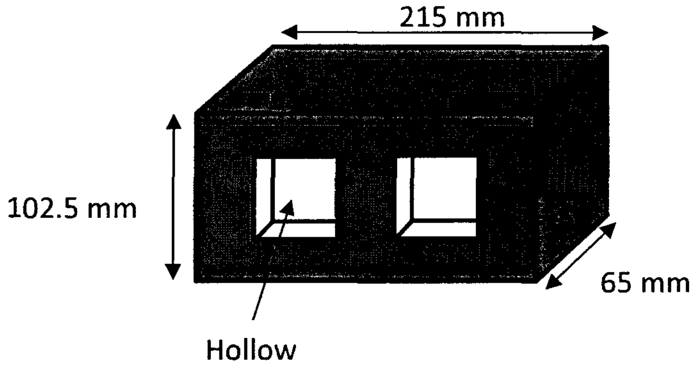


Figure 1.1 : Size of brick

The density of the foamed concrete brick is set to 1600 kg/m^3. Water-cement ratio and sand-cement ratio of this mixture is 0.50 and 1.5 respectively. Table 1.1 shows the ratio of each of the materials used for 1m^3 of the fresh foamed concrete.

Table 1.1 : Mix design for 1m^3 of lightweight foamed concrete

Materials	**Water (kg)**	**Sand (kg)**	**Cement (kg)**	**Foaming Agent (L)**
Per 1m^3	258	783	517	250

There were three sizes of opening of hollow bricks and one brick without hollow that going to be tested are shown in Table 1.2. The testing was conducted under two conditions of curing and tested in bed faced and stretcher faced position.

Table 1.2 : Sample description

Samples		Compressive Strength	
		Air-Curing	**Water-Curing**
A	**Bed**	5	5
	Stretcher	5	5
B	**Bed**	5	5
	Stretcher	5	5
C	**Bed**	5	5
	Stretcher	5	5
D	**Bed**	5	5
	Stretcher	5	5
		40	**40**
Total		**80**	

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter describes the nature of bricks that will apply lightweight foamed concrete (LFC) as the main materials. Due to the properties of foamed concrete can vary widely and it can be used in various applications, it is important to determine the performance requirements. LFC has become popular in recent years because of the advantages it deals over the conventional concrete. Modern technology of the concrete also helped a lot in the promotion and application of LFC. Research in comparing the solid bricks with hollow bricks never made before but research in hollow bricks masonry use in construction due to compressive strength had been made before.

This chapter review the essential background information related with the lightweight concrete and hollow bricks in general laterally with the materials used for produce the LFC and hollow bricks. In addition, background information on the basic engineering properties of lightweight concreted was presented including its physical and mechanical properties. There is a few research shows that, hollow bricks have the lower compressive strength compared with solid brick but it still achieve the minimum requirement of the strength. In the previous study also being compared the LFC when cured in different regimes which is in air-curing and water-curing condition. The result of this previous research has come out with the high compressive strength in water-curing.

2.2 LIGHTWEIGHT CONCRETE

Uses of lightweight materials in concrete are important in order to reduce the self-weight of concrete. Materials that are commonly used as lightweight aggregates are palletized ash, slag, expanded clay and other dust that is suitable as aggregates in concrete. Lightweight concrete is lighter compared with conventional concrete and commonly the density of conventional concrete is 2400 kg/m^3 while for lightweight concrete is between 300 to 1800 kg/m^3. There are three categories of lightweight concrete which is concrete with no fine aggregates, lightweight aggregate concrete and the aerated concrete or basically called as foamed concrete.

Foamed concrete has an astonishingly long history and was made in 1923, primarily for us as an insulation material. The first comprehensive review on foamed concrete was presented by Valore in 1954 and detailed treatment by Rudnai, Short and Kinniburgh in 1963, a summary of the composition, properties and application of cellular concrete, regardless of the method of formation of cell structures. An important increase in the last 20 years in fabrication equipment and better features of surfactants has allowed the use of foamed concrete on a larger scale.

D'Annunzio (2007) stated that lightweight concrete is typically used as a composite slab over metal deck extended that meets the requirements of ASTM A653 and the correct type and gauge to resist dead and live structural loads. Lightweight concrete can also be used as a slab of concrete deck structure topping. With the same cementitious ratio, lightweight concrete contains a high volume of water compared by standard concrete. So, the drying process will take a long time but not so significant (Craig and Wolfe, 2012).

Due to the lightweight concrete, any structure that using this kind of concrete can reduce dead load that allowed for structure designs. Although lightweight concrete provides these advantages over conventional concrete, the structural performance and material properties of lightweight concrete are not as well-known as those of conventional concrete. According to Girard (2006) said that the factor of using lightweight concrete in the construction industry is for weight saving due to the porous cellular structure of the aggregate particles. One of the types of lightweight concrete is foamed concrete which has been defined in various ways definitely it has properties that similar as cellular concrete and there is misunderstanding between LFC and alike materials likes air injected into concrete.

Foamed concrete history has begun much later than the lightweight aggregate concrete. As stated by Dubral (1992), the development of aerated concrete began about 100 years ago. Sweden was the very first country that discovered cement, lime, water and sand expanded by adding aluminum powder in the cement slurry to generate the hydrogen gas. Earlier, to add air into the concrete, it has been trying the beaten egg whites, yeast and other rare technique. Over 60 years ago has been reported that foamed concrete has developed in Europe more than 20 years and being the international market. Foamed concrete has a similarity to wood in features but without weakness in combustible, rot and termite damage. It displays a variety of features such as low weight, compression strength and good thermal insulation, fire resistant and good impact of sound insulation.

Nooraini et al. (2009) has stated that commonly the compressive strength of the LFC was in range 1 – 60 MPa as compared to the conventional concrete that can achieved up to 100 MPa. They also said that although LFC is becoming the popular materials nowadays, there was still the lack of knowledge about the credibility of the substance as a great insulator. For example, foamed concrete is also known as the porous material that has made up of mixture of sand, water and cement slurry that mixed with a foaming agent to produce the LFC.

LFC is a building material that has been introduced for new alternatives. According to Haziman (2004), foamed concrete produced by entraining a considerable amount of air into the cement using harsh chemical foaming agent once results in a strong lightweight concrete that contains millions evenly, consistently sized air bubbles or the cells. High air content causes a lower density, high porosity and lower strength. The porosity of LFC after replacing a large amount of cement to both confidential and unconfidently fly ash was found to depend mainly on the dry density of concrete and not on the type of ash. The volume of water absorbed by LFC was about twice of an equivalent cement but independent of the volume of air trapped and type of ash.

The definition of foamed concrete that has been stated by Jones (2005), the foamed concrete is the cementing materials that contain at least 20% of the volume of mechanical bubbles trapped in it. According to Aldridge (2005), another meaning of the term foamed concrete itself is confusing the vast majority that stated it does not contain large concrete aggregates which means only contained cement, water and foamed so the product should be more accurately described as having air content not less than 25% of distinguishes it from air trapped in it. In the basic form of foamed concrete mixture is sand, cement, water and pre-formed foam which in the mixture of pre-formed foam contained foaming agent, air and water.

2.2.1 Compressive Strength of Lightweight Foamed Concrete

Lightweight foamed concrete is one of the material existing that has a good mechanical strength and it can be formed in several density and properties that can be altered to suit specific requirements. The effect of water-cement ratio on the compressive strength of the LFC is not accurate as mentioned by Dransfiled (2000). He reported that with a decrease in water-cement ration, the compressive strength will reduced. Though the other reports have shown that the compressive strength of LFC reduces with increasing of water-cement ratio up to 0.45, the opposite flow above the value between 0.5 – 1.0. Normally, compressive strength increases linearly with density because different density of LFC will produce different value of compressive strength. However, LFC is varies inversely with moisture content. The better strength was obtained when finer sand was used in term of the influence of filler on the strength. Higher density ratio credited with moderate uniform distribution of pores in the LFC with fine sand while the pores were larger and uneven to mix with coarse sand (Nambiar and Ramamurthy, 2006). Same behavior seems sand was replaced by fine fly ash.

Kearsley and Wainwright (2001) conducted a study on the effect of replacing large volumes of cement up to 75% by its weight in two fly ash classified and not classified in the strength of LFC. The reduction in compressive strength of LFC without any significant is up to 67% of the cement replaced by fly ash ungraded and graded. The results indicate that the compressive strength of the LFC mainly dry density function and LFC mixed with fly ash required more time to meet the maximum strength that was observed is higher than that achieved by simply using the cement.

In previous research, Neville (1995) has pointed out that the compressive strength of concrete is usually considered as the most precious assets that provide an overview of the compressive strength of the concrete directly related to strengthening the structure cement paste. Visagie and Kearsely (2002) mentioned that the LFC compressive strength was decreased with increases in pore diameter for LFC dry density between 500 to 1000 kg/m^3. However, the air-pores are likely to have an influence on the compressive strength for density higher than 1000 kg/m^3, the composition of the paste determines the compressive strength. There are also others factors that affect the strength of the LFC such as the cement-sand ratio, water-cement ratio and types of curing regimes (Hamidah, 2005).

In previous study Narayanan and Rammamurthy (2000) has found that the strength of the LFC are inclined by the size and shape of the specimen, the method of pore formation, the loading direction, age, water content, features of materials used and the type of curing regime. They stated that between 28 days until 6 months, the strength LFC can be increased in range 30% to 80%.

2.2.2 Comparison Between Lightweight Foamed Concrete and Conventional Concrete

Lightweight foamed concrete was made up of cement, water, fine aggregates and foaming agent that have a very pore structure while this is obviously different with conventional concrete that made with combination of coarse aggregates, fine aggregates, water and cement. Foamed concrete was suitable for filling the voids such as the unused fuel tank, sewer system, pipelines and culverts especially where the access is difficult. It is a medium that is predictable for reestablishment the trenches. The properties of foamed concrete in good thermal insulation were appropriate enough for sub-screeds and filling the voids under the floor. In the other words, conventional concrete is not suitable as the filling agent because it was made up from coarse aggregates. The materials used in conventional concrete will cause the segregation if it is not compacted well. So, to avoid the segregation happened, compaction of the concrete must conducted properly. This was really differ with LFC that do not need a properly compaction work because it is just like the cement slurry that will flow in the moulds or formwork freely until it fill occupies space.

Foaming agent is used to absorb the moisture for as long the product is exposed to the atmosphere that allow the cement hydration process will continue to have enough strength development (Aldridge, 2005). The difference between foamed concrete and conventional concrete is the use of aggregate in foamed concrete was removed and replaced by cells of the same race created by the air in the form of small bubbles using air cell structure and non-traditional aggregates (Zaidi et al., 2008). Table 2.1 shows the difference between lightweight concrete and conventional concrete.

Table 2.1 : Difference between lightweight concrete and conventional concrete

Type of Different	Lightweight Concrete	Conventional Concrete
Density	300 - 1800 kg/m^3	2200 – 2600 kg/m^3
Materials	No coarse aggregates. Using fine aggregates only but the very fines one to achieve the density of it.	Have both fine and coarse aggregates

2.2.3 Advantages and Disadvantages of Lightweight Concrete

As for becoming the significant materials in construction industry, there are so many advantages of using lightweight concrete in nowadays construction. Lightweight concrete have main advantage is it consists of lighter weight compared to the other concrete. It has numerous advantages compared to other construction materials. It provides the reducing of the dead load of the structure that directly reduces the cost of coarse aggregates used in the construction. Besides that, it also easy for demolition process because contain no coarse aggregates. However, every materials used in construction also have the disadvantages as well. The disadvantages normally closely related with the sensitivity of the concrete. It also needs greater concern while handling it. Table 2.2 has shown the summary of advantages and disadvantages of the lightweight concrete.

Table 2.2: Advantages and disadvantages of the lightweight concrete

Advantages	Disadvantages
(i) Faster and simplest the construction (ii) More economic in transportation and reduce the forces in work (iii) Reduce the dead load that directs faster to build and lower cost (iv) A marked reduction in heaviness of frame structure, foundation or piles (v) Easy for do nailing and sawing work compared with conventional concrete (vi) Do not settle and not required the compaction of the concrete. (vii) Free flowing and spread freely to fill the voids (viii) Requires no compaction because it do not settled	(i) Slightly sensitive with the absence of water content in the concrete (ii) Time for mixing is longer compared with conventional concrete. It is ti make sure that the mixture was mixed properly. (iii) Inability to deliver a consistent compressive strengths and density all over the entire area (iv) Porous and shows poor resistance to heavy scratch. (v) Has low tensile strength and thus fracture easily.

2.2.4 Application of Lightweight Foamed Concrete

There are many uses of lightweight foamed concrete (LFC) in the scope of construction. One of the applications is lightweight foamed concrete brick and block. Block and panels can be made to partition and load bearing walls. They can be made in any dimension. This has been applied in India, China and Thailand to build the partition walls. The lightweight nature of the bricks means that they subjected a minimum loading on the building. Lightweight foamed concrete bricks also providing a good thermal and sound insulation. The application of LFC is being increasing day by day in all types of construction works. In general, the application of LFC is depending on its density. Usually, LFC is using for construction of houses, highways, blinding, void filling, footing, tunnel lining and roof insulation. Foamed concrete is widely used for roof insulation and to create a slope on a flat roof. It has excellent thermal insulation properties because it is lightweight foamed concrete and does not inflict a large loading on the building.

In Roman, lightweight concrete was presented by their people who constructed 'The Pantheon' in second century using the most commonly aggregates used at that time named pumice stone (Samidi, 1997). 'The Pantheon' building with lightweight concrete still intact manifest in Rome for about 18 centuries and it is proven that lightweight concrete has an economic advantage in construction industry. In addition, in South Africa has used foamed concrete as the roof insulation while the low density allows the creation of roof slope (Jones, 2005).

The using of foamed concrete as the wall panel has been using in Malaysia in last 10 years. The construction of Storm water Management and Road Tunnel (SMART) project in Kuala Lumpur is the first major application of LFC in Malaysia. Application of LFC in the field of structure can be used as lightweight bricks or blocks for high rise building, in panels or partition of wall with different dimensions, for precast or cast in-situ concrete for construction of a unit of low cost terrace house or other type of houses and in other sorts of insulation works such as cavity walls, in roofing and ceiling panels and in sound proofing application.

LFC also had being used on the bridge of the sub roadbed. This concrete is light in weight thus the loading imposed on the bridge could be reduced. In Sweden, the first lightweight concrete bridge was competed in October 1975. It is pre-stressed bridge that carry pedestrian across the road Handen – Vendelso. Except for the bottom slab and the main area of pre-stressed concrete bridge to be build lightweight aggregates using fly ash called as LB800. The concrete has compressive strength of 35 MPa at 28 days and the density is 1800 kg/m^3.

In the Middle East, LFC has been used as a roofing insulation over the years. Nevertheless, in recent years, there has developed an interest in using LFC as non-structural and semi-structural materials in building as advantages of the characteristics of lightweight and good insulation. The roof is probably the most widespread application of lightweight foamed concrete. Neville (1985) has stated that LFC has a number and is constantly increasing applications in all types of structure work among the most general application is shown in Table 2.3.

Table 2.3 : Application of lightweight foamed concrete

Density (kg/m^3)	**Applications**
300 – 600	Lightweight and insulating cements for floors foundation, heat insulation and slope for flat roofs, rigid floors or tennis court foundation, interspace concrete filling, raceways insulation, thermo insulating blocks, steel structures fireproofing, tunnels and pipelines compensating mass, dumps, foundation and coverings land reclamation and consolidation underground cavities infill and all types of infill where an elevated thermal insulation is required.
600 – 900	Stables and pig-ties foundation, industrial foundations partition and tamponing slabs, ceiling slabs, concrete and lightweight concrete mixed panels
900 – 1200	Blocks for outside walls, slab for partitions, concrete and lightweight concrete mixed panels for covering, foundations for elastic floors.
1200 – 1700	Prefabricated panels for civil and industrial buildings plugging, wall casting and garden ornaments.

LFC is also can be used as void filling because it is very fluid and can be applied for small opening. Besides that, it also can easily pour even in the most inaccessible area. It has been used to fill the old sewers, basements, storage tanks and also voids under the roadways that caused by heavy rain. This type of concrete has two benefits when it is used for the roof. The first benefit is that it provides a high level of thermal insulation. The second benefit is that it can be used to put a flat roof to fall which is to provide a slope for drainage. In the other words, nowadays, there are so many applications that using lightweight concrete in construction industry and this have been applied many years ago. This application also has been upgraded day by day to meet the optimum strength requirement that can be sustained in the future.

2.3 CURING OF CONCRETE

The appropriate curing of concrete is paramount to achieve the preferred strength and durability enactment in the field. There are various types of curing for the fresh concrete such as water-curing, air-curing, membrane curing, flue curing and many more. But the most type of curing that has been used in construction industry is air-curing and water-curing. The strength of concrete was depending on the type of concrete curing. Dry curing is the method when concrete were left in the open air to be cured under room temperature. Researchers have been working on natural air drying of concrete over the years ago. The experimental results showed that air-curing is not an effective method to achieve good assets of concrete hardened. Concrete requires a proper curing method and moisture content of at least 28 days for good heat hydration and high strength. Deficiency of appropriate curing can severely affect its strength and durability.

As stated by James et al. (2007), the most effective curing method was the water-curing because the compressive strength produced by the concrete was the highest as compared to other type of curing in his study. To achieve the good hardened properties of the concrete, he recommended that concrete must be cured under water-curing. The curing process basically begins after the placement and finishing of concrete that can develop the strength and hardness are required. According to study of Narayan et al. (2000), the process to prevent moisture loss from the concrete to obtain the best quality of concrete while maintaining a satisfactory temperature regime is very significant.

In previous study of Ling and Teo (2012), as compared to air-curing, they found that the result of the compressive strength under water-curing produced the compressive strength up to 25%. Aminur et al. (2010) also stated that water-curing condition of the concrete produce the higher strength compared to the other type of curing at all ages. This result was supported by Hameed (2005) as he also agreed that when concrete was cured under full water-curing, the compressive strength of the concrete will increased when compared to the concrete that cured under air-curing. Thus, we can conclude that the most effective curing method for the concrete is water-curing condition which is produced the highest compressive strength compared to other types of curing. This is because improving of the pore structure and lower porosity from greater degree of cement hydration reaction without any loss of moisture from the concrete specimen (Raheem et al., 2013).

2.4 HISTORY OF BRICKS

Brick is any masonry unit which is not same as block that having dimensions of length, width and height that is not more than 300 mm, 130 mm and 120 mm respectively. According to BS 3921:1985, the work size of a brick is 215 x 102.5 x 65 mm and it must not exceed the size of coordinating space provided to a brick which is about 10 mm for joints or called as mortar.

When the first concrete block was formed in 1882, concrete masonry has developed being the typical construction materials. Concrete blocks generate an economic structure, energy competent and implicate slight maintenance. To build small or large constructions, Concrete brick is generally used in the industrial and the most familiar is concrete masonry unit for building walls. However, there are also other uses of concrete masonry units such as to build the retaining walls, chimneys and shed fire safe of tunnels.

In United Kingdom, about 4% of bricks are made up from concrete. Basically, the raw materials that used to produce the concrete bricks are the Portland cement and aggregates. Before being placed in mould, the materials must be mixed then it will be vibrated or compacted in the mould and being cured. In BS EN 771-3, the requirements for concrete bricks do not specify the size of bricks but commonly the sizes in Table 2.4 are used. A range of compressive strengths are produced, typically from 7 – 40 N/mm^2. Concrete bricks are typically 30 – 40% heavier than clay bricks of similar dimensions.

Table 2.4: Dimensions of concrete bricks

Length (mm)	Height (mm)	Thickness (mm)
290	90	90
215	65	103
190	90	90
190	65	90

2.4.1 Solid Bricks

In BS6073-1:1981 has stated that a solid brick can be defined as a brick with small holes less than 75% of the volume of the brick. If the brick have frogs, the frogs should less than 80% of its volume only then it called as solid bricks. Frogs is a depression in the bed faces of a brick. A small hole is defined as less than 20 mm width or less than 500 mm^2 in area. Up to three larger holes, not exceeding 3 250 mm^2 each can be incorporated as a tool for handling in the amount of 25%.

2.4.2 Hollow Bricks

As stated in BS6073-1:1981, hollow brick is a masonry unit which contains cavities in more than 25% but not exceeding 60% of the gross volume of the unit. The hollow should not too small if not, it is consume as solid brick as well. Hollow concrete brick is a significant accumulation to the types of masonry units existing to the constructor and its use for masonry is a continuously rises (Maroliya, 2012) He also stated that hollow concrete brick also the new structural materials that have the advantages such as to speed the brickwork, more economic compared with solid brick and it has an adequate strength and structural stability.

Besides that, it also has some of the advantages of hollow concrete brickwork can reduced the usage of mortar, more lighter and more speed than the solid brick masonry. Brick units commonly have higher compressive strengths compared with other masonry materials and it makes hollow brick mostly compatible for reinforced masonry requests where the increased strength of the unit allow thinner wall sections to resist same loading act on it. In order to overcome the low tensile strength, hollow bricks are produced so that reinforcement can be put in it to provide the sufficient tensile and compressive strength of the masonry.

2.4.3 Foamed Concrete Bricks

In previous study, Prakash et al. (2013) has stated that foamed concrete bricks are the incorporating insulation and structural capacity as a material for walls, floors and roofs. The properties of its lightweight making the bricks are easy to cut. Besides that, nail and screw also easier to transmit in case for electrical conduits or small diameter pipe runs. They also said that, foamed concrete brick is exactly shaped and meet the tight acceptances. The brick can be put with a thin mortar layer due to high dimension precision.

2.4.4 Physical Properties of Bricks

There are several physical properties of the bricks such as the water absorption, density and moisture content. Water absorption is defined as the carriage of fluids in permeable solids due to surface tension acting on the capillary (Khatib & Mangat, 2002). Water absorption is not certainly specifying the performance of brick in weathering. Small absorption of less than 7% by mass generally show a high endurance to damage by freezing even though some types of brick higher absorption may also be resistant to frost. According to the study of Ling and Teo (2012), when the lightweight concrete bricks are curing for 28 days, the water absorption were between 10 – 14.5%

for under water-curing and 13 – 19.5% under for air dry curing. By comparing with the other masonry units, foamed concrete brick has the least density due to the substantial reduction in its mass and the dead load on the structure is lesser and structure is subject to lower loads which lead to a lower cost of structure (Prakash, Kumar, Karisiddappa & Raghunath, 2013).

2.4.5 Mechanical Properties of Bricks

The mechanical properties that will identify in this study are the compressive strength of the lightweight foamed concrete. The average value of the crushing strength often masonry units tested in accordance with compressive strength testing. In their previous study, Prakash, et al, (2013) found that although the foamed concrete bricks have the least compressive strength compared with any other masonry unit, it still achieves the minimum requirement of the bricks.

From the previous research has shown that with the proper compaction of concrete, the compressive strength of the hollow concrete blocks will be increased (Ambarish, et al, 2011). They also reported uniform hand compaction is more significant compared to the machine vibration compactor when the results obtained the higher compressive strength. In the previous study, Jonas et al., (2005) has stated that the strength of the foamed concrete do not affected if there is small change in the value of water cement ratio. However, due to the high water cement ratio, the compressive strength will increased. The compressive strength of the brick will reduce due to the increases volume of hollow or cavity of the brick. This was agreed by Ezeonkonkwo (2012) in his research that comes out the result with the strength of hollow masonry unit was decreased as the solid area of the unit was decreased.

2.4.6 Advantages of Hollow Bricks

Foamed contribute to the decrease of building dead load thus resulting in more economic structural design. Production of more economic structural design will reduce the amount of material used and eventually cutting down the cost of construction project itself resulting in profit increase to the contractor. Some of advantages of hollow bricks are as below:

(i) Highly Durable: The good concrete compacted by high pressure and vibration gives substantial strength to the brick. Proper curing increase compressive strength of the bricks.

(ii) Load Bearing, strength can be specified as per the requirement.

(iii) Provide thermal and sound insulation: The air in hollow of the brick does not allow outside heat or cold in the house.

(iv) Hollow brick needs low maintenance.

(v) The painting and color of hollow blocks withstand many years for external environmental factors.

(vi) The construction speed is high when compare to conventional construction systems.

(vii) It has high tensile strength.

(viii) Economical friendly and cheap rates.

(ix) The acoustic system of the room is good with hollow cement construction.

(x) It maintains the thermal balance, air conditioning system of any hollow block construction.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discussed on the methodology that being applied to conduct the study. Methodology is an approach taken in order to achieve the objectives of this study which is to determine the effect of different size of the hollow to compressive strength of foamed concrete bricks and to determine the compressive strength of hollow foamed concrete bricks under air-dry curing and water curing. Figure 3.1 shows the flow of the process of this research. The testing and procedures were based on guide of the British Standard.

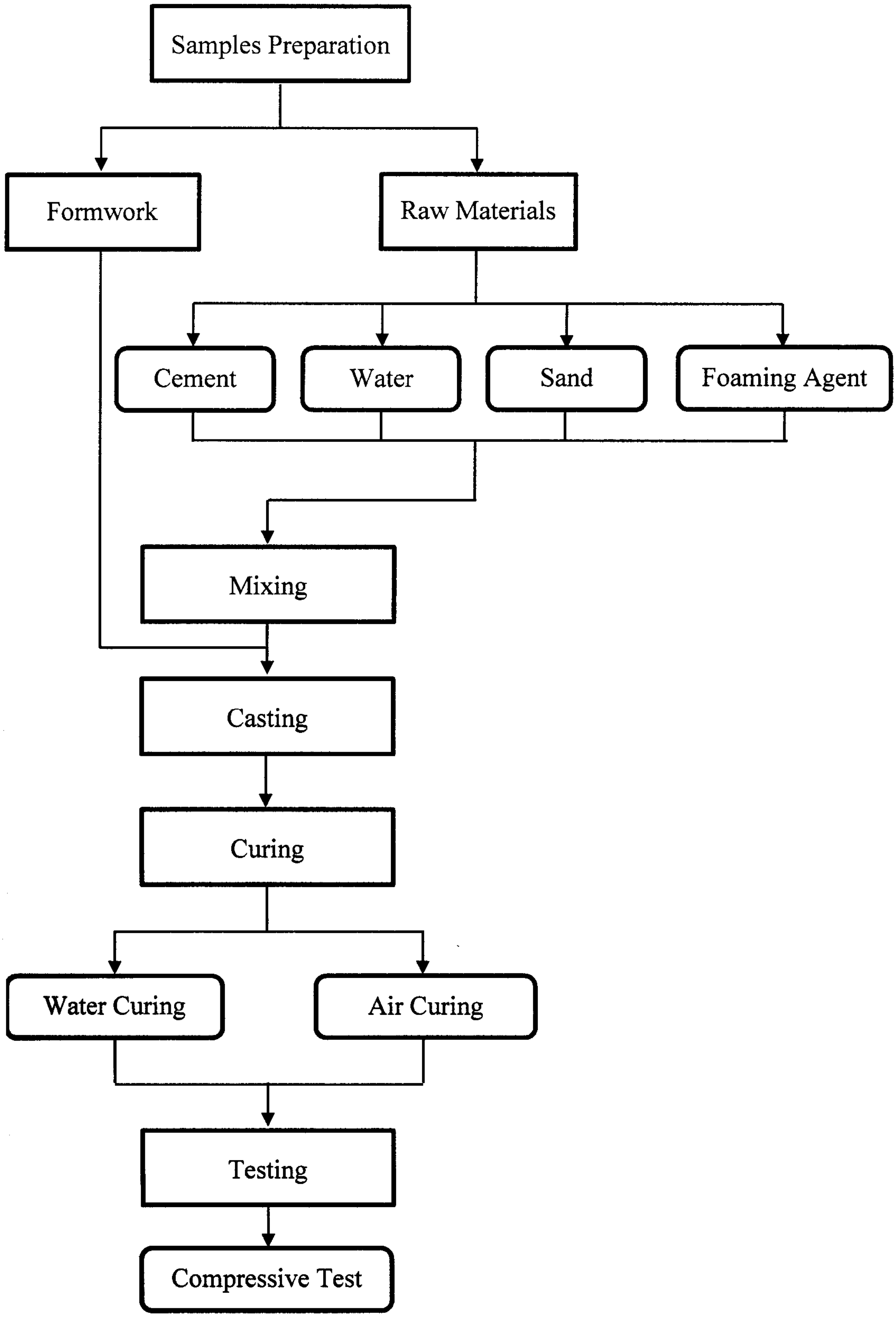


Figure 3.1: Flowchart of research study

3.2 FORMWORK PREPARATION

Formwork is the walls that support the concrete until it harden and the materials or in the other word, formwork is a mould or box what fresh concrete can be poured and compacted so that it will flow and finally set to the inner profile of the formwork. The material used in preparing the formwork is plywood with a thickness of 10 mm. By using plywood formwork, it is easy to cut and shape. In this research study, the formwork is prepared for 80 units of bricks. The row of the formwork that has 20 partitions of bricks samples which mean 4 rows of formwork have been prepared.

Figure 3.2: Making the hollow

For the hollow, the polystyrenes was cut into the size required which is 55 x 55 mm, 60 x 60 mm and 65 x 65 mm with the height of 65 mm for every samples. This shaped work was done properly to produce perfect hollow bricks. Figure 3.2 shows the process to make the hollow by put the polystyrene into formwork by using silicone to make it adhesive between the plywood and polystyrene. Type of silicone used in this research was type HA3000 Room-Temperature Vulcanizing (RTV) Silicone as shown in Figure 3.3 and this type of silicone rubber was a part of silicone that cures in the atmospheric moisture to a very durable and flexible rubber. RTV silicone rubber can be used to cast materials. Vulcanizing is a type of process of chemical that converted the rubber to become durable materials by the sulphur added.

Once the formwork has been sorted and other preparations are complete, the final check on the measurement of formwork and quantity of samples was required in order to make sure there was no any work that has been overlooked. The quantities of polystyrenes were checked so that the next stage of experiment can be done smoothly.

Figure 3.3: Silicon

3.3 PREPARATION OF MATERIALS

The making of lightweight concrete bricks was incorporated with raw materials such as cement, water, foamed and fine aggregates. All of these materials were well prepared to avoid from any shortage when conducting the experiment. Table 3.1 shows the parameter of each sample used in this research study.

Table 3.1 : Parameter for each sample

Sample	Parameter
Sample A	Solid Brick
Sample B	55 x 55 mm (28%)
Sample C	60 x 60 mm (33%)
Sample D	65 x 65 mm (38%)

3.3.1 Ordinary Portland Cement

Ordinary Portland Cement (OPC) as shown in Figure 3.4 has been used for this study and it is available in the University Malaysia Pahang (UMP) civil laboratory. OPC is the most common type of cement in general use around the world as a basic material of concrete or mortar. It is usually originates from limestone and comes in powder.

Figure 3.4: Ordinary Portland cement

The sieved OPC was kept in an airtight container to prevent air moisture contact as hydrated cement particle would affect the formation of a calcium silicate hydrate gel. The chemical composition for the OPC was shown in Table 3.2.

Table 3.2: Chemical composition

Cement	Mass (%)
Calcium Oxide, CaO	61-67 %
Silicon Dioxide, Si02	19-23 %
Aluminium Oxide, A12O3	2.5-6 %
Ferric Oxide, Fe2O3	0-6 %
Sulphate, S	1.5-4.5 %

3.3.2 Water

Water is one of the most significant components to produce concrete whether it is the conventional concrete or lightweight concrete. It initiates the chemical reaction with cement and the mix water was completely free from chlorides and sulphates. The water used should free from any impurities that can be harmful to the process of hydration of cement and durability of concrete.

The main material on concrete was water where once the water mixed together with cement it was acted as the paste that binds the fine aggregates and the cement. Water causes hardening of concrete through hydration. Hydration is a chemical reaction process in which the major compounds in cement form chemical bonds with water molecules and the hydration products. The water used must be clean and free from any impurities that could be dangerous hardening of concrete, durability, volume stability and change in colour. In this study, the water used is normal clean tap water.

3.3.3 Foaming Agent

Figure 3.5 shows the foam generator required air compressor to generate the foamed according to the prescribed density of foamed needed in this experiment. Before the foamed was produced, the foaming agent as shown in Figure 3.7 and water need to put in the foam generator. In this study, foaming agent named as surfactant was used and the dilution ratio that needed to form the foamed was 1:25 ratios of foaming agent and water respectively which mean that 1 liter of surfactant was mixed with 25 liters of water. Both of these materials were poured into the foam generator to produce foamed that needed to mix with the sample. This generator was connected to the air compressor as shown in Figure 3.6 so that it can produced the foamed and foamed was weighed based on required volume for foamed concrete mixed design.

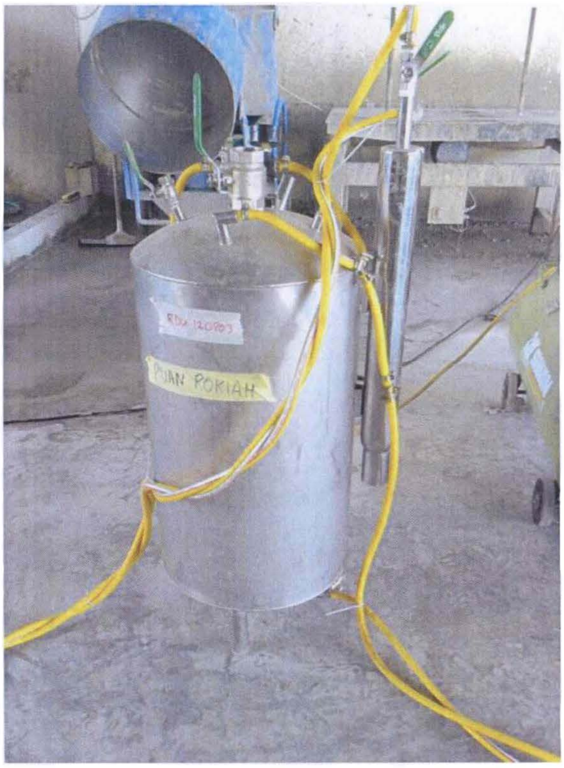


Figure 3.5: Foam generator

Figure 3.6: Air compressor

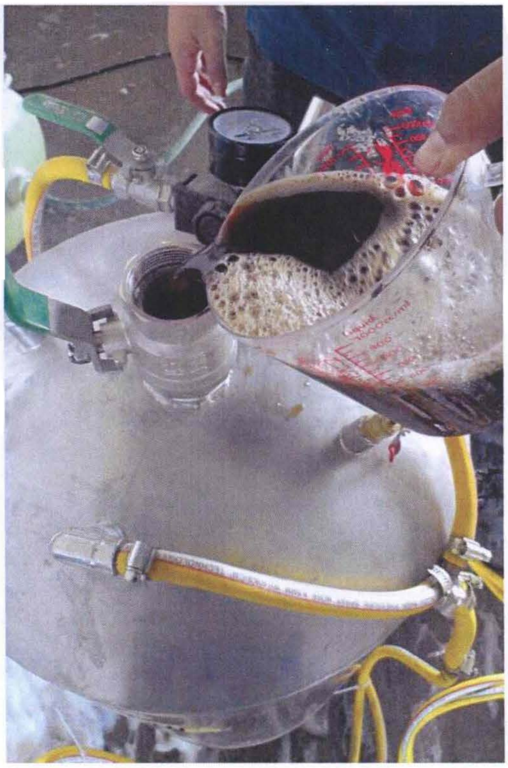


Figure 3.7: Foaming agent

3.3.4 Fine Aggregates

Normally the fine aggregate consist of natural sand or manufactured sand. In BS 3797:1990 has stated that fines sand for concrete is the particles with that passed the 5.0 mm in sieve test with an even distribution of sizes should be used for foamed concrete. This is because the using of coarser aggregates might settle in lightweight concrete mixture that can lead to failure when mixing the foam with concrete. The texture of the fine aggregates used was shown in Figure 3.8.

Figure 3.8: Fine aggregates

3.4 MIX DESIGN

The density of the foamed concrete brick was set to 1600 kg/m^3. Water cement ratio and sand cement ratio use were 0.50 and 1.5 respectively. Average volume for a brick is about 1.43 x 10^{-3} m^3. Table 3.3 shows the mix design proportion for a brick. In Appendix A, the mix design proportion for certain volume was attached.

Table 3.3: Mix design proportion for a brıck

Materials	Water (kg)	Sand (kg)	Cement (kg)	Foaming Agent (L)
Per $1m^3$	258	783	517	250
Per brick	0.37	1.12	0.74	0.36

The concrete was mixing after the material proportion was calculated and then the materials calculated were poured into the mixer machine a little bit by little it to make sure the mix of the concrete was mixed. For the first material, all weighed water was poured into the mixer and plugged on the mixer followed by the cement but not all weighed cement was poured into the mixer so that mixer can mixed the material well without any obstacle.

Then, the fine aggregates was poured and mixed together with other materials until they mixed well and the remaining material were added repeatedly until all of the cement and fine aggregates were poured into the mixer. Before foamed was mixed with other material, cement and fine aggregates must mixed properly to avoid any lumps between them. The mixture was turned into uniformly grey after both cement and fine aggregates were mixed. The last step of the mixing process was done by poured the foamed into the mixer as shown in Figure 3.9. After that, the concrete was weighed to achieve the set value of density of foamed concrete which is 1600 kg/m^3.

Figure 3.9: Foamed mixed with other materials

3.5 CASTING PROCESS

After all the materials mixed properly, as shown in Figure 3.10 the fresh foamed concrete was casted into the formwork that have been prepared before part by part according to the partition that have been made when prepared the formwork. Then, the surface of the brick was levelled properly so that after the concrete hardened, it face was not slanting and this will cause the error while do the compressive testing. It is because the slanting surface will not fully touch the plate of the compression machine.

Figure 3.3: Casting process

3.6 CURING

The important role on the strength of concrete is curing which it is the process to stop the fresh concrete from drying very quickly. This is because if the concrete is too dry, the bonding in the concrete will not function and will make the concrete is being weak and easy to crack. So, curing process is very important in any concreting work to avoid from any cracking or forming of honey comb. For this research study, two types of curing conditions were used which is water curing and air-dry were curing. Basically, concrete was cured in duration of 7, 14 and 28 days but for this research, the samples were cured for 28 days only.

3.6.1 Water Curing

General water curing was conducted by the surface of the bricks were fully soaked in the water to ensure it was kept continuously moist. Figure 3.11 shows the condition of the water-curing of the samples and the tank need to check every day so that water was not reduced and make the samples were not fully soaked.

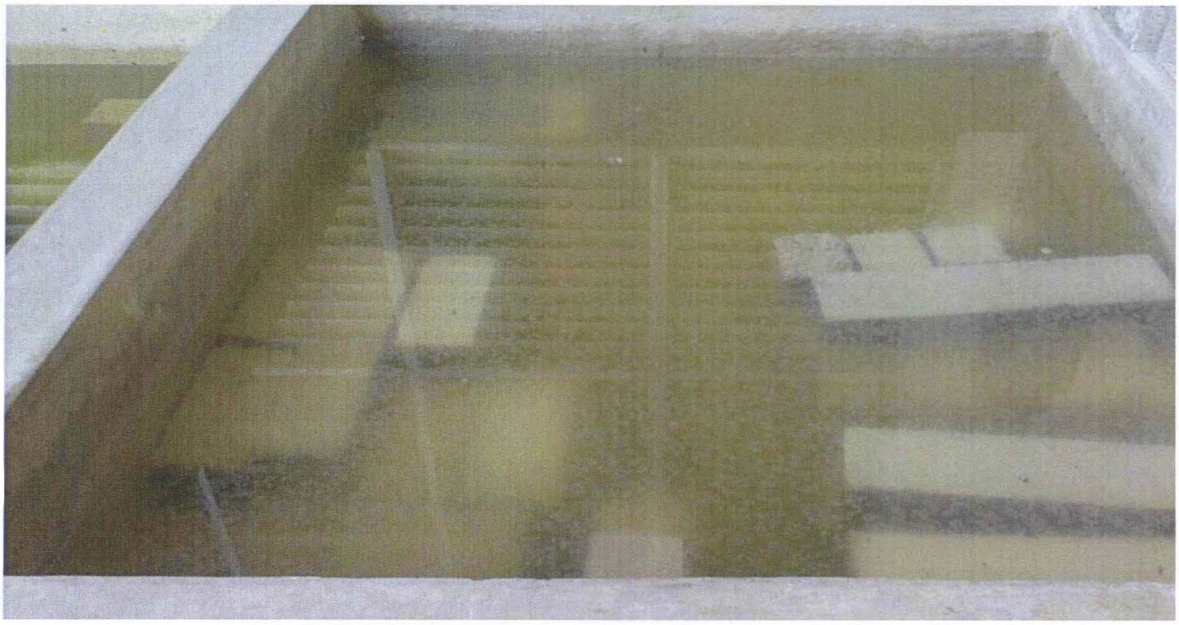


Figure 3.4: Water-curing

3.6.2 Air-Curing

After the bricks are taking out of the formwork, they are air-dried for about 28 days until the day of testing. The samples were arranged as shown in Figure 3.12 to give the sample cured properly and the air-curing samples were avoid from contact with water and they were kept in a place that free from water and far from area that exposed to the rainwater.

Figure 3.5: Air-curing

3.7 COMPRESSIVE STRENGTH TEST

For the compressive strength testing of the bricks, the procedure of testing were based on BS 3921:1985 in Appendix D. Compressive strength is the primary physical properties of concrete that being used for quality control purposes for lightweight foamed concrete. It is the ability of concrete to sustain the axial load. For the compressive strength test, the machine use is Compression Testing Machine as shown in Figure 3.13. It is a testing machine of appropriately capacity for the test and equipped with a means of providing the level of loading specified.

Each brick is placed based on the direction of application of load whether in bed position or stretcher position in the testing machine. Before the machine was started, the dimension of the surface of sample was set-up on the machine for the result of compressive strength. The load was applied onto the sample without shock and increases it continuously at a rate of 5 ± 0.5 N/mm^2 per minute. The appropriate loading rate was maintained as far as possible right up to failure. The test was stopped when the maximum load applied had failure the brick and the machine was automatically shows the result of maximum loading and maximum strength of the sample tested. Then, the data were recorded for every 80 samples of bricks.

Figure 3.6: Compression testing machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The results obtained from the experimental testing was analyzed and discussed in this part of report. The compressive strength of the bricks in bed and stretcher condition with different curing was discussed and comparisons and observations were made between the results. Data obtained from the experiment for Sample A, Sample B, Sample C and Sample D were compared due to effect of different size of hollow and different curing regimes. The maximum load data of the compressive strength of the bricks were obtained from the compression machine test.

4.2 COMPRESSIVE STRENGTH

Compressive strength test were conducted to determine the maximum load of the brick sample with different size of hollows and different curing regimes. In this testing, the load was applied continuously towards the sample until it was failed to resist more loading. By referring to the testing, the data maximum load and maximum strength for every sample were recorded until all the samples were tested. The compressive strength test of the bricks was based on the procedures stated in BS3921:1985.

4.2.1 Compressive Strength of Foamed Concrete Bricks due to Different Size of Hollow

Table 4.1 shows the compressive strength of bricks with different size of hollow under air-curing with testing on bed and stretcher position. For bed and stretcher position of Sample A, the compressive strength were 33.889 MPa and 15.094 MPa respectively while for Sample B was 23.648 MPa for bed position and 7.293 MPs for stretcher position. The compressive strength of Sample C was 19.096 MPa and 5.410 MPa respectively in bed and stretcher position. The compressive strength was valued 17.612 MPa and 3.583 MPa for bed and stretcher position of Sample D.

The compressive strength for bricks with different size of hollow under water-curing is shown in Table 4.2. Among the four samples of brick, Sample A has the highest value of compressive strength with 40.781 MPa and 15.663 MPa for bed and stretcher position while the second highest was Sample B with 27.376 MPa for bed position and 7.122 MPa for stretcher position. Sample D has the lowest compressive strength with value of 18.017 MPa and 3.769 MPa for both bed and stretcher position. For Sample C, values of compressive strength for bed and stretcher position were 20.396 MPa and 5.436 MPa respectively.

Table 4.1: Compressive strength with different size of hollow under air-curing

Samples (Air-curing)		**Compressive Strength (MPa)**
Sample A	**Bed**	33.889
	Stretcher	15.094
Sample B	**Bed**	23.648
	Stretcher	7.255
Sample C	**Bed**	19.096
	Stretcher	5.410
Sample D	**Bed**	17.612
	Stretcher	3.583

Table 4.2: Compressive strength with different size of hollow under water-curing

Samples (Water-curing)		Compressive Strength (MPa)
Sample A	**Bed**	40.781
	Stretcher	15.663
Sample B	**Bed**	27.376
	Stretcher	7.292
Sample C	**Bed**	20.396
	Stretcher	5.436
Sample D	**Bed**	18.017
	Stretcher	3.769

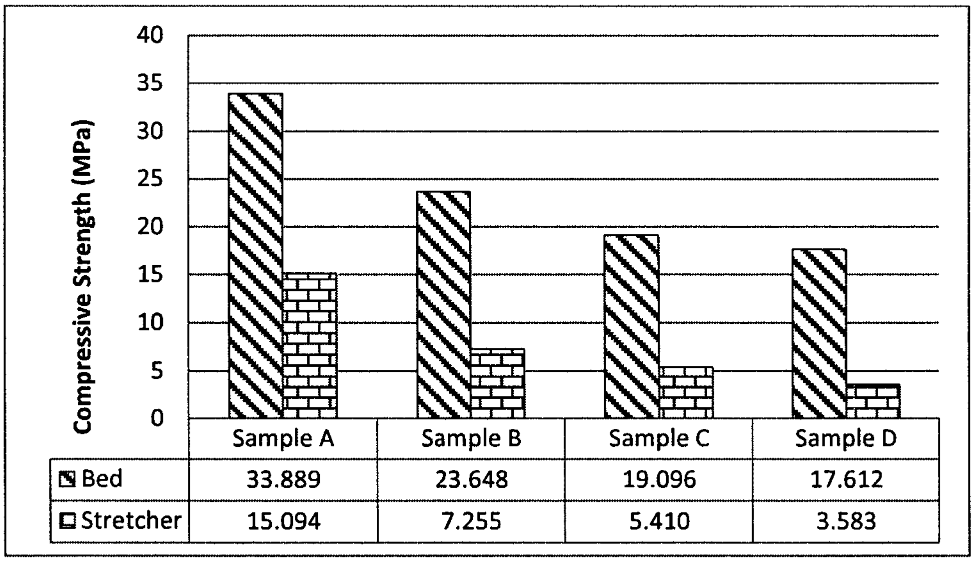
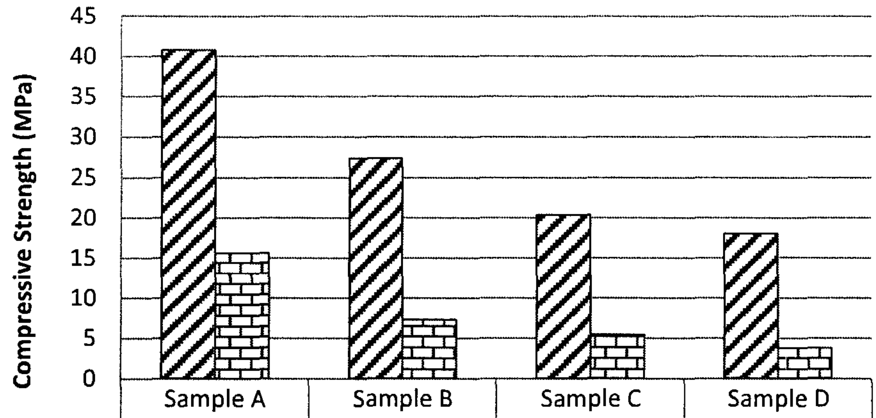


Figure 4.1: Compressive strength with different size of hollow under air-curing



	Sample A	Sample B	Sample C	Sample D
Bed	40.781	27.376	20.396	18.017
Stretcher	15.663	7.292	5.436	3.769

Figure 4.2: Compressive strength with different size of hollow under water-curing

The compressive strength for Sample A under air-curing shows the highest trend among the three other samples as shown in Figure 4.1. Sample B shows 30% decreases in bed position as compared to Sample A while Sample C and D decreases are 44% and 48% respectively. For the samples that have been tested under stretcher position, the graph also show the decreases in compressive strength as the increases in the hollowness of samples. The percentage decreases for Sample B, Sample C and Sample D were between 52% – 76%. It also show the decreases in the strength when the hollow of samples were increases.

As for water-curing, the pattern of graph in Figure 4.2 shows the same pattern as air-curing which is the bed position of the sample has the highest compressive strength rather than stretcher position. In bed position, graph for Sample B shows the decreases considerably in strength with 33% with percentage of hollow 28%. The compressive strength of Sample C and Sample D also decreases compared with Sample A with 50% and 58% respectively. In stretcher position, the graph also decreases steadily in value of compressive strength within 53% – 76% for Sample B, Sample C and Sample D.

As reported by Ezeonkonkwo (2012), the compressive strength of brick will decreases as the cavity volume increases. The measured strength of hollow bricks decreases as the solid area decreases. This result was supported by Raffiq et al. (2013)

that stated the strength of hollow concrete brick masonry wall is less than solid brick masonry wall but cost of construction is very less.

4.2.2 Compressive Strength of Hollow Foamed Concrete Bricks under Air-Curing and Water-Curing

The compressive strength due to different size of hollow shows the result that were analyzed based on the different size of hollow of the bricks at age 28 days under air-curing and water-curing and the samples were tested under different condition whereas in bed and stretcher. Table 4.3 shows the results for maximum strength acted on the different size of hollow bricks under different curing regimes that has been tested under bed faced condition. For air-curing, the values of compressive strength for Sample A, Sample B, Sample and Sample D were 33.889 MPa, 23.648 MPa, 19.096 MPa and 17.612 MPa respectively. While for the strength under water-curing, the values were 40.781 MPa, 27.376 MPa, 20.396 MPa and 18.017 MPa respectively for Sample A, Sample B, Sample C and Sample D.

In the Table 4.4 are the results for maximum strength acted on the stretcher position of the sample with different size of hollow under different curing regimes. For Sample A, Sample B, Sample C and Sample D, the values of compressive strength were 15.094 MPa, 7.293 MPa, 5.410 MPa and 3.583 MPa under air-curing and samples under water-curing, the compressive strength shows the values of 15.663 MPa, 7.122 MPa, 5.436 MPa and 3.769 MPa for Sample A, Sample B, Sample C and Sample D respectively. Sample C and Sample D show the lowest value if compressive strength for both bed and stretcher position of testing which is the values do not achieve the minimum requirement as stated in MS76:1972 that mentioned the minimum value is 7MPa.

Table 4.3: Compressive strength with different size of hollow under different curing regimes (bed)

Designated	Compressive Strength (MPa)	
	Air-Curing	Water-Curing
Sample A	33.889	40.781
Sample B	23.648	27.376
Sample C	19.096	20.396
Sample D	17.612	18.017

Table 4.4: Compressive strength with different size of hollow under different curing regimes (stretcher)

Designated	Compressive Strength (MPa)	
	Air-Curing	Water-Curing
Sample A	15.094	15.663
Sample B	7.255	7.292
Sample C	5.410	5.436
Sample D	3.583	3.769

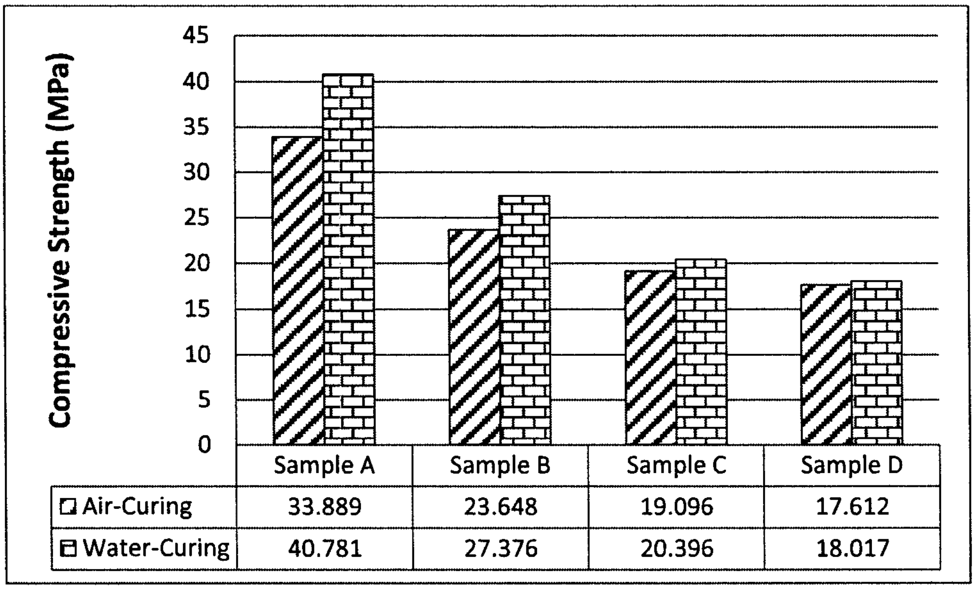
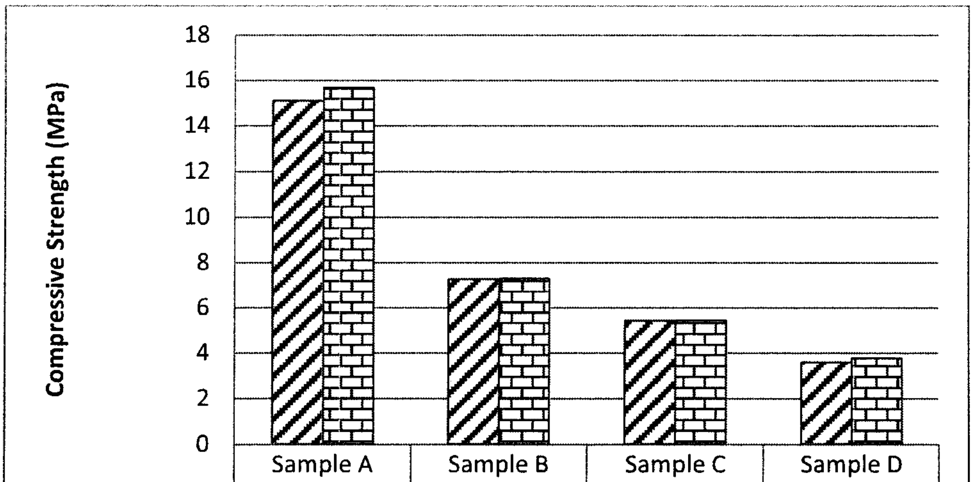


Figure 4.3: Compressive strength with different size of hollow under different curing regimes (bed)



	Sample A	Sample B	Sample C	Sample D
Air-Curing	15.094	7.255	5.410	3.583
Water-Curing	15.663	7.292	5.436	3.769

Figure 4.4: Compressive strength with different size of hollow under different curing regimes (stretcher)

Figure 4.3 shows the graph summary for compressive strength of samples with different size of hollow under different curing regimes in bed position and it shows that the graph increase gradually from Sample D to Sample A. However, in Sample C and Sample D, there is just a minor difference between air-curing and water curing with range 2.3 – 6.8% while for Sample A and Sample B, the difference under curing regimes is between 15.8 – 20.3%. The graph also shows that water-curing has the higher value of compressive strength than the air-curing among the four samples with different percentages.

As shown in Figure 4.4, the value of compressive strength of sample in stretcher position under water-curing still have the higher compressive strength than air-curing with range only between 0.48 – 5.1% only. This graph had the similarities with Figure 4.1 that showing the high compressive strength under water-curing and among the four samples, Sample A shows the highest strength value. The water-curing graph shows the increasing slightly as compared to air-curing for all of the samples.

As mentioned by James et al. (2007), due to improve in pore structure and lower porosity, the concrete produce the greater hydration of cement without any loss of moisture content of the concrete specimens. So, he agreed that concrete should be cured by water-curing method in order to achieve the good hardened properties. This was agreed by Aminur et. al. (2010) in his research conducted shows water-curing condition produced the higher strength compared to the other type of curing condition of concrete. Water-curing condition was the most effective method of curing because it produces the highest level of compressive strength. Furthermore, Ling and Teo (2012) also stated that water-curing produced highest compressive strength at all ages for all samples as compared to air-curing. However, all brick samples still achieved the minimum compressive strength of 7 MPa according to MS76:1972. In previous study, Raheem et al. (2013) recorded a 15% decreases in strength of brick of other curing compared with water-curing.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter present the conclusion made based on the experiment and data analysis that have be done in the research. Several recommendations to the research also being brought out in this chapter to improve the outcomes and results for this research study.

5.2 CONCLUSION

Based on the experimental result and analysis obtained, the objectives of this research study that have been stated in the early of this research have been achieved. From the results obtained in this research, the following conclusion can be concluding.

(i) Compared with the other hollow samples, Sample B with 28% hollowness showed the highest compressive strength of 27.376 MPa under water curing and 23.648 MPa under air-curing. As the hollow bricks, Sample B meets the minimum requirement of compressive strength in bed and stretcher position compared with Sample C and D. Further increases of the size of the hollow decreases the compressive strength of the samples.

(ii) Under the bed faced position, the compressive strength decreased between 30 – 56% with the increases size of the hollowness of bricks compared with samples under stretcher position with range 52 – 76% for both curing regimes.

(iii) As expected, from the research shows that the compressive strength of the bricks under the water-curing condition has higher value than the bricks under air-curing condition with 1 – 20% difference between air and water curing.

(iv) It is interesting to note that, all the samples in bed faced position achieved the minimum requirement of the compressive strength of bricks. However, in stretcher faced position, sample C and D do not achieve the requirement needed either in air-curing or water-curing condition

5.3 RECOMMENDATIONS

Based on the personal experience in conducting research and experimental results has been performed, there are several recommendations suggested. Several modifications should be made to the standard experimental procedures with respect to the scope of the study. This study can help for a better understanding of masonry unit and also to improve the future brick based on construction industry. There are several recommended made for this research study which are:

(i) Using the different shape of hollow such as round hollow to determine the compressive strength.

(ii) Replaced the lightweight foamed concrete (LFC) with the other materials or added other materials into the LFC to see if there is any influence on the strength of the samples.

(iii) The testing should be conducted in different time of curing for every sample to provide broader understanding of the compressive strength behavior.

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APPENDIX A

Design mix table

No	Mixture	Wet Density (kg/m^3)	Volume Mixture (m^3)	Actual Wet Density (kg/m^3)	Cement (kg)	Sand (kg)	Water (L)	Foamed	Total cube	Remark
1	B1600	1599	0.47	1644	249	374	125	119	4 beam	w/c – 0.5
2	B1600	1599	0.23	1871	125	187	62	59	2 beam	w/c – 0.5
3	B1600	1599	0.12	1841	62	94	31	30	1 beam	w/c – 0.5