# INVESTIGATION OF COMPRESSIVE STRENGTH FOAM BRICKWALL PANEL WITH DIFFERENT BONDING BY USING STRETCHER & FLEMISH BOND

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# ABSTRACT

Today, there are many types of masonry units that are available in the market which varies in shapes and sizes. Clay bricks are the most widely used masonry units for construct brick wall in construction industry. In developing construction industry, many alternative materials had used to replace the clay brick, such as foam concrete brick. A study to determine the compressive strength of foam concrete brick wall due to uniform distribution load by using Stretcher and Flemish bond was done. Various sets of wall panels using Stretcher and Flemish bond were made and have same dimension based on bonding type. In this research, the brick size used is based on standard dimension by British Standard which is 215 x 100 x 65 mm. The wall panels were tested to obtain the necessary information. Laboratory testing was done to obtain the compressive strength of wall panel for Stretcher and Flemish bond by using compressive strength test. The value of deflection and strain also obtained from the testing. Percentage of water absorption for foam concrete brick is determined by using water absorption test. Observation also was made during the test to evaluate the failure occurred to the wall panel under compression. From the observation made during the testing, the general failure mode occurred on the wall panel sample are obtained. The result indicated from the test and analysis had determined the compressive strength of wall panel sample, deflection, and strain for Stretcher and Flemish bonding.

# ABSTRAK

Pada masa kini, terdapat pelbagai jenis bata yang terdapat di pasaran dalam pelbagai saiz dan bentuk. Dalam pembinaan dinding bata, bata tanah liat digunakan dengan meluas dalam industri pembinaan. Dalam memajukan industri pembinaan, pelbagai bahan alternatif telah digunakan bagi menggantikan penggunaan bata tanah liat, antaranya adalah bata konkrit busa. Kajian ini menentukan tentang kekuatan mampatan dinding bata konkrit busa terhadap beban agihan seragam mengunakan ikatan Stretcher dan Flemish. Beberapa set dinding panel menggunakan ikatan Stretcher dan Flemish dibina dan mempunyai dimensi yang sama mengikut jenis ikatan. Dalam kajian ini, saiz bata yang digunakan adalah berdasarkan kepada dimensi yang ditetapkan oleh British Standard iaitu 215 x 100 x 65 mm. Sampel dinding panel tersebut diuji untuk mendapatkan informasi yang diperlukan. Bagi mendapatkan nilai kekuatan mampatan dinding panel untuk ikatan Stretcher dan Flemish, kajian makmal telah dijalankan mengunakan ujian kekuatan mampatan. Dari ujian tersebut, nilai pesongan dan regangan juga dapat ditentukan. Dengan mengunakan ujian serapan air, nilai peratusan serapan air untuk bata konkrit busa dapat diperolehi. Pemerhatian dibuat semasa ujikaji untuk menilai kegagalan yang berlaku kepada dinding panel dalam keadaan mampatan. Daripada pemerhatian yang dibuat, mod kegagalan umum yang berlaku kepada sampel dinding panel dapat ditentukan. Keputusan yang diperoleh dari kajian dan analisa yang dibuat telah dapat menentukan nilai kekuatan mampatan dinding panel, pesongan, dan regangan bagi ikatan Stretcher dan Flemish.

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| | | |
|---|---|---|
| ASTM | - | American Society for Testing and Material |
| LVDT | - | Linear Variable Displacement Transducer |
| FCB | - | Foam Concrete Bricks |
| IRA | - | Initial Rate of Absorption |
| UDL | - | Uniform Distribution Load |
| OPC | - | Ordinary Portland Cement |
| BS | - | British Standard |
| MS | - | Malaysian Standard |
| WA | - | Water Absorption |
| MPa | - | Mega Pascal |
| SG | - | Strain Gauge Location |
| L | - | Length Wall Panel |
| H | - | Height Wall Panel |
| W | - | Width Wall Panel |
| A | - | Bed Area |
| N | - | Maximum Loading |
| P | - | Compressive Strength |
| $M_D$ | - | Dry Mass |
| $M_W$ | - | Wet Mass |
| $x$ | - | Mean |

# CHAPTER I

# INTRODUCTION

## 1.1 Background of Study

Construction industry is a most important sector that contributes to the development and Malaysia economy growth. Based on Market Watch Malaysia 2009, the construction industry makes up an important part of the Malaysian economy. Conventional of brickwork in major construction are using the clay brick. In Malaysia construction industry, the clay brick are use widely for brickwork. However, by moving years there is a growing interest in developing and producing the alternative material for replacing the clay brick as a major material in brickwork. In determine the alternative material for brickwork, the Foam Concrete Brick (FCB) identifies has a large potential and ideal replacement for clay brick. In process of developing and enhancing the FCB, several significant researches have done in term to determine the factor that can be upgrade and maximize the FCB usage.

By determine the potential of FCB and its reliability in construction work, the testing of the FCB uses in brickwork are possibility to be proved. The comparison based on their compressive strength in wall panel with different bonding of brick installation. However, previous research has shown that foam concrete is good in workability, durability, fire resistance, thermal insulation, water absorption, consistency, and stability.

FCB generally has several of compressive strength based on various mixture composition and densities, (K. Ramamurthy *et al.*, 2009). But, it determined by individual block by using the compression test. The ordinary method of brick lying in brickwork is based on standard bond. Stretcher bond is one of the most common bonds. This bond type is easy to lay with little waste and composed entirely of stretchers set in rows and offset by half a brick. Other type of block orientation will be used is Flemish bond. Flemish bond consists of alternating headers and stretchers along each course with the headers centered on the stretchers layers above and below.

However, the compressive strength of the FCB is able to changing due to type of brick bonding of wall panel. By referring to FCB properties, it known has different compressive strength based in the densities as theoretically. Individual bricks have different properties and characteristics compare to brick construct in wall panel. The joint of the mortar could affect and increase the strength of the individual bricks. Other advantages of FCB also will be the point of comparison to shows that the bond in wall panel that would give the maximum of compressive strength of wall panel due to loading applied. This could be an important breakthrough in understanding the FCB would reach maximum compressive strength in wall panel by test with several types of bonding method. Therefore, the complete understanding of the characteristics of new material becomes so important in order to adapt in real possibilities.

## 1.2 Problem Statement

From our common construction work in Malaysia, the masonry brick are constructed using the Stretcher and Flemish bond for years. FCB also using the same method of bonding in construct the wall panel. In Malaysia, the technology of using the

FCB in brickwork is still new and not commercializes widely compare to other countries that already used the FCB widely for many years. The normally size of FCB uses in construction are in larger size and dimension and it not comply with the standard size of masonry brick stated in BS 3921:1985. To determine compressive strength of FCB in wall panel, the different types of brick bonding uses could prove it. The bonding by mortar joint could be increase the compressive strength of FCB in wall panel. By prove this problem, the conventional method could be upgrade and enhance the construction work, using the FCB as a major material in constructing wall panel. By using FCB in brickworks, it needs to test the wall panel that the maximum of the compressive strength that could be carried out. By testing the wall panel, it could be prove that FCB can be use commercially to replace of the masonry clay brick uses.

## 1.3 Objectives

The objective of the research is to establish a detail understanding of compressive strength of FCB in wall panel with different bonding. The results of these work supplemented with statistical studies and reviews of past research provides a useful guidance to brick properties for local production. These works will also provide data pertaining to current production of FCB which may be considered significant to any revision or amendment made to the existing Malaysian Standard for masonry MS 76:1972, currently under revision.

The objectives of the research are:

1. To determine the maximum load support of the FCB in wall panel by using two types of bond, Stretcher and Flemish bond.
2. To observe the cracking pattern and mode of failure of the FCB wall panel.
3. To determine the water absorption of the FCB.

## 1.4 Scope of Work

These types of wall panels with different orientation test under laboratory conditions as specified by the respective standards. The FCB properties will be examined to confine with thus studies are on maximum compressive strength, dimensional tolerance, maximum load, and water absorption. Majority of the tests are based on the Malaysian Standard MS 76: Part 2 1972, which is basically an adoption of British Standard, BS 3921:1969. Since then the British Standard for masonry has been revised several times to accommodate with the changes for current needs.

In determine the compressive strength of FCB in wall panel of wall panel each of Stretcher and Flemish bond will be constructed. Therefore, the samples that need to prepare is 3 samples of wall panels by each bond. It will be constructed based on standard of wall panel design that contains in British Standard, BS 5628-1:1992. However, it will be scaling to sample of wall panel dimension based on standard dimension of wall panel state in British Standard, BS 5628-1:1992. The FCB that will be used in this research is 1200 $kg/m^3$. By determine the maximum applied loading that each wall could be support, it is identify that applying the load at top of wall panel. Using this method, the cracking pattern can be observed by analyses the crack at joint between brick block and at brick surface.

## 1.5 Significant of Study

The application of FCB in brickwork in construction work is already a long time ago in construction industry history. However, in Malaysia the application of FCB is still new and not use widely and still not yet been commercialize. Thus, the research is to investigate the compressive strength of wall panel for different bond by using Stretcher and Flemish bond. By referring to the strength of FCB, theoretically the different of bonding, the different strength of FCB will gain. By investigate the strength, it can prove that the other bonding could be use in brickwork that produce more higher of compressive strength. From the strength investigation, it can determine that the FCB might be replaced the common brick uses and enhancing the brickwork method that use the lightweight material for brickwork. All of others advantages of FCB also will be analyzed and review. From this study, it could help the use of FCB become wider in the Malaysia's construction as the properties of this material in wall panel would be identified.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction

Definition of masonry is a building of structure from individual units laid in and bound together by bonding mixture known as mortar. The commonly used masonry unit in structure construction is brick. Other types of masonry units are blocks and tiles. Mortar and bricks had long been used in building structures. However, it is still far ahead to mastering the art of masonry construction. For that reason, research and investigations are done to understand more in the field of masonry construction.

The properties of bricks affect the appearance and the quality of brickwork construction. Therefore, emphasis has been given by codes and standards to specify the properties of units and component materials, in order to achieve the designated durability, quality and strength.

This chapter presents works conducted on bricks for specifications development and standardizations. Evaluation of bricks are made on compressive strengths, water absorption, and cracking pattern.

## 2.2 Bricks

A brick is a walling unit whose form may be generally defined as a rectangular prism of a size that can be handled conveniently with one hand (Lynch, 1994). Bricks are widely used since in the past centuries due to its values and advantages. Bricks also possess properties which are not commonly found in other materials.

### 2.2.1 Foam Concrete Bricks

FCB is a modern building material used as a constructional element in low-rise building, and as an effective insulator. FCB is light porous concrete, received after mortar hardening consisting of cement, sand, water, and foam. This foam provides necessary content of air in the concrete and uniform distribution of air bubbles in the concrete mass in the form of closed cells. The foam is made of foam concentrate.

FCB is inexpensive, economic, strong, ecologically clean, biologically comfortable material, on quality it is closer to wood, but does not burn and is durable. FCB combines advantage of stone and wood: durability, lightness, workability and nail ability. FCB represent an artificial cement stone with regularly distributed closed pores. Such a structure determines a number of high physico mechanical properties of the cellular concrete and makes it rather an effective building material, which in comparison with other kinds of light concrete is the most perspective for building. The most accessible and universal building material are the blocks of foam concrete or the FCB, which are used both in construction, and for reconstruction of the existing buildings and constructions.

According to BS 3921, a one-size standard work size of brick is 215 x 102.5 x 65 mm while the work size shall not exceed the coordinating size, which includes 10 mm mortar joints.

## 2.3 Properties of Foam Concrete Bricks

The properties of the FCB are depended on the density of the bricks. Several properties that majorly used to distinct the quality of FCB are compressive strength, water absorption, and fire resistance.

### 2.3.1 Compressive Strength

The compressive strength decreases exponentially with a reduction in density of foam concrete, (Kearsely, 1996). The specimen size and shape, the method of pore formation, direction of loading, age, water content, characteristics of ingredients used and the method of curing was reported to influence the strength of foam concrete in total. Other parameters affecting the strength of foam concrete are cement sand and water cement ratios, curing regime, type and particle size distribution of sand and type of foaming agent used. For dry density of foam concrete between 500 and 1000 kg/m$^3$, the compressive strength decreases with an increase in void diameter. For densities higher than 1000 kg/m$^3$, as the air-voids are far apart to have an influence on the compressive strength, the composition of the paste determines the compressive strength, (Visagie and Kearsely, 2002). It has been reported that small changes in the water cement ratio does not affect the strength of foam concrete as in the case of normal weight concrete, (Jones and McCarthy, 2006). At higher water cement ratios (within the consistency and stability limit) an increase in strength was observed with an increase in water cement ratio, just opposite to the trend usually noted for conventional concrete/mortar where the entrapped air content is only a few percentage by volume. It has been concluded by (Tam *et al.*, 1987) that:

1. The strength of moist-cured foam concrete depends on water–cement ratio and air–cement ratio
2. The combined effect should be considered when volumetric composition of air-voids approaches that of water voids.

### 2.3.2 Water Absorption

The bricks contain pores will allow passage of water. Due to capillary action at the pores of the bricks, the pores will absorb the water content from mortar that lay on the bricks. The absorption of water will affect the properties of the mortars and thus affect the bonding of mortar between bricks. The initial rate of absorption (IRA) by the clay bricks should fall between the range of 0.25 and 2.05 kg/min/m$^2$ in order to form strong bond between mortar and bricks. If the IRA of the clay bricks is less than 0.25 kg/min/m$^2$, the bricks do not absorb much water from the mortar and the water may tend to float on the mortar. If the IRA value is too high, too much moisture is drawn from the mortar (Robert, 1994). If too much moisture is drawn from the mortar, the mortar may dried and harden faster than the bonds made with the bricks. The bonds between mortar and bricks may be not strong enough although the mortar has hardened.

By the previous research, the value of water absorption was determined. Fired clay brick was found to exhibit the highest initial rate of absorption and unit water absorption. (Badorul *et al.*, 2007). Table 2.1 shows the value of water absorption and IRA obtain from the test results for calcium silicate, clay, and cement sand brick.

**Table 2.1** Value of Water Absorption and IRA for 3 Types of Bricks

| Parameter | Symbol | Units | Calcium Silicates Bricks | Fired clay bricks | Cement sand bricks |
|---|---|---|---|---|---|
| Brick Compressive strength | $F_{bc}$ | N/mm$^2$ | 24.79 | 30.51 | 6.53 |
| Water Absorption | WA | % | 11.93 | 20.78 | 12.77 |
| IRA | IRA | kg/m$^2$/min | 0.016 | 0.051 | 0.024 |

**Source** : Badorul *et al.* (2007)

Compare to the previous research, the percentage of water absorption of the FCB are lower than the clay bricks that stated by the manufacturer, Desjaya. The value of water absorption that obtained by the manufacturer is 14 %. Figure 2.1 shows the comparison of percentage water absorption for four types of bricks.

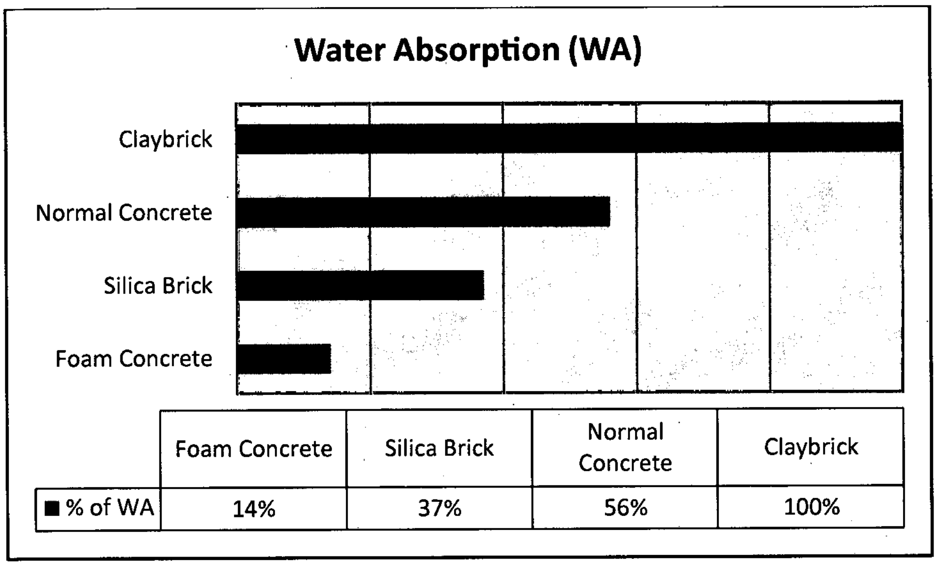


**Figure 2.1** Comparison of Percentage Water Absorption

**Source** : Desjaya (2010)

### 2.3.3 Fire Resistance

Traditionally, a fire resistance rating has been established by testing. The most common test method used is ASTM E119, Standard Test Method for Fire Tests of Building Construction and Material. Fire resistance tests on different densities of foam concrete indicated that the fire endurance enhanced with reductions in density. From the earlier studies of fire resistance stated by (Jones and McCarthy, 2005), the lower densities of foam concrete have proportional strength loss less than normal concrete. The lower densities of foam concrete have exhibited better fire resistance, while the higher densities stated to be reversed (Aldridge, 2005). From the studied by (Kearsley and Mostert, 2005) had conclude that foam concrete containing hydraulic cement with an $Al_2O_3/CaO$ ratio higher than two can withstand temperatures as high as 1450 °C without showing sign of damage.

The manufacturer, Desjaya stated that the FCB is an organic material and incombustible. The fire resistance of FCB is increased based on the thickness of the bricks. The Figure 2.2 shows fire resistances time (hours) based on the FCB thickness. For FCB with thickness 100 mm, the fire resistance time reached 3.5 to 4 hours. The hours are high compared to normal concrete that reached 1.5 hours.

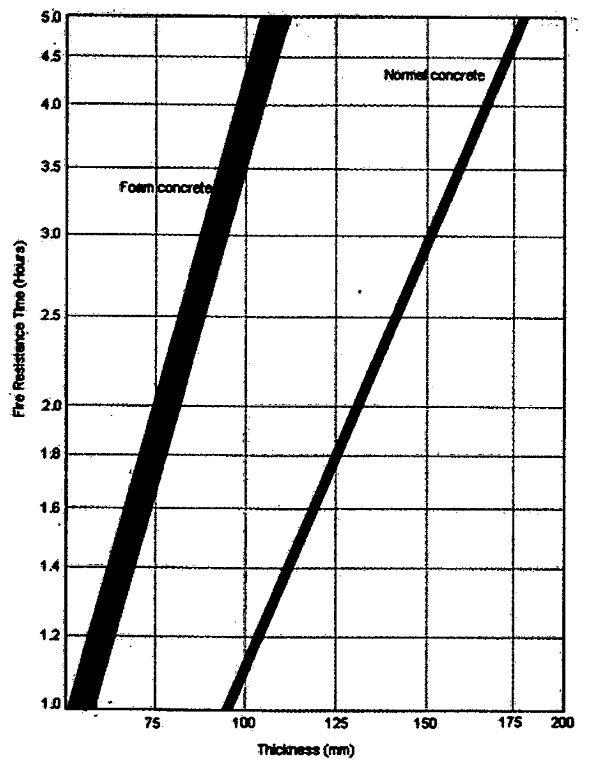


**Figure 2.2** Fire Resistance Time Based on FCB Thickness

**Source** : Desjaya (2010)