EFFECT OF HORIZONTAL PATTERN ON MASONRY PRISM STRENGTHENED USING CARBON REINFORCED POLYMER (CFRP) AND GLASS REINFORCED POLYMER (GFRP)

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ABSTRAK

Pembinaan berasaskan batu bata telah digunakkan dengan meluas di segenap pelusuk dunia khususnya dalam aplikasi pembinaan dinding sesuatu bangunan. Antara faktor pengunaan batu bata adalah disebabkan kerana mudah diperolehi, harga yang murah dan pengendalian kerja yang mudah. Namun, terdapat masalah yang timbul kesan daripada penggunaan batu bata tersebut antaranya ialah keretakan pada dinding bangunan apabila melebihi kapasiti bebanannya. Hal ini boleh diatasi dengan meningkatkan dan mengukuhkan daya tahan beban tanpa menukar bahan binaan. Dalam kajian ini untuk meningkatkan daya tahan struktur dinding batu, kaedah aplikasi polimer bertetulang gentian telah digunakan dalam pengukuhan kapasiti beban bagi batu bata. Terdapat empat jenis prisma batu konkrit telah diperkenalkan iaitu kedua belah bahagian dilekatkan dengan polimer karbon gentian diperkuatkan secara melintang (A), kedua belah bahagian dilekatkan dengan polimer karbon gentian diperkuatkan secara melintang (B), kawalan diikat secara menegak tanpa diperkuatkan dengan polimer kaca gentian (C), dimana setiap kumpulan berkuantiti 3 unit. Kesemua prisma diuji ini untuk membandingkan tingkah lakunya terhadap beban. Hasil pemerhatian dan ujian didapati nilai purata bagi beban gagal adalah seperti berikut (A) 148 kN , (B) 186 kN, (C) 180 kN, Kesimpulan dapat dibuat kekuatan prisma (B) berbanding (C) dan (A) adalah yang tertinggi membuktikan polimer bertetulang gentian boleh meningkatkan keupayaan struktur batu bata untuk menanggung beban yang tinggi disamping corak keretakkan dapat dikawal.

ABSTRACT

Brick construction is widely uses in all parts of the world over the last century especially wall construction. The use of these materials is closely related to several factors, among which are easily obtained, cheap and easy job control. However, there are some disadvantages arise in the application of brick construction which brick wall will eventually crack wherever exceed the load capacity of the brick. Therefore, the study is focus on the strengthening method on wall construction without changing the construction materials. In this study, strengthening method using fibre reinforced polymer method is selected in order to observe the maximum load capacity and compare behaviour against the loading that can be obtained when strengthen by fibre reinforced polymer. Characterization tests such as absorption test and compressive strength test were conducted on concrete masonry unit (CMU) to determine its characteristics before mortar mix were used as a binder for the specimens. Compression and flexural tests were conducted to characterize the mortar mix used. A total of 12 prisms specimens with four different conditions were produced for the compressive strength test. Those prism specimens are classified as strengthened with CFRP in horizontal orientation (A), strengthened with GFRP in horizontal orientation (B), control specimen without fibre polymer (C). Each condition has a total of three specimens each to compare their outcomes. The results of observations and tests found the average value of the failure load is as follows (A) 148 kN, (B) 186 kN and (C) 180 kN. The conclusion that can be made is strength (B) which specimen strengthened with GFRP in horizontal pattern is the highest compare (C) and (A) which prove it can increase the load capacity of structure and crack pattern could be controlled.

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LIST OF ABBREVIATIONS

ASTM	**A**merican **S**ociety for **T**esting and **M**aterials
GFRP	**G**lass **F**ibre **R**einforced **P**olymer
CFRP	**C**arbon **F**ibre **R**einforced **P**olymer
FRP	**F**ibre **R**einforced **P**olymer
CMU	**C**oncrete **M**asonry **U**nit
URM	**U**nder **R**einforced **M**asonry
LVDT	**L**inear **V**ariable **D**isplacement **T**ransducer
ANOVA	**A**nalysis **o**f **V**ariance

CHAPTER 1

INTRODUCTION

1.1 Background

Masonry construction has been used for at least 10,000 years in a variety of structures, homes, private and public buildings and historical monuments. For example, the Great Wall of China and many ancient buildings are some of the world's most significant architectural achievements that have been built with masonry. Through civilization, architects and builders have chosen masonry structure such as wall for its beauty, versatility, and durability.

Masonry wall started only using two major materials which are brick manufactured from sun-dried mud or burned clay and shale and natural stone. Sun-dried mud or burned clay were used in the construction of buildings more than 6,000 years ago. In order to prevent distortion and cracking of the clay shapes, chopped straw and grass were added to the clay mixture. About 4,000 B.C, masonry wall evolved as the manufactures began to produce brick in uniform shapes. Along with the shaping of brick, the move from sun bake to firing was another important change. This improved the durability of the masonry brick.

The evolution of brick construction designs led to the development of concrete block. The manufacturing and uses of concrete block or known as concrete masonry unit (CMU) evolved over a long period of time. Concrete blocks are produced with a mixture of cement, sand, and crushed stone, or lightweight aggregate. The production of concrete block is done in large amount in plants using automated system. The raw materials are loaded from trucks or rail road cars into bins. Then, the mix is weighed, transported to a mixer, and fed into the block machine. If necessary, colouring agent is added into the mixture. It takes the machine about six seconds to mould a block. The freshly moulded blocks are put into pallets and placed in steam-curing rooms. After the curing process, they are stacked and taken to a storage yard for delivery.

However, masonry walls constructed using CMU and mortar alone were not able to support to certain degree of tensile stress. Thus, strengthening method and technique has been introduced to cater the problems. Strengthening of masonry walls is required to prevent failure and collapse during major earthquake or addition of extra load on buildings. Strengthening of masonry walls also may be required during rehabilitation of buildings. Based on Babatunde (2017), some strengthening methods were involved in addition of new structural elements such as, steel plate bonding, external post tensioning, steel bracing and others. It has been applied in masonry wall and resulted in positive feedback. However, an innovative retrofitting technique using Fibre Reinforced Polymer (FRP) has gained recognition and acceptance (Babatunde, 2017)

Fibre-reinforced Polymers (FRP) material is a composite material that is increasingly used in the construction industry nowadays. Due to their light weight, high tensile strength, and corrosion resistance and ease of implementation make this material preferred solution for strengthening masonry wall. In this study, it is aimed to discuss the strength and effects of Glass Fibre Reinforced Polymer (GFRP) and Carbon Fibre Reinforced Polymer (CFRP) installation as a composite material in concrete masonry prism.

1.2 Problem Statement

Many researchers had performed studies in masonry technology and improve the masonry weakness especially on structural strength. According Cecchi and Rizzi (2010), many variables influence the mechanical behaviour of masonry, such as the brick and mortar properties, brick geometry, joint dimensions, and joint arrangement which results in heterogeneous masonry material. Thus, masonry structure will have different mechanical behaviour depending on the composition and method of construction.

Masonry unit has been used primarily as the gravity load-bearing material to resist compression. For example, masonry wall and columns are designed to resist vertical loads. A good masonry unit should have these criteria such as high compressive strength, low in water absorption, initial rate of absorption and porosity. Most common masonry unit uses in construction is concrete masonry unit known as CMU. In masonry construction CMU with hollow cores, give many advantages in masonry construction. These hollow core units come with difference size and strength. However, this hollow cores unit has structural limitation such as low capability to resist lateral load, tensile strength and twisting.

In order to mitigate the problem, various studies have been conducted throughout the years to develop a strengthening techniques which will improve the performance of masonry structures. According to Babatunde (2017). (2017), the strengthening methods were discovered throughout the studies as the addition of new structural elements, steel plate bonding, external post tensioning, steel bracing and many more have been applied with some degree of success. In this study, FRP or Fibre Reinforce Polymer will be used to strengthen the masonry structures. These innovative materials have the advantage over conventional materials because of its lightweight, high strength and highly durable against the environments. FRP consist of high strength fibres embedded in a resin matrix. This fibres are made from Carbon (CFRP) and Glass (GFRP). Throughout this study, concrete masonry prism is introduced to different types of FRP wrapped in horizontal direction to identify and compare the maximum strength capacity.

1.3 Objectives

The objectives of this study are:

1. To determine the strength of concrete masonry prisms with two difference strengthening material CFRP and GFRP
2. To compare the strength of concrete masonry prisms using CFRP and GFRP

1.4 Scope of Work

In order to determine the strength Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP), two types of concrete masonry prism specimen were prepared. Each type was conducted in average three specimens respectively. Every type of the concrete masonry prisms caters different variable which are CFRP and GFRP strips. Those specimens are control specimen without installation of any FRP. To study the effects of using FRP strips on concrete masonry prisms, one type of specimen was prepared. The sample was attached with GFRP strip in a horizontal orientation using adhesive epoxy resins applied to it. The strength and loading capacity for each sample were analysed after compressive strength test conducted. The properties of each sample were compared with that of control specimens.

1.5 Dissertation Outline

The dissertation is organized into five chapter. This section describes the general outline of the dissertation

Chapter 1- Introduction

This chapter is an introduction and overview of this dissertation. The chapter briefly explain the main idea of these studies followed by problem statement to identify and understand the reasons to carry out this research. Based on the problem statement, the objectives are set in order to achieve the purpose of the dissertation.

Chapter 2- Literature Review

This chapter is a compilation of reviews and researches related on the physical properties, mechanical properties and testing on the specimen. In this chapter further discuss on review on masonry history, concrete masonry unit and fibre reinforced polymer (FRP). The review more focus on the objectives of the dissertation which are strengthening method which enhance the maximum loading capacity of the specimen on different FRP materials. Thus, this chapter are discussing the previous studies on strengthening structural component using various type FRP and the effect of the FRP pattern on structural component.

Chapter 3 – Methodology

This chapter is focus on the methodology of this dissertation. In this chapter is discuss more on method on preparing the trial mix and testing for material and physical properties for CMU and mortar. Each test is based on qualified standard references further discuss in depth detail to enhance the understanding of the execution of this dissertation.

Chapter 4 – Results and Discussion

This chapter presents the results and discussion of this research to ensure that the objectives are achieved and produce substantial results to improve the future studies or to be used in real projects. Results from the specimens testing will be provided and justified. Then, results data of specimens was justified and compared with previous researches.

Chapter 5 – Conclusion

This chapter concludes the overall dissertation and a brief summary of the outcomes and recommendations for further research in the future will be discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the literature will be reviewed and summarized. This chapter will cover the contents and background about masonry, fibre-reinforced polymer (FRP) and strengthening method. This chapter also covers the related past study on FRP applications as a strengthening material and thermal effect of the masonry structure.

2.2 Masonry

Based on dictionary of construction, surveying and civil engineering, masonry is referring to the construction of walls, dwellings, buildings, etc. using essentially brick, mortar, and concrete. Generally, material of masonry construction can be classified into the following category-

i) Stone masonry

ii) Brick masonry

iii) Hollow block

iv) Concrete masonry

v) Reinforced masonry

vi) Composite masonry

The selection of materials depends on their purposes. The material is hand-placed as arrangement of material and bind together with mortar to form durable structural wall and other components. In some cases, metal ties and steel reinforcement are applied to enhance the masonry durability. The masonry work requires skilled and craftsman work as the materials used, the quality of the mortar, workmanship, and the pattern in which the units are assembled can substantially affect the durability of the overall masonry construction.

According to Consortium (2003), proper masonry construction depends on correct design, materials, handling, installation and workmanship. With a fundamental understanding of the functions and properties of the materials that comprise masonry construction and with proper design and construction, quality masonry structures are not difficult to obtain. Thus, both the raw materials and the method of manufacture affect masonry unit properties.

The nature of masonry is such that its construction can be achieved without very heavy and expensive plant. Although dependent on skilled labour for a high quality of construction, productivity has been maintained by the use of larger units, improved materials handling and off-site preparation of mortar.

2.2.1 Masonry Units

Common type of masonry walling units use in construction in the form of bricks and blocks are produced from clay, concrete and calcium silicate. Natural stone is also used but limited to country which has huge resources of natural stone. All units have broadly similar uses although their properties differ depending on the raw materials used and the method of manufacture.

There are five main types of concrete masonry units:

- Hollow load-bearing concrete block
- Solid load-bearing concrete block

- Hollow non-load-bearing concrete block
- Concrete building tile
- Concrete brick

It is available in various sizes and shapes to fit different construction needs. Bricks are typically 215 x 102 x 65 mm (length x width x height) whilst conventionally sized blocks are available in lengths 400-600 mm, heights 150-300 mm and a wide range of thickness between 60 and 250 mm (Hendry, 2001). Most common masonry unit uses in construction is concrete masonry unit or known as CMU. Concrete masonry blocks, especially those with hollow cores, offer various possibilities in masonry construction. They generally provide great compressive strength, and are best suited to structures with light transverse loading.

According to in Metric Technical Manual on Physical Properties (2001), full solid unit has a net cross-sectional area in all planes parallel to the bearing surface of 100% of the gross cross sectional area while for hollow has net cross-sectional area to the bearing surface of less than 75% of the gross cross-sectional area. A semi-solid unit has a net cross-sectional area in all planes parallel to the bearing surface of at least 75%, and less than 100%, of the gross cross-sectional area.

CMU block is categorised into heavyweight and lightweight depending on the aggregate used in their production. For lightweight CMU block and normal weight CMU block should meet specification of ASTM C-331 and ASTM C-33, respectively. Thus, the selection of the types of block depends on both the availability and requirements of the intended structure. Properties of constructed concrete block masonry which are often times important to building and element design.

2.2.2 Concrete Masonry Prisms

Masonry has been used primarily as the gravity load-bearing material to resist compression. For example, masonry wall and columns are designed to resist vertical loads. Therefore, the compressive strength of masonry prisms is the most important property required in the design of structural masonry.

Masonry prism behaviour and strength under vertical loading has been a fundamental research topic for the past six decades. Many influential parameters on the prism strength have been researched in the form of experimentation and numerical modelling.

It has been established that the compressive strength of the masonry assemblage differs from the compressive strength of individual components of the prism. The typical compressive strength of masonry units is relatively high but the compressive strength of mortar is low. The resulted prism strength is found to be somewhere in between.

Two failure modes are commonly observed for masonry prisms in compression. One is masonry crushing for weak units and the other is the vertical cracking through either the face-shell or web of the prism. For the latter mode, the vertical compressive stresses applied are transferred to the mortar, which results in the mortar expanding laterally. The masonry unit resists the expansion of the mortar and thus creates lateral confined compressive stresses in the mortar and lateral tensile stresses in the unit (Kaaki, 2013).

2.3 Fibre Reinforced Polymer (FRP)

Fibre Reinforced Polymer or also known as Fibre-reinforced plastic (FRP), is a composite material made of two primary constituents which are fibres and a polymer matrix. Generally, most common construction fibres are usually made of glass, carbon or aramid. In construction industry, Glass fibre reinforced polymer (GFRP) and carbon fibre reinforced polymer (CFRP) are the most preferred and used widely.

Aramid fibre reinforced polymer (AFRP) is extremely sensitive to environmental condition. Glass fibre reinforced polymer (GFRP) is excellence when subjected to creep under high sustained loading and degradation in alkaline environment meanwhile carbon fibre reinforced polymer (CFRP) offers premium cost compares to others.

FRP is manufactured in different forms which are in short fibre, chopped fibre, long fibre, and woven fibre. The primary role of fibres is to provide strength and stiffness to the material. But the fibre alone is brittle. Therefore, the fibres are encased in a coating of polymer materials. Polymer matrix holds the fibres in their position and transfers the loads between the fibres. It also contributes to the inter-laminar shear strength. There are several types of the polymer which include epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins. Each polymer has different chemical and physical properties thus, contribute differently to the composite structure. As a result, the composite properties are also different based on the polymer.

The polymer matrix must be able to properly saturate, and preferably bond chemically with the fibre reinforcement for maximum adhesion within a suitable curing period. The matrix must also completely envelop the fibres to protect them from cuts and notches that would reduce their strength, and to transfer forces to the fibres.

Numerous studies have revealed that Fibre Reinforced Polymer (FRP) is a convenient material for repair and strengthening of concrete structures compared to the traditional materials. According to Panjehpour (2011), FRP application has increasingly developed to the level that nowadays it is used in many modern construction projects and researches in the world due to their low labours costs, lightweight, high tensile strength to weight, and easy installation.

Other than that, FRP are highly resistant to temperature change without softening or brittleness. According to Benzarti et. al., (2011), FRP materials also have good resistance to UV radiation, humidity, atmospheric pollution. However, FRP has disadvantage of having a low flammability depending on the choice of resin.

2.3.1 Types of FRP

There are many types of FRP available in the market nowadays used in the construction industry. All of them have their own properties and uniqueness. Types of fibres are usually glass, carbon, or aramid, other fibres such as paper or wood or asbestos. While types of the polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins. Among these types of FRP, the most widely used FRP materials in construction are Carbon Fibre Reinforced Polymer (CFRP) and Glass Fibre Reinforced Polymer (GFRP) (Tan, 2012).

2.3.1.1. Glass Fibre Reinforced Polymer

Glass fibre reinforced polymer (GFRP) is a composite material, which consists of polyester thermosetting resin as matrix and glass fibres as reinforcement. GFRP is mainly used as structural sections and as structural rehabilitation and repair material.

Glass fibre is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fibre and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favourable when compared to metals, and it can be easily formed using moulding processes.

The plastic matrix may be epoxy, a thermosetting plastic (most often polyester or vinyl ester) or thermoplastic. Common uses of glass fibre include boats, automobiles, baths, hot tubs, water tanks, roofing, pipes, cladding, casts and external door skins.

The manufacturing process for glass fibres suitable for reinforcement uses large furnaces to gradually melt the silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals to liquid form. Then it is extruded through bushings, which are bundles of very small orifices (typically 5-25 micrometres in diameter for E-Glass, 9 micrometres for S-Glass). These filaments are then sized (coated) with a chemical solution. The individual filaments are now bundled together in large numbers to provide a roving. The diameter of the filaments, as well as the number of filaments in the roving, determine its weight (Mackrill,2013).

2.3.1.2. Carbon Fibre Reinforced Polymer (CFRP)

Properties of Carbon Fibre Reinforced Polymer known as CFRP is similar to GFRP. Carbon Fibre Reinforced Polymer (CFRP) is a composite material originally used in aerospace industry. However, the application CFRP was expanded more in automotive industry and buildings construction. CFRP were discovered to have excellent material properties such as high rigidity, tensile strength, chemical resistance, temperature tolerance and thermal expansion with a low weight fibre material.

CFRP is known for its lightweight properties was made of thousands of carbon atom fibres in diameters of 5 to 10 micro meters. The carbon fibre were bundled together to form carbon weaves fabric. The carbon fibre were arranged in a symmetrical and parallel depending on the pattern. The arrangement of carbon fibre will give carbon fibre its strength and the ability to be lightweight.

CFRP will gain extreme rigidity and high strength to weight ratio when embedded together with binding polymer. The ratio mixture of binding polymer was one of factor which effect the strength of the composite. The binding polymer is often a thermoset resin such as epoxy resin. CFRP composite is an improvement on building construction method using metal reinforcement. Metal reinforcement on the other hand is more limited on the shape it can provide. Carbon fibre composites typically weigh a quarter of the weight of steel, but has the same amount of rigidity, making it 4 times as stiff on a weight-to-weight basis.

In order to get more information and understanding about this project, some literature was reviewed based on previous journals. Some literatures on previous research related to this project are presented in Table 2.1

Table 2.1 : Previous Works Reported By Other Authors

No	Author	Title	Description
1	Albert et. al., (2001)	Strengthening of Unreinforced Masonry Wall using FRPs	This paper conducted an experimental program which shown that externally applied FRP are effective in increasing the load-carrying capacity of URM that are subjected to out-of-plane flexural loads. 10 walls with a height of 4 m were used to conduct 13 tests in two series which are both undamaged and slightly damaged walls were tested. Overall results show that the strength and ductility of the specimens are increased significantly when strengthened with FRP

2	Gustavo et. al., Conference Paper (May 2001)	Strengthening of Masonry Structures with FRP Composites.	The paper studies in unreinforced masonry (URM) walls are prone to failure when subjected to out-of-plane and in-plane loads. FRP materials offer viable solutions to solve or lessen the effects of overloading.
3	Borri et. al., (2004)	Seismic Upgrading of Masonry Structures with FRP	The paper studies on the determination of shear strength of masonry specimens reinforced using carbon and glass FRP. The application of FRP inhibits the out-of- plane mechanisms of masonry walls and permits the transfer of stresses to the wall parallel to the direction of seismic action and increases the ductility of the masonry structures.
4	Yousef, A. A., & Tarek, H. A (2004)	Load Capacity of Concrete Masonry Block Walls Strengthened with Epoxy-bonded GFRP Sheets	This paper investigates the results of the experimental work carried out to investigate the capability GFRP laminates in strengthening the concrete block walls subjected to out-of-plane and in-plane vertical and lateral stresses. By using deformation compatibility and force equilibrium, simple design equations are presented to estimate the strength of masonry walls and their possible mode of failure
5	Shrive (2006)	The use of fibre reinforced polymers to improve seismic resistance of masonry	The paper studies on fibre reinforced polymers to improve seismic resistance of masonry. GFRP applied on both sides of wall were increased the flexural strength up to 32 times self-weight of wall. The service temperature of most structures,

			the binding resins are stable, but as the temperature increases, the resin breaks down and evaporates
6	Proenca et. al., (2012)	Strengthening of masonry wall load bearing structures with reinforced plastering mortar solution.	The paper studies the strengthening effects and to identify the most effective detailing procedures for this solution. The initial testing stage was focused on the behaviour of composite mortar-mesh specimens, subjected to tensile tests. The improvement to the strength, energy dissipation and deformability is even more significant when the seismic actions are in the plane of the wall.
7	S.S.Saileysh et.al., (2013)	GFRP Strengthening and Applications of Unreinforced Masonry wall	This paper study on out-of-plane shear behaviour of Burned Clay Brick Masonry Walls and strengthened with Glass Fibre Reinforced Polymer (GFRP) over the Burned Clay Brick Masonry Walls surface. Thus, masonry structure is subjected to lateral inertial loads during an earthquake, the walls develop shear and flexural stresses. The effectiveness of increasing the shear strength of brick masonry coating with epoxy-bonding by Glass Fibre Reinforced Polymer (GFRP) overlays to the exterior surfaces was evaluated.

8	Y. Wei Lin et al., (2014)	In-plane strengthening of clay brick unreinforced masonry wallettes using ECC shotcrete	The paper studies on predominant failure modes that occurs in URM buildings is diagonal shear cracking of masonry piers. The stress then remained relatively constant as the cracked upper section of the wallettes slid along the horizontal mortar joints of the stepped diagonal crack
9	Mohamad et. al., (2017)	Strength, behaviour, and failure mode of hollow concrete masonry constructed with mortars of different strengths	The paper studies on the failure modes of hollow concrete masonry prisms, taking into account the block and mortar stress-strain behaviour. The typical failure mode observed during testing for this type of masonry was due to tensile stresses developed in the block.
10	J. Kubica and G. Iwona (2017)	Comparison of Two Ways of AAC Block Masonry Strengthening Using CFRP Strips Diagonal Compression Test	The paper investigates the optimal layout of strip strengthening of the masonry wall which horizontal, vertical or diagonal. It results in CRFP strips allowed for larger deformations of the masonry walls at failures. It is significant increase in the ultimate force destroying the strengthened walls.
11	A.B Samuel (2017)	Review of strengthening techniques for masonry using fibre reinforced polymers	This paper reviews these strengthening techniques, their advantages, disadvantages and limitations of FRP. Different strengthening techniques are available to increase the flexural and shear strength and ductility of masonry structures using FRP materials.

12	N.Reoul (2018)	Two-way bending behaviour of hollow concrete block masonry walls reinforced by composite materials	This paper investigates the effectiveness of externally bonded composites to improve the out-of-plane behaviour of masonry walls. By observation, the performance of each strengthening configuration was estimated by considering the out-of-plane load capacity, ductility, energy dissipation and crack pattern.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will elaborate the plans and flows of the laboratory work involved in the investigation of material, the substances used and the characterization of the masonry prisms. This chapter also will further discuss on the material characteristics, application of GFRP strip to the samples and method to conduct compressive strength test and thermal test.

Throughout the study, we controlled the FRP strip orientation on masonry prisms and only addressed on difference composite material of FRP. The effect on these parameters on the loading capacity of concrete masonry prism based on objective 1 and compare the maximum compressive strength in two composite material based on objective 2. Then, the composite will undergo thermal conductivity test for maximum temperature resistance of concrete masonry prism in objective 3. Figure 3.1 shows the flow for this study.

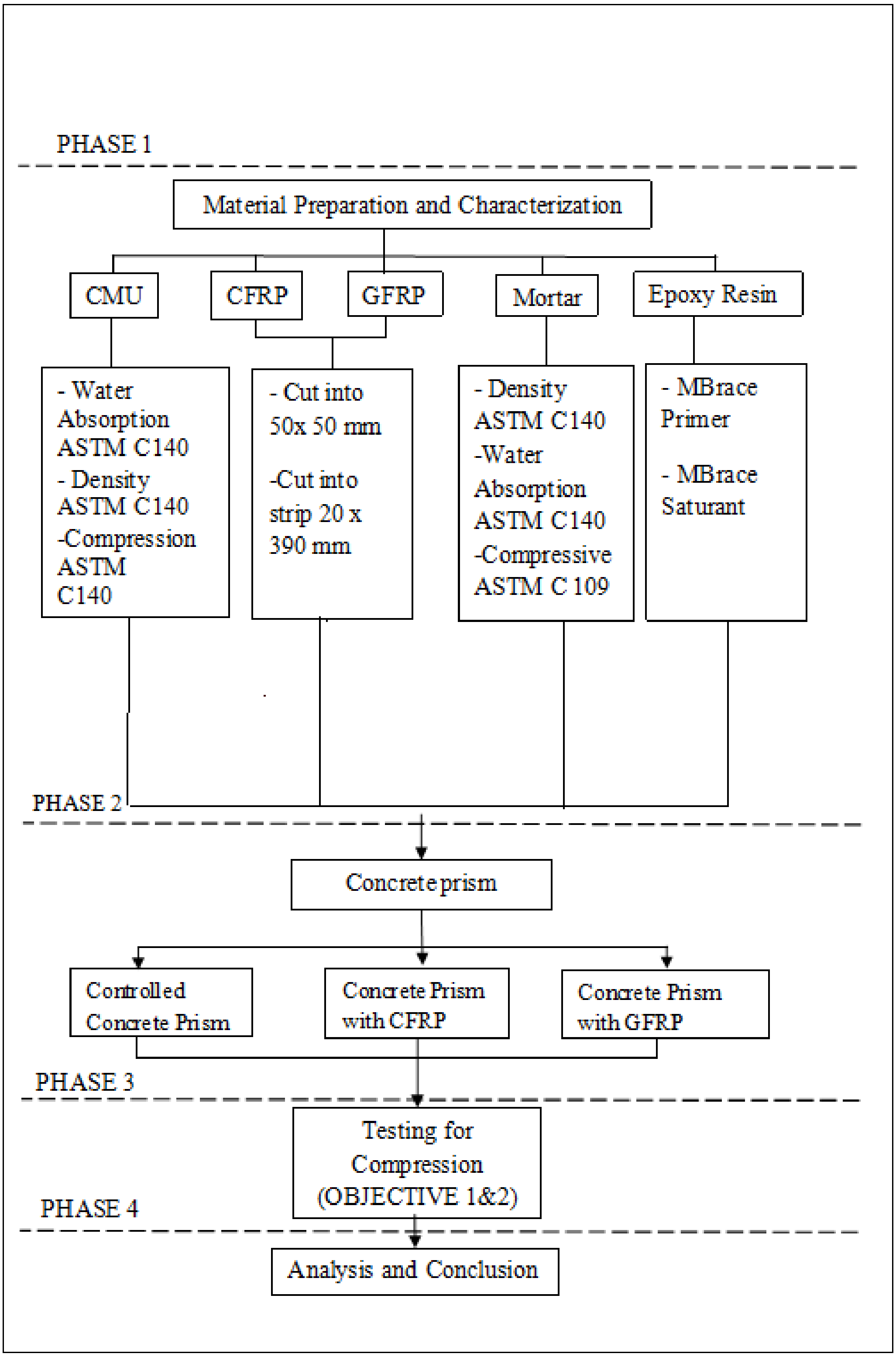

Figure 3.1: Flow chart of the study

3.2 Material Preparation

3.2.1 Concrete Masonry Unit (CMU)

In this study, concrete masonry unit (CMU) or known as a concrete block was the main material to construct the prisms specimen. Concrete block was made from a mixture of Portland cement, water, and aggregate which are sand and gravel. The cement-aggregate ratio in concrete masonry blocks was 1:6. The concrete block was made up of 60% fine aggregate and 40% coarse aggregate. Lightweight CMU and normal weight CMU should meet the specification of ASTM C-331 and ASTM C-33 respectively. There was various selection of CMU depending upon types of structure, shape, size and manufacturing of processes concrete blocks. In general, concrete blocks are classified as hollow, semi-solid, or full solid.

ASTM C-90-91 specifies the compressive strength requirements of concrete masonry unit should be at least 3 N/mm^2 for lightweight masonry unit. This produces a light grey block with a fine surface texture and high compressive strength. The concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixtures used for general construction purposes.

For this study, Figure 3.2 shows hollow concrete block that was selected to find the loading capacity for each type of prism specimens. The masonry units shall be free of organic impurities that will cause rusting, staining or pop-outs and shall contain no cinders. Moreover, fatty acid products were not accepted in masonry unit accepted. Lastly, the manufacturer provides the certification of a qualification test of performance and date of yearly certificate for further information during experiment.

Figure 3.2: CMU used in this study

3.2.2 Mortar

Mortar is one of the important materials used in masonry structures. Mortar is used to bind the masonry unit to form masonry structure. Through the study, the concrete block was arranged and sealed using mortar to form concrete prism.

According to BS EN 998-2 (British Standard Institute, 2003), the mix ratio used is 1:4 which represent 1 part of cement and 4 parts of fine aggregates. The quantity of water was based on the absorption rate of concrete masonry unit (CMU) and surrounding humidity. Therefore, quantity of water was 1.5 times the quantity of cement. The same mixture was used to prepared for 6 prisms. Table 3.1 shows the calculated quantity of material based on mix ratio.

The fine aggregate was prepared based on ASTM C136-05 standard method. Firstly, 2 kg of river aggregate was placed on a set of standard sieve size. The pan was placed below sieve number No 200 or 600 micro meter size before proceeding with the process on sieve shaker. The time required for each batch of 2 kg river aggregate in sieving process was between 3 to 5 minutes and should not be less than 3 minutes in order to have fully sieve condition. Figure 3.3 shows the sieving process of the aggregate.

Figure 3.3 : Sieving process of the aggregate

Table 3.1 : Quantity used based on mix ratio

Material	Cement Content (Portland cement type 1)	Fine Aggregate (<600 µm)	Water Content
Ratio	1	4	1.5
Quantity (kg)	2.50	10.00	3.75

The mortar was prepared first by mixed thoroughly fine aggregate of sand with Ordinary Portland cement in dry condition. Then, clean water was slowly added into the mixture and continue mix it again. The step was repeated until the mixture gain desired consistency and workability. The mortar was mixed using automated machine. Figure 3.4 shows the mortar mixture in mould.

Figure 3.4 : Mortar mixture in moulds

3.2.3 Composite Material (FRP)

3.2.3.1. Glass Fibre Reinforced Polymer (GFRP) and Carbon Fiber Reinforced Polymer (CFRP)

In this study, GFRP and CFRP strips are known as strengthening materials in concrete masonry prisms. The type of GFRP and CFRP used were MBrace ® EG900 and Build Seal CFFS 300 respectively. The material properties of glass fibre and carbon fibre are shown in Table 3.2 and Table 3.3 respectively.

Table 3.2 : Properties of glass fibre (MBrace ® EG900)

MBrace ® EG900	
Tensile strength (N/mm^2)	1667
Tensile E-modulus (N/mm^2)	72400
Thickness (mm)	0.353
Width (mm)	500
Density (g/cm^3)	2.58
Ultimate Tensile Elongation	2.00%

Table 3.3 : Properties of Carbon Fibre (Build Seal® CFFS 300)

Build Seal ® CFFS 300	
Tensile strength (N/mm^2)	4900
Tensile E-modulus (N/mm^2)	2300
Thickness (mm)	0.176
Width (mm)	320
Density (g/cm^3)	1.79
Ultimate Tensile Elongation	1.60%

Glass Fibre Reinforced Polymer (GFRP) and Carbon Fibre Reinforced Polymer (CFRP) were prepared into 2 sets of experimental testing. CFRP and GFRP were cut into small piece with size 20 x 190 mm for 3 samples of concrete masonry prism respectively. Figure 3.5 shows CFRP and GFRP were cut in size 20 x 190mm. Then, GFRP and CFRP were cut into 25 x 25 mm of one set of composite sample and another