EFFECTS OF PLASTERING AND GLASS FIBRE REINFORCED POLYMER (GFRP) ON CONCRETE MASONRY PRISM STRENGTH CAPACITY

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By

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Pembinaan berasaskan kerja batu telah lama digunakan dalam pelbagai jenis struktur, rumah, bangunan awam, swasta dan juga monumen bersejarah. Kapasiti beban terutamanya untuk dinding galas beban boleh ditingkatkan dengan menggunakan pelbagai kaedah yang ada. Dalam usaha untuk meningkatkan daya tahan struktur dinding batu, kaedah yang boleh digunakan adalah dengan cara melepa dan pengukuhan. Dalam kajian ini, empat jenis prisma batu konkrit telah diperkenalkan untuk membandingkan tingkah lakunya terhadap beban. Spesimen-spesimen tersebut dikelaskan sebagai spesimen kawalan tanpa dilepa, sebelah bahagian dilepa, dua belah bahagian dilepa, dan spesimen diperkukuhkan dengan jalur Polimer Diperkuat Gentian Kaca (GFRP) dalam orientasi menegak. Ujian pencirian seperti ujian penyerapan dan ujian kekuatan mampatan dijalankan ke atas unit batuan konkrit (CMU) untuk menentukan ciri-cirinya sebelum campuran mortar digunakan untuk ikatan. Ujian mampatan dan ujian lenturan telah dijalankan untuk mencirikan campuran mortar yang hendak digunakan. Sebanyak 12 prisma spesimen dengan empat keadaan yang berbeza dihasilkan untuk ujian kekuatan mampatan. Setiap keadaan mempunyai sebanyak tiga spesimen untuk membandingkan keputusannya. Hasil ujian menunjukkan bahawa spesimen lepaan dua belah mempunyai purata kapasiti muatan tertinggi iaitu 209 kN. Dalam kajian ini, semua jenis spesimen menggunakan kaedah yang sama semasa proses penghasilannya dan membuktikan bahawa spesimen dengan lepaan dua belah boleh meningkatkan keupayaan struktur lepaan untuk menanggung beban yang tinggi.

ABSTRACT

Masonry based construction has long been used in various types of structures, houses, public and private buildings and also historical monuments. The loading capacity of masonry especially for the load-bearing wall can be increased by various methods available. In order to increase the resilience of a masonry structure, methods that can be used are plastering and strengthening. In this research, four types of concrete masonry prisms have been introduced to compare its behaviour against loading. Those specimens are classified as controlled specimen without any plaster, one-sided plastered, two-sided plastered, and specimen strengthened by Glass Fibre Reinforced Polymer (GFRP) strip in a vertical orientation. Characterization tests such as absorption test and compressive strength test were conducted on concrete masonry unit (CMU) to determine its characteristics before mortar mix are applied for bonding. Compressive test and flexural test were conducted to characterize the mortar mix used. A total of 12 prisms specimens with four different conditions was produced for the compressive strength test. Each condition has a total of three specimens each to compare their outcomes. The test results showed that two-sided plaster specimen have the highest average loading capacity of 209 kN. In this study, all conditions used the same method during the production process and proved that both sides plaster can improve the ability of the masonry structure to resists high loading.

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LIST OF ABBREVIATIONS

ANOVA	**A**nalysis **of** **V**ariance
ASTM	**A**merican **S**ociety for **T**esting and **M**aterials
CF	**C**arbon **F**ibre
CFRP	**C**arbon **F**ibre **R**einforced **P**olymer
CMU	**C**oncrete **M**asonry **U**nit
FRP	**F**ibre **R**einforced **P**olymer
GFRP	**G**lass **F**ibre **R**einforced **P**olymer
LVDT	**L**inear **V**ariable **D**isplacement **T**ransducer
OA	**O**rthogonal **A**rrays
SRW	**S**egmental **R**etaining **W**all
URM	**U**nder **R**einforced **M**asonry

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. The masonry of ancient time involved two major materials: brick manufactured from sun-dried mud or burned clay and shale; and natural stone.

The first masonry structures were unreinforced and intended to support mainly gravity loads. The weight of these structures stabilized them against lateral loads from wind and earthquakes. Concrete masonry was introduced to construction during the early 1900s and, along with clay masonry, expanded in use to all types of structures. In the last 45 years, the introduction of engineered reinforced masonry has resulted in structures that are stronger and more stable against lateral loads, such as the wind and seismic.

The first type of plaster was made from mud. At that time, houses were made from sticks and reeds and the mud was used to cover these items protecting them from the exterior elements. Same as we can see today, the functions of plastering is to cover up the rough surface of masonry by obtaining an even, smooth, regular, clean and durable surface.

Nowadays, drying time is not a big deal. By the time passes, gypsum plaster began to replace lime and therefore reduce the time taken for the plaster to dry. Drying time has also been reduced from the advancements of plastering industry and processing methods. Although the materials used in plastering have been developed and twisted throughout history, the tools used to apply and finish plaster have remained technically the same. People are still looking for innovative new plastering tools in order to make the job of a plasterer easier and more effective (Emma, 2015).

There are several different patterns in the plastering of the masonry. Among them are the one side and two side plaster pattern. Both patterns use the same method throughout the completion process. The important aspects to be identified on both pattern in the construction of a concrete masonry wall is the differences in loading capacity. In this study, differences in plaster pattern will be analysed.

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 effects of Glass Fibre Reinforced Polymer (GFRP) usage as a composite material. It is noted that the mechanical properties of these materials show a useful behaviour for strengthened theoretically to satisfy safe cross-section with FRP materials.

GFRP were chosen as the main strengthening material. When compared with carbon fibres, the lower axial stiffness of GFRP seems more appropriate to use for low strength and low stiffness masonry structures, reducing stress concentrations along the bonded length. It is anticipated that the use of FRP on masonry will involve walls resisting in-plane and out of –plane loads and, possibly, in-fill panels. Indeed, the majority of the work conducted to date has been on the out-of-plane capacity of walls with externally applied FRP. Potential applications include strengthening walls for changes in the wind or seismic requirements, improving the lateral capacity of below-grade walls, as well as retrofitting construction errors.

1.2 Problem Statement

A concrete masonry wall is conventionally used for various types of building especially for a building that applied the load bearing concept. Most of the load bearing wall are plastered but sometimes not plastered due to some aesthetic purposes. In this situation, people have many options either to plaster on one side or both side of the wall and also can strengthen it. Traditional strengthening techniques can be labour intensive, add considerable mass, and cause a significant impact on the occupant all resulting in very high costs. So, in this project, the different conditions of concrete masonry prisms specimens were introduced to compare their compressive strength capacity. Those conditions are controlled specimen without plaster, one-sided plaster, two-sided plaster and specimens with GFRP applied. By using GFRP as strengthening materials, the ease which can be installed on the exterior of masonry structures makes this form of strengthening attractive to the owner considering both reduced installation cost and downtime of the occupied structure.

1.3 Objectives

The objectives of this study are:

1) To determine the strength of concrete masonry prisms with one-sided and two-sided plastering.
2) To compare the strength of concrete masonry prisms strengthen by Glass Fibre Reinforced Polymer (GFRP) with controlled specimens.

1.4 Scope of Works

In order to determine the strength of one sided and two sided plastering, three types of concrete masonry prism specimen were prepared. Those specimens are controlled specimen without plastering, a specimen with one-sided plaster and specimen with two-sided plaster. To study the effects of using GFRP strip on concrete masonry prisms, one type of specimen are prepared. The sample was attached with GFRP strip in a vertical 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 controlled specimens.

1.5 Dissertation Outline

The research consists of five chapters in order to explain all processes from the beginning until completion. This section describes the general outline of this thesis and explanation for each chapter.

Chapter one introduces the overall background of this research, followed by problem statement to identify and understand the reasons to carry out this research. Then, it was followed by the objectives in order to set the desired target to be achieved.

Then, in the second chapter, a literature review on the research title, plastering, concrete masonry and fibre reinforced polymer (FRP). Plastering method and strengthening will be focused in this research as the way to enhance the maximum loading capacity of the specimen. Previous studies using FRP as strengthening materials will be further discussed in this chapter.

After the concept was fully understood in the previous chapter, chapter three will focus on the methodology of this research. In this chapter, the methods, tests conducted, and standard references will be presented in detail to enhance the understanding of the execution of this research. Methods of specimen preparation, purposes of tests carried out and its relevance to this research will be justified.

Next, chapter four presented the results and discussion of this research to ensure that the objectives have been achieved and produced substantial results to improve the future studies or to be used in real projects. Results from the specimens testing will be provided and justified.

Finally, in chapter five, the overall research will be concluded and a brief summary of the outcomes will be written 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 summarily presented. This chapter will cover the contents and background about masonry, plastering, fibre-reinforced polymer (FRP) and so on. This chapter also covers the related past investigations on plastering and FRP applications as a strengthening material.

2.2 Masonry

The word “masonry” is a general term that applies to construction using hand-placed units of clay, concrete, structural clay tile, glass block, natural stones and the like. One or more types of masonry units are bonded together with mortar, metal ties, reinforcement and accessories to form walls and other structural elements.

Masonry consists of a variety of materials. Raw materials are made into masonry units of different sizes and shapes, each having specific physical and mechanical properties. Both the raw materials and the method of manufacture affect masonry unit properties.

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 (Consortium, 2003)

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

Masonry walling units in the form of bricks and blocks are produced from clay, concrete and calcium silicate. Natural stone is also used but only to a limited extent. All units have broadly similar uses although their properties differ depending on the raw materials used and the method of manufacture. Bricks and blocks are produced in many formats, solid, perforated and hollow. 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 thicknesses between 60 and 250 mm (Hendry, 2001)

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 and many influential parameters on the prism strength have been researched in the form of experimentation and numerical modelling. Figure 2.1 shows a schematic diagram of a prism test specimen.

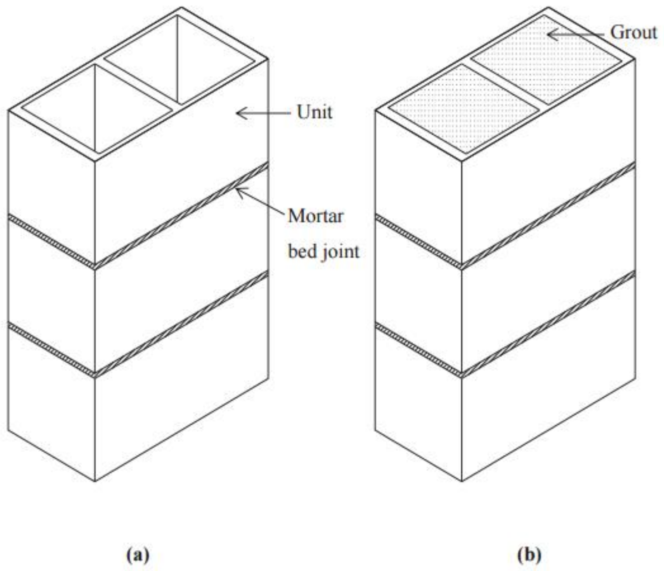

Figure 2.1: Schematic diagram of (a) hollow prisms and (b) grouted prism

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 Plastering

Plastering is a process of obtaining a smooth surface on the rough surfaces of walls, roofs, columns and ceilings etc. for long lasting purposes and to meet its estimated design life period. Besides, make the rough surface become smooth, plastering also make it good looking and attractive. Also, it helps in preventing damp proofing. The coat formed on the rough surface is called plaster when applied inside of the building and it is called as rendering when applied outside of the building i.e. at outer wall exposed to direct environmental condition

The materials used for plastering is common of two types. These are categorised as general plastering material and special plastering material. General plastering materials are the materials used for plastering everywhere and irrespective of any special requirements and these forms the parent material even for special plastering materials and commonly used in residential as well as commercial buildings. Special materials are used as per requirement of the environment, radiation, atmospheric exposure and type of decoration etc.(Panda, 2017).

2.4 Fibre Reinforced Polymer (FRP)

Fibre Reinforced Polymer is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon or aramid although other fibres such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRP can provide a strengthening alternative for unreinforced and under reinforced masonry (URM). Due to their light weight, high tensile strength, and corrosion resistance and easy implementation make these material preferred solutions for strengthening method of masonry wall elements and also reinforced concrete structural elements.

2.5 Types of FRP

There are many types of FRP available in the market nowadays that used in 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)

2.5.1 Glass Fibre Reinforced Polymer (GFRP)

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)

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

Table 2.1: Previous works reported by other authors

Author	Title	Description
McNary & Abrams (1985)	Mechanics of Masonry in Compression	-Investigated the strength and deformation of clay-unit masonry under uniaxial concentric compressive force. - A numerical model based was used to compute the force-deformation relationship for a stack-bond prism. - Results of the study indicated that mechanics of clay-unit masonry in compression could be well represented with a relatively simple model, and the most significant parameter to consider was the dilatants behaviour of the mortar. - Prism strength was also found to be dependent on the strength of the masonry unit under biaxial tensile-compressive stresses.
Albert et. al. (2001)	Strengthening of Unreinforced Masonry Wall using FRPs	- Conducted an experimental program which shown that externally applied fibre reinforced polymers (FRPs) are