STRENGTHENING OF UNDER-STRENGTH CONCRETE USING FRP FABRIC

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ABSTRACT

Applications of Fiber-Reinforced Polymer (FRP) composites as reinforcement for concrete structures have been growing rapidly in recent years because of its properties. Reasons of failures can be caused by environmental factors such as corrosion or severe blast winds, weakened members caused by negligence in maintaining proper damages, earthquake or under strength concrete manufactured during construction. This study focuses on the effect of strengthening of concrete under compression using CFRP and GFRP fabric. Concrete samples of grade 20 were made with different shapes such as circular, square, rectangular and cube. The effect of sharp edges and circular corner on the strengthened samples was also investigated. The concrete samples were wrapped either by continuous or intermittent methods. The result of the study shows that the strength of the strengthened concrete was increased by approximately 50 percent. The circular corner samples recorded higher compressive strength than sharp corner samples. The results also show that continuous wrapping was better than intermittent wrapping. All of the findings indicated that the strength of the under strength concrete can be enhanced using strengthening technique.

ABSTRAK

Aplikasi komposit Fiber-Reinforced Polymer (FRP) sebagai penguatan struktur konkrit telah berkembang pesat dalam beberapa tahun terakhir disebabkan sifat-sifatnya. Punca-punca kegagalan adalah disebabkan oleh faktor alam sekitar seperti pengaratan atau hentaman angin yang kuat, anggota lemah disebabkan oleh kecuaian dalam pembaikpulih kerosakan gempa bumi atau kekuatan konkrit yang korang semasa pembinaan . Penyelidikan ini dijalankan untuk mengkaji kesan penguatan konkrit yang tidak kekuatan mampatan menggunakan fabrik CFRP dan GFRP. Sampel konkrit Gred 20 dibuat dengan pelbagai bentuk seperti bulat, empat segi, segie mpat tepat dan kubus. Kesan buku tajam dan yang dibulatkan juga dikaji. Sampel konkrit diperkuatkan menggunakan samada kaedah secara berterusan atau berselang-selang. Keputusan kajian menunjukkan kekuatan mampatan konkrit yang diperkuatkan meningkat sekitar 50 peratus. Sampel bucu yang dibulatkan mencatat kekuatan mampatan yang lebih tinggi daripada sampel bucu tajam. Keputusan menunjukkan bahawa penguatan secara berterusan adalah lebih baik daripada pembungkusan berselang-selan. Semua penemuan menunjukkan bahawa kekuatan kekuatan konkrit yang kurang dapat ditingkatkan dengan menggunakan teknik penguatan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Fibre Reinforced Polymer (FRP) for civil engineering structures are being increasingly studied in recent years. These materials are being used in the aerospace, automotive and shipbuilding industries for almost two decades [1]. In general, FRP offer excellent resistance to corrosion, good fatigue resistance (with the possible exception of some glass-based FRP), low density, high stiffness and strength, and a very low coefficient of thermal expansion in the fibre orientation. Garden and Hollaway [2] have described FRP materials as having superior mechanical and physical properties than steel, particularly with respect to tensile and fatigue strengths. Furthermore these qualities are maintained over a wide range of temperatures. However, its higher price, relatively low failure strains, and unknown long-term performance have for many years restricted the use of FRP for civil engineering structures [3]. Until recently some FRP can cost as much as 10 times conferred to traditional structural materials, such as structural steel. Notwithstanding the lack of practical knowledge of FRP, this fact alone probably would have kept FRP from becoming commonly used in the construction industry. Despite declining prices in composites as a result of improved manufacturing processes, FRP still remains relatively expensive when compared to traditional materials. Thus, FRP is usually considered only for special applications, such as in non-magnetic structures, or for use in aggressive corrosive environments. However, the usage of FRP can be more economical than using steel plates. This is because the material costs in a rehabilitation project rarely exceed 20 percent of the total cost of the repair. The remaining 80 percent is spent primarily on labour and implementation costs. It is in this 80 percent that FRP can significantly reduce the cost of rehabilitation [4]. The application process for the FRP can be carried out from alight scaffolding or a mobile platform, often during a 24 hour period, as compared to several days required applying heavy steel plates using complex scaffolding systems.

Several FRP systems are now commercially available for the external strengthening of concrete structures. Grace italic. [5] described the fibre materials commonly used in these systems which include glass, aramid, and carbon. The fibres are available in many forms such as pultruded plates, uniaxial fabrics, woven fabrics and sheets. Amongst the material available, CFRP laminate is a popular choice of material due to its high strength. Although, FRP are more effective for flexural strengthening rather than shear strengthening due to its anisotropic properties, shear strengthening can be achieved if the fibre orientation is changed. For strengthening Reinforced Concrete beams, the FRP application techniques on soffit of the beam are similar to steel plate application.

The combination of two or more materials (reinforcement, resin, filler, etc.) differing in the form or composition on a macro scale. The constituents retain their identities, i.e., they do not dissolve or merge into each other, although they act in concert. Normally, the components can be physically identified and exhibit an interface between each other. Fiber Reinforced Polymer (FRP) Composites are defined as: “A matrix of polymeric material that is reinforced by fibers or other reinforcing material” [5], The Composites Institute identifies eight market segments (plus a ninth - miscellaneous) for composite applications including Transportation, Construction, Marine, Corrosion-resistant, Consumer, Electrical/Electronic, Appliance/Business and Aircraft/Defense as shown in Table1.1.

Table 1.1: Composites Institute identifies eight market segments for composite applications

N	application	percentage(%)
1	Transportation	30.6
2	Construction	20
3	Marine	11.6
4	Corrosion-Resistant	12.4
5	Consumer	6
6	Electrical/Electronic	10
7	Appliance/Business	5.3
8	Aircraft/Defense	0.7
9	Other	3.4

FRP is good alternative material for various applications because of it's:

i) High Tensile Strength

ii) Lightweight

iii) Corrosion Resistance

iv) Durable

v) Non-magnetic

vi) High Resistance to Abrasion

vii) Toughness

viii) Fatigue

Composites are composed of polymers, reinforcing fibers, fillers, and other additives. Each of these ingredients plays an important role in the processing and final performance of the end product [3].

The polymer is the “glue” that holds the composite and influences the physical properties of the composite end product. The reinforcement provides the mechanical strength properties to the end product. The fillers and additives are processing aids and also impart “special” properties to the end product. Other materials that will cover include core materials. Depending on the application, core materials provide stiffness while being lightweight [5].

There are many reinforcing fibers commercially available for use in composites. They are of both natural and synthetic or man-made origin. The most prominent reinforcing fibers in terms of both quantities consumed and product sales value would be aramid, boron, carbon/graphite, glass, nylon, polyester, and polyethylene. Of these, glass fiber represents the predominant reinforcement because of its relatively low cost, good balance of properties, and a 40 year experience base. Figure: 1.1 shows the density of different fibres. It can be seen that s-glass fibre has the higher density compared to other fibres. The Figure 1.2 shows the graph of stress-strain with different fibers [5].

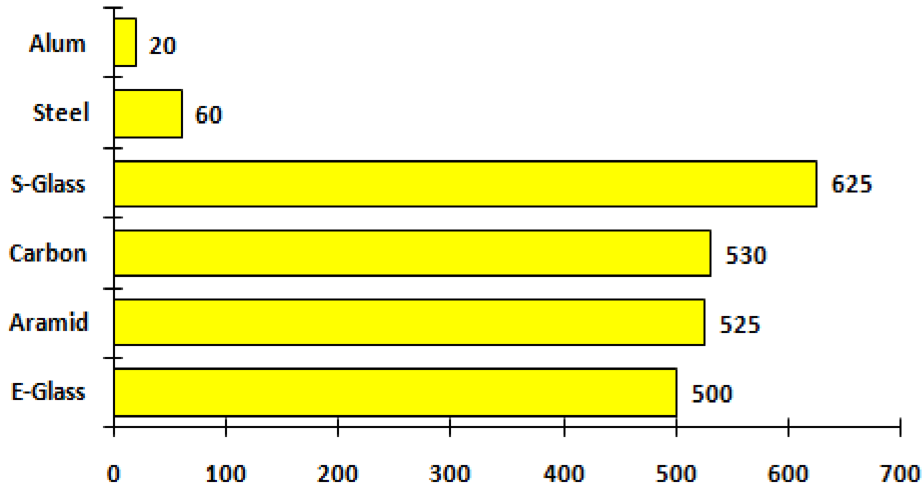

Figure 1.1: Density of different fibre (g/cm^3) [6]

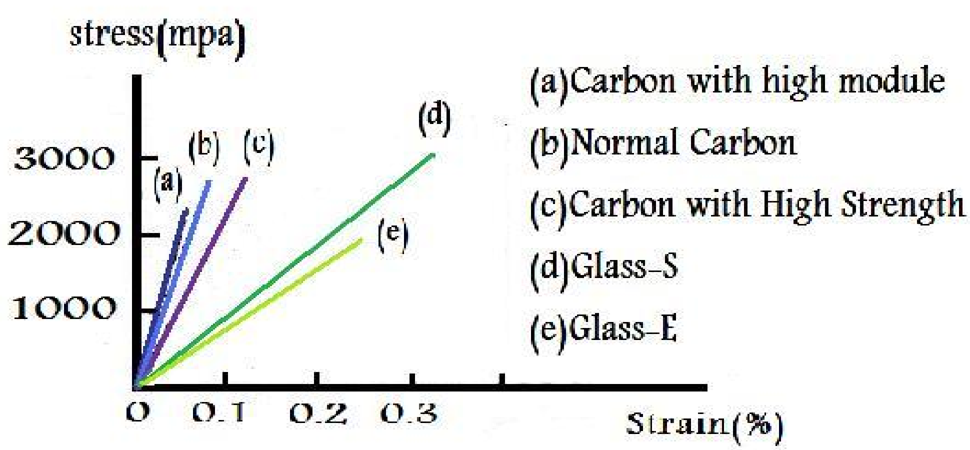

Figure 1.2: Shows the graph of stress-strain with different fiber [6]

Glass has very good impact resistance due to their high strain to failure, when compared to other fibers. Aramid also has excellent impact resistance, particularly to ballistic impact. Figure 1.3 shows the thermal conductivity between different fibres. It can be seen that s-glass fibre has the higher thermal conductivity compared to other fibres.

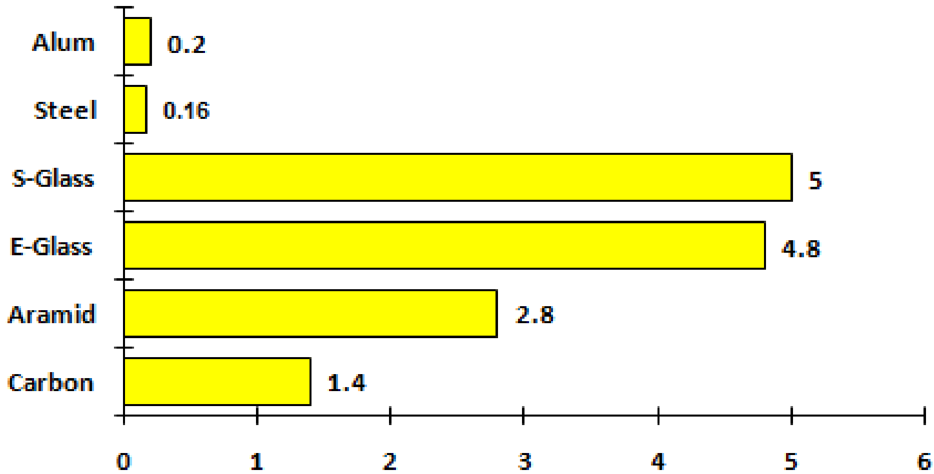

Figure 1.3: Fiber properties thermal conductivity W/°C [6]

Many raw materials are used to produce glass. Silica sand is the primary ingredient, accounting for more than 50 percent of the raw materials. Additional materials that may be used include limestone, boric acid, and clay, in addition to a variety of metal oxides. The combination and amounts depends on which type of glass is being produced [5].

Glass is generally the most impact resistant fiber but also weighs more than carbon or aramid. Glass fibers have excellent strength characteristics, equal and higher than steel in certain forms. The lower modulus requires special design treatment in applications where stiffness is critical. Processing characteristics required of glass fibers include: choppability, low static buildup and good fiber matrix adhesion [7].

Glass fibers are insulators of both electricity and heat and thus their composites exhibit very good electrical and thermal insulation properties. They are transparent to radio frequency radiation; therefore, they are used extensively in radar antenna applications [7].

Glass filaments are extremely fragile, and are supplied in bundles called strands, rovings or yarns. Strands are a collection of continuous filaments. A roving refers to a collection of untwisted strands or yarns. Yarns are collections of filaments or strands that are twisted together. Carbon/graphite fibers combine high modulus with low density and make them very attractive for aircraft and other applications where weight saved can be directly translated to cost savings and, therefore, justify their higher material cost [7].

To summarize the discussion about reinforcements, one should remember that with composites, the mechanical strength properties are dependent on the type, amount, and orientation of the reinforcement that is selected for the particular product. With the variety and many different forms of reinforcements that are commercially available, an almost limitless number of composite systems are available to meet the strength requirements of any applications.

Additionally, the ability to orient the composite strength characteristics to the specific performance requirements of the application provides a unique advantage for composites that translates to weight and cost advantage as compared to traditional homogeneous structural materials. Reinforcing fibers contribute to the mechanical strength characteristics of the composite [7]. The strength is dependent on:

i) The type or species of fiber

ii) The amount of fiber

iii) The orientation of the fiber

iv) The fiber surface treatment

v) Its compatibility with the matrix polymer

By varying these parameters, a broad range of mechanical properties are possible. For example, a composite which has all the fibers aligned in one direction, it is stiff and strong in that direction, but in the transverse direction, it will have a lower modulus and low strength. Also, the fiber volume fraction heavily depends on the method of manufacture. Generally, the higher the fiber content the stronger the composite.

By carefully selecting the fiber, resin and manufacturing process, designers can tailor composites to meet final product requirements that could not be achieved using other materials. Fiber orientation can maximize strength in one or more directions. This allows wall thickness variations, complex-contoured parts, and various degrees of stiffness or strengths. Composite laminates may be designed to be isotropic (uniform properties in all directions, independent of applied load) or anisotropic (properties only apparent in the direction of the applied load), balanced or unbalanced, symmetric or asymmetric depending on the forces from the application [3].

One of the important things in this paper is selection of the appropriate FRP system. The choice on whether to use a sheet or laminate system is based on the application, cost and designers preference. The orientation of the main fibers in the FRP is also an important consideration. The applied forces are resisted by the main fibers, which may run in one direction only (unidirectional) or in two directions (bi-directional). Carbon fiber (sheet or laminate) appears to be more economic for use in flexural or shear strengthening [3].

Carbon has better fatigue properties than glass and is preferred when required to carry fluctuating live loads. Glass, because of its lower modulus of elasticity is more suitable for use in confinement of concrete. However, in certain circumstances it can be used for flexural enhancement. Because of its low modulus, E-Glass is seldom used for shear enhancement. Laminates can only be applied to plane surfaces and carbon or glass sheets are best suited to curved surfaces or wrapping situations. Bi-directional E-Glass is used for increasing the shear strength of masonry walls. Lighter weight E-Glass is used where the substrate strengths are low, such as in old and historic masonry or brick buildings [4].

1.2 Objective of Study

The main objectives of this study are as follows:

i) To investigate the effect of GFRP and CFRP fabric on strengthening material to the strength capacity of concrete.
ii) To study the effect of different shapes of concrete sample on the strengthening performance.
iii) To compare the performance of CFRP and GFRP fabric as strengthening materials.

1.3 Problem statement

Fiber Reinforcement Polymer (FRP) composite materials are very attractive for use in civil engineering applications due to their high strength-to-weight and stiffness-to-weight ratios, corrosion resistance, light weight and potentially high durability. Their application is most important in the constructed facilities infrastructure such as buildings, bridges, pipelines, etc. Recently, their used has increased in the upgrading or retrofit of concrete structure.

In some cases, it is necessary to change the existing structure system due to the change of usage rather than rebuilt a new structure. A common example is appeared cracks on the beams or columns in the structure or crack occur at the beams with the increase of load due to stress concentration. The application of FRP reinforcement is able to overcome this problem.

1.4 Scope of the study

The scope of study is established to achieve the objectives and this will be mainly concentrated on experimental works. Experiments regarding to the compressive strength test on the concrete beams with different shapes, and strengthening of concrete with GFRP and CFRP, and in this project will consider:

i) The behavior of concrete sample strengthened with CFRP and GFRP under compression

ii) The mode of failure of the control concrete sample and the strengthened concrete sample (strengthening with CFRP and GFRP).

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