HYBRID FIBER REINFORCED CONCRETE; STEEL AND COCONUT COIR

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ABSTRACT

Hybrid fiber reinforced concrete can be defined as concrete that reinforced by two or more types of fibers. This study aims to study the mechanical properties of hybrid fiber reinforced concrete where the fibers used were consists of steel fiber and coconut coir fiber. For this purpose six mixes, one normal control mix and five hybrid fiber reinforced concrete mixes were prepared. The total content of two fibers is 3% by volume of mix where the total content of each fiber varied from 0.5% to 2.5%. Slump Test and Compaction Factor Test was carried out for each mix in the fresh state in order to determine the workability of the hybrid fiber reinforced concrete. Meanwhile, compressive test and flexural test were carried out to study the mechanical properties of the hybrid fiber reinforced concrete. From the slump test and compaction factor test, all specimens show low workability except the samples which contain more steel fibers than coir fibers. These two mixtures of samples give results of very low workability. For the result of Compressive and Flexural Test, the normal control mix shows normal strength development but all the hybrid fiber reinforced concrete mixes gain their strength lower the normal control mix. The expected outcome which is the strength of hybrid fiber reinforced concrete is higher than the strength of normal concrete did not achieved. So, further research need to be carried out with some adjustments of methods or materials.

ABSTRAK

Konkrit bertetulang gentian hibrid boleh ditakrifkan sebagai konkrit yang diperkukuh oleh dua atau lebih jenis gentian. Kajian ini bertujuan untuk mengkaji sifat-sifat mekanikal gentian hibrid konkrit bertetulang di mana gentian yang digunakan adalah terdiri daripada gentian keluli dan kelapa serat sabut. Untuk ini enam campuran tujuan, satu kawalan campuran biasa dan lima hibrid gentian bertetulang campuran konkrit telah disediakan. Jumlah kandungan dua serat adalah 3% dengan jumlah campuran di mana jumlah kandungan serat setiap diubah daripada 0.5% kepada 2.5%. Ujian kemerosotan dan Faktor Pemadatan Ujian telah dijalankan bagi setiap campuran dalam keadaan segar untuk menentukan kebolehkerjaan konkrit bertetulang gentian hibrid. Sementara itu, ujian mampatan dan ujian lenturan telah dijalankan untuk mengkaji sifat-sifat mekanikal gentian hibrid konkrit bertetulang. Dari ujian kemerosotan dan ujian pemadatan faktor, semua spesimen menunjukkan kebolehkerjaan yang rendah kecuali sampel yang mengandungi gentian keluli lebih daripada gentian sabut. Kedua-dua campuran sampel memberi keputusan kebolehkerjaan yang sangat rendah. Untuk keputusan Ujian mampatan dan lenturan, campuran kawalan biasa menunjukkan pembangunan kekuatan normal tetapi semua gentian hibrid diperkukuh campuran konkrit mendapat kekuatan mereka lebih rendah berbanding campuran kawalan biasa. Hasil yang dijangka di mana kekuatan serat hibrid diperkukuhkan konkrit adalah lebih tinggi daripada kekuatan konkrit normal tidak dicapai. Jadi, kajian lanjut perlu dijalankan dengan beberapa penyesuaian kaedah atau bahan-bahan.

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LIST OF ABBREVIATIONS

CFRC	Coir Fiber Reinforced Concrete
GFRC	Glass Fiber Reinforced Concrete
HFRC	Hybrid Fiber Reinforced Concrete
NFRC	Natural Fiber Reinforced Concrete
OPC	Ordinary Portland cement
PNF	Processed Natural Fibers
PNFRC	Processed Natural Fiber Reinforced Concretes
SFRC	Steel Fiber Reinforced Concrete
UMP	Universiti Malaysia Pahang
UNF	Unprocessed Natural Fiber
USSR	Union of Soviet Socialist Republics
W/C	Water Cement

CHAPTER 1

INTRODUCTION

1.1 General

Concrete is an essential material with a worldwide estimated consumption of between 21 and 31 billion tons of concrete in 2006, concrete is the second most consumed substance on Earth after water. Concrete is a mixture of sand, gravel and/or other aggregates, bound together by a water-based binder, cement. Admixtures as modifying agents and additives such as fine mineral powders are sometimes introduced to improve the characteristics of the fresh concrete, of the mixing process and/or of the final hardened material. ((Bureau International du Béton Manufacturé) BIBM, 2013)

Concrete is a building material that has been applied in construction field since a long time ago. It is also a tremendously popular structural material to its low cost and easy of fabrication of construction. In building industry, concrete means a hard and solid material made from mixture of cementitious material, water and aggregate. There are many types of cementitious material such as lime, geo-synthetic, polysynthetic and mud; but the mostly used is Portland Cement.

Although concrete is very strong and durable; but it has some weaknesses. One of them is low tensile strength. To increase the tensile strength of concrete, it needed to be reinforced by other material. The most popular method is steel reinforcement bar or 'rebar'. Instead of rebar, this research use fibers.

Fiber Reinforced Concrete is the concrete that reinforced by fibers, continuous filaments or thread. There are many types of fibers that have been applied in concrete. Some examples are steel, glass, natural and synthetic. Initially, fibers are used to prevent and control plastic and drying shrinkage in the concrete. Besides that, normally only one type of fiber is mixed with concrete. After some research and improvement, the addition of fibers material in the concrete can also improve the other properties such as flexural strength, flexural strength fatigue resistance, and post crack strength (Pehbahani, 2010). There are also in some previous research, more than one types of fibers mixed in concrete. The concrete that reinforced with more than one type of fiber is called Hybrid Fiber Reinforced Concrete.

1.2 Problem Statement

To increase the flexural strength of concrete, it must be reinforced by high flexural strength material. At this case, steel fiber would be the suitable material. But, to use all steel fiber as the reinforcement would be costly because steel fiber is quite expensive due to its manufacturing and transferring. So, to reduce the cost, some percentage of steel fiber need to reduced and replaced with other material. In this study, natural fiber is used to replace some proportions of the steel fibers.

Natural organic fibers exist in reasonably large quantities in many countries of the world. The coconut coir are the seed-hair fiber obtained from the outer shell (endocarp) or husk of the coconut. In Malaysia, there are tons of coir which not usable and just be wasted, mostly from rural and coast side villages. So, here an attempt has been made to investigate the possibility of reusing these locally available rural waste fibrous materials as concrete composites. This kind of fiber is also one of the most cheap among all material, low manufacturing cost and easy to process.

1.3 Objectives

The objectives of this research are

a. To study the workability of hybrid fiber reinforced concrete
b. To study the mechanical properties of hybrid fiber reinforced concrete

1.4 Scope of Study

The scope of study is established to achieve the objectives. This study will be mainly concentrated on experimental works in laboratory where Slump Test and Compaction Factor Test were carried out to determine the workability while Compressive and Flexural Test were carried out to determine the mechanical properties. Compressive and Flexural Test were carried on 7^{th}, 28^{th} and 60^{th} day after the specimens have gone through curing process. The parameter of the study is the percentage of fibers amount. The total content of fiber in all mixture of hybrid fiber reinforcement concrete is 3% where it varies from 0.5% to 2.5% for each fiber. The testing methods and procedures are executed according to British Standard.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Generally, concrete is strong in compression and weak in tension. Plain concrete is characterized by a relatively low tensile and brittle tensile failure. In structural application, the concrete will provide the reinforcing bars to carry the tensile forces once the concrete has cracked so that if remains largely in compression under load. In addition, the tensile failure strain of the reinforced concrete is significantly lower than the yield strain of the steel reinforced and the concrete crack before any significant load is transferred to the steel. (Shahiron, 2009)

2.2 Properties of Concrete

Concrete is a material made of Portland cement, water, and aggregates. When first mixed the water and cement constitute a paste which surrounds all the individual pieces of aggregate to make a plastic mixture. A chemical reaction called hydration takes place between the water and cement, and concrete normally changes from a plastic to a solid state in about 2 hours. Thereafter the concrete continues to gain strength as it cures.

Permissible stress is the strength that the hardened concrete gained in certain time. The stresses are tested in term of compressive strength. To measure the compressive strength of the hardened concrete, the samples which are in shape of cubes or cylinders are compressed until they failed. Then, the loading readings which are the values of permissible stress are taken when the specimens fail. The permissible stress requirements depend on the concrete grade, the type of structure and the purpose of the structure.

A typical strength-gain curve is shown in Figure 1. The industry has adopted the 28-day strength as a reference point, and specifications often refer to compression tests of cubes or cylinders of concrete which are crushed 28 days after they are made. (Camp, 2012)

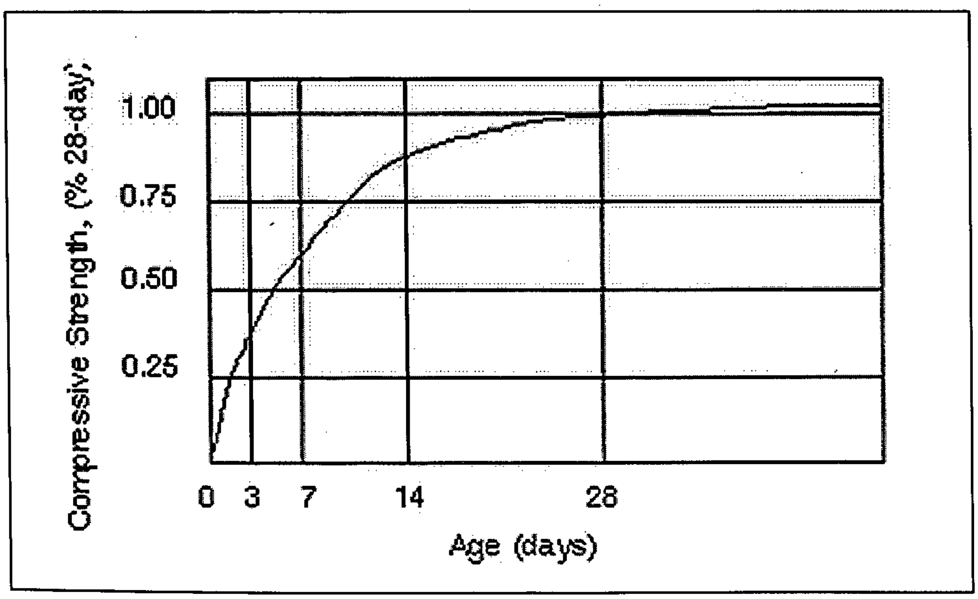

Figure 1: Typical Strength-Gain Curve

Source: (Camp, 2012)

2.3 Fiber Reinforced Concrete

2.3.1 Introduction

Concrete is the most frequently used construction material in the world. However, it has low tensile strength, low ductility, and low energy absorption. An intrinsic cause of the poor tensile behavior of concrete is its low toughness and the presence of defects. Therefore improving concrete toughness and reducing the size and amount of defects in concrete would lead to better concrete performance. An effective way to improve the toughness of concrete is by adding a small fraction (usually 0.5–2% by volume) of short fibers to the concrete mix during mixing. (Wang, Wu, & Li, 2000)

Reinforced concrete is also becoming an increasingly popular construction material due to its improved mechanical properties over unreinforced concrete and its ability to enhance the mechanical performance of conventionally reinforced concrete. Though much research has been performed to identify, investigate, and understand the mechanical traits of fiber reinforced concrete, relatively little research has concentrated on the transport properties of this material.

The applications of fibers in concrete have some advantages. One of them is the method of fiber placement in concrete is easier compare to reinforcement steel bar. Due to its light and easy to handled, placing fibers can save cost of casting and less worker intensive. Fibers also can be made into thin or irregular shape. So then, fibers always applied for reinforcement when placing reinforcement bar is difficult. The only disadvantages of fibers are the efficiency factor is lower compare to steel bar reinforced concrete and not highly effective in improving compressive strength.

Table 1: The Advantages and Disadvantages of Fiber Reinforced Concrete

Advantages	Disadvantages
• Easily placed – cast, sprayed, less labor intensive than placing rebar • Can be made into thin or irregular shapes • Used when placing reinforcement bar is difficult	• Efficiency factors as low as 0.4 2-D(spray placement method), or 0.25 3-D placement(casting method) • Not highly effective in improving compressive strength

Source: (Kūrtis, 2007)

2.3.2 History of Fiber Usage in Concrete

Fibers have been used as reinforcement since the Middle Ages. Horsehair was used in mortars and straw was used in mud bricks as reinforcement. In the beginning of 1900 asbestos fibers were being used. In the 1950's the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. There was also a need for the search of materials to replace asbestos used in concrete and other building materials. By the 1960's steel, glass and synthetic fibers such as polypropylene fibers were used in concrete. (Hein, 2007)

Asbestos cement construction products are widely used throughout the world today. However, primarily due to health hazards associated with asbestos s, alternate fiber types were introduced throughout the 1960s and 1970s. In modern times, a wide range of engineering materials (including ceramics, plastics, cement, and gypsum products) incorporate fibers to enhance composite properties. The enhanced properties include tensile strength, compressive strength, elastic modulus, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics, and fire resistance. (M.Kunz & Sehmi, 2010)

Experimental trials and patents involving the use of discontinuous steel reinforcing elements—such as nails, wire segments, and metal chips - to improve the properties of concrete date from 1910. During the early 1960s in the United States, the first major investigation was made to evaluate the potential of steel s as reinforcement for concrete. Since then, a substantial amount of research, development, experimentation, and industrial application of steel Fiber reinforced concrete has occurred. (M.Kunz & Sehmi, 2010)

Use of glass fibers in concrete was first attempted in the Union of Soviet Socialist Republics (USSR) in the late 1950s. It was quickly established that ordinary glass fibers, such as borosilicate E-glass s, are attacked and eventually destroyed by the alkali in the cement paste. Considerable development work was directed towards producing a form of alkali-resistant glass s containing zirconia. This led to a considerable number of commercialized products. The largest use of glass fiber reinforced concrete is currently for the production of exterior architectural cladding panels. (M.Kunz & Sehmi, 2010)

Considerable research, development, and applications of FRC are taking place throughout the world. Industry interest and potential business opportunities are evidenced by continued new developments in reinforced construction materials. These new developments are reported in numerous research papers, international symposia, and state-of-the-art reports issued by professional societies. (M.Kunz & Sehmi, 2010)

2.3.3 Fiber Reinforced Versus Conventionally Reinforced Concrete

Unreinforced concrete has a low tensile strength and a low strain capacity at fracture. These shortcomings are traditionally overcome by adding reinforcing bars or prestressing steel. Reinforcing steel is continuous and is specifically located in the structure to optimize performance. s are discontinuous and are generally distributed randomly throughout the concrete matrix. s are being used in structural applications with conventional reinforcement. Because of the flexibility in methods of fabrication, fiber reinforced concrete can be an economic and useful construction material. (M.Kunz & Sehmi, 2010)

2.3.4 Classification of Fiber Reinforced Concrete

There are 4 Classifications of fiber that usually used in concrete; Steel fiber, Glass fiber, Synthetic fiber, and Natural fiber.

2.3.4.1 Steel Fiber Reinforced Concrete (SFRC)

Steel Fiber reinforced concrete (SFRC) is concrete made of hydraulic cements containing fine or fine and coarse aggregate and discontinuous discrete steel s. In tension, SFRC fails only after the steel fiber breaks or is pulled out of the cement matrix. Figure below shows a typical fractured surface of SFRC.

Properties of SFRC in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. The mechanics of how the fiber reinforcement strengthens concrete or mortar, extending from the elastic pre-crack state to the partially plastic post-cracked state, is a continuing research topic. One approach to the mechanics of SFRC is to consider it a composite material whose properties can be related to the fiber properties (volume percentage, strength, elastic modulus, and a fiber bonding parameter of the fibers), the concrete properties (strength, volume percentage, and elastic modulus), and the properties of the interface between the fiber and the matrix. A more general and current approach to the mechanics of fiber reinforcing assumes a crack arrest mechanism based on fracture mechanics. In this model, the energy to extend a crack and debond the s in the matrix relates to the properties of the composite. (M.Kunz & Sehmi, 2010)

SFRC has advantages over conventional reinforced concrete for several end uses in construction. One example is the use of steel fiber reinforced shotcrete (SFRS) for tunnel lining, rock slope stabilization, and as lagging for the support of excavation. Labor normally used in placing mesh or reinforcing bars in these applications may be eliminated. Other applications are found in the allocation section.

2.3.4.2 Glass Fiber Reinforced Concrete (GFRC)

It is a composite of Portland cement, fine aggregate, water, acrylic co-polymer, glass fiber reinforcement and additives. The glass fibers reinforce the concrete, much as steel reinforcing does in conventional concrete. The glass fiber reinforcement results in a product with much higher flexural and tensile strengths than normal concrete, allowing its use in thin-wall casting applications. GFRC is a lightweight, durable material that can be cast into nearly unlimited shapes, colors and textures. There are two basic processes used to fabricate GFRC – the Spray-Up process and the Premix process. The Premix process is further broken down into various production techniques such as spray premix, cast premix, pultrusion and hand lay-up. (Reynolds Advanced Materials, 2012)

2.3.4.3 Synthetic Fiber Reinforced Concrete (SNFRC)

Synthetic fibers are man-made fibers resulting from research and development in the petrochemical and textile industries. There are two different physical fiber forms: monofilament fibers and fibers produced from fibrillated tape. Currently there are two different synthetic fiber volumes used in application, namely low-volume percentage (0.1 to 0.3% by volume) and high-volume percentage (0.4 to 0.8% by volume). Most synthetic fiber applications are at the 0.1% by volume level. At this level, the strength of the concrete is considered unaffected and crack control characteristics are sought. Fiber types that have been tried in cement concrete matrices include: acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene. (Cement & Concrete Institute, 2010)

2.3.4.4 Natural Fiber Reinforced Concrete (NFRC)

Discontinuous short fibers are widely used in both types of FRC all over the world. In this part, attention is focused on the use of naturally occurring fibers for reinforcing concretes, mortars, and cements. Concretes reinforced with naturally occurring fibers are generally termed natural fiber reinforced concrete (NFRC).

Many natural reinforcing materials can be obtained at low levels of cost and energy using locally available manpower and technical know-how. Such fibers are used in the manufacture of low fiber content FRC and occasionally have been used in the manufacture of thin sheet high fiber content FRC. These fibers are typically referred to as unprocessed natural fibers (UNF). However, other natural fibers are available that have been processed to enhance their properties. These fibers are derived from wood by chemical processes such as the kraft process. Kraft pulp fibers are used in sophisticated manufacturing processes, such as the Hatschek process, to produce thin sheet high fiber content FRC. These fibers are typically referred to as processed natural fibers (PNF) and concretes made from them as processed natural fiber reinforced concretes (PNFRC). (M.Kunz & Sehmi, 2010)

Although historically many fibers have been used to reinforce various building materials, until recently little scientific effort has been devoted to the use of natural fibers for reinforcement. The use of some of the best known natural fibers such as sisal, coconut, sugarcane bagasse, plantain (banana), palm, etc., have mostly been limited to the production of fabrics, ropes, mats, etc.

Naturally available reinforcing materials can be used effectively as reinforcement in Portland cement concrete. Natural fiber reinforced concrete is suitable for low-cost construction, which is very desirable for developing countries. It is important for researchers, design engineers, and the construction industry to vigorously pursue the use of local materials. For economical engineering solutions to a variety of problems, natural fiber reinforced concrete offers a viable alternative that needs to be fully investigated and exploited. Wood fibers derived from the Kraft process possess highly desirable performance-to-cost ratios, and have been successfully substituted for asbestos in the production of thin-sheet cement products, such as flat and corrugated panels and non-pressure pipes.

2.4 Coconut Coir Fiber

2.4.1 Introduction

Coconut cultivation can be found spreading across the tropical and subtropical regions between the latitudes 20 o N and 20 o S. It can be seen in most of Asia countries especially Thailand, Indonesia and India and Malaysia and the tropical climate countries like Hawaii and Fiji Islands. Coconuts are mainly cultivated on the coastal clays and sands. Coconut tress can grow up to 30 m height. (Hashim, 2005)

Coconut coir fiber is classified as natural fiber. It extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut Fiber is Coir, Cocos nucifera and Arecaceae (Palm), respectively. There are two types of coconut Fibers, brown Fiber extracted from matured coconuts and white Fibers extracted from immature coconuts. Brown Fibers are thick, strong and have high abrasion resistance. White Fibers are smoother and finer, but also weaker. Coconut Fibers are commercial available in three forms, namely bristle (long Fibers), mattress (relatively short) and decorticated (mixed Fibers). These different types of Fibers have different uses depending upon the requirement. In engineering, brown Fibers are mostly used. (Ali, 2010)

2.4.2 Effect of Coir Fiber to Concrete

In term of concrete workability, according to Ali, Liu, Sou, and Chouw; the water cement ratio increase and slump decrease with an increase of fiber content as shown in figure 2 and figure 3. In their study, the static and dynamic properties of Coir Fiber Reinforced Concrete (CFRC) were investigated. Coir fiber length of 7.5 cm with fiber content of 1%, 2% and 3% were used for preparing CFRC.