MECHANICAL PROPERTIES OF KENAF FIBER REINFORCED CONCRETE WITH DIFFERENT WATER-CEMENT RATIO

MOHD FIKREE BIN BADDERI

A thesis submitted in partial fulfillment of the
requirements for the award of degree of
Bachelor of Civil Engineering with Environmental.

Faculty of Civil Engineering & Earth Resources
Universiti Malaysia Pahang

JUNE 2012

ABSTRACT

Kenaf is one of the natural fibers which have many advantages as an alternative reinforcement for fiber reinforced concrete such as low cost, lightweight and high tensile strength. The development in using of kenaf fiber as reinforced in the concrete is a possible forms to improvement the concrete properties. Therefore, this report presents an overview of the developments made in kenaf fiber reinforced concrete (KFRC), in terms of water-cement ratio and mechanical properties. In this study, constant volumes of kenaf fiber are used and difference water-cement ratio (w/c) in concrete to be main focus. This study concentrated on the compressive strength, flexural strength and splitting tensile strength of KFRC compared to conventional concrete. All of the specimens were conducted in different w/c ratio (0.5, 0.6 and 0.7) and cured in water for 7, 14 and 28 days. The result determined that compressive and flexural strength of KFRC are lower than conventional concrete. Meanwhile, the KFRC splitting tensile strength is higher than conventional concrete. This is shows that addition of kenaf fiber is not contributing increase the strengths. The result also determined that strengths of the KFRC are decreasing with increasing w/c ratio. As a conclusion, w/c ratio is significantly affecting the concrete strengths.

ABSTRAK

Kenaf adalah salah satu daripada gentian semulajadi yang mempunyai banyak kelebihan sebagai tetulang alternatif bagi konkrit bertetulang gentian seperti kos rendah, ringan dan kekuatan tegangan yang tinggi. Kemajuan dalam penggunaan gentian kenaf sebagai tetulang di dalam konkrit adalah satu bentuk yang dapat menambahbaikan sifat-sifat konkrit. Oleh itu, laporan ini membentangkan gambaran keseluruhan perkembangan yang dibuat di gentian kenaf konkrit bertetulang (KFRC), dari segi nisbah air-simen dan sifat-sifat mekanik. Dalam kajian ini, peratus gentian kenaf ditetapkan dan perbezaan nisbah air-simen (w/c) di dalam konkrit menjadi fokus utama kajian. Kajian ini tertumpu kepada kepada kekuatan mampatan, kekuatan lenturan dan kekuatan belahan terikan KFRC berbanding konkrit biasa. Semua spesimen yang telah dijalankan dalam nisbah yang berbeza w/c (0.5, 0.6 dan 0.7) dan dimatangkan di dalam air selama 7, 14 dan 28 hari. Keputusan menunjukkan bahawa kekuatan mampatan dan lenturan KFRC adalah lebih rendah daripada konkrit biasa. Manakala, kekuatan belahan terikan KFRC adalah lebih tinggi daripada konkrit biasa. Ini menunjukkan bahawa penambahan gentian kenaf tidak menyumbang peningkatan dari segi kekuatan. Keputusan juga menunjukkan kekuatan KFRC akan menurun dengan peningkatan nisbah w/c. Kesimpulannya, nisbah w/c telah menjejaskan kekuatan konkrit ini.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, concrete is the most widely used building material in the world because of its strength, durability, and other benefits. Concrete is used in nearly every type of construction, including homes, buildings, roads, bridges, airports and subways. Concrete can be defined as a mixture of cement, water, aggregate (fine and coarse) and admixture. There are many advantages of concrete such as high compressive stress, fire resistance and also only require little maintenance on it. However, concrete also have disadvantages such as concrete has low tensile strength and can be crack easily. Cracking is the most common indication of the distress in a concrete structure. Therefore, this problem can be encounter with using reinforced of steel bars or meshes or fibers. There are many study have conducted to improve the properties of the concrete such as producing the fiber reinforced concrete (Gambhir, 2004).

Fiber reinforced concrete (FRC) is a concrete that mixed with short discrete fibers which the short discrete fibers containing in the concrete whether are randomly dispersed or oriented uniformly placed in. Fibers can be categorized into several types such as steel fibers, glass fibers, synthetic fibers and natural fibers. Recently, the developments using natural fiber to mix with concrete is significantly popular due to the renewable resources and have marketing appeal. In this present study, the used of Hibiscus Cannabinus L. (kenaf) as fiber will be introduced. According to the Somayaji (2001), noted that kenaf is a plant type of natural fiber that currently gains interest by many researchers as FRC product.

Kenaf is a high-yielding cordage crop traditionally grown for the production of twine, rope and sackcloth. Newer applications for kenaf include paper product, absorbents, and building materials (Yu and Yu, 2007). In previous study conducted by Nishino et al., (2003), noted that kenaf exhibits low density, non-abrasiveness during processing, and high specific mechanical properties. Recently, kenaf is used as a raw material to be alternative to wood in pulp and paper industries for avoiding destruction of forests, and also used as non-woven mats in the automotive industries, textiles, and fiberboard. The characteristic of kenaf which is high tensile strength and low density give this type of fiber is have potential to overcome the weakness in concrete where concrete is known with higher in compression strength but lower in tension strength.

Strength is one of the most important properties of concrete since the first consideration in structural design is that the structural elements must be capable of carrying the imposed loads. Furthermore, strength characteristic is also vital because it is related to several other important properties which are more difficult to measure directly. Strength is also important in order to determine material ability, especially under extreme and critical conditions, which are directly connected with engineering performance. However, the major issue that treating the strength of FRC is the ability of kenaf fiber absorbing moisture inside the concrete.

In previous study by Akil et al., (2010), noted that most plant fibers except for cotton, are composed of cellulose, hemicelluloses, lignin, waxes, and several water-soluble compounds; where cellulose, hemicelluloses, and lignin are the major constituents. The main constituent of any plant fiber is cellulose and the characteristic of cellulose is hydrophilic. Hydrophilic is defined as a strong affinity to water or moisture and readily to absorb the water. Furthermore, most fibers swell due to moisture absorption. This absorption leads to alterations in weights and dimensions, as well as in strengths and stiffness. Nevertheless, in order to overcome this issue which can prevent the absorption of moisture is with controlling the water to cement ratio in concrete. Water to cement ratio can be control by determined the ratio is at optimum mix proportion, which this ratio can overcome the issue of water absorption by Kenaf fiber. Hence, in this present study, the mechanical properties of concrete reinforced with kenaf as fiber due to different water/cement ratio in order to improve FRC will be investigated.

1.2 Problem Statements

In Malaysia, Lembaga Tembakau Negara stated that duties reduced on tobacco imports which making local tobacco farming here is less competitive, government has recommended converting tobacco farm into kenaf farm. By this action, the plantation of kenaf can added the farmer's income besides paddy. Recently, kenaf is a material to process into paper, car accessories and clothing. However, kenaf now identified as fiber material same characteristic as jute that can be used for improve building material.

The major issue of kenaf is its ability of absorbing water. The main constituent of any plant fiber is cellulose and the characteristic of cellulose is hydrophilic. Most fibers swell due to moisture absorption. This absorption leads to alterations in weights and dimensions, as well as in strengths and stiffness (Akil et al., 2010). Then, the most common issue when lying concrete is cracking. The characteristic of concrete that is in brittle manner also will lead concrete into sudden failure. To overcome this manner, a study conduct by (Sivaraja et al., 2009) concludes that natural fibers enhance all the strength and flexural performance of concrete.

1.3 Objectives of Study

This study has two main objectives which are:

(i) To study the mechanical properties of kenaf fiber reinforced concrete with different water-cement ratio.

(ii) To determine the suitable water-cement ratio for mix proportion (1:2:3) of kenaf fiber reinforced concrete.

1.4 Scopes of Study

This study concentrated on investigation of mechanical properties of kenaf fiber concrete reinforced with different water/cement ratio. The mechanical properties were subjected to compressive strength test, flexural strength test, and splitting tensile strength test. In order to determine the mechanical properties of kenaf fiber concrete reinforced (KFRC), the KFRC will be designed based on 1:2:3 mix proportion. In addition, the concrete without kenaf fiber will be considered as a control mix. For KFRC mixes, the concrete with kenaf fiber will be investigated. The kenaf fiber used was obtained from kenaf plant where the bast and core will be separated by using machine and the component that will be use is the bast. Then, the kenaf fiber will be dried and cut into size with ranges 25 mm to 38 mm.

All the concrete mixes will be designed accordance to the designs of concrete mix based on the Department of Environment (DOE) United Kingdom specification in order to reach the specific strength. The kenaf fiber will be added into the concrete mixes with constant percentage of 2% from total volume of concrete mix. The different water-cement (W/C) will be considered are 0.5, 0.6 and 0.7 with formulation of 1:2:3 composed of cement, aggregate, sand, water and kenaf fiber.

All the concrete specimens will be cured in water by immersion in curing pond at normal temperature. The harden concrete will be tested at the specific ages namely 7, 14 and 28 curing days. The hardened KFRC is tested for compressive strength test, flexural strength test and splitting tensile strength test as accordance to BS 1881:119:1983, BS 1881:118:1983 and ASTM C496 respectively. KFRC cubes with dimension of 100 mm x 100 mm x 100 mm are used for compression strength test. KFRC prisms with dimension of 100 mm x 100 mm x 500 mm are used for flexural strength test and cylinder specimen of minimum 100 mm diameter is used for splitting tensile strength test.

1.5 Significant of Study

This study will provide knowledge or records that can be useful in the development and innovation of new technology in the future field of Civil Engineering. The reason is all necessary information that students of Civil Engineering can be used in their future research. Therefore, this also encourage others to study other alternative materials that can be used in construction. To the government, that they may utilize different source of reinforcement in their infrastructures mainly in their concrete buildings, highways and bridges. Then, Government action may generate livelihood and more jobs since this research needs to extract the natural fibers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Structures that made of steel reinforced concrete normally suffer from corrosion of the steel by the salt, which results in the failure of those structures. Constant maintenance and repairing is needed to enhance the life cycle of those structures. There are many ways to minimize the failure of the concrete structures made of steel reinforce concrete. The custom approach is to adhesively bond fiber composites onto the structure. This approach helps to increase the toughness, tensile strength and improve structures from cracks and deformation activity. This approach is to support the concrete with fibers to produce a fiber reinforced concrete and this is termed as FRC. Basically this method of reinforcing the concrete substantially alters the properties of the non-reinforced cement which is brittle in nature and possesses lower tensile strength compared to the inherent compressive strength.

Nowadays, ecological concern has resulted in a renewed interest in natural materials and issues such as recyclability and environmental safety are becoming increasingly important for the introduction of new materials and products. Environmental legislation as well as consumer pressure is all increasing the pressure on manufacturer of materials and end-products to consider the environmental impact of their products at all stages of their life cycle (Garkhail, 2000).

2.2 Fiber Reinforced Concrete

Concrete is relatively brittle and its tensile strength is typically lower than the compressive strength. For many applications, it is becoming increasingly popular to reinforce the concrete with small, randomly distributed fibers. The main purpose of fibers is to increase the toughness of the material. In addition, also help to increase in tensile and flexural strength. Fiber reinforced concrete (FRC) is a composite concrete material consisting of a cement matrix reinforced with discontinuous discrete fibers (metal, glass, or other synthetic or natural fiber material). The modern development of fiber reinforced cement composites dates back to the 1960s. Since then, fibers used as reinforcement materials have diversified. More research studies now focus on the natural fiber reinforcement. A unique aspect of these fibers is the low amount of energy required to extract these fibers. Only a low degree of industrialization is required for their processing. Therefore, the applications of natural fibers in concrete have provided an exciting prospect to the construction industry (Li et al., 2004).

Nowadays, there are many studies have been conducted to improve the properties of the concrete such as producing the fiber reinforced concrete. According to Brown (2002), FRC is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, the small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. Fibers help to improve the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and shrinkage cracks. According to Li et al., (2004), reported that to utilize natural fibers as reinforcement in concrete, it is important that the fiber reinforced concrete has appropriate physical and mechanical properties for an application. Work on the behavior of concretes reinforced with jute fiber, rice straw, sugar cane fiber and wood fiber has also been reported. It can be concluded that the addition of these natural fibers does not improve FRC's compressive strength significantly compared to plain concrete. However, both the flexural load and energy absorption capacity of the FRC are increased over those of plain concrete.

2.2.1 Classification of Fiber

Several types of fibers have been used to reinforce the concrete. The choice of fibers varies from synthetic organic materials such as polypropylene or nylon, synthetic inorganic such as steel or glass, natural organic such as natural fiber to natural inorganic such as asbestos. Currently the commercial products are reinforced with steel, glass, polyester and polypropylene fibers. The selection of the type of fibers is guided by the properties of the fibers such as diameter, specific gravity, young's modulus, tensile strength and the extent these fibers affect the properties of the cement (Brown, 2002). The classifications of fiber are shown in Table 2.1.

Table 2.1: Classification of Fibers

(Source: Brown, 2002)

Classification	Variables
Synthetic Organic	Polyprolene, Nylon, Carbon
Synthetic Inorganic	Steel, Glass
Natural Organic	Plant, Animal
Natural Inorganic	Asbestos, Fibrous Brucite, Wollastonite

2.2.2 Natural Fiber Reinforced Concrete

According to Elsaid (2010), the use of natural fiber reinforced concrete (NFRC) has been studied quite heavily over the past 40 years. The advantages of (NFRC) including increased toughness, enhanced cracking behavior, enhanced durability and improved fatigue and impact resistance have been well documented previously. The properties of NFRC are dependent on a number of factors including the type and the length of fibers used and the volume fraction. Previous research studies indicated that the minimum fiber volume fraction required to provide significant improvement in the mechanical properties of cement composites was approximately 3%. In previous study by Elsaid (2010), noted that the impact resistance was improved regardless of the fiber content, but other properties did not improve significantly at lower fiber contents. Studies of jute fiber reinforced concrete indicate that in general, compressive strength is not significantly affected by the addition of fibers, while tensile and flexural strength and toughness are all substantially increased. Applications of NFRC for large-scale structural purposes have traditionally been limited to special applications which are practically and economically justified. One of the most promising fields for their application is that of composite construction in which the NFRC forms a permanent strong and tough covering over a weaker core.

2.2.3 Classification of Natural Fiber

Over the past few decades, there has been a growing interest in the use of natural fibers in composite applications. These types of composites present many advantages compared to synthetic fibers, such as low tool wear, low density, availability, and biodegradability. The most common natural plant used in applications is bast fibers, such as hemp, jute, flax, kenaf, and sisal. One of the reasons for this growing interest is that natural fibers have a higher specific strength than glass fiber and a similar specific modulus. With these properties and cheaper sources, these natural fibers theoretically offer desirable specific strengths and modulus, at a lower cost. These natural fibers, found in all life cycles of all walks of life, are shown in Figure 2.1.

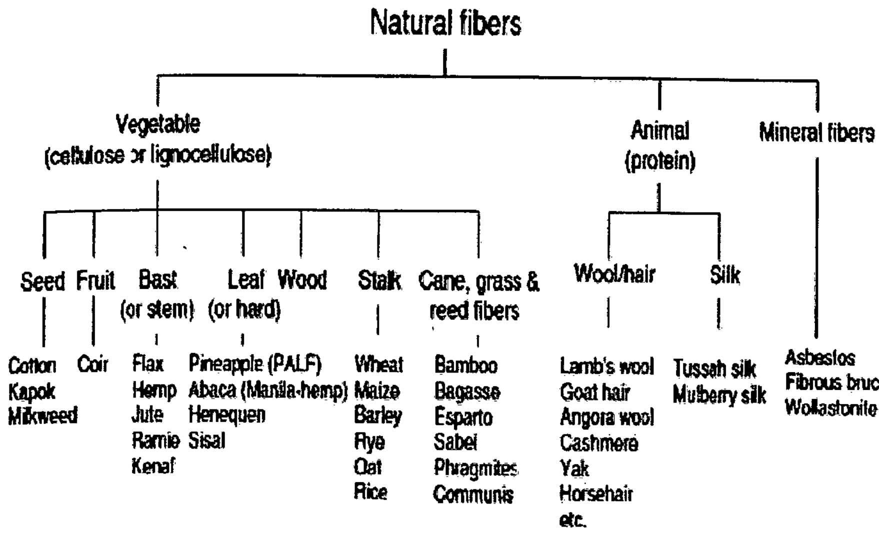

Figure 2.1: Classification of Natural Fiber

(Source: Elsaid et al., 2010)

2.3 Kenaf Fiber Reinforced Concrete

Natural fibers like jute, coir, bamboo and sisal have already been used as reinforcement materials in cement matrices for many years, especially in developing countries. As well as kenaf, which recently kenaf has received encouraging response from the researchers to produce new strong and tough reinforced concrete. Kenaf fiber reinforced concrete (KFRC) is a concrete that mix with kenaf fiber as reinforcement (Zhijian, 2006).

2.3.1 Properties of Kenaf Fiber Reinforced Concrete

Previous study by Enyew (2010), the contribution of fibers to the compressive strength is usually at the early age of concrete, the case of which is more prominent to natural fibers. Under compressive loading the small cracks in the solids come under a local tension at their tips causing wide and unstable crack due to the interaction between other small cracks. When the fibers are present in the concrete, it affects the crack by increasing the resistance to sliding of the initial small cracks. This phenomenon signifies that fibers can be exploited to increase the compressive strength and in consequence provide a passive confining pressure. Similar to kenaf fiber study, noted by Li et al., (2004) that an optimum addition of natural hemp fiber increases the compressive and flexural properties of natural hemp fiber reinforced concrete.

Noted in previous study that conducted by Jorillo and Shimizu (2003), that plain concrete is weak in tension, and the limiting tensile force is carried between cracks. When fibers are added to the plain concrete, the tension capacity is increased through the transfer of tensile forces at the cracks by fiber interferences. In addition to the increase in tensile strength capacity, fibers can reduce crack width with further improvement in the rigidity of the FRC. Enyew (2010) noted that the tensile strength of FRC made with high tensile fibers largely depends on the pullout resistance between the fiber and matrix. This interfacial bond between the fiber and the matrix can be improved through chemical treatment of the fiber or physical manipulation over the geometry of the fiber.

Study conduct by Li et al., (2004), stated that fibers control the major cracks, thus preventing sudden collapse. Fiber reinforced concrete also has an important behavior of absorbing enormous amount of energy. There can be as much as 100% increase in flexural toughness with the inclusion of natural kenaf fibers. Apart from the increase in toughness and ductility, the increase in post-cracking strength with the incorporation of fibers maintains the equilibrium and structural integrity of the whole system (Li et al., 2004).

2.4 Background of Kenaf Fiber

Kenaf is a 4000 years old crop with roots in ancient Africa which has been recently introduced. The kenaf plant can grow to heights of 3.5 m – 4.5 m within 4 – 5 months. Kenaf is a hardy plant with a fibrous stalk which is resistant to insect damage and requires few to no pesticides. Kenaf is adaptable to various soils and requires only minimal chemical treatment, typically some fertilizer and a single herbicide treatment, to grow effectively (Elsaid et al., 2010). The use of natural fibers and unsaturated polyester matrix is highly beneficial because the strength and toughness of the resulting composites are greater than those of the unreinforced plastics. Moreover, cellulose-based natural fibers are strong, light, cheap, abundant, and renewable. In recent years, natural fibers reinforced unsaturated polyester materials are used in many applications such as automotive, sporting goods, marine, electrical, industrial, construction, and household appliances (Abdalla et al., 2010).

The stalk of the kenaf plant is made up of two primary components known as the outer periphery and fiber core (inner part). The outer periphery is made up of long fibers called the bast fibers, which comprise approximately 30 – 40% of the total plant weight and the length of the fiber is typically 2.6 mm when processed. This portion of fiber was suitable for used as raw material in manufactured of paper. Meanwhile, the fiber core which comprises approximately 60% of the total plant weight and its diameter is capable of measuring 6 mm after processed. The fiber is comparable to the fiber derived from hardwood in which the fibers of this type are commonly used in the production of several types of paper products. (Akil et al., 2010)

According to Aji et al., (2009) also noted that kenaf is a plant known as a dicotyledonous plant meaning that the stalk has three layers; an outer cortical also referred to as bast tissue layer called phloem, an inner woody core tissue layer xylem, and a thin central pith layer which consist of sponge-like tissue with mostly non-ferrous cells. The kenaf stalk component is shown in Figure 2.2.

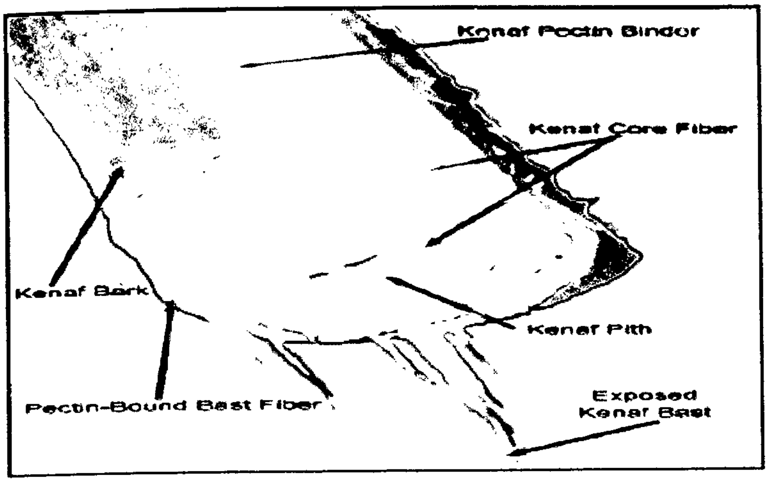

Figure 2.2: Kenaf Stalk Component

(Source: Aji et al., 2009)

2.4.1 Application of Kenaf Fiber

Table 2.2: Application of Kenaf Component

(Source: Aji et al., 2009)

Component	Application
Leaves	i. Livestock feed
Bast	i. Bags, cordage, rope, twine, coarse cloth. ii. Plastic composites, drilling fluid loss iii. Preventative for oil drilling mud
Core	i. Engineered wood, insulation, ii. Clothing-grade cloth, soil-less potting mixes, animal iii. Bedding, packing material and material that absorbs oil and liquids. iv. Papers
Seed	i. Hydro mulch for erosion control ii. Environmental mats (grass mats)