# WORKABILITY AND COMPRESSIVE STRENGTH OF KENAF FIBER REINFORCED CONCRETE WITH DIFFERENCE WATER-CEMENT RATIO

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## ABSTRACT

The development of civil engineering products made from natural resources are increasing worldwide, due to resources renewable issue and environmental friendly concept. Among many different types of natural resources, kenaf plants have been extensively exploited over the past few years. Therefore, this report presents an overview of the developments made in kenaf fiber reinforced concrete (KFRC), in terms of water-cement ratio and their physical 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 workability and compressive strength of KFRC compared to conventional concrete. Three tests were conducted for workability of fresh KFRC namely slump test, vebe test and compacting factor test. Meanwhile, cubes sample were subjected to compressive strength test. All of the specimens were cured in water for 7, 14 and 28 days. The result indicated that the fresh KFRC exhibit a significant increase in workability with increasing of w/c ratio in concrete mixture. However the strength of the KFRC is decreasing with increasing w/c ratio. Besides that, the strength of KFRC is lower than normal concrete. This is shows that addition of kenaf fiber in concrete did not increase the compression strength of concrete.

## ABSTRAK

Pembangunan produk kejuruteraan awam dari sumber asli semakin meningkat di seluruh dunia berikutan isu penggunaan semula sumber dan konsep mesra alam sekitar. Antara pelbagai jenis sumber asli, pokok kenaf telah dieksploitasi dengan meluas sejak beberapa tahun kebelakangan ini. Oleh itu, laporan ini membentangkan gambaran perkembangan yang dibuat menggunakan konkrit bertetulang berserat kenaf (KFRC), dari segi nisbah air-simen dan juga sifat fizikalnya. Dalam kajian ini, isipadu malar serat kenaf digunakan dan perbezaan nisbah air-simen (w/c) di dalam konkrit untuk menjadi tumpuan utama.. Kajian ini tertumpu kepada kebolehkerjaan dan kekuatan mampatan KFRC untuk dibandingkan bersama konkrit biasa. Tiga ujian telah dijalankan untuk kebolehkerjaan KFRC basah iaitu ujian kemerosotan, ujian vebe dan ujian faktor pemadatan. Sementara itu, sampel kiub digunakan didalam ujian kekuatan mampatan. Semua spesimen diawet di dalam air selama 7, 14 dan 28 hari. Hasilnya menunjukkan bahawa KFRC segar mempamerkan peningkatan yang selari dalam kebolehkerjaan konkrit dengan peningkatan nisbah w/c di dalam campuran konkrit. Walau bagaimanapun, kekuatan KFRC menurun apabila nisbah w/c konkrit meningkat. Selain itu, kekuatan KFRC adalah lebih rendah berbanding konkrit biasa. Ini menunjukkan bahawa tambahan serat kenaf di dalam konkrit tidak meningkatkan kekuatan mampatan konkrit.

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| | | |
|---|---|---|
| FRC | - | Fiber Reinforced Concrete |
| NFRC | - | Natural Fiber Reinforced Concrete |
| KFRC | - | Kenaf Fiber Reinforced Concrete |
| w/c | - | Water-Cement Ration |
| BS | - | British Standard |
| Control0.50$_{w/c}$ | - | Conventional Concrete with 0.50 water-cement ratio |
| KFRC0.50$_{w/c}$ | - | Kenaf Fiber Reinforced Concrete with 0.50 water-cement ratio |
| KFRC0.60$_{w/c}$ | - | Kenaf Fiber Reinforced Concrete with 0.60 water-cement ratio |
| KFRC0.70$_{w/c}$ | - | Kenaf Fiber Reinforced Concrete with 0.70 water-cement ratio |
| MPa | - | Mega Pascal |
| Mm | - | millimeter |
| s | - | second |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Fiber is one of material that usually use in concrete to control cracking due to shrinkage. The concrete containing fibrous material is called as fiber-reinforced concrete (FRC). Fibers in concrete include steel, glass, synthetic and natural fiber. FRC has known many developments and numerous studies have been carried out on this material during the last three decades in order to overcome the tension weakness common to all types of concretes. 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 advantages of natural FRC, including increased toughness, enhanced cracking behavior, enhanced durability and improved fatigue and impact resistance have been well documented previously. Among the many different types of natural fiber, *Hibiscus Cannabinus L.* (kenaf) plants have been extensively exploited over the past few years.

Kenaf is a common wild plant of tropical and subtropical Africa and Asia. It has been a source of textile fiber for such products as rope, twine, bagging and rugs. Kenaf is a member of the mallow (Malvaceae) family, with okra and cotton as relatives. The stem's outer bark contains the long soft bast fibers which are useful for cordage and textiles. Bast fibers make up 20% to 25% of the stem on a dry weight basis. Kenaf fiber is extracted from bast fiber of kenaf plants. Kenaf fiber is unique and potentially reliable. Properties of kenaf fiber composite are comparable to conventional fiber composites. Kenaf fiber composite can be produced using conventional fiber composite manufacturing. Kenaf fiber composite have a bright future due to its renewability and eco-friendly. Besides that, kenaf fiber is one of natural fiber that able to receive high tensional strength in the long term. Thus, this characteristic enables to receive high tensional strength making it applicable and ideal for fibrous material use in concrete. Inspection indicates that the tensile properties of kenaf fibers are comparable to those of other natural fibers, such as jute, flax and bamboo, which have been previously used to produce natural fiber reinforced concrete.

However, the fibers are basically comprised of a rigid, crystalline cellulose microfibril reinforced amorphous lignin, and/or hemicelluloses matrix. 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. An important attribute of plant fibers is their ability to absorb moisture from the atmosphere in comparatively large quantities, because cellulose is hygroscopic. Most polymeric fibers swell due to moisture absorption. This absorption leads to alterations in weights and dimensions, as well as in strengths and stiffness. Thus, besides able to receive high tensional strength, kenaf fiber has very good performance in water absorption which tends to decrease of the workability in concrete.

An addition of kenaf fibers to concrete leads to reduced workability due to the increased surface area and water absorption of the fibers. It is important, however, that the mix be workable. A mix that is too stiff or too dry could lead to an inadequately compacted final product which is likely to contain voids and/or honeycombs. Beside that mix that is too wet will lead to unnecessary strength reduction. Therefore, the right quantity of water-cement ratio (w/c) is crucial to produce the concrete with the optimum workability and strength.

In fact, w/c has hidden meaning which is directly linked to the spacing between cement particles in the cement paste. The smaller the spacing, the faster the cement hydrates fill in the gaps between cement particles, the stronger the links created by these hydrates, and most importantly, the stronger the concrete. Additionally, the smaller this spacing, the smaller the sizes of the pores created by self-desiccation and the larger the stresses generating autogenous shrinkage. Furthermore, w/c is inversely related to concrete strength and workability, where the lower w/c, the grater the strength but the lower workability (Dale and Pierre, 2008). In fact, too much water in fresh concrete will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave the concrete as it hardens, resulting in microscopic pores that will reduce the final strength of the concrete.

In this present study, the consistency of concrete reinforce with kenaf fiber will be reviewed. However, most of the research only focuses on volume or percentage of fiber in concrete mixture without concern about correct w/c for optimum workability and strength of concrete. Hence, the optimum and ideal w/c will be investigated to find the optimum strength and workability of kenaf FRC. Also, effect of using difference w/c to concrete strength will be observed.

## 1.2 Problem Statement

Many researches has been conducted to identify the potential of *Hibiscus Cannabinus L.* (kenaf) in sector involving paper and particle board and related sectors after it was introduced by National Tobacco Board (NTB) to make kenaf as a substitute in the production of fiber crops to recover the affect of national tobacco income after the planting of tobacco slightly affect because of the quota system imposed by some word's government due to the adverse impact of tobacco on human health. Thus, a joint effort by government has undertaken to review the kenaf plant in detailed.

Kenaf fiber is known as natural fiber that cheap and has the high tensional strength that works as same as jute, flax and bamboo. Besides that, it is easy to produce and readily available in the raw. However, besides able to receive high tensional strength, kenaf fiber has very good performance in water absorption which makes decrease of the workability in concrete. The influence of the glucose retardant from kenaf fibers also known as moisture absorption from concrete leads to reduced workability due to the increased surface area and decrease of water-cement ratio. Therefore future study must be conducted to investigate the ideal water-cement ratio (w/c) in concrete with kenaf fiber as additive. In addition, increasing w/c without controlling of amount or ration may result in bleeding and decrease the concrete strength. The w/c should be considered to ensure the suitable mix proportion and concrete strength.

## 1.3 Objective of Study

The objectives of this study are;

i) To determine the workability of fresh KFRC in different water-cement ratio (w/c).

ii) To determine the compressive strength of concrete reinforced with *Hibiscus Cannabinus L.* (kenaf).

## 1.4 Scope of Work

In this study, the workability of fresh concrete with kenaf fiber will be investigated and the strength of hardened concrete will be controlled. The workability of fresh concrete containing constant percentage of kenaf fiber will be focused on the effectiveness of using difference w/c to concrete mix design. There are four (4) types of mix design prepare which are control sample (no kenaf fiber), 0.50 ($KFRC0.50_{w/c}$), 0.60 ($KFRC0.60_{w/c}$) and 0.70 ($KFRC0.70_{w/c}$) of water-cement ratio (w/c) with constant mix proportion of cement to fine aggregate to coarse aggregate (1:2:3). The control concrete sample ($Control0.50_{w/c}$) is made for grade 30 with constant w/c of 0.50. An additional of kenaf fiber to concrete mix design will be fixed to 2% from total volume of concrete mix and the lengths of kenaf fiber will be approximately of range of 25 mm to 38 mm.

The workability of the fresh concrete mixes will be tested through several testing namely slump test, vebe test, and compacting factor test. All the testing will be followed the standard such as BS 1881-102:1983 for slump test, BS 1881-104:1983 for vebe test and BS 1881-103:1983 for compacting factor test. In addition, for the compression concrete cube tests are accordance to BS 1881: Part 116:1983 and 36 cube sample will be prepared with dimension of 100 mm x 100 mm x 100 mm. The hardened concrete will be cured at water condition for 7, 14 and 28 day of curing age before 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.

Government may utilize different sources of reinforcement in their infrastructures and structures mainly in their concrete buildings, highways and bridges. Then, this move may generate livelihood and source of income since this research needs human capital to extract the natural fibers.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Background

Concrete is a composite material commonly used in construction work. Concrete is a combination of four main element such as cement, coarse aggregate, fine aggregate and water. This materials is added at a specified mixing ratio to produce concrete in accordance with scale and strength that required by the industry. Concrete is the one of the most important building materials and widely used in a construction project. Concrete is used more than any other man-made material in the world. In year 2000, about 7.5 billion cubic meters of concrete are made each year, more than one cubic meter for every person on Earth (Bjorn Lomborg, 2001). It was estimated that the present consumption of concrete in the world is the order of 11 billion metric tons every years. Concrete is compulsory materials used in construction which must be workable, meet desire qualities of the hardened concrete for example, resistance of freezing and thawing and deicing chemicals, low permeability, wear resistance and strength and economy (Metha and Monteiro, 2006). Although it is popular, it has limited properties such as low tensile strength, ductility and energy absorption, shrinkage and cracking associate with hardening and curing.

To overcome the problem that occurred in the concrete, various additives are introduced including fiber reinforce concrete (FRC). FRC is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel, glass, synthetic and natural fiber.

## 2.2 Fiber Reinforce Concrete

Concrete has been well known as a low cost building material with high strength and versatility. Though high in compressive strength, concrete is quite brittle with a tensile strength of only 10% of its compressive strength (Midness et al., 2003). An alternative method to improve concrete's brittleness is to mix short fibers into concrete or known as fiber reinforced concrete, (FRC). Short natural fibers, such as horse hair, hay and straw have been used for centuries to reinforce brittle materials. Commercial fibers were first developed during the early 1900's using wire and metal clips. FRC are structural materials developed through extensive research and development during the last two decades. The earliest research into FRC date back to the 1960's (Romualdi et al., n.d) and since then extensive research and development has been carried out (Shah, 1986). Nowadays, fibers can be made or extracted from various types of materials such as steel, plastic, carbon, natural and glass and used in variety of applications such as industrial floor, tunneling, precast wall and shotcrete.

Over 30 years have passed since the initiation of the modern era of research and development on FRC. In the early 1960s Romualdi, Batson and Mandel published the papers (Romualdi et al., n.d) that brought FRC to the attention of academic and industry research scientists around the world. The writer can report that at that time there was a strong sense of discovery and an air of excitement regarding the promise that FRC held for the future development of composite materials based on Portland cement concrete. According to terminology adopted by the American Concrete Institute (ACI) Committee 544(2010), Fiber Reinforced Concrete, there are four categories of FRC based on fiber material type. These are SFRC, for steel FRC; GFRC, for glass FRC; SNFRC, for synthetic FRC including carbon fibers; and NFRC, for natural FRC.

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed volume fraction ($V_f$). $V_f$ typically ranges from 0.1% to 3%. Aspect ratio *(l/d)* is calculated by dividing fiber length,*(l)* by its diameter,*(d)*. Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fiber in concrete usually subjected of changes the flexural strength and toughness of the concrete. However, fibers which are too long tend to "ball" in the mix and create workability problems.

## 2.3 Natural Fiber Reinforce Concrete

The use of natural fiber reinforce concrete (NFRC) has been studied quite heavily over the past 40 years. Natural fibers are prospective reinforcing materials and their use so long has been more traditional than technical. They have long served many useful purposes but the application of the material technology for the utilization of natural fibers as the reinforcement in concrete took place in comparatively recent years. Economics and other related factors in many developing countries where natural fibers of various origins are abundantly available, demand construction engineers and builders to apply appropriate technology to utilize these natural fibers as effectively and economically as possible to produce good quality fiber reinforced concrete materials for housing and other needs.

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. NFRC further provides architectural and ornamental features (Wells, 1982). Sisal fiber reinforced concrete tiles, corrugated roofing sheets, pipes, gas tanks, water tanks and silos are also being used extensively in some African countries (Swift, 1978).

### 2.3.1 Properties of Natural Fiber Reinforce Concrete

The properties of natural fiber reinforce concrete (NFRC) are dependent on a number of factors including the type and the length of fibers used and the volume fraction. Early research indicated that the minimum fiber volume fraction required to provide significant improvement in the mechanical properties of cement composites was approximately 3% (Rancines and Pama, n.d). NFRC constitute a new and distinct group of building materials which exhibit almost the same behavior in performance as that of conventional fiber reinforced concrete (FRC) produced from steel and other inorganic or synthetic fibers. Like conventional FRC, the reinforcement in NFRC consists of small diameter discontinuous, discrete natural fibers of various origins randomly dispersed throughout the concrete matrix.

The fibers act as crack-arresters which restrict the growth of flaws in the concrete matrix from enlarging under stress into visible cracks which ultimately cause failure. By restricting the growth of cracks, the usable tensile strength of the concrete matrix is increased to a useful and predictable level. The dispersion of fibers in the brittle matrix offers convenient and practical means of achieving improvements in many of the engineering properties of the materials such as fracture, tensile and flexural strengths, toughness, fatigue and impact resistance. Studies by Mansur and Aziz in year 1982 revealed that jute FRC indicate that the compressive strength is not significantly affected by the addition of fibers, while tensile and flexural strength and toughness are all substantially increased.

Besides that, another studies conducted by A. Elsaid et al, (2011) shows that decreasing compressive strength occured with increasing fiber content. Reduction of strength is likely due to several factors such as additional water added to the concrete mixture while adding the fibers in order to maintain the workability of the NFRC at an acceptable level. Besides, reduction of compression strength is due not only because of increasing of the w/c ratio necessary for workability, but also due to the presence of high volume fraction of natural fibers in the concrete.

#### 2.3.1.1 Properties in Fresh State

The incorporation of natural fibers into a mix decreases the workability and increases the void content due to entrainment of additional air (Lewis and Mirihagalia, 1979). The decrease in workability is basically due to the surface area and especially the size and shape of the fibers in relation to the other constituent particles in concretes. Unworkable mixes generally lead to non-uniform fiber distribution resulting in variation between specimens from the same mix. The increase in void content is also due to the inadequate compaction of the unworkable mixes. The amount of fibers that can be added to a mix is limited by the phenomenon of 'balling' (Mansur and Aziz, 1982). If the fibers are long, which it have a high aspect ratio - greater than 100, the fiber have a strong tendency to intermesh and form fiber balls which cannot be easily separated. The balling of fibers results in an unworkable and segregated mix which ultimately produces a highly porous and honeycombed concrete. The balling of fibers when large volume fractions are used can be reduced by reducing the coarse aggregate content (Mansur and Aziz, 1982).