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THE SHEAR BEHAVIOR OF STEEL FIBER REINFORCED CONCRETE BEAM

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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I declare that this project report entitled "The shear behavior of steel fiber reinforced concrete beam" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father

And my family

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ABSTRACT

During the last four decades, steel fiber reinforced concrete has been increasingly used in structural applications. It is generally accepted that addition of steel fibers significantly increases tensile toughness and ductility, also slightly enhances the compressive strength. Several studies have reported previously the favourable attributes of steel fiber reinforced concrete (SFRC) On compression, tension and shear behavior .As the models proposed so far can, at best, describe only a few aspect of SFRC with a given type and amount of fibers, establishing simple and accurate generalized equations to describe the behavior of SFRC in tension, compression and shear that take into account the fiber type and content is essential. This research investigated the shear behavior of SFRC and to formulate generalize models for the ultimate shear strength of SFRC. The effect of the fiber volume fraction on the shear response of SFRC with optimum steel fiber content has been studied. Six different volume contents ranging from 0% to1% was used in the test specimens. Direct shear tests were conducted and finally, an equation model was developed to predict the ultimate shear strength of SFRC in terms of steel fiber content.

ABSTRAK

Start here Sejak empat dekad terakhir ini, konkrit bertetulangkan serat keluli (SFRC) telah semakin banyakdigunakan dalam aplikasi struktur. Hal ini berlaku pada umum nya kerana penambahan serat keluli telah secara ketara meningkatkan kekuatan tegangan dan kemuluran, juga meningkatkan sedikit kekuatan mampatan. Beberapa kajian telah dilaporkan sebelumnya yang menemui kelebihan sifat-sifat konkrit serat keluli didalam kekuatan mampatan, tegangan dan riceh. Model persamaan yang dicadangkan setakat ini hanya dapat menjelaskan beberapa sifat fizikal dan mekanikal SFRC dengan jenis tertentu dan kadar kandungan serat. Oleh itu, membina persamaan umum yang mudah dan tepat untuk menggambarkan sifat SFRC dalam tegangan, mampatan dan ricih yang mempertimbangkan jenis serat dan kandungan sangat penting. Penyelidikan ini meninjau kelakunan riceh SFRC dan merumuskan satu model umum untuk kekuatan ricih muktamad SFRC. Pengaruh kandungan serat keluli pada kelakunan riceh SFRC telah dikaji. Enam kandungan serat keluli yang berbeza dari 0% hingga 1% telah digunakan pada bahan kajian.Ujian ricih terus telah dilakukan dan akhirnya, sebuah model persamaan telah dibentuk untuk meramalkan kekuatan riceh muktamad SFRC dalam dengan kandungan serat keluli yang berbeza.

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A_e	-	The effective area of the compression region
A_s	-	Area of tension reinforcement
A_v	-	Total cross-section area of links
a_v	-	Length of that part of a member traversed by a shear failure
b	-	Beam width
C	-	The compressive force
d	-	Effective depth
f'_c	-	Characteristic strength of concrete
f_{ct}	-	splitting tensile strength
f_t	-	Characteristic strength of tension of concrete
f_y	-	Characteristic strength of tension reinforcement
F_{vy}	-	Characteristic strength of links
I	-	Moment of inertia of cross section about neutral axis
L	-	Total span length
L0	-	Effective span length
V_b	-	fiber pullout forces along the inclined crack
V_c	-	Design concrete shear stress
V_f	-	fiber volume fraction percentage
V	-	Design shear stress at a cross-section
V_n	-	The nominal shear strength
V_u	-	The ultimate shear strength of the section

γ_m	-	Partial safety factor for strength of material
ρ	-	Percentage area of tension reinforcement
τ_0	-	Shear strength of plain concrete
τ_{max}	-	Ultimate shear strength of the section

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Steel fibers aids in converting the brittle characteristics of concrete to a ductile one. The principal role of fibers is resisting the formation and growth of cracks by providing pinching forces at crack tips. In addition, a marginal improvement in tensile strength also results and steel fiber reinforced concrete has higher ultimate strain than plain concrete.

The mechanical behavior of steel fiber reinforced concrete beams in shear the major test variables are the volume fraction of steel fibers and the ratios of stirrups to the required shear reinforcement.

Increase in the fiber content will improve the ultimate shear strength in beam at the range between 0.0 % to 1.0 % volumes ratio. The present researches that fiber reinforcement can reduce the amount of shear stirrups required and that the combination of fibers and stirrups may meet strength and ductility requirements.[D. H. Lima, and B. H. Oh,1999]

According to Naaman (1985), even though the concept of using fibers to reinforce concrete is not new, the application of SFRC in the concrete industry did not flourish until the early 1960s. Fibers are made from various materials (steel, glass, carbon, or synthetic material) and with different geometrical characteristics (length, diameter, longitudinal shape, cross-sectional shape, and surface roughness). Among the various types of fibers, steel fibers are most widely used in the concrete industry. Steel fibers are short (typically from 15 to 60 millimeter) and generally deformed to enhance bond with the concrete (Fig. 1-2). Available commercial steel fibers have a tensile strength of up to approximately 2000 MPa.

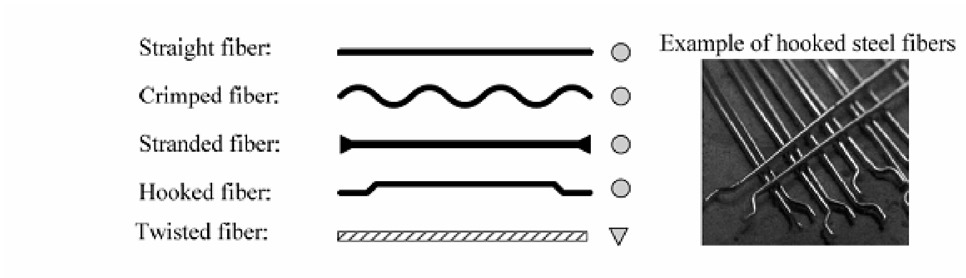

Figure 1.1 Different shape of steel fiber

In general, the concept of using fibers to improve the characteristics of concrete include enhancement of compressive strength, tensile strength, flexural toughness, shear strength, durability and resistance to impact. The physical properties of composites depend on the type and the dosage of the added fibers.

The steel fiber is still under research for that to predict and consider the steel fibers materials during the calculation of resistance shear force is under A theoretical approach to proposed and predict the shear strength of reinforced concrete beams containing steel fibers correlation base on obtained test data. To allows more efficient structural application of steel fibers for shear reinforcement in reinforced concrete structures to apply and for this research trying to predict same correlation with many parameters affected on shear behavior corresponding the steel fiber.

1.2 Problem Background

Shear failure of concrete members is different from flexural failure in that it is brittle and should be avoided by all means. Plane concrete sections resist shear forces by aggregate interlock and concrete strength, which control the propagation of cracks. In reinforced concrete sections, shear forces are usually resisted by shear links. Introducing steel fibers to prevent crack growth may become an economical way of increasing the shear capacity. Current design codes provide guide to design of reinforced concrete beams containing steel fiber. Therefore it is desirable to predict the behavior of these members due to the addition of steel fiber and subsequently determine percentage increase in shear capacity, optimum content of steel fiber.

1.3 Research Questions

Based on this research, its hope that the following research questions will be answered:

i. What is the improvement due to the increase of steel fiber content on the behaviors of beam under shear force resistance?

ii. What is the optimum volume ratio of steel fiber to improve shear resistance?

1.4 Research Objectives

The objectives of this research are:

i. To study the effects of fiber content on shear behavior of steel fiber reinforcement concrete beam.

ii. To study the formulation of shear design of beam.

1.5 Significant of Study

This research presents the effectiveness of steel fiber in improving shear resistance of reinforced concrete beam. This can lead to reduction in quantity of links in section.

1.6 Scope of Study and limitations

This research is to investigate the shear behavior of SFRC due to the effect of the fiber volume fraction on the shear. Since the research has its own time constraint, several limitations have been made to ensure that the research can be completed within the time given. Followings are the scope and limitations of this research:-

i. The research considers steel fiber reinforced concrete beam without shear reinforcements.
ii. The research considers six different volume contents ranging from 0% to 1% by incremental percentage 0.2 %.
iii. All specimens are tested to measure the ultimate shear capacity.
iv. Design of mix proportion of concrete and percentage ratio of steel fiber

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Several previous studies have demonstrated the effectiveness of fiber reinforcement in improving the shear performance of structural concrete. Batson and Jenkins replaced the vertical stirrups in conventional reinforced beams loaded in flexure by steel fibers of various shapes, sizes, and volume concentrations and concluded that steel fibers had some advantages over vertical stirrups or bent-up flexural steel. First, the fibers are randomly distributed through the volume of the concrete at much closer spacing than can be obtained by the smallest reinforcing rods. Secondly, the first crack tensile strength and the ultimate tensile strength were increased by the steel fibers.

Swamy and Bahia4 tested T-beams and rectangular beams with 50 mm-long crimped steel fiber at volume fractions of up to 1.2% and found that the presence of steel fiber reduced shear deformations at all stages of loading and this phenomenon was more apparent as the fiber content increased. Fibers Controlled both cracking and displacement in the dowel Zone and enabled the beam to fully develop the dowel action. Fibers were effective shear reinforcement, increased the shear strength by approximately 80%, and allowed shear deficient beams to reach their full flexural capacity resulting in ductile flexural failures.

Li, Ward, and Hazma5 tested beams without shear stirrups and with up to 2% of aramid, polyethylene, acrylic, and steel fiber reinforcement. They found that while beams without fiber reinforcement failed by diagonal shear cracking, those with fibers resulted in an increase in the ultimate shear strength by up to 183%, thus preventing shear failure and allowing beams to fail ultimately in flexure.

Narayanan and Darwish6 tested fiber-reinforced concrete (FRC) beams with crimped steel fiber at dosage rates of up to 3% by volume and found that the crack patterns developed in beams with FRC were generally similar to those in corresponding concrete beams reinforced with conventional stirrups. Fibers reduced the crack spacing to approximately a fifth of that in companion beams with stirrups, thus indicating a more uniform redistribution of stresses in beams made of FRC.

They also concluded that at least 1% fiber by volume is needed to avoid shear failure and to change the mode of failure from shear to flexure. Beyond 1% fiber volume, little improvement in shear strength was noted. Found that the compressive strength of concrete played a major role and the increases measured in shear strength of FRC beams with higher strength matrices were greater.

Modeling of shear behavior of (SFRC) Fibers can be effective shear reinforcement, and may increase the shear strength by as high as 80%. Addition of fibers in concrete allowed shear-deficient beams to reach their full flexural capacity resulting in ductile flexural failure [Mirsayah and Banthia 2002].

The use of deformed steel fibers in place of minimum stirrup reinforcement is currently allowed in ACI Code Section 11.4.6 (ACI Committee 318, 2008) The benefits of using steel fiber reinforcement for shear resistance, however, have not been fully exploited yet, primarily due to lack of understanding of the role which steel fibers play on the shear behavior of beams with and without stirrup reinforcement. The development of steel fibers, their application in the concrete industry.

The empirical expression for the ultimate shear strength proposed by Mirsayah and Banthia is expressed as a function of the fiber volume fraction.

$$\tau = \tau_0 + K V_f^{\,n} \qquad \text{Equation (2.0a)}$$

Where :

τ_0 = shear strength of plain concrete;

K, n = experimental constants;

V_f = fiber volume fraction.

This expression explicitly takes into account the fiber content and implicitly the fibers quality (in the constants k and n). However, the shear strength of plain concrete before the addition of fibers needs to be known in advance. This can be estimated if the compressive strength of the plain concrete is known, but it is more common in field applications to mix the fibers together with other materials before making the FRC; rather than preparing the normal concrete first (to evaluate its shear strength) then adding the fibers and mixing again to produce FRC.

They also noted significant stiffening in beams with fibers based on moment curvature relationships. There is still no standardized test method in the ASTM or CSA standards to measure the material properties of FRC in shear such as shear strength or shear toughness.

Even in the most advanced and most recent design methods, the contribution of fiber reinforcement to shear is completely ignored. Consequently, no design codes allow a reduction or removal of stirrups or dowels from beams or slabs, although these are used solely to provide properties that are easily obtainable through fiber reinforcement. [Mirsayah and Banthia, 2002].

Shear force is present in beams at sections where there is a change in bending moment along the span. It is equal to the rate of change of bending moment. An exact analysis of shear strength in reinforced concrete beam is quite complex. Several experimental studies have been conducted to understand the various modes of failure that could occur due to possible combination of shear and bending moment acting at a given section.

The distribution of shear stress on the cross section of an RC beam subjected to shear is uncertain. However, it is generally accepted that shear strength in beams is provided by reinforcement through dowel action, aggregate interlock, and the concrete compression region. Of these components, dowel action is considered to be minor compared to the other two, particularly in beams with a low flexural reinforcement ratio. Over the years, two schools of thought have clearly emerged. The first school emphasizes the importance of aggregate interlock, while the second assigns a dominant role to the concrete compression region. Researchers in the first group include Mitchell and Collins (1974), Nielsen (1984), Vecchio and Collins

(1986), Marti (1986), and Berlabi and Hsu (1995). Those from the second group, including Zwoyer and Siess (1954), Bresler and Pister (1958), Kani (1964), and Frosch (2003), assume that shear resistance comes primarily from the shear stresses in the concrete compression region. The next section summarizes important concepts from each school of thought

The Work of Bresler and Pister (1958). used the concept of average shear stress and average normal stress in the compression region to calculate the ultimate shear strength of RC beams. The average shear stress τ and average normal stress σ are defined as follows:

$$\tau = \frac{V_u}{A_e} \qquad \text{Equation (2.0b)}$$

$$\sigma = \frac{C}{A_e} \qquad \text{Equation (2.0c)}$$

Where V_u is the ultimate shear strength of the section; C is the compressive force acting on the compression region; and A_e is the effective area of the compression region resisting shear, defined by Figure 2.0.By equilibrium, the compressive force C equals the tensile force T in the reinforcement, which is assumed to yield at ultimate strength. Compressive stress

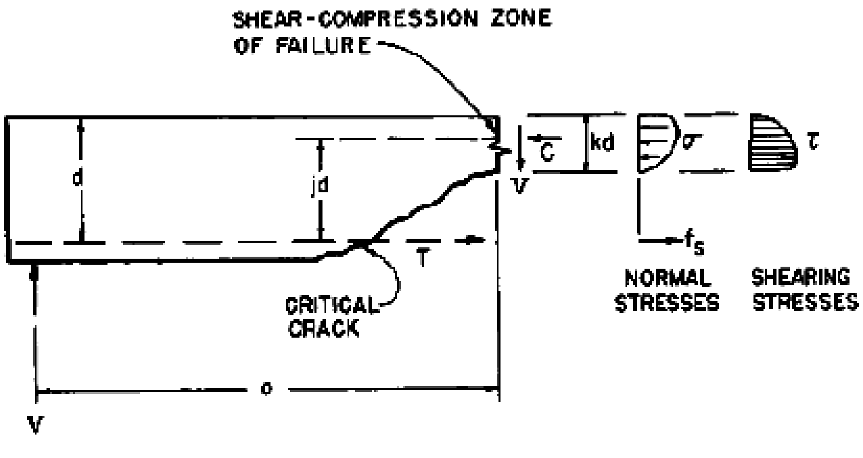

Figure 2.1 Stress distribution in RC beams (Bresler and Pister)