STUDY ON THE DEPTH REDUCTION OF CONCRETE BEAM USING MEGA MESH POLYPROPYLENE FIBRES UNDER FLEXURAL LOAD

CHEAH KAR JUN

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Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

Nowadays, rapid development in construction uses a lot of concrete as building materials. While during producing concrete, it causes certain problem which will cause environment pollution. Beside that deep beam will decrease the clear height of the floor due to the space allocation used up for the ceiling to cover the beam. This research deals with the effect of additional mega mesh polypropylene fibre (MMPF) on the depth reduction of concrete beam. The objective of this research was to find out the flexural strength of MMPF concrete beam and the optimum depth can be achieved by MMPF in strengthening flexural strength of the concrete. This research first is to prepare the concrete with grade M30 and additional fibre in different depths of 100mm, 90mm, 80mm, 70mm, 60mm, 50mm and a control beam without fibre with 100mm depth for flexural test. While cylinder concrete with fibre and without fibre were cast to determine for compressive strength and elastic modulus properties. Based on the strength and the statistical analysis conducted on the tested specimens. The addition of mega mesh polypropylene fibres in concrete shows an increase in flexural load able to be sustained by the concrete. The inclusion of MMPF in fresh concrete decreased the workability up to 19.52% lower than plain concrete, however addition of MMPF was able to increase the compressive strength up to 57.13% higher than plain concrete. The elastic modulus also shows 54.08% increment as compared to control. Based on the result, the optimum depth can be achieved by MMPF to improve flexural strength of concrete beam was 90mm. Therefore, the addition of MMPF in concrete beam has a good potential as one of the depth reduction variable in concrete beam.

ABSTRAK

Pada masa kini, pembangunan yang pesat dalam pembinaan menggunakan banyak konkrit sebagai bahan binaan. Walaupun dalam menghasilkan konkrit, ia menyebabkan masalah tertentu yang akan menyebabkan pencemaran alam sekitar. Selain itu rasuk dalam akan mengurangkan ketinggian jelas lantai kerana peruntukan ruang yang digunakan untuk siling untuk menutup rasuk. Ini tawaran penyelidikan dengan kesan tambahan jaringan mega serat polypropylene (MMPF) pada pengurangan kedalaman rasuk konkrit. Objektif kajian ini adalah untuk mengetahui kekuatan lenturan rasuk konkrit MMPF dan kedalaman optimum boleh dicapai dengan MMPF dalam mengukuhkan kekuatan lenturan konkrit. Kajian ini pertama adalah untuk menyediakan konkrit dengan gred M30 dan serat tambahan dalam kedalaman yang berbeza daripada 100mm, 90mm, 80mm, 70mm, 60mm, 50mm dan rasuk kawalan tanpa serat dengan kedalaman 100mm untuk ujian lenturan. Walaupun konkrit silinder dengan serat dan serat tanpa dibuang untuk menentukan kekuatan mampatan dan sifat modulus elastik. Berdasarkan kekuatan dan analisis statistik yang dijalankan ke atas spesimen yang diuji. Penambahan serat polypropylene jaringan mega dalam konkrit menunjukkan peningkatan dalam beban lenturan dapat dialami oleh konkrit. Kemasukan MMPF dalam konkrit segar menurun kebolehkerjaan sehingga 19.52% lebih rendah berbanding konkrit biasa, bagaimanapun penambahan MMPF dapat meningkatkan kekuatan mampatan sehingga 57,13% lebih tinggi daripada konkrit biasa. Modulus elastik juga menunjukkan kenaikan 54,08% berbanding dengan kawalan. Berdasarkan keputusan, kedalaman optimum boleh dicapai dengan MMPF untuk meningkatkan kekuatan lenturan rasuk konkrit adalah 90mm. Oleh itu, penambahan MMPF dalam rasuk konkrit mempunyai potensi yang baik sebagai salah satu pembolehubah pengurangan mendalam dalam rasuk konkrit.

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LIST OF SYMBOLS

%	Percentage
mm	Millimeter
kg/m^3	Kilogram per meter cube
m^2/ kg	Meter square per kilogram
mins	Minutes
MPa	Mega Pascal
≤	Smaller than or equal to
≥	Greater than or equal to
L/m^3	Little per meter cube
kN	Kilo newton

LIST OF ABBREVIATIONS

MMPF	Mega mesh polypropylene fibres
PF	Polypropylene fibres
GF	Glass fibres
SF	Steel fibres
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
PFRC	Polypropylene fibre reinforced concrete
FRC	Fibre reinforced concrete
SFRC	Steel fibre reinforced concrete
MS	Malaysia Standard
BS	British Standard
EN	European Standards
CB	Control beam
NC	Normal concrete cylinder
MMPFC	Mega mesh polypropylene fibres concrete cylinder

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Concrete was an important building material used all around the world for more than a century. It was composite construction material which normally make out from three major material that was cement, water and aggregate. Concrete widely use in all the constructions work include foundation, structural of a building, bridge, dam, roads, etc. (Patel and Kulkarni, 2013). Concrete was choose to be the major construction material because of it high compressive strength, production step easy, component can get in everywhere and relatively inexpensive (Brandt, 2008). It can be cast in any shape from rectangular beam or column to cylindrical power plant. The advantage of concrete are well common to high compressive strength and low maintenance which have long service life as compare to other construction material (i.e. timber and steel). However this plain concrete material is a quasi-brittle material (poor tensile strength) and easily cracked even small stress induce on it owing to its inherent weakness in resisting external forces (Wang et al., 2011). The disadvantage of concrete is notified since ancient years ago and fibre-reinforced materials started with straw fibres reinforced in mud bricks and horsehair in mortar (Mohsin, 2012).

Now the day with the developing of the world, the normal concrete was not good enough for the construction use already. More and more special concrete was researched to improve the quality of the concrete in term of it durability, compressive strength, tensile strength, flexural strength, etc. One of the special concrete develop for overcome the problem was fibre reinforcement concrete. The major reason of this reinforcement concrete be produce was to overcome the brittle problem of the concrete. In 1900, a technology was invented to produce roofing plates, pipes plates, etc. The technology wan names as Hatschek technology. After this Biryukovichs wan proposed to use glass fibres for reinforcement of cement paste and mortar (Brandt, 2008). In the 1960s, many alternative fibres such as steel, glass, and synthetic fibres are used as new initiative for asbestos fibre replacement in fibre-reinforced concrete (Mohsin, 2012). Fibers such as steel fibres, glass fibres, carbon fibres, plastic fibres (i.e. polypropylene, graphite etc), and natural fibres (i.e. hemp, kenaf etc) are popular to be found in the market (Mohsin, 2012).

Fibres are used to enhance the properties such as shrinkage, toughness, and the energy absorption capacity and more (Altun et al., 2007; Johnston, 1994). In order to achieve higher tensile and flexural strength, it is important to reduce the brittleness of plain concrete as well as crack control or closure mechanism thus changing the failure mode to one that includes post-cracking ductility (Hannant, 1978). It is important to ensure the bonding between the fibres and the matrix, therefore various sizes and shapes (e.g. deformed) to provide this anchorage effect (Mohsin, 2012). According to Hannant (1978), the maximum particle size in fibre-reinforced concrete is restricted to 20 mm to ensure that sufficient bonding is accomplished. In addition, the post-cracking behaviour can be affected by the number of fibres across a specific crack, effectiveness of fibre orientation, bond strength and the resistance to fibre pull-out.

While polypropylene fibre (PF) was one of the popular fibre used in concrete industry, because through the research show that polypropylene fibres can improve concrete flexural ductility, durability of concrete, compressive strength and spalling resistance (Sun and Xu, 2009). Polypropylene fibers was a kind of chemical fibers, about 4 million tons of this fibres was manufacture every years. Polypropylene fibres were used as admixture in Portland cement concrete since 1960s (Tautanji, 1999, Madhavi et al., 2014, and Prasad et al., 2013). In 1965 polypropylene fibre concrete was meant for the US Corps of Engineers because it was the first time polypropylene fibre was suggest to use as an admixture for construction of blast resistant buildings (Madhavi et al., 2014).

1.2 PROBLEM STATEMENT

In the near future, every country development increases year by year. Many high rise building was built all around the world. While with the increasing of construction, the amount of concrete produce will be increase same goes to cement will increase due to the demand. In a building beam used up a lot of concrete for the structural part. The production of the cement will emit huge amount of carbon dioxide into the environment which will lead to greenhouse effect. Cement production can produce about 7% of the total global loading of carbon dioxide which is 1.6 billion tons of carbon dioxide. Mining large amount of raw material of cement and aggregate for producing concrete will result to the top-soil loss and also extensive deforestation. Furthermore, while producing concrete need a lot of fresh water supply. Beside that ready mixed concrete industry and water curing will used up large quantities of fresh water as wash water. Only for concrete mixing, approximately 1 trillion L of fresh water was used up every years (Mehta, 2001).

As mention above, use of too much concrete will cause environment effect. So with the reduction of the concrete beam in the structure, it help save the used of the concrete and also the environment due to the effect of using concrete. Especially to the high rise building normally deep beam are needed, so more concrete were needed. In a building high of the floor will be determine by the depth of the beam. Cause the high of the ceiling will be set below the beam so the beam can be cover inside the ceiling. Therefore the floor high be reduced cause by the depth of the beam. By reducing the depth of the beam it can increase the clear high of the floor.

Concrete was well known as a brittle material, it was good to resist compressive stress but not good in resist tension or tensile stress. So reinforced steel bar was installed into the concrete to absorb the tensile forces. But most of the time the reinforced steel bar will be corrodes by the ingress of chloride ions. Chloride ion will penetrates into the concrete to promote corrosion and make the steel rusted. When the steel rusted, the volume inside the concrete will increased which will produces large tensile stress in the concrete. This will cause the concrete crack and spalling happening on the surface of the concrete (Brown et al., 2002).

1.3 OBJECTIVES OF THE RESEARCH

The main objectives of this research are:

- To determine the flexural strength of beam specimen containing mega mesh polypropylene fibres (MMPF)
- To determine the optimum depth can be achieved by mega mesh polypropylene fibres in strengthening the flexural strength of concrete

1.4 SCOPE OF RESEARCH

In this research, only one type of fibres was chosen that was mega mesh polypropylene fibres. The amount of MMPF used was 0.9kg per m^3 according to the specification of the product. The concrete design used will refer to the characteristic of 30MPa using Ordinary Portland Cement (Type 1). The MMPF concrete beam covered in this research are with different depth of 50mm, 60mm, 70mm, 80mm, 90mm, and 100mm with length 500mm and width 100mm. Control beam without fibres with depth 100mm was casted. The specimens tested in flexural machine on 7, 14, and 28 days. For 7 and 14days 2 specimens tested, while at 28days 3 specimens tested to get an average result. So a total amount of 49 beam specimens casted and tested. For compressive strength, 6 concrete cylinder each 3 samples with fibres and without fibres were tested in compression machine at 28 days to get the compressive strength. All the specimens were put in the water tank for water curing until the testing days. Elastic modulus was get by using strain and stress data taken by using strain gauge and compression machine generate by computer software. The fine and coarse aggregate chosen were available in the lab with maximum size 5mm and 20mm.

1.5 RESEARCH SIGNIFICANCE

The purpose of this research was to increase the flexural strength of the concrete beam with adding MMPF into the concrete beam. Other than that this research was to found out the optimize depth of concrete beam with addition of MMPF under flexural load. The additional of MMPF in concrete beam result a depth reduction compare to plain concrete beam, hence the usage of the concrete can be reduced. When the concrete usage can be reduced then the environmental effect can be reduced.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW OF FIBRE

There are various types of fibres available in the market nowadays. According to Labib and Eden (1990) research fibres can be obtained by various shape and sizes which produced from different types of material and produce steel fibres, glass fibres, natural organic and mineral fibres (e.g. wood, bamboo, cotton, asbestos and rockwool), polypropylene fibres and other synthetic fibres (e.g. Kevlar, polyester and nylon). Polypropylene and steel fibres are the main fibres that used all around the world for many years in construction floor slab (Kelly, 1990). The properties of fibre stiffness, strength and the ability of the fibres to bond with the concrete is important for fibre. While bond normally is dependent on the aspect ratio of the fibres (ACI Committee 544, 2002).

2.1.2 Polypropylene Fibres (PF)

The PF are a kind of thermos plastics which produce from a polymerizing monomer unit C_3H_6 which are an unsaturated hydrocarbon, PF in the presence of catalysts under controlled high temperature and pressure only can become a long polymer chain (Madhabi et al., 2014, Dwivedi et al., 2014 and Brown et al., 2002). While thermos plastics was produced by propylene gas which can be obtain from cracking of natural gas feed stock or by product of petroleum, so I was an ecofriendly fibre which use waste product to produced. Figure 2.1 and 2.2 show the structural formula of propylene and polypropylene chain

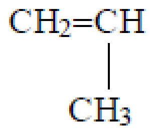


Figure 2.1: Propylene structural formula

Source: Brown et al. 2002

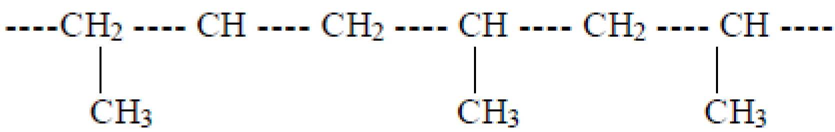
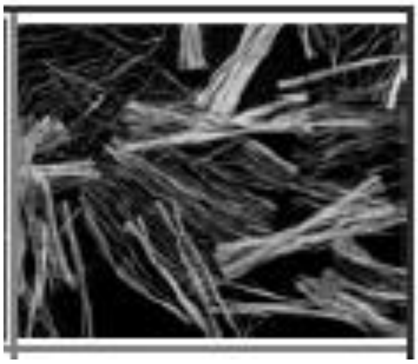


Figure 2.2: Structure of polypropylene chain

Source: Brown et al. 2002

James et al., (1992) in his report is classified PF into monofilament fibres and film fibres. Monofilament fibres have a benefit that it can be cut in to different length as requested after it produced out by an extrusion process through the orifices in a spinneret and this kind of fibres was first type of PF which used to make fibre reinforced concrete. Brown et al., (2002) report mention that PF can be divided into two form which are monofilaments and multi-filaments. Monofilaments was produces by composed of a single extruded polypropylene filament, while multi-filaments was produced by several individual monofilaments grouped into one to form it. Singh (2011) said the way to manufactured PF was to extruding the plastic film with rectangular cross-section or by pulling the wire procedure with circular cross section and then they appear in the form of fibrillated bundles mono filament or microfilaments. The fibrillated polypropylene fibers are formed by expansion of a plastic film, which is separated into strips and then slit.



a) Monofilament fibre b) Fibrillated fibre

Figure 2.3: Types of polypropylene fibre

Source: Singh 2011

Below are some of the properties of the PF form several research. PF have average melting point around 160 °C to 170 °C. Beside that PF is a good chemical inert substance which can resist chemical come in contact with the concrete (Madhavi et al., 2014, James et al, 1992, and Brown et al., 2002). PE water demand is nil and it hydroponic surface can prevent balling effect will not happen during concrete mixing, this will help the worker to mix concrete easily without any troublesome of water required effect cause by PE (Singh, 2011). PF can be said as the most successful commercial application because this fibre non corrosive, low density and are chemically inert which make it suitable for reinforcement in concrete (Patel et al., 2012). PF was often be recommended for concrete structure because of it effective cost-benefit-ratio. The properties of the harden concrete will be affect by polypropylene fibres varies depending on different issue such as nature of the concrete material used, volume, type and also length of the fibre.

PF is hydrophobic material which means that it does not absorb water. So PF are not going to bond chemically in the concrete matrix but the bonding will occur by mechanical interaction. The melting point and elastic modulus are lower compare to other fibres because PF are produced from homopolymer polypropylene resin. However, refractory product manufacturers use polypropylene fibers for early strength enhancement and because they disappear at high temperatures, providing a system of "relief channels" or use in controlling thermal and moisture changes (ACI Committee 544, 2002).

2.1.3 Glass Fibres (GF)

GF are produced in a process in which molten glass is drawn in the form of filaments, through the bottom of a heated platinum tank or bushing. Normally 204 filaments will be drawn at the same time and they solidify which cooling outside the heated tank. After that they are collected on a drum into a strand consisting of 204 filaments. Before to winding, the filaments need to coat with a sizing which help to bind them together in the strand, as well as protecting the filaments against weather and abrasion effect (Shakor et al., 2011).

Fibres can be categories into five category:

- A-glass (close to normal glass)
- C-glass (resist chemical attack)
- E-glass (insulation to electricity)
- AR-glass (alkali resistance)
- S-glass (high strength fiber)

Component	A-glass	E-glass	Cem-FIL AR-glass	NEG AR-glass
SiO_2	73.0	54.0	62.0	61.0
Na_2O	13.0	—	14.8	15.0
CaO	8.0	22.0	—	—
MgO	4.0	0.5	—	—
K_2O	0.5	0.8	—	2.0
Al_2O_3	1.0	15.0	0.8	—
Fe_2O_3	0.1	0.3	—	—
B_2O_3	—	7.0	—	—
ZrO_2	—	—	16.7	20.0
TiO_2	—	—	0.1	—
Li_2O	—	—	—	1.0

Figure 2.4: Chemical composition of selected glasses (%)

Source: ACI Committee 544 2002

2.1.4 Steel Fibres (SF)

From Labib and Eden (1990) research, there are a lot of shape of SF in the market. Many efforts have been made in recent years to optimize the shape of SF to achieve improved fibre-matrix bond characteristics, and to enhance fibre dispensability in the concrete mix. ACI Committee 544, 2002 ASTM A 820 provides a classification for four general types of SF based upon the product used in their manufacture which are Type I—Cold-drawn wire, Type II—Cut sheet, Type III—Melt-extracted and Type IV—Other fibers. In reinforced concrete, SF are defined as short, discrete lengths of steel having an aspect ratio (ratio of length to diameter) from about 20 to 100, with any of several cross section, and that are sufficiently small to be randomly dispersed in an unhardened concrete mixture using usual mixing procedures. SF have a relatively high strength and modulus of elasticity. For the fire resistance application, stainless SF may be required. Types of SF should be consider base on the types of application. ASTM A820 state that a minimum tensile yield strength required was 345Mpa.

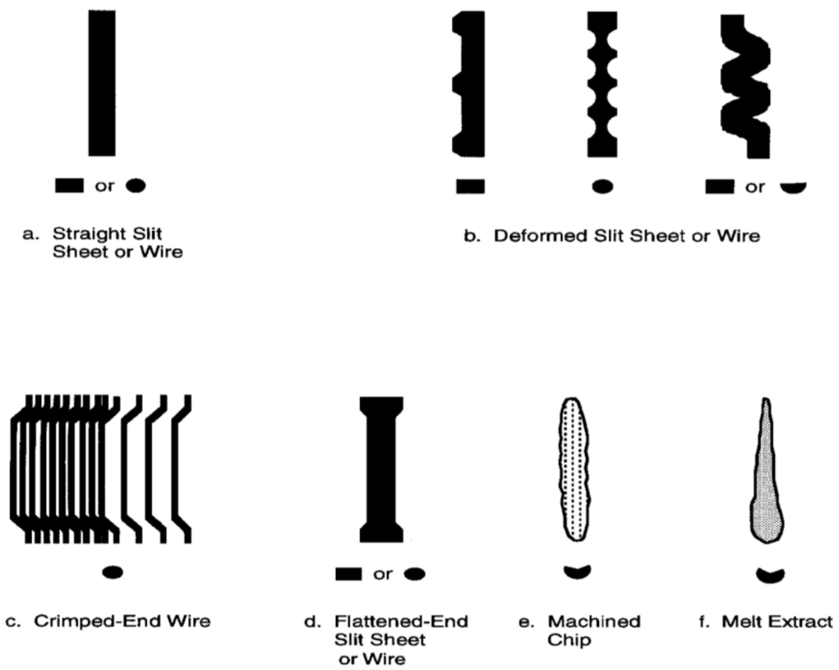


Figure 2.5: Various steel fiber geometries

Source: ACI Committee 544 2002

2.2 PREVIOUS RESEARCH OF POLYPROPYLENE FIBRES REINFORCED CONCRETE (PFRC)

During 1960s, PF was first suggested and used as admixture to the concrete hence increase the production of fibrillated materials for PFRC because polypropylene fibres was produce from fibrillated of polypropylene films (Singh, 2011, Prasad et al., 2013 and Ali, 201). PFRC normally use on constructing pavements, bridge decks, overlays and toppings, offshore structures, machine foundation etc. where the composite is subjected to cyclically varying load during its lifetimes (Patel et al., 2012 and Madhavi et al., 2014).

PFRC normally applied on non-strcutural and non-primary load bearing application. Current applications include residential, commercial, and industrial slabs on grade, slabs for composite metal deck construction, floor overlays, shotcrete for slope stabilization and pool construction, precast units, slip form curbs, and mortar applications involving sprayed and plastered Portland cement stucco. (ACI Committee 544, 2002).

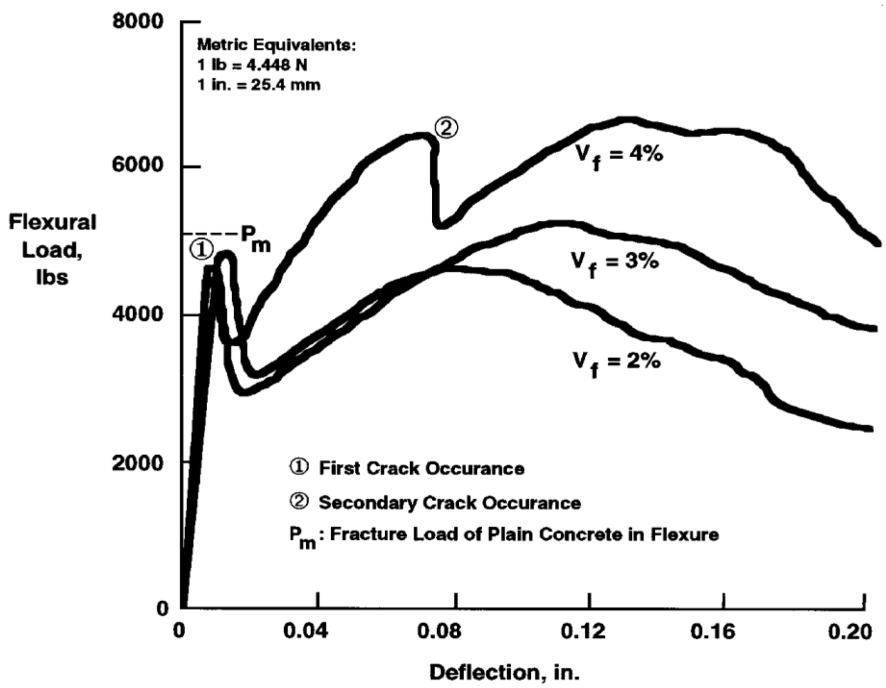


Figure 2.6: Typical flexural load-deflection curves of polyethylene fiber reinforced concrete for various fiber contents.

Source: ACI Committee 544 2002

Singh (2011) research state that being wholly synthetic there is no corrosion risk for the concrete. PFRC good in resistance impact force compare to normal reinforced brittle concrete. With the use of PFRC the working environment will be safety and by controlling the bleeding while the concrete is in plastic stage can help to improve the abrasion resistance in concrete floor. The potential to increase the tensile strength and impact resistance result it have to opportunity in weight and thickness reduction in structural components.

Fibres influence the cracking of cement-based matrix. The fibres will help to replace the large single crack with dense system of microcrack. When cracking become microcrack in term of safety and durability viewpoint it can be acceptable. Fine fibres control opening and propagation of microcrack as they are densely dispersed in cement matrix. While longer fibres with 50mm to 80mm help to control large cracks and help in contribute final strength of fibre reinforced concrete.

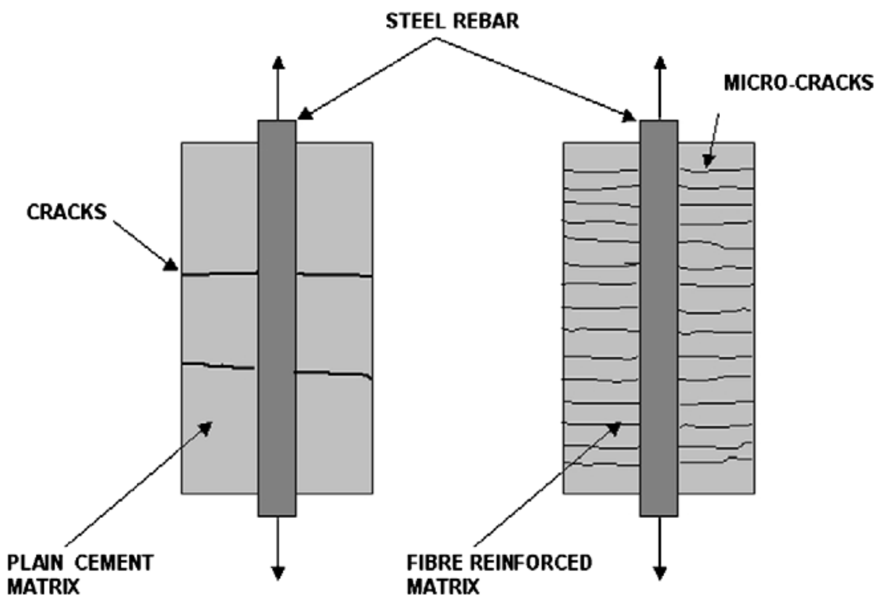


Figure 2.7: Crack pattern in reinforced concrete and fibre reinforced concrete elements subjected to tension.

Source: Brandt 2008

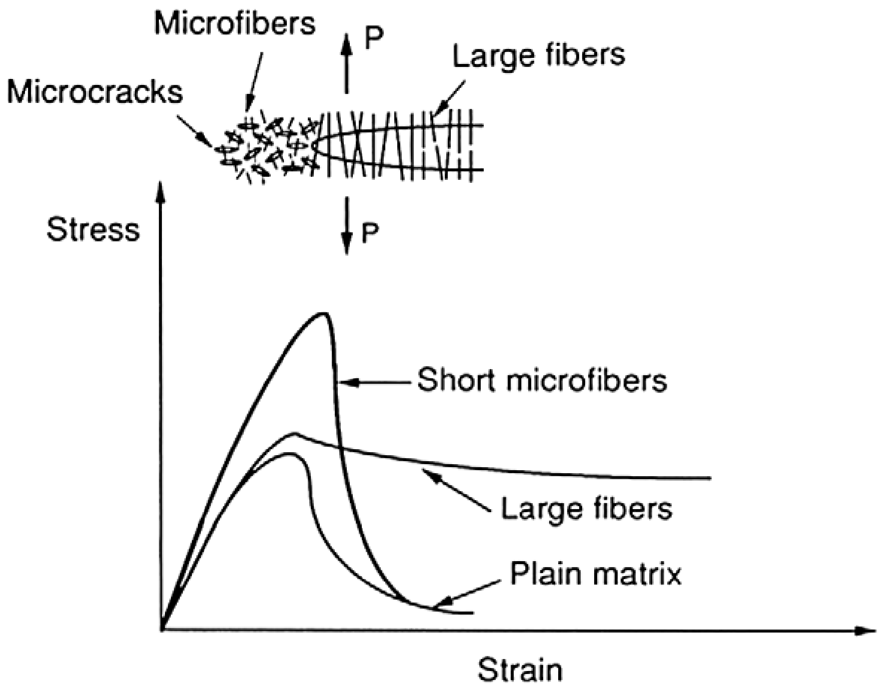


Figure 2.8: Structures of long and short fibres controlling the crack propagation.

Source: Brandt 2008

2.2.1 Bonding in PFRC

Fibre reinforced concrete can be namely as concrete composites. Concrete composites are defined as composites with two main components, the fibres and the matrix. Normal concrete only obtain matrix where the main bonding are in between cement and aggregates. When fibres added in the concrete, the bonding of the concrete will be changed.

Fibre play important role in fibre reinforced concrete, with the additional of fibres strength and elastic properties. The improved fibres will help in energy absorption through the accumulated of their orientation within the matrix. Hence the statistical probability of cracks encountering fibres is depend on the percentage of fibres added. The fibre specific surface is directly related to the amount of energy that is absorbed in encounters. Figure 2.9 demonstrates the way which fibres act to absorb energy and control crack growth.