CONTRIBUTION OF STEEL FIBER IN A SMALL SCALE REINFORCED CONCRETE BEAM

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Bachelor of Engineering (Hons) in Civil Engineering

UNIVERSITI MALAYSIA PAHANG

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Report submitted in fulfillment of the requirements for the award of the degree of Bachelor of Engineering (Hons) in Civil Engineering

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Dedicated to my parents and my siblings

FOR INFINITE SUPPORT

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ABSTRACT

Since today, fiber reinforced concrete is one of the most realistic materials to develop the use of concrete in load-bearing structure. The hooked-end steel fiber with two different the aspect ratio were used in this study. They are 65 mm aspect ratio with 0.55mm in diameter and 35 mm in length and 0.75 mm in diameter, 60 mm in length with 80 mm in aspect ratio. The volume fraction for both of steel fiber used is 1%. There are four concrete batches and each of batches consists of 3 beam specimens with dimension 750 mm x150 mm x150 mm and 6 cube specimens with 150 mm x 150 mm x 150 mm dimension. The beams were tested at 28 days under two-point load. The result showed that the addition of steel fiber in concrete improved the first cracking load, ultimate load, and ductility of the concrete beam. In comparison in terms of concrete compressive strength, SF35 improved for 12.94% and SF60 improved for 26.51% at 7days. Meanwhile, the compressive strength improved for 14.15% and 23.58% at 28 days for SF35 and SF60, respectively. The first crack (Pcr) was determined for the result obtained in experimental and SFRC showed significant increases to first crack load over conventional reinforced concrete beam. The SFRC beam with SF35 increased for 56.33% and SF60 for 68.67% for ultimate load (Pu), when compared to conventional reinforced concrete beam. This shows that longest SF was effective in resisting beam ultimate load compared with shortest SF.

ABSTRAK

Pada masa sekarang, serat konkrit bertetulang merupakan salah satu bahan yang paling realistik untuk membangunkan penggunaan konkrit dalam struktur menanggung beban. Gentian keluli ketagih akhir dengan dua berbeza nisbah aspek yang telah digunakan dalam kajian ini. Mereka adalah 65 nisbah aspek mm dengan 0.55mm diameter dan 35 mm panjang dan 0,75 mm, 60 mm panjang dengan 80 mm dalam nisbah aspek. Pecahan jumlah untuk kedua-dua serat keluli yang digunakan adalah 1%. Terdapat empat kumpulan konkrit dan setiap kumpulan terdiri daripada 3 spesimen rasuk dengan dimensi 750 mm x 150 mm x 150 mm dan 6 spesimen kiub dengan 150 mm x 150 mm x 150 mm dimensi. Rasuk diuji pada 28 hari di bawah beban dua mata. Hasilnya menunjukkan bahawa penambahan gentian keluli dalam konkrit bertambah beban pertama retak, beban muktamad, dan kemuluran rasuk konkrit. Sebagai perbandingan dari segi kekuatan mampatan konkrit, SF35 baik untuk 12,94% dan SF60 baik untuk 26,51% pada 7days. Sementara itu, kekuatan mampatan yang lebih baik untuk 14,15% dan 23,58% pada 28 hari untuk SF35 SF60 dan masing-masing. Keputusan retak pertama (PCR) telah diperolehi melalui eksperimen dan SFRC mengalami kenaikan signifikan kepada beban retak pertama ke atas konkrit bertetulang konvensional rasuk. SFRC rasuk dengan SF35 meningkat untuk 56,33% dan 68,67 untuk SF60% untuk beban muktamad (Pu), berbanding konvensional rasuk konkrit bertetulang. Ini menunjukkan bahawa paling lama SF berkesan dalam melawan beban muktamad rasuk berbanding singkat SF.

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LIST OF ABBREVIATIONS

SFRC	Steel Fiber Reinforced concrete
LI	Literature Review
AR	Aspect Ratio
SF	Steel Fiber
RI	Reinforcement Index

LIST OF SYMBOL

Pcr	First crack
Pu	Ultimate load
fcu	Compressive strength
L	Length
D	Diameter
L/D	Aspect ratio

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, the application of fiber reinforcement in concrete is not new.There are many researchers focused on fiber application. The fiber can be made from either natural material (asbestos, sisal and cellulose) or a manufactured product such as glass, steel, carbon and polymer (Guneyisi. E. et al., 2013). Among the various types of fibers, steel fiber is the most commonly used for most structural and non-structural purposes (Bolat,H et al,2014).In this research steel fiber have been used. The application of the steel fiber is mostly utilised in construction due to its ability in resisting the formation and growing of cracking, abrasion and enhances the flexural strength, fatigue strength of reinforced concrete (Altun. F. et al,, 2012). From the study, the tensile and flexural strength of concrete enhanced significantly due to addition of steel fiber(Shahiron.S.,2009).

In this study, the behaviour of reinforced concrete beam with different aspect ratio of steel fiber added into mixture were focused. According to the ACI 544, 3R-08, aspect ratio is referred to the ratio of fiber length over the diameter. Normal range of aspect ratio for steel fiber is from 20-100mm. Aspect ratio of steel fiber greater than

100mm is not recommended because it will cause inadequate workability, formation of mat in the mix and also non uniform distributed

1.2 PROBLEM STATEMENT

The properties of the concrete in brittle material which is low in tensile strength and low in strain capacity. Low tensile strength and low strain at fracture were major deficiencies in plain concrete (Suguna. K. et al., 2015). The low tensile strength was attributed to numerous micro cracks in plain concrete. The rapid propagation at these cracks under applied stress was responsible for low tensile strength and brittle failure of material.

In structural application, the concrete will provide the reinforcing bars to carry the tensile force once the concrete has cracked, so that it remains largely in compression under load. As mentioned earlier, 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 to transfer to the steel. In industry application, the steel reinforced needed to carry the tension forces in the concrete.

According to the problem of steel reinforced concrete in structural application and needed in industry application, a new application of reinforced concrete need to develop. So, from the previous research additional fiber is one of the methods to improve the mechanical properties of the structural concrete. According to M. Behloul, 2008, fiber reinforced concrete is one of these new materials ways for concrete structure. Because of that, in this study focused on the contribution of the steel fiber in mechanical properties of the reinforced concrete beam and the effect of aspect ratio the steel fiber in structural behaviour also was investigated.

1.3 RESEARCH OBJECTIVE

The objectives of this research are:

i. To determine the contribution of steel fiber in reinforced concrete beam under flexural load.
ii. To study the effect of fiber aspect ratio to the structural behaviour of reinforced concrete beam.

1.4 SCOPE OF STUDY

The scope of study for this research includes:

i. Type of fiber :

   Steel fiber with aspect ratio, *l/d* 80 mm and 65 mm

ii. Volume fraction, V_f = 1 %
iii. Concrete grade = 25 Mpa
iv. Type of specimens:
   I. Cube specimen = (width x breadth x height)
   = (150 mm x 150 mm 150 mm)
   II. Beam specimen = (length x width x height)
   = (750 mm x 150 mm x 150 mm)

1.5 RESEARCH SIGNIFICANCE

Numerous researches have been performed on mechanical properties of fiber concrete and concrete structural member with fiber under various loading. So, the study of the behaviour to the reinforced concrete beam with steel fiber was studies. In the present investigation, the influence the aspect ratio of steel fiber on strength and flexural behaviour of concrete beam were studies.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the characteristics of steel fiber are discussed and assists with its application. The application of fiber widely used in construction, by adding the fiber in concrete. Reffering to the previous studies, the fibers can improve the mechanical and ductility of concrete, reduced the plastic shrinkage and improve the abrasion. It is proven by Mirzac.F, (1996) the Polypropylene fiber reinforced concrete (PPFRC) not increase the strength of concrete but can improve its ductility, toughness and impact resistance. Rana.A,(2013) also mentioned in his studies that the steel fiber used in concrete to control cracking due to both of drying shrinkage and plastic shrinkage. Then the fibers also reduce the permeability of concrete and thus reduce bleeding of water.

Among types of fibers such as glass, natural and synthetic polymer, the focus given on steel fiber because it is used in this research. The reason using the steel fiber because it can improve the durability of concrete and increase the impact resistance of concrete. Then,the steel fiber having a various types with different properties. The properties of steel fiber have discussed more in this chapter.

2.2 HISTORICAL DEVELOPMENT

Historically, the steel fiber are commonly used since 1980 in united states, Japan and Europe. The steel fiber have proven track record and has been used for a decade to economically toughness concrete floor and precast. Today the steel fibers are major application to industrial in the world. In addition the other major application of steel fiber includes shortcrete and precast element. In Malaysia, the applications of steel fiber are not widely used in industry. So, the researchers of steel fiber reinforced concrete in Malaysia are needed for the further application

2.3 STEEL FIBER CHARCTERISTIC

Generally due to the application of steel fiber in construction, there is a lot of research about the properties of steel fiber in normal concrete. From the previous study there are various types of steel fiber and have their own characteristics. Because of this, the committee member from concrete society has been done the research about the fiber and the steel fiber is one of it. From their research, a standard and the design guide for world application**.** According to the technical report *Fibers as structural element for the reinforced of concrete* and previous study, there indicated that the properties of steel fiber are necessary to define and it also need for experiment work purpose. The characteristics of the steel fiber divided into two parts, there are mechanical properties and physical properties.

2.3.1 Mechanical Properties

Table 2.1: Mechanical Properties of Steel fiber

Steel fiber (Hooked end)	Density	7.85g/cm3
	Modulus of elasticity	205 GPa
	Poison Ratio	0.29
	Yield strength	12.75 MPa
	Tensile strength	1100 MPa

Source: S. Shahidan, 2009

The mechanical properties of steel fiber including the density,modulus elasticity, yields strength and tensile strength. There are various type of steel fiber but based on the previous study, almost the researcher using the steel fiber with hooked end.This is due to its mechanical properties more give a good performance than the other. It is proved by Altun.F. et al., 2006. Based on the LI from other research, it can conclude that the mechanical properties of steel fiber (hooked end) shown at table 3.1(S.Shahidan, 2009). According to the table 3.1, it indicated that the mechanical properties of steel fiber for all types steel fiber. From the table, the modulus of elasticity of steel fiber as higher and it will similarly to the steel reinforcement. However, the yield strength of steel fiber can assist the concrete bonding during cracking propagation. It cause of the high value of the yield strength for steel fiber.

2.3.2 Physical Properties

Regarding to the technical manual, steel fiber are supplied in many different type of shapes as shown in figure 2.1.Regarding to S.Shahidan, 2009, steel fiber have a greater tensile strength than traditional fabric reinforcement and it significantly greater surface area to develop bond with the concrete matrix. Some of the physical characteristics of steel fiber affect on the concrete performance. The reasons are considered to be influenced on the performance of the concrete are the anchorage mechanism (e.g, deformed shape or hooked end) fiber length, diameter and volume fraction added into the concrete.

According to Altun.F,2012, the fiber length types hooked end are reduced the severity of the failure mode which can change from a brittle shear into a ductile flexure failure, the volume fraction of steel fiber also nfluence the improving strength and ductility of the concrete. Futhermore, the length of steel fiber also taking into account to develop the ultimate strength of it. However, from the few studies on LI, one can successfully enchance the flexural toughness of steel fiber reinforced concrete are by using the large aspect ratio of steel fiber. Many research have been done show the evidence that aspect ratio in concrete performance. The detail explanation about the behaviour of steel fiber will be more discussed in this chapter.

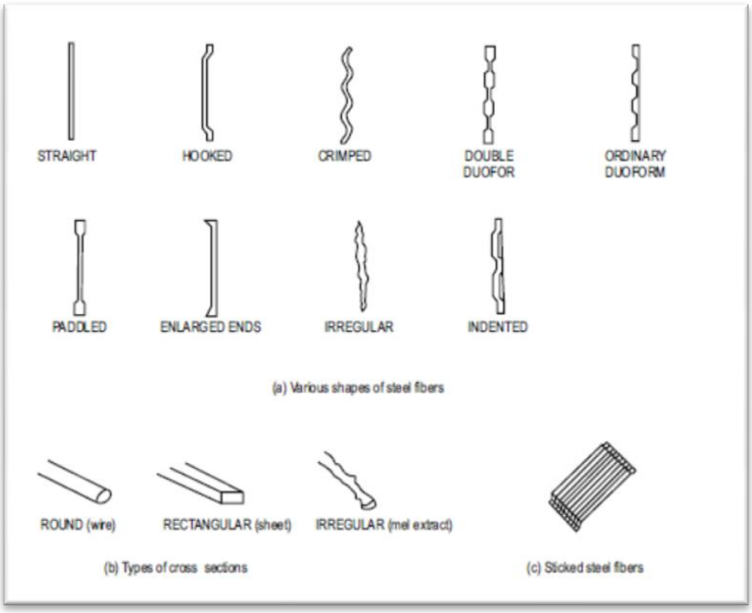


Figure 2.1: Different forms steel fiber

Source: Technical manual of fibers

2.4 MECHANICAL PROPERTIES OF SFRC

The behaviour of the steel fiber reinforced concrete under compression, flexural strength, physical properties and tensile strength will be discussed in this topic. Review from the previous studies, the volume fraction of steel fiber effect the behaviour of concrete. It is proven by Yazici.S. et al., 2006, that in steel fiber reinforced concrete (SFRC) the most important factor affecting the concrete properties are *l/d* ratio and V_f of fibers. Aspect Ratio (AR) is the ratio of fiber length against the diameter (I/d). The higher the AR and volume concentration of the fiber, the better is the performance with respect to the flexural strength, flexural fatigue, toughness, abrasion, impact and crack resistance.

2.4.1 Compressive Strength

From the previous research, by adding the steel fiber to the mixture, the compressive will increase. According to Yazici.S et.al the length of the steel fiber effect the compressive strength. When the *l/d* is 45mm, the compressive strength is 53.7 MPa and for the 65mm is 58.3 MPa. The steel fiber also proved that effect the compressive strength when Nguyen.V.C state in his investigation that, even in members which contain conventional reinforcement in addition to the steel fiber, the fibers have effect on the compressive of concrete. Then, when the steel fiber added into mixture of reinforced concrete beam, it improves the performance of compressive of the structure. (Altun.F. et al., 2012).The Volume of fiber also effect the performance of the concrete in compressive.

Based on investigation by Nguyen.V.C,(2012) the increase of the fiber content the peak of stress-strain curve is increase.(Refer Figure 2.2).Referring to the figure 2.2, the addition of SF can increase the strain at peak load and more reproducible descending branch. Besides that, the SFRC also can absorb much more energy before start to failure compare the plain concrete. The test result by Nagakar ,(1987) indicated that the compression strength increase by addition of SF in plain concrete which is the strength increase 13%- 40% for fibrous concrete.

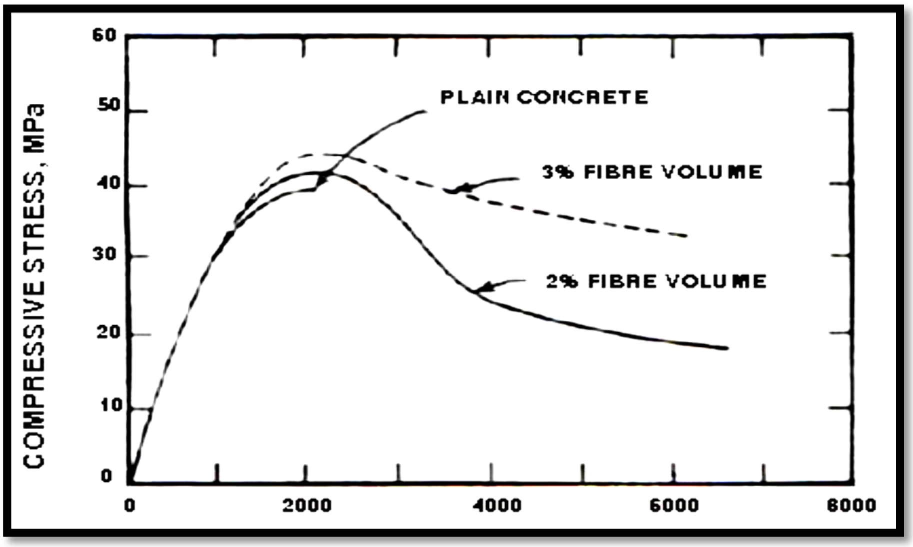


Figure 2.2: Stress-Strain curve

Source: Nguyen.V.C,

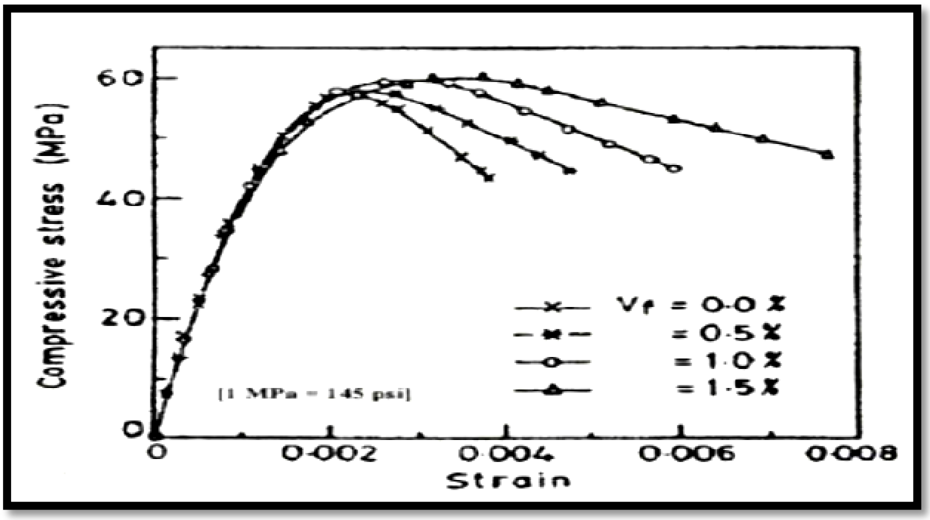


Figure 2.3: Compressive stress versus strain curve

Source: A. Hossein et.al (2012)

The effect of addition SF in compressive behaviour also studied by Hossein.A, 2012. Based on the authors, normal concrete with the high compressive strength usually show more brittle behaviour. For small amount of fiber add to concrete, the compressive strength in concrete does not significantly improve. However, post cracking ductility of the composite may be improved with the addition of steel fiber. From the result obtained by the author which is shown at figure 2.3, it can seen that the volume fraction of steel fiber influence the compressive stress of concrete.

Then, based on the previous research, Naaman, 1987, the strength and toughness of the composite were found to increase the higher loading based on the aspect ratio. Besides that, the shape of steel fiber such as deformed fiber and hooked end will to provide the good energy absorption. The result shows that the concrete improved in 60% from the plain concrete.

2.4.2 Flexural Strength

The behaviour under flexural is the most important aspect ratio for steel fiber, because the practical application is subjected some kind of bending load. Based on previous research by Mohammadi, 2008, according to his testing result, maximum strength are increased in static flexural strength for concrete.The result obtained as shown in figure 2.4, the maximum increase in ultimate load deflection of 61%, 95% and 167% concrete specimen when having length 100 long fiber for 1.0%, 1.5% and 20% fiber respectively.

Maximum flexural loads, first crack loads and corresponding deflections						
Fibre mix proportion by weight		Fibre volume fraction (%)	Maximum flexural load and corresponding deflection		First crack load and corresponding deflection	
50 mm long fibres (%)	25 mm long fibres (%)		Deflection (mm)*	Load (kN)*	Deflection (mm)*	Load (kN)*
0	0	0	0.338	11.88	0.338	11.88
100	0	1.0	0.545	16.68	0.397	13.76
65	35	1.0	0.498	16.92	0.396	14.49
50	50	1.0	0.526	16.56	0.385	14.38
35	65	1.0	0.506	16.64	0.392	14.38
0	100	1.0	0.434	15.92	0.401	14.92
100	0	1.5	0.661	20.98	0.399	15.19
65	35	1.5	0.650	20.12	0.401	15.35
50	50	1.5	0.653	18.75	0.399	15.00
35	65	1.5	0.588	17.73	0.394	15.55
0	100	1.5	0.495	17.17	0.399	15.85
100	0	2.0	0.902	23.83	0.405	15.89
65	35	2.0	0.720	22.32	0.405	16.28
50	50	2.0	0.768	19.81	0.402	16.35
35	65	2.0	0.613	18.75	0.408	16.83
0	100	2.0	0.483	18.01	0.401	17.66

* Average of three batches.

Figure 2.4: Maximum flexural test plain concrete and SFRC

Source: Mohammadi et al. (2008)

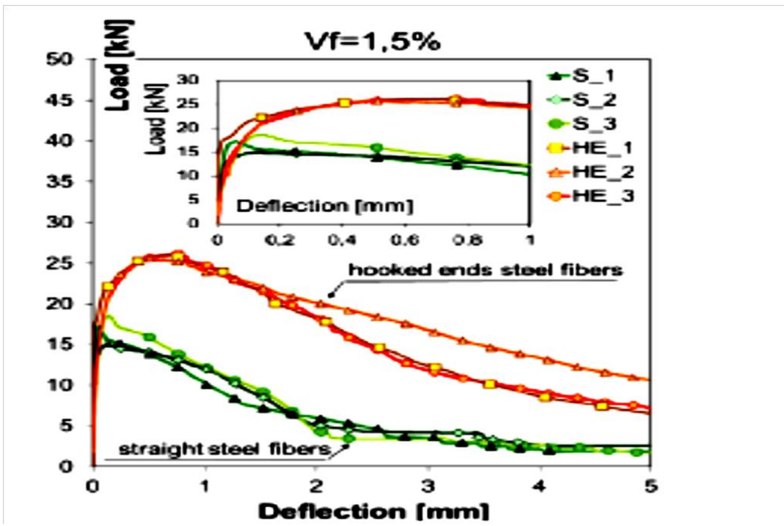


Figure 2.5: Result Load-deflection

Source: Pajak.M. et al. (2013)

Pajak.M and Poniskiweski, 2013 were studied about the flexural behaviour of reinforced concrete beam with two different types shape of steel fiber. The result as shown in Figure 2.5.

Based on the authors, both types of steel fiber in the reinforced concrete beam with higher fiber content indicated the higher flexural strength. The shape of steel fiber strongly influences the flexure strengthen concrete. From, the result, the hooked end steel fiber are more effectiveness to improving the flexural strength of the tested beam than the straight ones.The result shows that the strength is 3.4 times higher that the plain concrete, meanwhile for the straight steel fiber about 2.2 times.

Then, the flexural behaviour can be conformed to the Naaman's classification of fiber reinforced concrete (FRC). The deflection hardening response was observed in case of hooked end steel fiber and deflection softening of flexural response for straight steel fiber. According to Naaman, the observed flexural behaviour can be mainly attributed to the length of the fibers and their bond strength. The short strength steel fiber brigde the micro cracks only during strain localization, so this not influences mush the post-peak of the load deflection curve. On the other hand the hooked end provides bridging stress cross the cracks. which are the result of delay the micro cracks. This result improves the toughness of the concrete.

2.4.3 Tensile Strength

Steel fiber also affects tensile strength of concrete. It can proved from the previous studies. Reffering to the findings by S.Shahidan, 2009, the tensile strength of the concrete varies with the volume fraction of the steel fiber in concrete. Nguyen Van, 2010, also have founded that the volume fraction of the steel fiber affect the tensile strength. Referring to the figure 2.6, the aspect ratio of the also effect the tensile strength of concrete. When the aspect ratio was increased, the tensile strength also increased.

Based on Olivito.R.S., 2007, the failure mode is affected by the presence of fibers, while concrete elements usually fails suddenly and break in their middle section, steel fiber reinforced specimen started micro-cracking symmetrically on their side and fiber bridging effect arounded the sudden failure.From that, the steel fiber can improve the tensile strength of the concrete.Then, S.Yazici et.al, 2007 has founded that the tensile strength of SFRC are higher about 11-54% than the control mixture.

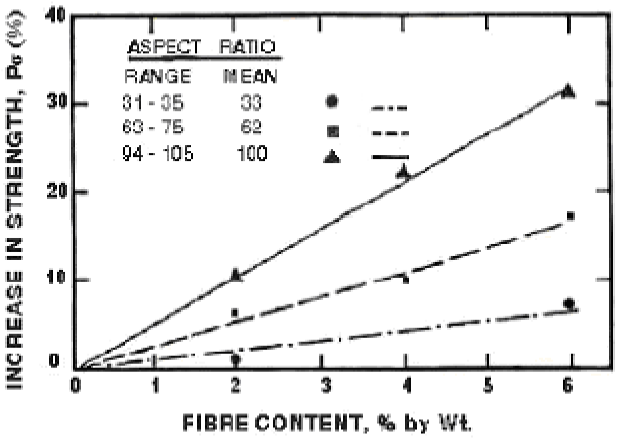


Figure 2.6: Variation of increasing in strength and fibre content

2.5 SUMMARY

After reviewing the previous study about the effect of steel fiber into the concrete and comparing it with plain concrete, the performance of the specimen with addition of steel fiber more better in term of mechanical behaviour than plain concrete. There a variety types of steel fiber and their have own characteristic. Some of the steel fiber may be influences the performance of the concrete but some of it not. From the previous research , there a few authors mentioned there are some factor need to consider for example the volume fraction, shape and aspect ratio of steel fiber will affect the concrete performance. Many researchers have investigate about the effect of volume fraction and different types of shape .There is just few study about the effect of aspect ratio of steel fiber used in structural member like reinforced concrete beam with the different aspect ratio but same length of steel fiber. So, in this study were investigated the effect between the short length with longer of steel fiber but the shape is same.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discussed about how this research were conducted. All the experimental work in this study was explained which include all the material used. Then, detail explanation on the casting and testing progress were also included.

In this research the laboratory work conducted at Heavy structure Laboratory at University Malaysia Pahang (UMP). All the equipment for preparing the material, casting and testing used in this laboratory.

3.2 EXPERIMENTAL PROGRAMS

Figure 3.1 shows the flow of the research conducted experiment. There are 3 main stage in this research as shown in the figure 3.1. Stages 1 involve doing some studies from the previous research from the journal, article and internet related with this. All the information were gathered and analyse as a reference during conducted this research.

Stages 2 includes prepare all the material were used for prepare the specimen. Firstly, the raw material was prepared. The aggregate were sieve maximum 10 mm using the sieve machine and for make sure that the aggregates in clean from the dust because it will affect the weight of the aggregate in during casting. Then, the sand and cement also were sieved to ensure that no other things on it. Stages 2 also including the casting progress. All the sample casted according to their mix proportion. Casting progress took 28 days for complete all the batches. After the specimens were casting, the concrete were curing using wet gunny.T he concrete were curing for age 7 days and 28 days before testing.

Stages 3 is a stage testing the specimens. After 7 days, the concrete cube were testing for compressive strength testing detail explanation about this compression testing was discussed in testing procedure. Then, after 28days curing age, the concrete cube again tested for compressive strength to know the concrete achieved the concrete grade targeted. The concrete beam was testing under flexural load.

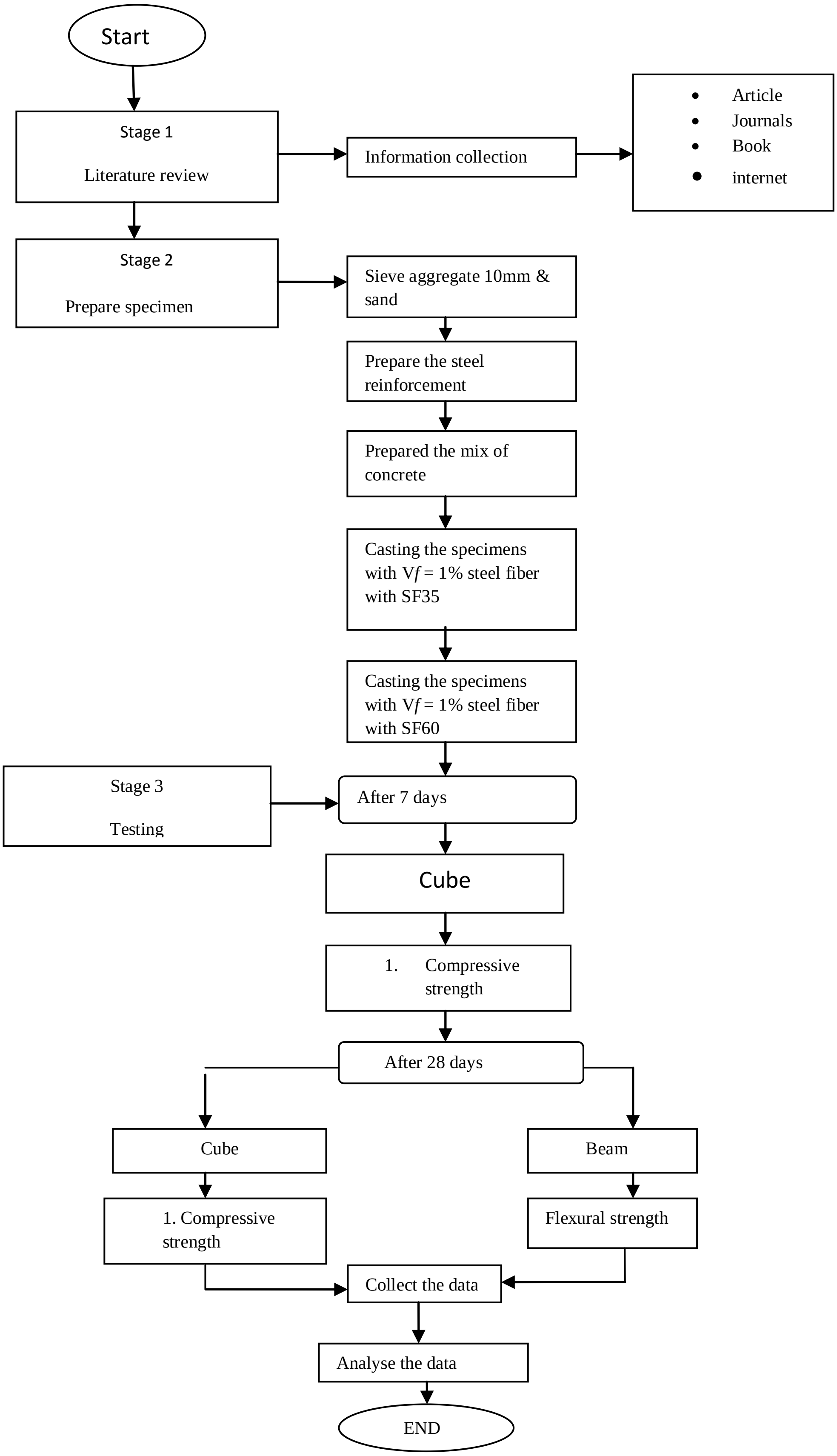


Figure 3.1: Flow chart of project

3.3 MATERIAL COMPOSITION

The materials that were be used in this current study are :

I. Steel fiber
II. Steel bar
III. Cement
IV. Sand
V. Admixture
VI. Water

Meanwhile, table 3.1 shows the summarize of material composition for each concrete batch

Table 3.1: Material composition

Sampel	Cement, kg/m3	Fine aggregate kg/m3	Coarse aggregate Kg/m3	steel fiber, *vf* ,(1%)	Sp, kg
SF0a	24.78	62.27	70.01	none	0.198
SF0b	24.78	62.27	70.01	none	0.198
SF35	24.78	62.27	70.01	SF35	0.198
SF60	24.78	62.27	70.01	SF60	0.198

3.3.1 Steel Fiber Reinforcement

Table 3.2 shows the specification of each type of steel fiber used in this research.

Table 3.2: Steel fiber Specification

Code	HE 0.75/60	HE 0.55/35
Aspect ratio	80mm	65mm
Length	60mm	35mm
Equivalent diameter	0.75mm	0.55mm
Deformation	Hooked end	Hooked end

The type of the steel fiber is Stahlcon Steel fiber. The shape of the fiber is hooked end.This steel fibres are made from cold drawn high tensile steel wires, in accordance to ASTM A820, type 1 and shall have a minimum tensile strength 1100 N/mm. The figure 3.2 shows the steel fiber with length 60mm, meanwhile figure 3.3 shows the steel fiber with length 35mm.

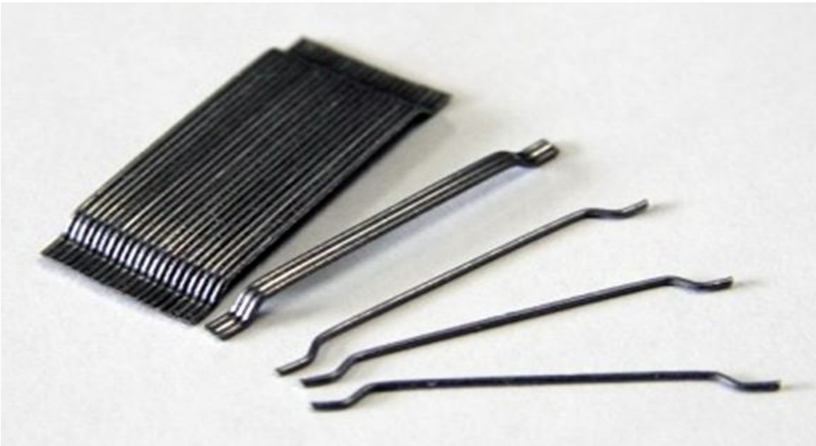


Figure 3.2: SF60

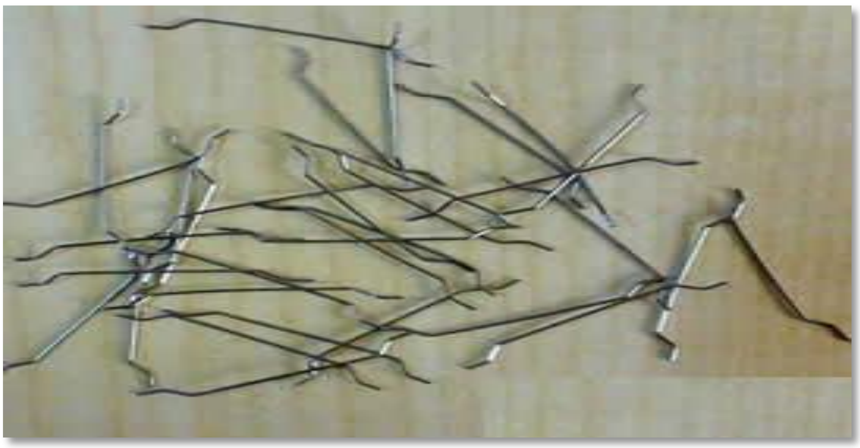


Figure 3.3: SF35

3.3.2 Steel Reinforcement

The steel bar is 2Y10 which is, two steel bar with 10mm diameter. The size of the link is 6mm with cover concrete 25mm.The Figure 3.4 shows the schematic diagram arrangement of steel reinforcement.

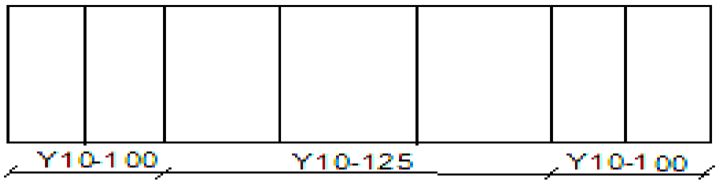


Figure 3.4: Steel Reinforcement

3.3.3 Cement

Cement generally can be described as a material with bonding agents and cohesive properties, which makes it proficient to bond mineral fragments into a solid whole. The cement that will be used in this research is Ordinary Portland Cement (OPC), which is acceptable in terms of strength and hydration. This cement commonly used in the construction. The OPC is in accordance with BS 12:1958.Figure 3.5 shows the sampel of cement powder.

Figure 3.5: Cement powde

3.3.4 Sand

According to the engineering term, sand is defined as a loose, granular material high SiO_2, resulting from the disintegration of rock. The name sand refers to the size of grain and not to mineral composition. There are two types of sand namely ; natural sand and crushing gravel sand.In this study, river sand is used is 600µm size and in is accordance to BS8110 Part 1:1997.Figure 3.6 shows the sand used in research.

Figure 3.6: Sand

3.3.5 Water

The purpose of mixing water with cement is to make sure the hydration process is taking place. The water play a major role during the mixing process and any particle or contaminant in the water must be avoided.

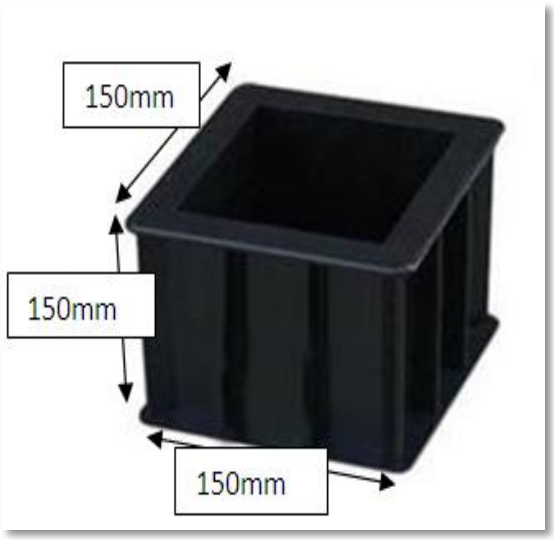
3.3.6 Admixture

Superplasticizer(sp) admixture was added to the fresh concrete for accelerating early strength. The amount of the Sp added to fresh concrete based on the weight of the cement.Types of admixture is Naphthalene Sulphonate with colour brown liquid. Figure 3.7 shows the sampel of admixture

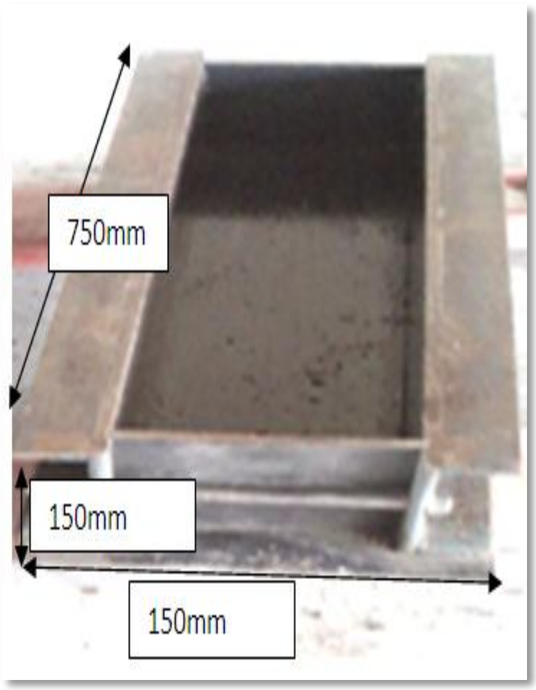
Figure 3.7: Admixture

3.4 Specimen Preparation

In preparing the cube and beam specimens, the mould in the laboratory concrete in UMP were used according to their size respectively. The size for concrete cube is 150 mm x150 mm x 150 mm(length x width x height) and for the beam is 750 mm x 150 mm x 150 mm(length x width x height).



a) Mould for cube



b) Mould for beam

Figure 3.8: Mould of specimens

3.4.1 Details of Specimens

Table 3.3 shows the details of specimens for each batch.The table describe the details of specimens which is SF0a and SF0b is a plain specimens, meanwhile SF35, the mixture is added with the steel fiber 35 mm length and SF60 the mixture for this batch added with 60 mm length of steel fiber.

Table 3.3: Details of Specimens

Batch	**Cube**	**Beam**	
		Main reinforcement	**Secondary reinforcement/SF**
SF0a	none	2Y10	none
SF0b	none	2Y10	none
SF35	35 mm	2Y10	35 mm
SF60	60 mm	2Y10	60 mm

3.5 EXPERIMENTAL PROCEDURE

3.5.1 Preparing the Material

All the raw material are prepared for casting. Firstly, the aggregate were sieved to the maximum size of 10mm using the sieve machine. (Refer figure 3.9.).Then the sand, cement and water were prepared. All this material was prepared one day before the casting process.

Figure 3.9: Sieve Machine

3.5.2 Procedure for Casting the Specimen

The aggregate mixed with the cement according to the mix design. Then, pour the sand and followed by the water into the mixer. For the first batch, this is plain concrete which contains 6 cube and 3 beam specimen. Then the second batch, also plain concrete but the beam has the reinforcement bar

Then, followed by the third batch, the specimen were added with 1% volume fraction of steel fiber with 65mm aspect ratio (SF35) and then the last batch the specimens added with 80mm aspect ratio (SF60).Figure 3.10 shows the mixing process and Figure 3.11 shows the fresh concrete which is added with steel fiber.

Figure 3.10: Mixing Process

Figure 3.11: Fresh concrete

The curing method used in this research is wet gunny, it means that the specimens covered by the wet gunny and the cure two times in a day; morning and evening. During the curing period, the gunny was ensuring that in wet condition to avoid the hydration of the concrete. it because that, it can causes the strength of the concrete will decreased.

Figure 3.12: Curing process

3.5.3 Slump test

A slump is a measurement of concrete workability and fluidity. Slump test is a method used to determine the consistency of concrete. The consistency or stiffness indicates how much water has been used in the mix. The Stiffness of the concrete mix should be matched to the requirements for the finished product quality. The concrete slump test is an empirical test that measures the workability of fresh concrete.

The first step in doing slump test, the cone is placed on the plate.After that, fill the cone 1/3 full by volume and rod 25 times with 5/8 inch diameter x 24 inch long hemispherical tip steel tamping rod. Disturbing roding evenly over entire cross section of the sample. After putting the concrete into the cone,it must blow for 25 times for each layer.Then, remove the excess from the top of the cone using the tamping as a screed and clean overflow from base to cone. After that, immediately lift cone vertically with slow and make sure that not touching the slumped concrete. Then, lay the straight edges across the top of the slump cone and measure the amount of slump height. Figure 3.13 shows slump test that was carried out in laboratory.

Figure 3.13: Slump test

3.6 TESTING PROGRAM

3.6.1 Compressive strength test

After the 28 days curing time, the specimen were remove from the wet gunny and wipe out the excess water from the surface. Before the testing the dimension and the weight of the specimen was measured.

Before place the specimen into the machine, make sure clean the bearing surface of the testing machine to avoid any error. Then, place the specimen in the machine in such manner that load shall be applied to the opposite sides of the specimen cast. Align the specimen centrally on the base plate of the machine and apply the load gradually without shock with continuously at the rate .For the compression test, the maximum load will be recorded and the any unusual features of the type of failure every specimen.

Figure 3.14: Compression test machine

3.6.2 Flexural Test

Before run the testing, the specimen need to placed properly into the machine. Turn the specimen on its side respect to its position when molded, and center it on the supporting bearing blocks.The load-applying block shall be brought in contact with the upper surface at the center line between the support.Make sure that the load applying block is in full contact with specimen surface.The load is applied with a hand pump.

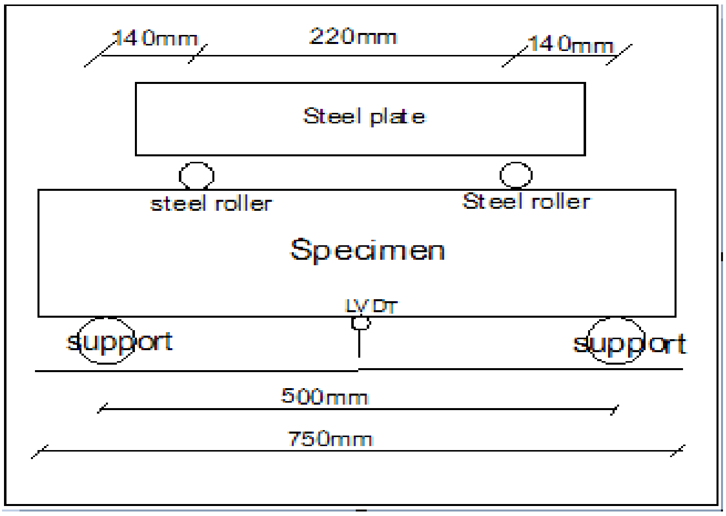


Figure 3.15: Schematic diagram of testing beam

Figure 3.16: Actual arrangement of beam

Figure 3.15 shows the actual arrangement of the beam testing with four-point loading. The LVDT placed on the center and below the specimens. All the result in this experiment automatically were recorded in the computer and the first crack load of the concrete beam known through the result. The duration for the entire beam complete tested, it took 28days.

3.7 Equipment

In this research, there are few equipment used, whether during the preparing material or during casting process. There are ;

i. Scales

Used for weighed the material before casting and weighed the specimens before testing.

Figure 3.17: Scales

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ii. Pallet Truck

Pallet trucks were used to lifting and move the material and specimens during the preparation and casting process.

Figure 3.18: Pallet truck

iii. Poker Vibrator

This equipment were used to vibrate the fresh concrete to ensure the fresh concrete was compacted well. During the compaction, the fresh concrete poured into mould was layer by layer .

Figure 3.19: Poker Vibrator

CHAPTER 4

RESULT AND DISCUSSION

4.1 REINFORCEMENT INDEX

Reinforcement index (RI) is defined as the product of the volume fraction and the aspect ratio and expressed in equation 1 :

$$RI = V_f(L/D)$$

Where;

V_f = volume fraction of fiber (%)

L = Length of fiber (mm)

D = Diameter of fiber (mm)

From the previous study, RI used to expressed as the indication of the improvement of the mechanical properties of SFRC.As Hwang. S, 2004 mentioned in his study, the improvement in mechanical properties of steel fiber was expressed as a function of fiber reinforcing index. Then, based on the Hannan, 1978, the role played by both of the volume fraction, V_f and the aspect ratio, (L/D) in the workability and strength enhancement of SFRC. Then, the authors also captured that the strength contribution of the fiber in the composite through the combined influence of both factors through RI.

4.2 COMPRESSIVE STRENGTH

For compressive strength, all the concrete batches were compared each other. From the graph plotted in figure 4.1.The parameter of each concrete batches shown at table 4.1.Sampel SF0a and SF0b,is plain concrete which is sampel SF0a act as a reference specimen, meanwhile SF0b as a control in this study. The differences with this two sampel, SF0b have steel bars as longitudinal bars. The sampel SF35, the specimens were added steel fiber with length 35mm and SF60, means the specimens added with 60mm steel fiber.

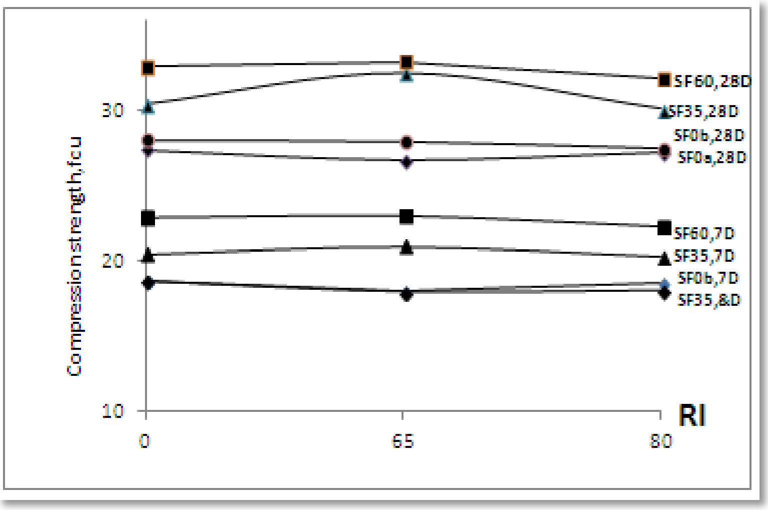


Figure 4.1: Compressive strength versus RI.

Referring to the figure 4.1, by comparing all the samples, for SF0a and SF0b have same compressive strength for both 7days and 28days because it is plain concrete. From the figure, when comparing the fibrous and non-fibrous specimens, the fibrous specimens show has a higher compressive strength than the plain concrete. The compressive strength for specimens with different aspect ratio of steel fiber was compared. From the experimental result, the average value for compressive strength at 28days for aspect ratio 80mm is 33.45Mpa, meanwhile for the aspect ratio 65mm the average value for compressive strength at 28days is 31.15Mpa.It can summarized that the increased of aspect ratio increasing the compressive strength and steel fiber can improve the behaviour of concrete in compressive. Figure 4.2 shows the improvement the fibrous concrete from the reference concrete or plain concrete.

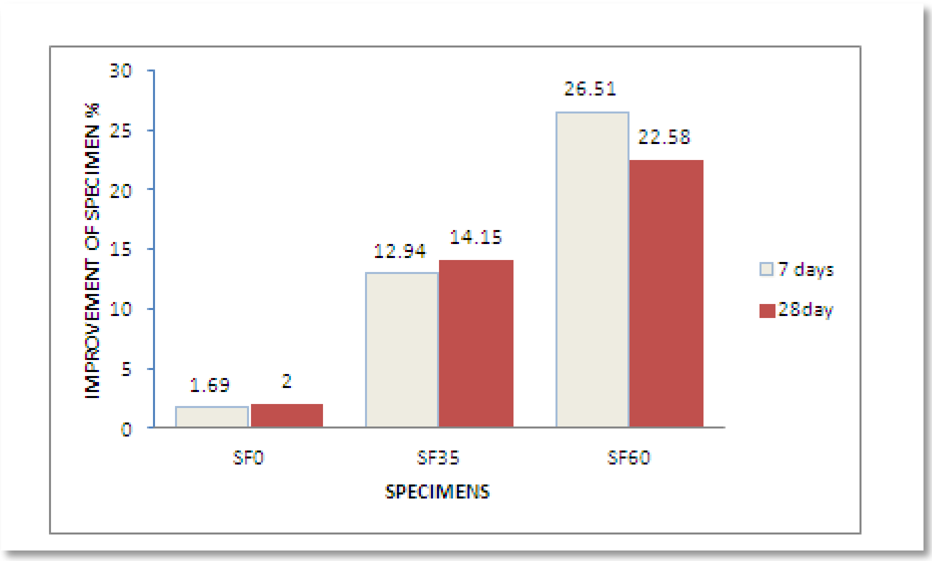
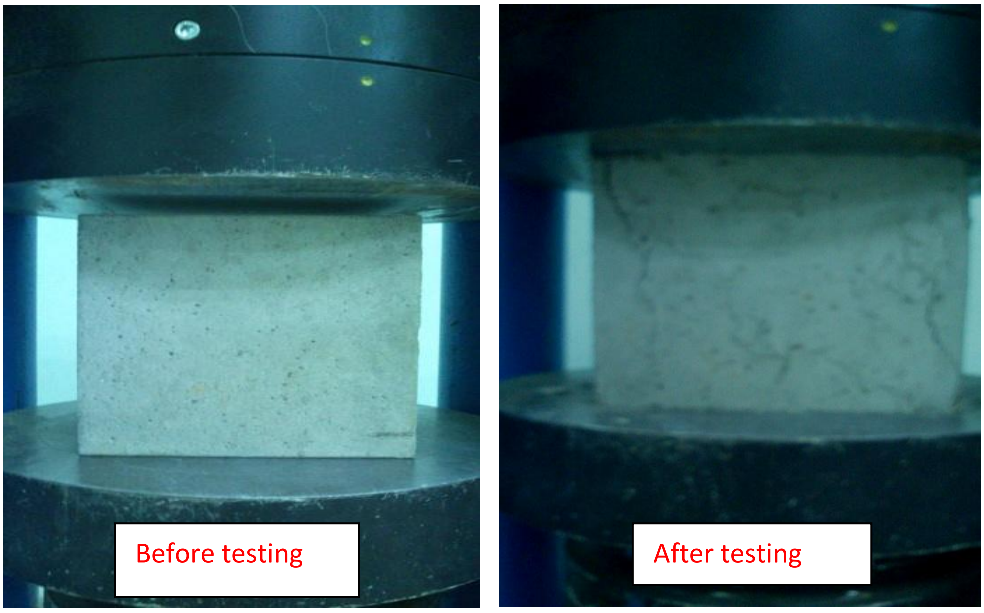
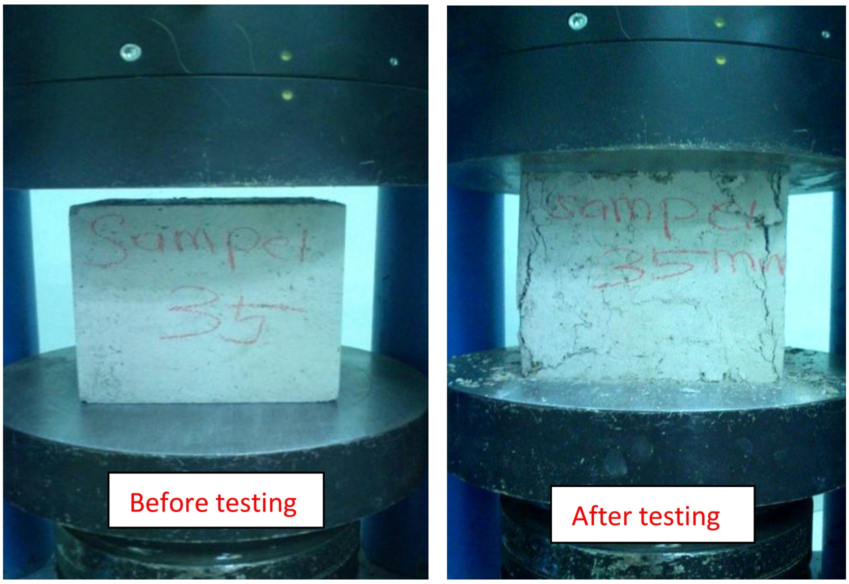


Figure 4.2: Improvement the specimens from the references specimens.

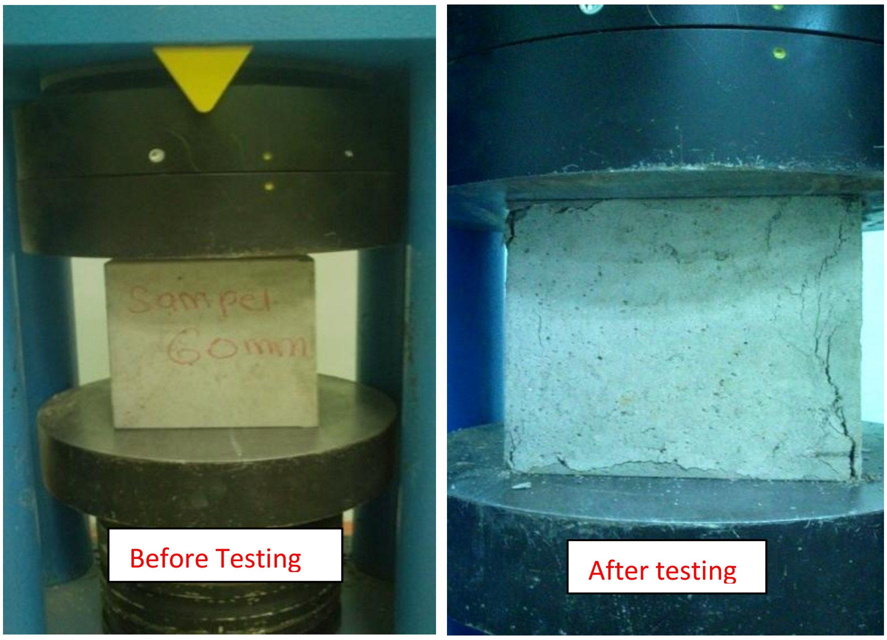


a) Control

Figure 4.3: Cube before and after compressive strength test



b) SF35



c) SF60

Figure 4.3: Cube before and after the compressive strength test.

From the bar chart in figure 4.2, it shows that the specimens with addition of steel fiber have improvement for mechanical properties than the plain concrete. It also revealed from the observation during the testing which is there is significant changes failure of the concrete cube as the steel fiber included in the mix and also as the increases of aspect ratio of steel fiber added to the mix. Figure 4.3a, Figure 4.3 b and figure 4.3c shows the cube specimens for the different mix after failure. It noticed that as the fiber aspect ratio increased, the failure of cube specimen decreased. This is due to the strong bond between the concrete and fiber and the effect of fibers in preventing concrete from sudden explosive failure.

4.3 FIRST CRACK LOAD

The concrete and reinforced concrete beam (RCB) which had been kept under the cure condition for 28days following the production were tested by loading on four point with a simple bending effect. In this experiment, the behaviour of the RCB with steel fiber were studied. The development of the cracks in the RCB to which steel fiber added and its effect on the behaviour were determined. In the RCB with steel fiber, the value in which the first crack (P_{cr}) occurred is defined as the first crack displacement. The displacement values during the loading at RCB were recorded automatically on computer. The variation of the steel fiber delays the development of cracking in RCB shown at figure 4.4.

Figure 4.4 shows the graph of development first crack on reinforced concrete beam for all the specimens. Based on the figure 4.4, it can seen that the SF0a has a minimum load when the crack was start occurred in concrete beam which is 13.25KN, this is because SF0a, no reinforced bar and no steel fiber were added into it. Then, the specimens SF60 has higher loading when the first crack appeared which the average is 40.89KN.

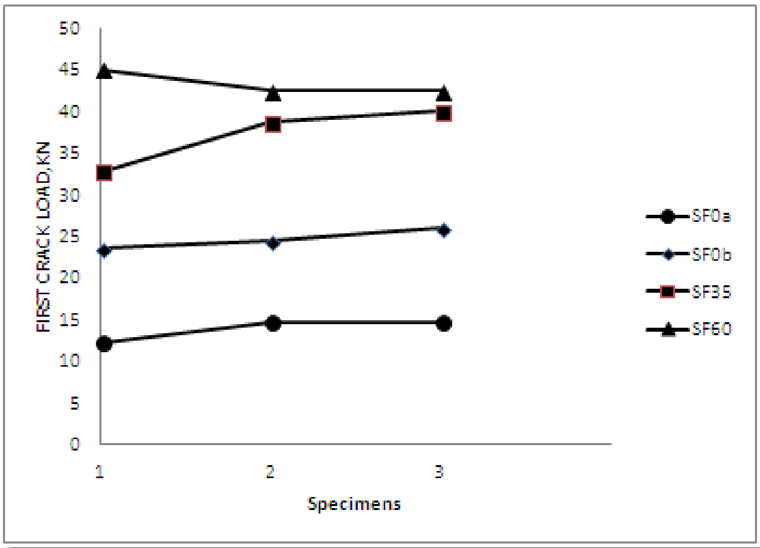
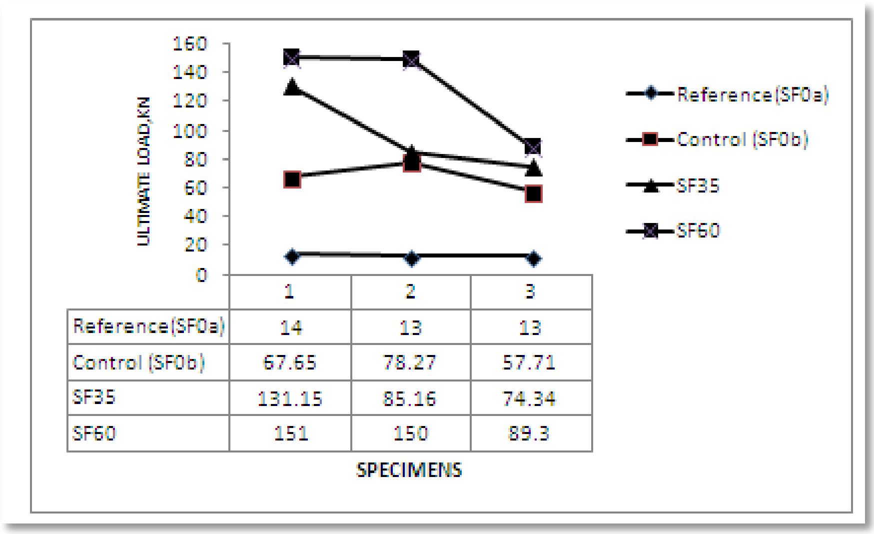


Figure 4.4: Variation effect of steel fiber in delay crack development

4.4 ULTIMATE FLEXURAL CAPACITY OF BEAM



	1	2	3
Reference(SF0a)	14	13	13
Control (SF0b)	67.65	78.27	57.71
SF35	131.15	85.16	74.34
SF60	151	150	89.3

Figure 4.5: Ultimate load versus Specimens

The micromechanical advantage for adding steel fiber in conventional concrete can seen by its post cracking affect, ductility and energy absorption (Altun.F, 2013). The steel fiber when uniformly dispersed throughout the specimen act as reinforcement and help for better distribution of stresses. Therefore cracks that occurred in SFRC specimens were smaller size compared with the conventional concrete and even more did break up at ultimate load. Based on the result in figure 4.10, the SFRC beam with 1% volume fraction of fiber showed an average increase of ultimate load for aspect ratio 65mm is 56.33% meanwhile for the aspect ratio 80mm is 68.67% from the plain concrete. Hence, it can be said that the addition of steel fiber caused the increase of both ultimate load and first crack load. This increase can be due to the crack arresting mechanism to the closely spaced fiber.

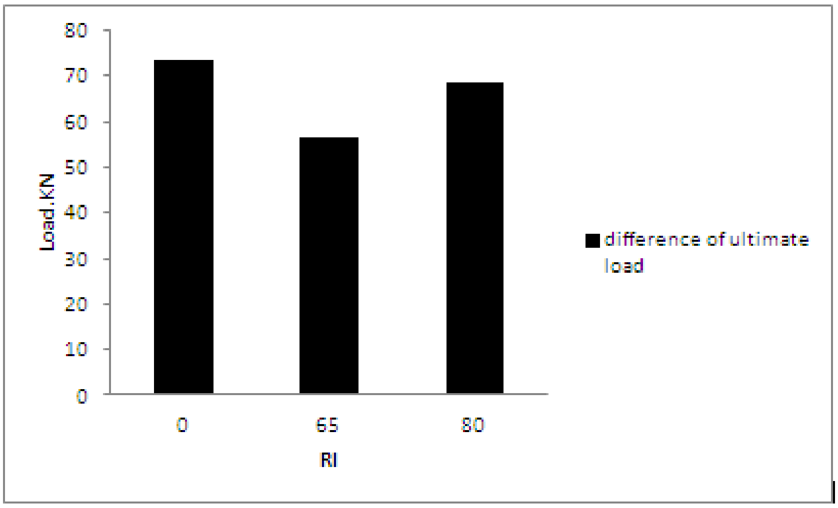


Figure 4.6: Average ultimate load

4.5 LOAD AND DEFLECTION CHARACTERISTICS

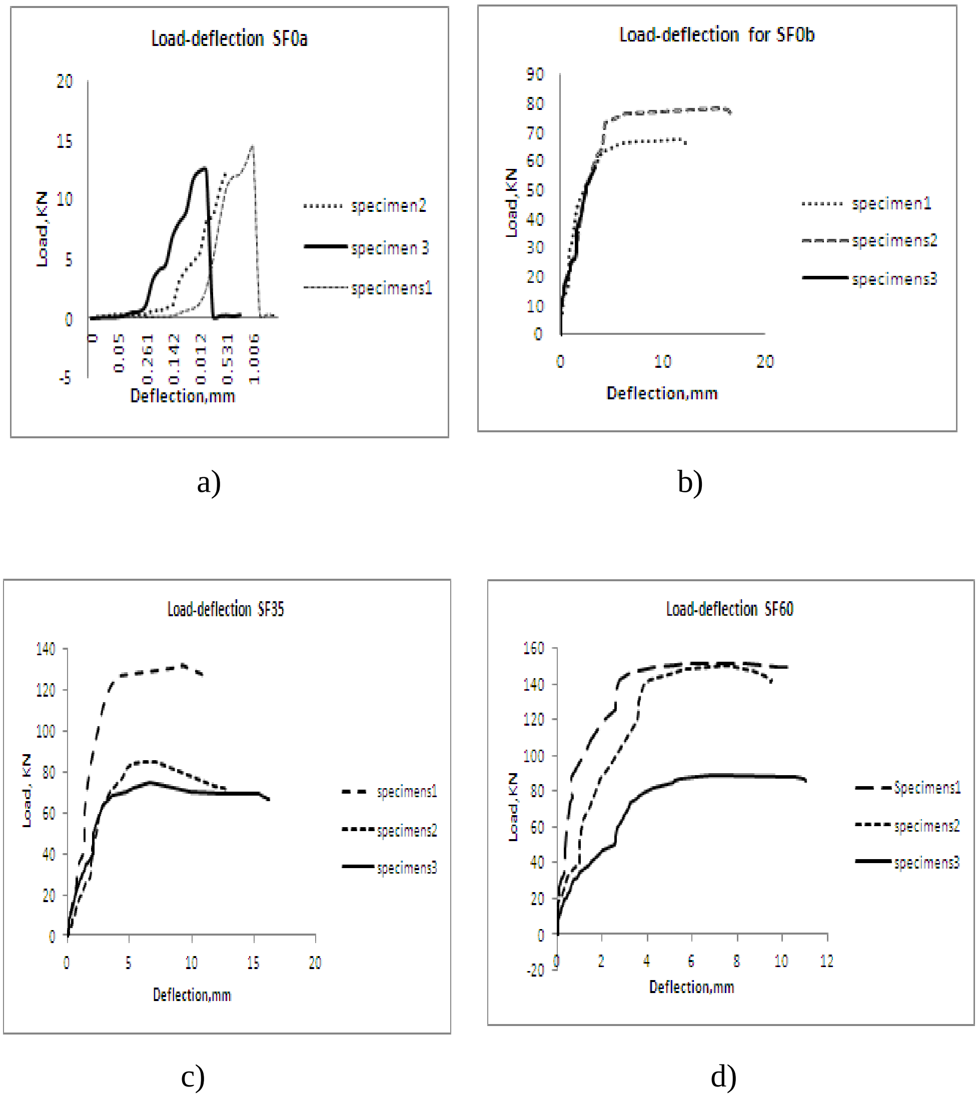


Figure 4.7: Load-deflection graph

Figure 4.11 shows the load-deflection curve for the entire sampel concrete beam in this study. Figure 4.11 (a) and (b) is a plain concrete meanwhile figure 4.11(c) and (d) the concrete beam added with steel fiber. Fibers may significantly increase the peak strength while affecting a relatively small increase in residual load capacity and specimen's toughness at specified deflection. The area under the load deflection graph showed the ductility of the beam (Hossein. A ,2012).

From the figure 4.11, when curve compared between SFRC beam with conventional concrete beam, it can be seen that the peak strength of SFRC beam is higher than the conventional concrete beam. It also seen that the area under beam containing steel fibers was more than the normal concrete. Hence it can be said that SFRC beam had more ductile behaviour normal concrete beam. The SFRC beam also shows has a higher ultimate load the deflection when the average is 130.10KN, 96.88KN for SF60 and SF35 respectively. From this, it shows that the addition of steel fiber increased the ultimate load the deflection at ultimate load. Hence, it can summarize that the SFRC beam were stiffer than conventional concrete beam. The reason can be due to the effect of steel fiber and good bonding between steel fiber with surrounding concrete which was act confinement to the concrete.

When the specimens were loaded in bending setup, the maximum tension stress occur at the bottom and first crack develops. For the conventional concrete beam, crack develops at near the center and suddenly collapse. On the other hand, ductility was enchanced with the addition of fiber. It revealed during the experimental that the specimens with fiber never collapse suddenly and steel fiber holds crack part together which good for making reliable buildings (A.Kamura, 2005).Hence, it can said that addition of steel fiber in the concrete mix significantly influenced the cracking behaviour and ultimate strength at beam. On the other hand, inclined crack went through a slow process of widening and extension in SFRC beam.

Based on Fatih.Altun, 2013 , in the study the main reason for incorporating steel fiber in concrete was to impart ductility to an otherwise brittle material. So, the steel fiber enables the concrete to continue to carry load after cracking has occurred, so it is called post crack behaviour or toughness.

4.6 MODE OF FAILURE

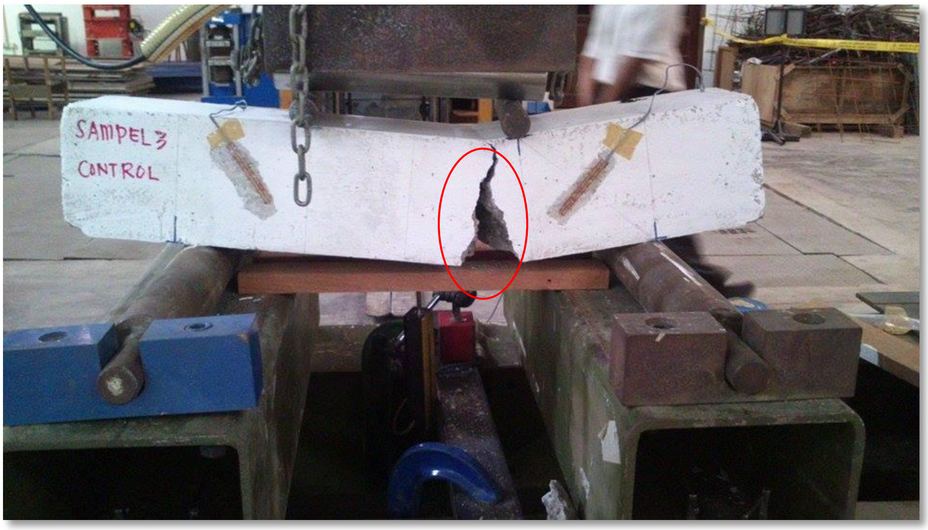


Figure 4.8: Specimens SF0a after testing

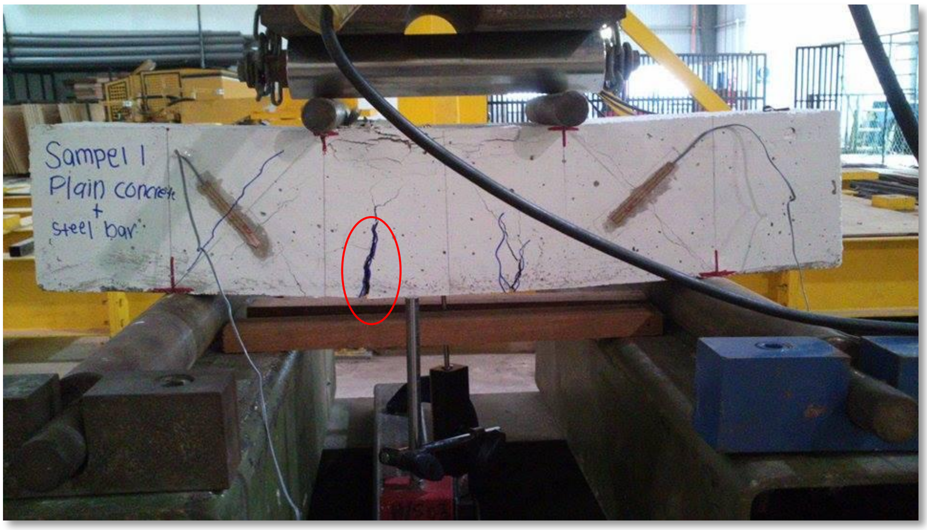


Figure 4.9: Specimens SF0b after testing

Figure 4.10: Specimens SF35 after testing

Figure 4.11: Specimens SF60 after testing

As expected, in case of beam reinforced with randomly distributed steel fiber Significantly influence the flexural behaviour of the tested beam.The maximum load were increased when the increasing the aspect ratio of the steel fiber. Based on the figure 4.5, figure 4.6, figure 4.7, figure 4.8, the cracking pattern in all beams were almost symmetrical and characterized by the load induced that created the flexural.

By comparing the reinforced concrete beam with the normal concrete in figure 4.5, the normal concrete without reinforced bars, break into two pieces but for the reinforced concrete beam in figure 4.6, figure 4.7, and figure 4.8, it just a cracking but not break into two pieces. As recommend by ACI committee 544, “when used in structural application. Steel fiber reinforced concrete (SFRC) should only be used in a supplementary role to inhibit cracking, to improve resistance, to impact or dynamic loading and to resist material disintegration. In structural members where flexural or tensile load were occur, the reinforcing steel must capable of supporting the total tensile load.”Thus, while there are a number of techniques for predicting the strength of beam reinforced only with steel fiber, there are no predictive equation large SFRC beam (V.Nguyen).Since these would be expected to contain conventional reinforcing bars as well. The behaviour of the crack propagated on the conventional beam under bending showed that the crack started from the extrema flexure substrate and gradually inclined to finally approach the near point (Hossein. A, 2012).

In comparison reinforced concrete beam with the controlled beam, the RCB with steel fiber shows has the higher load for first crack. It is because in concrete beam, the vertical flexural crack were formed first, usually the bottom face of the beam close mid span. The width of these initial crack was very small, it can seen in figure 4.8.In fact, the steel fiber can sustain the stress after cracking at strain beyond the normal for the failure of conventional concrete beam (Hossein. A, 2012).This mechanism caused the neutral axis of the section to move up, thus the moment of resistance and ultimate load was increase significantly. This behaviour was mainly attributed to the role of steel fiber in releasing fracture energy around crack tips which was required to extent crack growing by transferring stress from side one to another side .It also due to the increased in crack resistance of the composite and the ability of fiber to resist forces after the concrete matrix had cracked.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The aim of this study was to provide determination the contribution of steel fiber in reinforced concrete beam under flexural load compared to the conventional concrete beam and study the effect aspect ratio of steel fiber to the structural behaviour of reinforced concrete beam. Generally, in this study, the addition of steel fiber improved the mechanical properties of concrete and reinforced concrete beam (RCB).Then, the aspect ratio of fiber also effect the behaviour of the concrete which is the longer the steel fiber the much better the performance of concrete.

5.2 CONCLUSION

I. The contribution of the steel fiber in reinforced concrete beam was determined from the experimental result.

   In general, the significant improvement in various strength when the steel fiber added to the conventional concrete. From the findings, the steel fiber delay the cracking development in concrete beam. It proved from the result obtained from the first crack load for concrete beam. In the study the main reason for incorporating steel fiber in concrete to impart the ductility to an otherwise brittle material. They enable concrete to continue carry load after cracking.

In this study, all the SFRC beam showed significant increase in first crack load over reinforced concrete beam. The addition of steel fiber increased the ultimate load but the deflection at ultimate load was less than the conventional concrete beam. Hence, it can be said that the SFRC beam were stiffer than the conventional concrete beam. The reason due to the effect of steel fiber and good bonding between steel fiber with the surrounding concrete which act as confinement to the concrete.

II. From this study, the structural behaviour of reinforced concrete beam was affected by the aspect ratio of steel fiber.

Based on the findings of this study, the affection of the aspect ratio to the structural behaviour were drawn : addition of steel fiber increase the compressive and flexural strength of concrete. In comparison with the control sampel, the maximum strength increase in the 7days 26.51% and 22.58% in 28days age. The increase in compressive strength due to attributed to the capability of steel fiber to delay the unstable development of micro crack as well as to limitation the propagated and the composite effect for concrete and steel fiber under load. From the experimental result, it shows that the aspect ratio also taking part in effecting the compressive strength. The increasing the compressive strength of the concrete as the aspect ratio is increased.

5.3 RECOMMENDATION

I. For reinforced concrete beam, use the longer aspect ratio but not more than 100mm.

II. During the curing process, make sure the gunny always in wet condition especially during evening to avoid the hydration of the concrete.

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