International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://dx.doi.org/10.7324/IJASRE.2018.32648

Volume 4, Issue 3
March - 2018

Effect of Steel Fibre Contents with High Strength Fibre Reinforced Concrete

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ABSTRACT

This study investigated the effect of different steel fibre contents by volume (Vf = 0, 0.5%, 1%, and 1.5%) on mechanical properties of High Strength Fibre Reinforced Concrete (HSFRC). The properties included flowability, compressive strength, and direct tensile strength. The results indicated that increased steel fibre contents gradually decrease the flowability of HSFRC. However, had significant effects at 28 days on compressive strength by about 102.5 M.Pa and direct tensile strength by about 7.07 M.Pa of HSFRC with incorporation of 0.5% steel fibre. While, the compressive strength of 1.0% and 1.5% of steel fibre contents are 87.51 M.Pa and 80.75 M.Pa, respectively, whereas direct tensile strength with 1% and 1.5% of steel fibres achieved 6.54 M.Pa and 5.66 M.Pa. The result shows the higher compressive strength and direct tensile strength obtained by 0.5% of steel fibre content. The value of direct tensile strength close to JSCE 2004, over 5 M. Pa.

Key Words: *Steel Fibre, Flowability, Compressive Strength, Direct Tensile Strength.*

1. INTRODUCTION

The normal concrete advances in matrix and fibres since 1960s while the development of high-performance cement composites was from 1970s in the United States and Europe [1]. In 1980's the High Strength Concrete (HSC) was popular to be used in concrete design [2, 3] and in the mid of 1990s, the introduced of Ultra-high performance concrete (UHPC) and ultra-high performance fibre reinforced concrete (UHPFRC) were present [4]. Generally, the concrete at the age of 28 days with a compressive strength exceeding 150 M.Pa described as ultra-high performance concrete (UHPC); and when fibres are added into the mixture the term ultra-high performance fibre reinforced concrete (UHPFRC) is used [5,6]. The result of new concrete achieved the better compression strength [5]. Before UHPC was invented, HSC with the compressive strength is between 50 and 90 M.Pa. While the concrete by adding steel fibre with a compressive strength 80-120 M.Pa refer to High Strength Fiber Reinforced Concrete (HSFRC) [7].

The utilized of steel fibres in the matrix produces HSFRC can enhance the ductile behaviour in tension and change the fragile failure to the ductile failure in the compression [8]. Therefore, the influence of the steel fibre content on performance requires further exploration to characterize it completely after cracking behaviour and fibre efficiency after cracking.

In terms of FRC's compressive reaction, it was concluded that the addition of steel fibres was enhanced in post-peak behavior but the decreasing part of the strain pressure diagram was mainly depends on the characteristics of fibres such as bond between the fibre and the matrix, content, geometry, fibre stiffness, and different fibre combinations, orientation and distribution while the stress–strain curve is to evaluate the ductility of material [7].

From the issues highlighted above, the purpose of this study is to examine the effect of steel fibre contents of compressive strength by using cube samples to measure the strength and the mode failures while the stress–strain curve in direct tensile by using dog bone shaped samples to evaluate the ductility in term of strain hardening or strain softening. The compressive tests consist of 3 cube samples of 100 mm³ mould for each batch of steel fibre contents (%) and direct tensile tests by using 3 dog bone shaped samples with dimension begins with the cross section of 30 x 40 mm and changes 20 x 40 mm in prismatic shape after 30 mm away from each ends of the samples with length of cross section 90 mm as shown in Figure 1 for each steel fibre contents (%) were conducted. The steel fibres contents of 0.5 %, 1 % and 1.5 % were used in this study in order to coM.Pare with without steel fibre (0%).

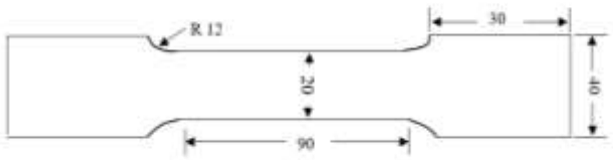

Figure1. Detailed geometry of dog bone shaped Specimen.

Figure 1. Detailed geometry of dog bone shaped with cross section starts with 30 x 40 mm and changes to a prismatic shape of 20 x 40 mm after 30 mm away from each ends of the samples with length of cross section 90 mm

2. EXPERIMENTAL INVESTIGATION

2.1 Raw materials

The raw materials of high performance concrete incorporate of aggregate, cement, water, additives, admixtures and steel fibre. The difference between HSC and conventional concretes mix design lies in particular in the amount of binder, the size of the aggregate and the presence of fibre. The dense matrix is achieved by optimizing the density of packing of all granular raw materials, such as cement, silica fume and aggregate [9]. Optimization of raw materials yields in high performance concrete [10]. The following sections discuss the raw materials of high performance concrete in details.

2.2 Cementitious components

High performance concrete mix compositions characterized by high content of cement, silica fume and superplasticizer [11]. A cementitious composite with superior mechanical and durability properties must contain ultrafines such as silica fume, fly ash, slag and metakaolin [12]. Cement has a low alkali content, low to medium fineness, and a low C3A-content can reduce water content, ettringite formation, and heat of hydration [10]. This concept generally apply for mixtures which containing fly ash, blast furnace slag, limestone powder or other secondary cementitious material [13].

2.3 Portland cement

Portland cement is the most important ingredient that acts as binder that holds fine and micro fine particles [14]. Portland cements with low C3A content can be recommended as the water demand is low [9]. Considering that the high cost of high performance concrete is a disadvantage that restricts its wider usage, some industrial by-products such as ground granulated blast-furnace slag and silica fume, have been used as a substitute for partial cement [12]. The use of many additional cement materials, such as fly ash and slag for partial/complete replacement of cement and silica fume, could significantly reduce the materials cost without sacrifice of strength [10]. Replacing Portland cement such as fly ash, slag and silica fume due to pozzolanic activity and latent hydraulic activity [15].

2.4 Silica fume

Silica fume, also known as microsilica or condensed silica fume is a by-product of silicon metal or ferrosilicon alloys [16]. Typically, ultra-fine particles are silica materials, commonly known as silica fume, microsilica or nanosilica [8]. Silica fume acts as a microfiller in high performance concrete.

Pozzolanic materials are very important in production of high performance concrete. The pozzolanic reaction of silica fume is strongly influenced by hydration of cement, which has a cement priority to form hydrated products [11]. The silica fume reaction usually very fast at the beginning and then slows down considerably [17]. Another important effect of silica fume is the increased interfacial transition zone between binder and aggregates and between binder and steel fibres [18-22]. Silica fume with a low carbon content capability to increase the concentration of solid mixture provide the best workability and compressive strength for high performance concrete.

The importance of silica fume on the strengthening was demonstrated previously from early ages [10]. However, by using silica fume to fill the voids between the cement particles, large amounts of Silica fume is required, typically between 10-30 % of the cement mass. The addition of 14 % of silica fume is enough to meet the maximum strength at 28 days. Numerous studies [8-9] prescribed silica fume dosages of 20–30 % of the total binder material to achieve denser particle packing in the proportion of the mixture, leading to higher strength properties.

In experiment were proofed, that high amount of silica fume is not required to provide the best workability and the result of compressive strength. Higher density mixture also could be achieved by selecting the aggregate, cement, and thus amount of silica fume could be reduced.

2.5 Superplasticizers

In order to achieve concrete with sufficient workability the use of superplastizisers is important. Large quantities, which are up to 5 % of cement mass, are required. However, however, only the third generation of plasticizer (polycarboxylate ether, PCE) which allows for sufficient amount of water to make concrete can be implemented [23]. Whereas the polycarboxylic eter based superplasticizer is used to adjust high performance concrete workability [24]. To ensure concrete workability at low w/c ratio plasticizers and superplasticizers are used [25]. For this reason, and depending on their effectiveness, they are known as water-dissipation agents (plasticizers) and superplasticizers of high-range water-tightening agents. Pure, clean-free from impurities and uses that are appropriate to the use of extra power superplasticizer [26].

Previous studies show that only superplasticizers can dilute high performance concrete effectively [27] because mechanical research has focused on the interaction between superplasticizer and cement [13]. The type of cement and superplasticizer species may affect the time required by the superplasticizer. Additionally, the addition of superplasticizer was found to increase high performance concrete workability due to the better spread effect [28] Note CEM 1 52.5 R is highly affected while CEM 1 42.5 R is not affected [8]. Show that the hydration cement is very slow in the initial period is not affected by the additional method of superplasticizer [29].

As a result, to ensure mix ability, super high levels and hyper coatings should be included in the mix [30]. The desired dose of superplasticizer depends on the suitability of the mixture and the type of superplasticizer used [31]. The results show that, at high doses, the superplasticizer not only has a significant effect on the early cement hydration process but also on later microstructure development. The effects of superplasticizers on the kinetic properties and mechanical hydration of Portland cement paste [32].

2.6 Steel Fibres

Steel fibres are used to enhance the hardness of the concrete. Fibres added to concrete increases mechanical resistance and ductility, thereby reducing plastic shrinkage, increasing abrasion resistance, fires and effects. One of the most important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. The fibres can hold matrix even after extensive cracking [14]. Steel fibres (hooks, twisted, straight and short) are consistently used as part of the high performance concrete mixture due to their high strength, high resistance in alkali environments and high modulus of elasticity [30]. The type of crimped and hooked steel has a slight iM.Pact on the load-deflection behavior, the ultimate moment capacity, the crack pattern, while in in resilience and toughness, the beam specimen with the reinforced steel fibre shows slightly better behavior coM.Pared to the crimped steel fibre. Samples of high performance concrete with hooked-end fibres have the lowest flowability coM.Pared to straight and corrugated fibres [33] This is because the deformed fibres can increase the friction between the fibres and the aggregate to improve coherence with the matrix, thereby reducing the flowability of mixture [34] In addition, the change in the form of fibres leads to the strengthening of the effects of the fibres, which make the fibres vulnerable to one another.

Although three types of fibres, smooth, hooked-end and twisted, were chosen to cover different behavior and bond mechanisms differing between fibre and matrix, the results analysed showed a small difference in tensile strength, tension on peak strength and energy absorption capacity. It is hypothesized that this behavior is attributed to the iM.Pact of the fibre group in composites and the surprisingly high bonding strength observed between the smooth fibres and the ultra-high strength matrix designed, which enables the development of high tensile stress in smooth fibres [35]. Higher material utilization of smooth fibre mitigates, in part, the need for additional mechanical bonding, present in the hooked-end and twisted fibres.

Additionally, by adding steel fibres to the composition may alter the crack pattern, slowing down the appearance of the crack and preventing the development of cracks in concrete specimens [36] while inserting short fibres improves concrete ductility, flexural strength and reduces the risk of crack formation [37]. The integration of long fibres (lf> 10 mm) may affect the structure level, which contributes to the development of material defects.

3. EXPERIMENTAL PREPARATION

3.1 Mix Design of HSFRC

The mixture proportion of HSFRC matrix investigated in this study were shown in Table 1, which was designed for a target compressive strength of 28 days to provide a selfcoM.Pacting characteristic. To increase the matrix strength the cementitious material used in this study are Portland Cement Type I- CEM 52.5N, silica fume, sieved sand with size in the range of 150 to 600 μm, micro-steel fiber and type of Glenium 51 superplasticizer. Furthermore the utilised of silica fume and superplasticizer can increases the packing density.

DOI: dx.doi.org/10.7324/IJASRE.2018.32648

To investigate the effect of fibre contents, two varies types of micro steel fibres as shown in Figure 2 were demonstrate three steel fibers volume of 0.5 %, 1.0 % and 1.5 %. The composition of HSFRC mixtures were following the recipe which given in Table 1.

Table 1. HSFRC mixture proportion with different steel fibre volume (%)

Constituent	Mix			
	1	2	3	4
Portland Cement	1.00	1.00	1.00	1.00
Fine Sand[a]	0.18	0.18	0.18	0.18
Silica fume	0.05	0.05	0.05	0.05
Superplasticizer	0.05	0.05	0.05	0.05
Water	0.20	0.20	0.20	0.20
Steel Fibre (%)	0	2	4	6

[a] Range of fine aggregate size = 150 to 600 µm, [b] Steel fibre length = 6 mm , 14 mm

Figure 2. Types of micro-steel fibres: a) 6 mm length, b) 14 mm length

4. MIXING PROCEDURE AND SAMPLES PREPARATION

In this study, four different types of steel fibres volume (0%, 0.5%, 1.0 % and 1.5%) with aspect ratio (lf / df = 14 / 0.175, lf / df = 6 / 0.25) were investigated. HSC refers to without fibre while HSFRC refers to fibre contents (0.5 %, 1.0 % and 1.5 %). The mixture for each HSC and HSFRC groups with different steel fibres volume (%) is used by bowl mixer. Firstly, starting with laying dry materials (cement, silica fume and fine sand) are inserted alternately to achieve the better spread between the dry materials used. When a mixture of dry ingredients is mixed up to 2 minutes then 80% of the water content is poured into the dried mixture and then added with the superplasticizer slowly. It is allowed to hang out for 2 minutes to reach the homogeneity paste. After that, the process goes on by pouring the remaining water and is lined up with the balance of the superplasticizer. After the mixture has sufficient viscosity, the steel fibres is dispersed into the mixture [7].

When the mixture is ready, immediately prepared for slump flow test according to ASTM C1611 [38] to get the dispersion of workability of cement paste. Next, the each concrete group were filled into 3 mould cube samples of 100 mm³ and 3 dog bone samples with the detailed dimensions shown in Figure 1. The cube moulds were filled with three layers of fresh concrete and vibrated the samples about 60 s by using the vibrating table to occupy between matrices and fibres. The vibration goal for casting concrete into the mould is to further enhance the mixing of the mix, especially with the use of steel fibres. After 24 hours demolding, all specimens were wrapped with plastic sheet to make sure the moisture of samples and then stored in the room temperature at (27 ° C ± 2) until the test date to increase strength and accelerate strength as recommended [39].

5. EXPERIMENTAL TESTING

5.1 Flowability of HSFRC

Flow ability test was conducted in this study based on ASTM C 1611 [38]. The slump flow test is mainly used to assess horizontal free flow without delays or in other words is the ability to fill up the concrete. The test also gives some indication of resistance to segregation. It measures two parameters which flow spread and flow time. The period between the moment of the cone released from the base plate and the self-consolidating concrete first touches the diameter of 650 mm were consider as the slump flow time. At first, moisturized or oily the base plate and area inside the cone. Then place the base plate on the stable ground at the cone centered on the base plate and firmly hold it. After that fill the cone with a scoop. Just strike a concrete stage with conical cone with trowel. Raise the cone vertically 225 ± 75 mm in 3 ± 1 sec and allow the concrete to flow and record the time simultaneously as shown in Figure 3. Calculate the slump flow using equation:

$$S = \frac{d_1 + d_2}{2} \quad (1)$$

where S is refer to slump flow, d_1 is the largest diameter of the concrete spread, d_2 is the concrete spread at an angle approximately perpendicular to d_1.

Figure 3. Raise the cone vertically to measure the flowability

5.2 Compression test

The compressive strength of mix proportions with different steel fiber volumes were evaluated according to BS 1881-116:1983 [40] with a loading rate of 1 kN/s. The purpose of compression test is to determine the strength of the concrete mixture can achieve. The samples undergone compression test after curing process for 7 and 28 days. In this study, the unit weight of the cube samples were found out between 2500-2600 kg/m³.

5.3 Direct Tensile Tests on Dog bone Shaped

The direct tensile test were carried out in this study by dogbone-shaped sample with a cross section starting with 30 x 40 mm and turning into a prism of 20 x 40 mm after 30 mm from each end of the sample with a length of 90 mm as shown in Figure 1. The preparation of this test involves planning the jigs and end plates connected to 12 mm diameter steel rod. The samples will be held by jig to reduce the alignment and then two final plates will be fixed at each end of the sample using epoxy resin. Epoxy will be used at least 24 hours before the test to achieve its ultimate strength. Test preparation in Denison displacement control machine with a capacity of 25 kN. In this test, the displacement control at the rate of 0.6 mm / min were applied to the steel rod and the tensile load delivered to the sample to get the accurate reading of stress strain curve [41].

6. EXPERIMENTAL RESULTS AND DISCUSSIONS

The results tabulate in Table 2 shows the value for each sample by using specified testing method refer to variable parameters whereas Figure 5 shows the compressive strength of cube samples on 7 and 28 days.

Table 2. Results of slump flow, compressive strength and direct tensile strength

Testing parameters					
Samples	Steel fibre contents	0%	0.5%	1%	1.5%
Slump flow	Diameter, mm	830	710	620	570
Mean compressive strength (M.Pa)	7 days	66.03	84.15	77.75	69.25
	28 days	72.3	102.5	87.51	80.75
Direct tensile strength (M.Pa)	28 days	5.01	7.07	6.54	5.66

6.1 Effect of Steel Fibres on Flowability

The slump values by different steel fibre contents of mixtures can be seen in Table 2, the slump flow of HSFRC batch without fibre by about 830 mm. In general, by using higher steel fibre volumes led to decrease the slump flow. With incorporation of 1.5 % steel fibre, the slump flow gradually decreased as contrasted to HSFRC at lower steel fibre contents (0.5 %) and without steel fibre content (0 %). The slump flow was determined by the mean value of two diameters perpendicular d_1 and d_2.

6.2 Effect of steel fibres on the compressive Strength

The compressive strength of different steel fibres volume mix proportions were evaluated. The compressive strengths at 7 and 28 days were recorded and tabulated in Table 2. As discussed in the earlier the different steel fibres volume (%) were used in this study from 0 % - 1.5 % steel fibres volume were mixing into mix proportion of HSFRC. The curing process of cube samples were

DOI: dx.doi.org/10.7324/IJASRE.2018.32648

demolded after 24 hours of casting and kept in the curing room (27 °C ± 2). Samples were taken from curing rooms and tested in age of 7 and 28 days. The compression test were followed BS 1881-116:1983 [40] standard with the loading rate of 1 kN/s.

Figures 4, shows the graphical representation of 7 days and 28 days compressive strength of samples. It can be observed that the compressive strength of 0.5 % of steel fiber volume samples are very high. At 7 days with 0.5 % volume of steel fibre is 84.15 M.Pa of compressive strength when coM.Pared to 1.0 % and 1.5 % volume of steel fibre with 77.75M.Pa and 69.25 M.Pa respectively. Whereas at 28 days strength of 0.5 % volume of steel fibre is 102.5 M.Pa of compressive strength when coM.Pared to 1.0 % and 1.5 % volume of steel fibre with 87.51 M.Pa and 80.75 M. Pa respectively. It's clearly shows that without steel fibre volume contributing to the least of compressive strength which is 66.03 M. Pa at 7 days and 72.3 M.Pa at 28 days. From this results, its clearly shows the low volume of steel fibre (0.5 %) can be used besides there is a need for high early strength (i.e. in shear keys) [41].

The use of low volume of steel fibre (0.5 %) resulted higher in early strength at 7 days higher with 12.07 %, 3.95 %, 9.68 % than without, 1.0 % and 1.5 % of steel fibres, respectively. Whereas at 28 days the use of low volume of steel fibre (0.5 %) resulted higher with 12.07 %, 3.95 %, 9.68 % than without, 1.0 % and 1.5 % of steel fibres, respectively. which is 17.28 %, 7.89 % and 11.87 % higher than the samples made of without, 1.0 % and 1.5 % of steel fibres, respectively. It can be concludes that compressive strength can be illustrated increasing uniformly at 7 and 28 days.

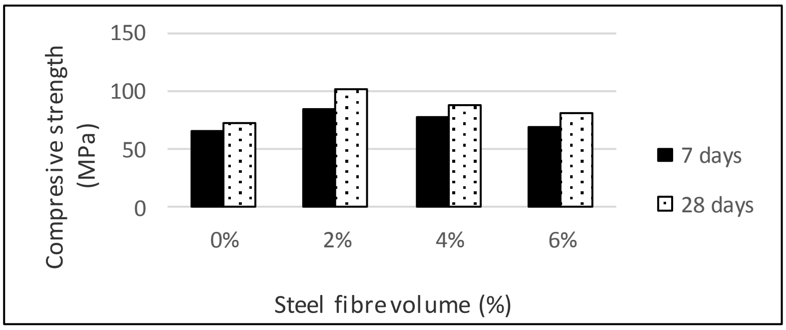

Figure 4. Compressive strength of 7 and 28 days

6.3 Modes of Failure of Cube Samples

The failure mode can clearly be seen when the sample is tested referring to a pattern of failure occurring. The fracture pattern of the sample is to describe the properties of the sample whether it represents a failure of an unsatisfactory or satisfactory failure. The concrete cube samples of 100 mm³ in size were analysed according to BS EN 12390: 2009 [42]. Those modes of failure are determined by the specimen failure area. For compression tests, failure is divided into two types of fractures that are cracking and tension cracking as shown in Figure 5.

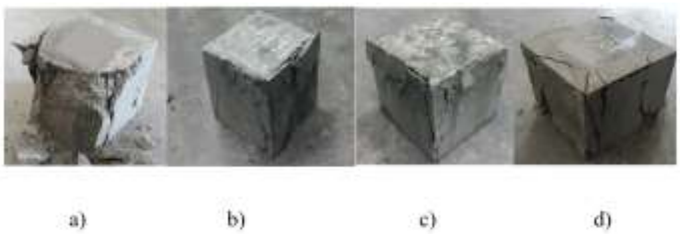

Figure 5. Crack Pattern of Cube a) satisfactory failures, b) unsatisfactory failures (BS EN 12390: 2009) [42]

Explosive cracks are considered common failure while stress cracking is considered to be an abnormal failure. Figure 6 shows the crack patterns of HSC and HSFRC. Figures 6 show the failure pattern of different steel fibres volume within 0 % - 1.5 %. The minor cracks were observed from samples with steel fibre contents, whereas HSC samples marked as unsatisfactory failures.
These crack patterns were obtained during the testing of four different steel fibers volume (0 %, 0.5 %, 1.0 % and 1.5 %). From Figure 6, it can be seen that the crack pattern of HSC in category of unsatisfactory failures number which is an abnormal or unacceptable crack for cube samples while the crack pattern of HSFRC containing 0.5 %, 1.0 % and 1.5 % steel fibres volume is under satisfactory failure category with minor damage to the face in contact with platens. The main factor that affects the crack pattern influences the bond between matrix and steel fibers volume [43].

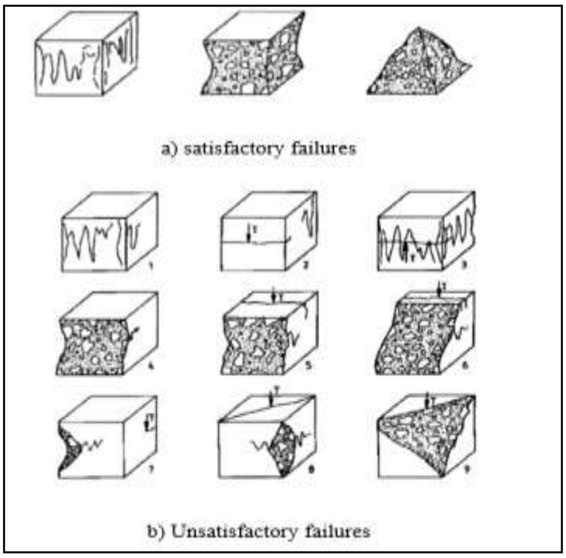

Figure 6. Crack Patterns of cube samples a) 0 % steel fibre volume b) 0.5 % steel fibre volume c) 1.0 % steel fibre volume and d) 1.5 % steel fibre volume

6.4 Effect of steel fibres on direct tensile strength

Direct tensile tests were carried out by using dog-bone shaped samples. As outlined in Table 1, the samples are categorized into 4 groups according to steel fibres volume (%). A total of 4 types of different steel fibre contents, each consists of HSFRC with 0 % 0.5 %,1.0 % and 1.5 % steel fiber volume were made and casted into dogbone shaped with having a cross section of 20 x 20 mm^3. The HSFRC mixtures are characterized by excellent workability in Table 4, with self-consolidating properties however mixtures with steel fibers volume were more difficult to place them in the molds then non steel fibre. After the 28 curing days, the samples were tested to investigate its tensile behavior [44].

Based on Figure 7 shows the typical types of failure as observed after the test was done. It can be seen from Figure 7 a) the experimental tensile strength tests of HSC ended with sudden brittle failures and show no falling branch. On then other hand, the samples made of HSFRC containing 0.5 %, 1.0 % and 1.5 % of steel fibers Figure 7 b); show ductile behaviors with a gradual falling branch [45].

In this study, each batches of steel fibre contents were tested by direct tensile test with can classified as either "strain-softening" or "strain-hardening" in tension. Figure7 a) illustrated the average of HSC do not contribute to hold the cracks together. However, HSFRC with steel fibres with 0.5 %, 1.0 % and 1.5 % may increase the tensile strength. Its clearly shows that HSC exhibit a strain-softening and with fibres the concrete exhibit a hardening behaviour which is the fibres stitch the concrete together when it cracks. The detailed of tensile strength at 28 days test results were tabulated in Table 2.

In Figure 8, the tensile behavior of four different steel fibre contents shows the higher tensile strength and an improvement in strain at maximum stress have been achieved while using a smaller volume fraction of fibre which is 0.5 %. To further optimize the tensile response of the composite, a blend of steel fibres with different volume (%) was used in this study. The results shows type of 0.5 % steel fibre volume developed a tensile strength of 7.07 M.Pa at a strain of 2.5 %, whereas 1.0 % and 1.5 % steel fibres volume developed a tensile strength of 6.54 M.Pa at a strain of 2.2 % and 5.66 M.Pa at a strain of 2 % respectively. The different results between them occur due to the variety of fibre (in properties and volume) being used, will definitely influence to the tensile strength test results [45].

In this study by using two types of straight steel fibres in 6 mm and 14 mm were improved the ductility then without steel fibre content. At a volume fraction of 0.5 % led to a postcracking tensile strength of 7.07 M.Pa. From Figure 8 it describes the stress-strain response of four mixture types with different steel fibres volume (%) develops a higher tensile strength due to the smaller in fiber volume fraction (%). These results of tensile strength values are close to those suggested by JSCE 2004 [46], namely 5 M.Pa.

DOI: dx.doi.org/10.7324/IJASRE.2018.32648

Figure 7. Typical failure occurred in the tensile strength test specimens: a) HSC, and b) HSFRC 0.5 %, 1.0 % and 1.5 %

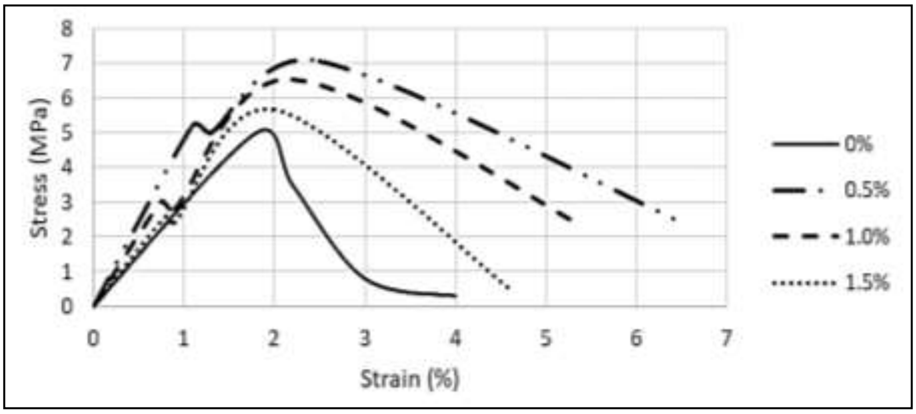

Figure 8 . Tensile strength of HSC and HSFRC with different steel fibre volume (0.5 %, 1.0 % and 1.5 %)

7. CONCLUSIONS

This paper addresses effect of steel fiber contents with High Strength Fibre Reinforced Concrete to investigate the compressive strength and direct tensile strength. Based on the results from this study, the following conclusions can be drawn:

- The incorporation of steel fibre significantly reduced the flowability of HSFRC. With the increase of steel fibre contents, the flowability gradually decreased. The flowability of HSC was 830 mm coM.Pared with HSFRC of 0.5 %, 1.0 %, and 1.5 % straight steel fibres, the flowability decreased by about 7.79 %, 14.48 % and 18.57 % respectively.
- At 7 days the compressive strengths of HSC samples were 66.03 M.Pa. With incorporation of 0.5 %, 1.0 % and 1.5 % of straight steel fibres, the corresponding values reached are 84.15 M.Pa, 77.75 M.Pa and 69.25 M.Pa respectively at 7 days. Whereas at 28 days the compressive strengths of HSC samples were 72.3 M.Pa. With incorporation of 0.5 %, 1.0 % and 1.5 % of straight steel fibers, the corresponding values reached are 102.5 M.Pa, 87.51 M.Pa and 80.75 M.Pa respectively at 28 days. It can be concludes that compressive strength can be illustrated increasing uniformly at 7 and 28 days [44]. From this results, its clearly shows the low volume of steel fibre (0.5 %) can be used besides there is a need for high early strength (i.e. in shear keys).
- In compressive strength, the use of low volume of steel fibre (0.5 %) resulted higher in early strength at 7 days higher with 12.07 %, 3.95 %, 9.68 % than without, 1.0 % and 1.5 % of steel fibres, respectively. Whereas at 28 days the use of low volume of steel fibre (0.5 %) resulted higher with 12.07 %, 3.95 %, 9.68 % than without, 1.0 % and 1.5 % of steel fibres, respectively. which is 17.28 %, 7.89 % and 11.87 % higher than the samples made of without, 1.0 % and 1.5 % of steel fibres, respectively. It can be concludes that compressive strength can be illustrated increasing uniformly at 7 and 28 days.
- The tensile behavior of four different steel fibre contents shows the higher tensile strength and an improvement in strain at maximum stress have been achieved while using a smaller volume fraction of fibres which is 0.5 %. To further optimize the tensile response of the composite, a blend of steel fibres with different volume (%) was used in this study. The results shows type of 0.5 % steel fibre volume developed a tensile strength of 7.07 M.Pa at a strain of 2.5 %, whereas 1.0 % and 1.5 % steel fibre volume developed a tensile strength of 6.54 M.Pa at a strain of 2.2 % and 5.66 M.Pa at a strain of 2 % respectively.
- Based on this study, with incorporation of 0.5 % straight steel fibre, the higher result in compressive and direct tensile strengths were reached about 102.5 M.Pa and 7.01 M.Pa at 28 days.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support received under Fundamental Research Grant Scheme (FRGS: Grant No. 9003-00105) provided by the Ministry of Higher Education of Malaysia (MOHE) and Faculty of Civil Technology, Universiti Malaysia Perlis (UniMAP).

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