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Strength Behavior of Steel Fiber Reinforced Concrete in Fiji

Samuela Loaloa Vukicea[1]

[1]School of Building and Civil Engineering, Fiji National University, Suva, Fiji.

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Abstract: Cement concrete is relatively brittle and its tensile strength is typically only about one-tenths of its compressive strength. It is becoming increasingly popular in various applications to reinforce the concrete with small, randomly distributed fibers. The main purpose is not only to increase the energy absorption capacity, called the toughness of the material, but also to increase the tensile, compressive and flexural strength of concrete. This experimental analysis is to carry out Compressive and Split Tensile Strength Tests on Steel Fiber Reinforced Concrete (SFRC) and determine their mechanical properties particularly in their hardened state. A steel fiber obtained for steel shavings having a diameter of 0.50 mm is being used being to investigate the effects of fiber quantity on tensile strength on coconut fiber-reinforced concrete.

Using three completely different weight fractions which are 1.5%, 3%, and 5% by weight fraction thoroughly mixed with a standard fiber length which is 30 mm. A M20 grade concrete is chosen with plain concrete being used as control mix and an aspect ratio of 60 is used for this experiment. Analysis has been carried out on its workability. It has been deduced that the optimum fiber content for enhanced concrete strength is 5% by weight of cement.

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I. INTRODUCTION

Steel fiber reinforced concrete (SFRC) is a composite material whose components include the traditional constituents of Portland cement concrete, hydraulic cement, fine and coarse aggregates admixtures and a dispersion of randomly oriented short discrete steel fibers. (Prasad et al., 2017). Steel fibers can improve the characteristics of hardened concrete, plays a vital role in producing extra strength in concrete and is often used to improve the mechanical properties of concrete, especially the post-cracking tensile resistant (Malhotra et al., 2017). Steel Fiber Reinforced Concrete is durable and efficient material that has achieved the high strength and has been considered the type of concrete to use for the construction of large structures and may also be used at the construction prefabricated structures (Kanagaraj et al). Addition of steel fibers to concrete increases the compressive strength of concrete marginally, increases the tensile properties of concrete, improves resistance to cracking, increases the flexural strength and the increase the volume offraction of fiber and get good strength (Prasad et al., 2017).

Addition of steel fibers in the concrete mix resulted in improved structural performance measure in terms of ultimate load carrying capacity, crack widths, deflection and curvature ductility factor of beam specimens of all the series and the important properties of steel fiber reinforced concrete (SFRC) are its superior resistance to cracking and crack propagation (Narwal et al., 2013), In general, (SFRC) is very ductile and particularly well suited for structures which are required to exhibit, resistance to impact, blast, shock loads and high fatigue, shrinkage control of concrete, very high flexural, shear and tensile strength, resistance to splitting, erosion and abrasion, high thermal, temperature resistance and resistance to seismic hazards (Sharath et al.,2017). The study on the effect of fibers with different sizes and properties can still be a promisingwork as there is always a need to overcome the problem of brittleness of concrete where the brittleness of concrete can also be improved by addition steel fibers than glass fibers, since concrete is very weak in tension, the steel fibers are beneficial in axial-tension to increase tensile strength (Kene et al., 2012). Plain concrete is a brittle material and fails suddenly while the addition of steel fibers to concrete changes its brittle mode of failure into a more ductile one and improves the concrete ductility while workability of concrete gets reduced; the reason for this is due to increase in percentage of fiber content (Ulape et al., 2015).

SFRC is responsible for distributing localized stresses, reduces maintenance and repair cost, provides tough and durable surface, reduces surface permeability, dusting and wear, saves cost, act as a crack arrestor, increase tensile strength and toughness, offer resistance to impact, freezing and thawing (Savita et al., 2018). Steel fiber reinforced concrete (SFRC) is distinguished from plain concrete by its ability to absorb large amount of energy and to withstand

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large deformations prior to failure and as such a new application of reinforced concrete needs to develop, so, from the previous research additional fiber is one of the methods to improve the mechanical properties of the structural concrete. (Raju et al., 2018).

Fiber reinforced concrete (FRC) is concrete containing short discreet fibrous material that are uniformly distributed and randomly oriented which increases its structural integrity and the fibers are now used as a secondary reinforcement, which act as a crack arrester improves toughness and mechanical properties (Aravind et al., 2017). The experimental tests showed the different behavior of SFRC with respect of the different fiber content and length and based on the experimental results, an analytical model, reported in literature and used for the theoretical determination of direct tensile strength,was applied with the aim of making a comparison with experimental results and comparison showed good overall agreement (Olivito and Zuccarello, 2010). High strength Steel-fiber reinforced concrete is being used increasing day by day as a structural material and as such the study of high strength concrete has become interesting as concrete structures grow taller and larger and the usage of high strength concrete in structures has begun to make an impact worldwide and is known as “High strength concrete” explained on the basis of its compressive strength measured at a given age (Sumathi and Saravan, 2015).

Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement are initially used to prevent/control plastic and drying shrinkage in concrete however, further research and development revealed that addition of steel fibers in concrete significantly increases its flexural toughness, the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability (Behbahani et al. 2011).

An alternative to increasing the load carrying capacity of concrete in tension is the addition of fibers with well dispersed fibers in concrete act to bridge the cracks that develop in concrete and the incorporation of fibers in a cement matrix leads to an increasein the toughness and tensile strength, and an improvement in the cracking and deformation characteristics of the resultant concrete (Harish et al., 2016).

Generally, with increasing steel fibers, the maximum strength and displacement increase, although this increment has limitation with the volume fraction of steel fibers and by addition of steel fibers to the concrete mix, the main crack is localized in the central part of the beams and the number of cracks is less in comparison with the specimen without steel fiber (Ranbaran et al., 2017). The use of fibers in concrete has gained momentum in the infrastructural and industrial applications such as industrial floors, pavements and overlays, marine structures, repair and rehabilitation and retrofitting of structures, earthquake resistant structures and slope stabilization (Ramadoss et al., 2013).

The addition of steel fibers in concrete has shown the ability to improve the tensile/flexural properties, fracture energy, and cracking behavior of an otherwise a quasi-brittle material, however, the compressive strength of the concrete material is not particularly affected by the addition of steel fibers to the mix and in tensile/flexural members, steel fibers act as crack arrestors by bridging the crack surfaces and restrict thepropagation of cracks (Karzad et al., 2020).

The experimental results revealed that fiber addition improves the mechanical properties and also the ductility and energy absorption of the concrete and furthermore the results also demonstrate that the hybrid steel polypropylene fiber reinforced concrete performs better in compressive strength, split tensile strength, flexural strength and impact resistance than mono steel and mono polypropylene fiber reinforced concrete (Kanagaveland Arunachalam., 2015).

Steel fiber has not been used for field applications locally and this research will hopefully help to initiate further research for the design and implementation of Steel fiber field applications locally.

II. MECHANICAL PROPERTIES OF CONCRETE

Compressive strength is a measure of the ability of concrete to resist crushing Compressive strength and is the most widely used measure of concrete quality because it is readily determined and because most of the other properties of concrete improve with increases in compressive strength (Basic Guide to Concrete Construction – Australia, 1982). On the other hand, Tensile strength is a measure of the ability of concrete to hold together or the ability to withstand a pull force without breaking. The Tensile strength of concrete is measured by the units of N/mm 2 or MPa. Although the tensile strength (3-5 MPa) of concrete is small in comparison with it’s compressive strength (20-50 MPa), it is of importance to certain types of concrete, notably unreinforced concrete pavements, floor slabs and the like. (Basic Guide to Concrete Construction – Australia, 1982),

III. MATERIALS AND METHODOLOGY

- *Materials*

The materials used in the concrete were cement, fine and coarse aggregates, Steel fiber and water. On the other hand, locally available clean and dry river sand passing through AS 4.75 mm sieve is used for casting the specimens. Coarse aggregate passing through AS 19 mm sieve and retained on 13.2 mm sieve is used for casting all specimens and the properties of coarse aggregate. The properties of cement, sand and Coarse Aggregate added are mentioned in Table 1.

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Table 1 Properties of Cement, Sand and Coarse Aggregate

Properties of Cement	**Values**
Grade of Cement (standard)	PPC 53
Specific Gravity (standard)	3.15
Initial Setting	28 min
Final Setting Time	600 mm
Properties of Sand	**Values**
Specific Gravity (standard)	2.65
Fineness Modulus	2.25
Properties of Coarse Aggregates	**Values**
Specific Gravity	2.77
Size of Aggregates	19 mm Passing the waste Plastic through and 13.2 mm Sieve retained
Fineness Modulus (standard)	2.46

➢ *Methodology*

In the current research, Twelve 100 × 100 ×100 mm cube specimens (for compressive strength) and four 150mm × 300mm diameter of cylindrical specimens (for split tensile strength) were used to cast the Steel fiber and control mix. In addition, slump testing and analysis were done to observe the best mix design ratio to be used. The extensive experimental testing and evaluation tests were done after 7, 14 and 28 days to observe the Compressive strength and Tensile strength analysis of the concrete. M20 grade concrete has been used with a design ratio of 1:1.5:3. Steel fibers were used to replace the fine aggregates when mixing with water and cement. The amount of fiber added to each mix are 0%,1%, 2% and 3% by weight of specimen. Moreover, concrete with 0%, 1%, 2% and 3% Steel fiber were prepared and compared with each other to find out the variations in the performance of concrete with different percentages of fiber used and the plain concrete mix.

➢ *Experimental Work*

The main purpose of this experimental study is to carry out Compressive and Split Tensile Strength Tests on Steel Fiber Reinforced Concrete (SFRC) and determine their mechanical properties particularly in their hardened state. A steel fiber obtained for steel shavings having a diameter of 1.50 mm is being used.

Using three completely different weight fractions which are 1.5%, 3%, and 5% by weight fraction thoroughly mixed with a standard fiber length which is 30 mm. A M20 grade concrete is chosen with plain concrete being used as control mix and an aspect ratio of 60 is used for this experiment.

➢ *Test Results on Hardened Concrete Properties - Compressive Strength*

- The following graph gives compressive strength result for M20 grade of concrete with 0%, 1.5%, 3% and 5% steel fibers for aspect ratio 60.
- The following tables below shows the compressive strength experimental results for various considerations.

The following tables below shows the actual compressive load and strength experimental results for various considerations.

Table 2 Actual Compressive Strength of Concrete Cubes for Different % Steel Fiber by Weight in MPa at 7, 14 and 28 days curing.

% Fiber added byweight in Concrete Cube Specimens	Actual Compressive Test Load [KN] and Compressive Test Strength[MPa]					
	7 days		14 days		28 days	
	Test Load [KN]	C/Strength[MPa]	Test Load [KN]	C/Strength[MPa]	Test Load [KN]	C/Strength [MPa]
0	147.2	14.72	153.7	15.37	207	20.7
1.5	183.4	18.34	188.9	18.89	224.3	22.43
3	229	22.9	253.8	25.38	276.1	27.61
5	307.8	30.78	318.8	31.88	350	35.00

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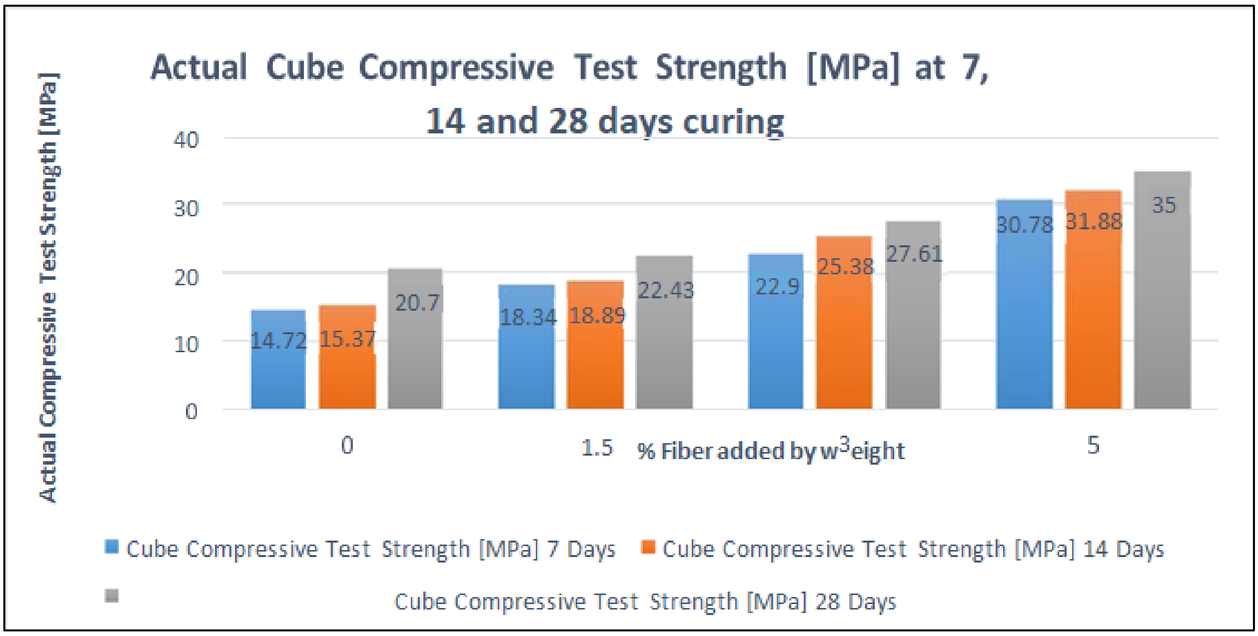

Fig 3 Actual Compressive Test Strength at 7, 14 and 28 Days for M20 Grade Concrete [MPa].

➤ *Split Tensile Strength Test*

Split Tensile Tests Load and Strength for Steel Fiber Reinforced concrete at 7, 14 and 28 days.Table of Results Split Tensile Load and Strength at 7, 14 and 28 days

Table 4 Compressive Strength of Concrete Cubes for different % Steel Fiber by Weight in MPa at 7, 14 and 28 days curing.

%Fiber added byweight in Concrete Cube Specimens	Actual Split Tensile Test Load [KN] and Split Tensile Test Strength[MPa]					
	7 days		14 days		28 days	
	Test Load [KN]	T/Strength[[MPa]	Test Load [KN]	T/Strength [MPa]	Test Load [KN]	T/Strength [MPa]
0	18.7	1.87	23.9	2.39	26.2	2.62
1.5	23.2	2.32	25.7	2.57	28.3	2.83
3	29.0	2.90	31.8	3.18	35.0	3.50
5	39.0	3.90	40.3	4.03	44.3	4.43

Graphs representing Actual Split Tensile Load [KN] and Strength [MPa] were plotted against % Steel Fiber at 7, 14 and 28 days curing.

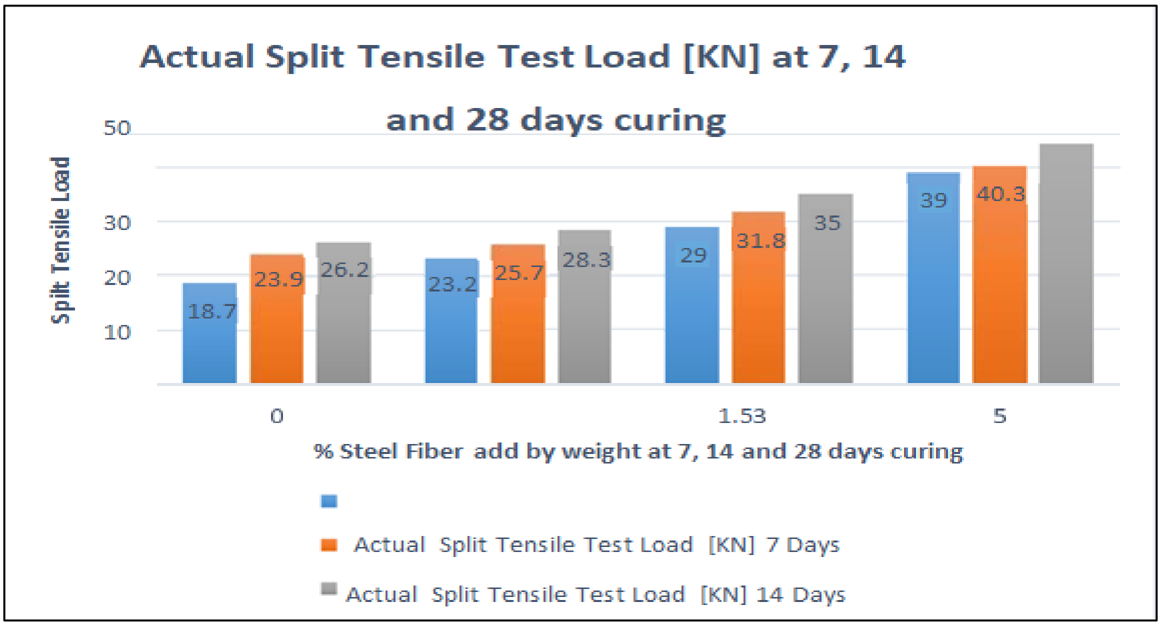

Fig 4 Effect of Steel Fiber on Split Tensile Load [KN] at 7, 14 and 28 days.

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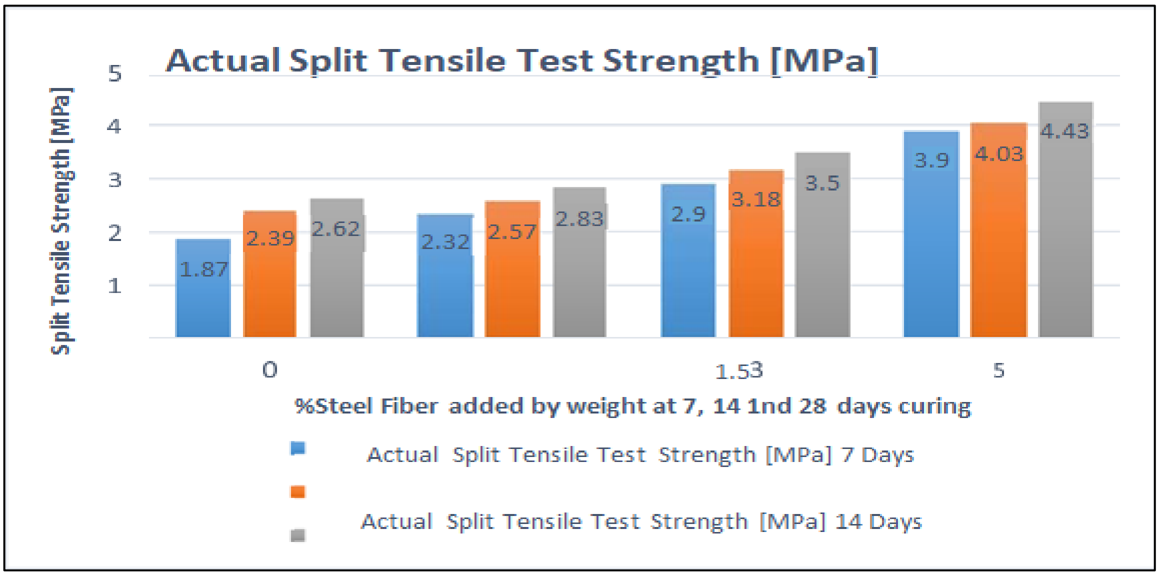

Fig 5 Effect of Steel Fiber on Split Tensile Strength [MPa]

Fig 6 Steel Fiber on Weighing Scale


Fig 7 Slump Test is Conducted

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Fig 8 Preparation of Concrete Cubes

Fig 9 Compressive Test Cube Setup and Failure

IV. DISCUSSION ON RESULTS

The general trend of the compressive strength for % Steel Fiber added is clearly shown in the graphs Fig. 2 and 3. For increase in % Fiber there is a corresponding increase in Compressive Test Load and Strength. For the various % Fiber added, the Optimum Compressive Strength was achieved at 5% Steel Fiber as predicted.

As predicted, the workability tends to decrease as we increase the % Steel Fiber.

From the Split Tensile Strength test performed it was observed from graphs plotted in Fig. 4 and 5 that Optimum Tensile Strength can also be achieved when 5% Steel Fiber is added.

Although reinforced concrete from steel fiber has numerous advantages, discussed below are some area of concerns that still need to be fully resolved:

- Complications of achieving uniform fiber dispersal and consistent concrete characteristicsare involved.
- Using steel fiber reinforced concrete requires a more accurate configuration than normalconcrete.
- Another problem is that the desired improvements cannot be obtained unless steel fibers are added in sufficient quantities.

V. CONCLUSIONS

From the analysis of experimental results, it can be said that the objective of the experiment was achieved in identifying the Optimum % Steel Fiber content of the Steel Fiber Cement Concrete which is 5% Steel Fiber by weight for both Compressive and Tensile Strength.

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Workability was affected by the increase in % Steel Fiber and this could be controlled by using short steel fibers with increased aspect ratios.

Based on previous experiment and literature review, it could also be concluded that the optimum tensile strength will also be achieved with the addition of 5% Steel Fiber by weight. On the industrial scene in Fiji and Pacific this experimental results can be integrated with the technical knowledge and development already achieved in this area for the concrete industries in Fiji like Humes Industries, Standard Concrete Industries to name a few. This will prove to save cost, reduce construction timeline and promote sustainable construction and maintenance due to effort that is taken to seal micro cracks that propagate along cement structures. The main idea developed from this major thesis project could be the key component in solid concrete structures since cracks are common and unpredictable and can occur at any time. Therefore, steel fiber reinforced cement concrete can be used for construction in Fiji and the Pacific Region due to low cost, time saving with increased compressive, tensile strength as well as there is great reduction incracks and furthermore repair of cracks can also be addressed. In summary, steel fibers which is the most suitable for construction as reinforced cement concrete structures as compared to natural coconut coir fiber and plastic PET fiber could provide mitigation on all these ongoing issues as discussed above and could take the construction of concrete structures development in Fiji and Pacific region to another level.

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