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To Investigate The Effects Of Steel Fibers On Mechanical Properties Of Normalconcrete

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ABSTRACT

Concrete, the most commonly used construction material is prone to cracking for a variety of reasons.These cracks may be recognized as economic, environmental and structural but these cracks are generated because materials are naturally weak in resisting tensile forces.Also, shrinkage causes concrete to crack when restrained Steel fiber reinforcement in the concrete offers a resolution to this problem of cracking by improving tensile strength of concrete.“Fiber Reinforced Concrete” is that concrete in which short-fibers with smaller cross-sectional dimension are added.These are randomly oriented steel fibers in all directions, added reinforcement to the concrete.The mechanical properties of concrete consist of flexural strength, ductility, impact resistance, and, compressive, tensile and abrasion resistance.Improvements in mechanical properties depends upon geometry, the fiber matrix interfacial bond characteristics, volume fraction, the matrix mix proportions, type, material properties of fibers,.In this research the effect of varying steel fiber volume fraction on the mechanical properties of concrete are observed in compressive, tensile, flexural and impact resistance of concrete. The test results are analyzed and the optimum fiber volume fraction and aspect ratio of steel fibers is identified.

Keywords: *SFRC, UTM, Split Tensile Strength, Cracks, Compressive Strength.*

1. INTRODUCTION

Concrete, the most commonly used construction material is prone to cracking for a variety of reasons. These cracks may be recognized as economic, environmental and structural but these cracks are formed due to the natural weakness of the materials to withstand tensile forces. Also, when concrete shrinks it restrained and get crack. Steel fiber reinforcement in the concrete offers a resolution to this problem of cracking by improving tensile strength of concrete.

The short-fibers having small cross-sectional size added to the fresh concrete mix forms a “Fiber Reinforced Concrete”. The randomly oriented steel fibers in all directions, added reinforcement to the concrete. The mechanical properties of concrete composed of impact resistance, ductility, and abrasion resistance, compressive, tensile and flexural strength. These improvements in mechanical properties depends on the geometry, type, volume fraction, material properties of fibers, the matrix mix proportions and the fiber matrix interfacial bond characteristics.

Extensive research on steel fiber reinforced concrete has shown that the most significant of adding steel fibers in concrete is to control the tensile cracking of the composite material. The role of the Steel fiber reinforcement is to slowly control the growth propagation of inherent unstable tensile cracks in concrete. This crack controlling properties of the fiber reinforcement, in turn delays the flexural and shear cracking, imparts extensive post- cracking behavior and significantly enhances the ductility and energy absorption capability of the composite.[1].Over the last few decades, attempt have been made to determine the effect of steel fibres on the properties of concrete [2] as well as their properties and their improvement in shear resistance in the structural elements [3]. The steel fibers plays a vital role in resisting the bending behavior of structural beams. Steel fibre percentage from 0.5- 2 have a significant effect on the post cracking of concrete. [4] it is imperative that there is a certain limits for the amount of steel fibers and above which there is only slight increase in strength properties. From past experimental outcomes this limit is around 1.0% [5].

The fibers can act most effectively if they are aligned in the direction of the largest tensile stresses. This principle is applied in reinforced and pre stressed concrete. However, only in a few cases, the direction of maximum tensile stresses is known in advance, and production of aligned short fiber reinforcement is difficult.[9] A great deal of research has been carried out on the combination of FRC and the conventional steel reinforcement, using a variety of fiber types. Fibers cannot, in general, be used to simply replace the conventional steel reinforcement. Steel bars are placed at specific locations in the structural members, to withstand the designed tensile, shear or compressive loads. Fibers are not very effective in this regard, since they are randomly oriented throughout the matrix. [10]

Fibers are most beneficial when large strains occur in the cement matrix. Since the tensile strain capacity of the matrix is small, fibers will be activated. The aim of the addition of fibers should be to keep the crack widths as small as possible and to resist the tensile forces which are no longer taken by the cement matrix in its softening stage. The fibers should act during both the early and mature age of the matrix.

2. ECONOMICAL BENEFITS OF USING SFRC

In a diverse range of applications Steel fiber reinforced concrete (SFRC) is used since its commercial debut in 1970. The addition of this discontinuous steel fiber reinforcement to concrete enhances many of the properties in the hardened composite. The most significant property is to make concrete, a very brittle material, ductile. This ductility is exemplified by fracture toughness, dynamic and thermal shock control, and crack and spall resistance.

2.1. Materials Selection

The matrix and the fiber are the two main constituents of fiber-reinforced concrete. Generally the matrix contains of Portland cement, fine aggregate (Sand), coarse aggregate (Crush) and the fibers used in this investigations are metallic. The Ordinary Portland cement (Type-I) from Kohat cement factory has been selected in this research work. The sand was selected from Lawrencepur quarries, where as Margalla Crush (Islamabad) coarse aggregate selected for this research. Maximum size of coarse aggregate used was **0.5".** The aspect ratio of steel fibres were approximately 55. The properties of steel are fibre are shown in Table 1.

Table 1. Properties of Artificial fibers

Fiber	Sp. Gravity	Tensile St	Youngs Modulus	Elongation At Failure	Volume Fraction	Common Dia (In)	Common Length (In)
St eel	**7.8**	**50-300**	**30**	**30**	**1-3**	**0.0005-0.04**	**0.5-3.0**

2.2. Converting Wires Into Fibers:

The wire was cut with the help of a mechanical cutter and then manually converted into three different end conditions as shown in figure 3.1. A colossal effort was required. **"Z"** . type end conditions provided better result in laboratory testing

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Figure 1: 'Z' shape Steel fibers.

3. EXPERIMENTATION DETAILS & TEST SETUP GENERALFIBERS

In view of the above situation, it was decided to look for alternatives in local markets. After some investigations, wires (steel) available was selected for detailed investigations.

For achieving desired workability with low w/c ratio ''Ultra Superplast 470'' were also based on ASTM C494**.**

Figure 2: Admixture (ultra-superplastic 470) and admixture are adding in water

4. TRIAL MIX PROPORTIONS

Five trial mixes, varying the basic constituents of matrix but keeping the fiber content 10% as constant, were prepared as shown in table 3.6. Water to cementitious material ratio was kept as 0.55 for all mixes. Samples were casted and tested for compression and split cylinder at 7 days. As shown in table 3.6, Mix no.1, gave the best results and was selected for detailed investigation.

Table 2. Selected Ratio

Mix No	Mix Proportions	Fiber Content	Aspect Ratio	Remarks
1	1:2:4	0	0	✓ The percentage of fiber contents is by weight of cement. ✓ L/d ratio is constant throughout all the tests. ✓ W/c Ratio is constant, that is 0.55.
2.	1:2:4	5%	55	
3.	1:2:4	10%	55	
4.	1:2:4	15%	55	

5. CONCRETE TESTING

Concrete mix selected from trial mix proportions was investigated in details, varying the fiber contents as well as the aspect ratio (L/d). A variable dosage was used in fabrication of steel fiber reinforced concrete. Six mixtures were prepared, details of which are shown in table 3.7. For the purpose of determining the compressive strength and indirect tensile strength concrete cylinder (6″x 12 ″) were used. For the mechanical properties, the following tests are conducted to study the effect of amount of fibers and the length of fibers on the compressive, tensile, capacity.
1) Compressive Strength of concrete cylinders (ASTM C39)
2) Split Tensile Strength of concrete cylinders (ASTM C496)

5.1. Capping

At the time of casting of specimens, all efforts were made for smooth capping with trowel, but true plane surface was difficult to achieve. In order to overcome the problem of uneven top, capping procedure of ASTM C 617-87 was followed. Sulphur as capping material was used.

Figure 3. Capping and Curing of cylinders

5.2. Compressive Strength

The following standard tests were followed for compressive strength testing of specimens;
ASTM C 192 – 90. Practice for making and curing test samples in the laboratory.
ASTM C 39-86. Compressive strength testing of cylindrical concrete specimens.
ASTM C 617-87. Practice for capping cylindrical concrete specimens.
ASTM C 470-87. Moulds for casting concrete test cylinders vertically.

Figure 4. Testing of Specimen in Compression and in tension

5.3. Testing of Specimen in Compression and Tension

For tensile strength Splitting test was adopted as per ASTM C 496 – 86. . Cylinders were placed with the axis horizontal between the plates of testing machine. Metallic strips were placed on concrete specimen. These were used as contact material between the cylinders and Plates to overcome the effects of unevenness of cylinder surface. Continuous loads were applied and without shock with uniform rate i.e. 125 psi/min. The load indicated by testing machine at the failure was recorded. Results of split cylinder tests are presented in chapter IV, table 4.2, and Fig: 4.2.Table 3. Trial Mix Proportions

Mix No	Mix Proportions	7 days strength results		Remarks
		Compressive Strength (psi)	Flexural Strength (psi)	
1	**1: 2: 4**	**3018**	**419**	W/C = 0.55 Fiber Content = 10% by weight of cement. L/d = 55
2.	1: 1.75: 3.5	2639	365	
3.	1: 1.5: 3	2613	387	
4.	1: 2: 3	2764	375	
5.	1: 1.9: 3	2896	411	

6. RESULTS AND DISCUSSIONS

In this research work, steel fiber reinforced concrete is studied regarding two aspects Details of test samples are shown in table 4.1 & 4.2. For all specimens, the selected ratio was unchanged. The results of these test specimens were analyzed and compared with the P.C.C.

6.1. COMPRESSION TESTS

Test results of compression test are presented in table 4.1 and graphically represented in fig 4.1. From the tests results, it can be concluded, The maximum enhancement of compressive strength with addition of fibers in concrete which is reasonable, as the role of fibers towards the compressive strength is limited.

Rate of gain of compressive strength in SFRC is rapid during the early stage i.e. up to 14 days and is slow in the later stage. This is because of the development of matrix-fibers bond at early age. With increase in volume fraction of fibers, overall increase in compressive strength is increased. It followed the simple rule of, "increase in fiver volume resulted in increase in compressive strength".

Failure mechanism of the test samples changed completely. In case of PCC samples, after the appearance of first crack, the samples failed suddenly whereas, in case of SFRC samples, the failure was gradual. PCC samples failed with a single major crack, whereas the SFRC samples developed many cracks before failure in a ductile manner. So addition of steel fibers in concrete makes it ductile as compared to PCC, which is highly brittle in nature.

6.2. TENSILE TEST

Test results of split cylinder test are presented in table 4.2 and graphically represented in fig 4.2. During the course of testing, it is concluded;SFRC samples exhibited more elastic behavior than P.C.C. This was more pronounced with increase in fraction fibers volume.With increase of fraction volume of fibers, splitting tensile strength is higher.
The rate of gain of tensile strength is rapid in the early age of SFRC and it slows down with time, as the bond between the fibers and the matrix developed rapidly in early stage.
Improvement in tensile strength of SFRC is more pronounced as compared to compressive strength.

Table 4. Test Results – Compression

S. No	Type of Concrete	Compressive Strength (Psi) (Average of 3 specimen each)		
		14 days	28 days	% Increase
1.	SFRC (0% steel fibers) or P.C.C	2890	3863	-
2.	SFRC (5% steel fibers)	3245	4233	8.7
3.	SFRC (10% steel fibers)	3560	4420	4.3
4.	SFRC (15% steel fibers)	3821	4680	5.6

Table 5. Test Results – Tensile (Split Cylinder)

S/No	Type of Concrete	Tensile Strength (Psi) (Average of 3 specimen each)		
		14 days	28 days	% Increase
1.	SFRC (0% steel fibers) P.C.C	386	475	-
2.	SFRC (5% steel fibers)	416	501	5.2
3.	SFRC (10% steel fibers)	470	529	5.3
4.	SFRC (15% steel fibers)	496	567	6.7

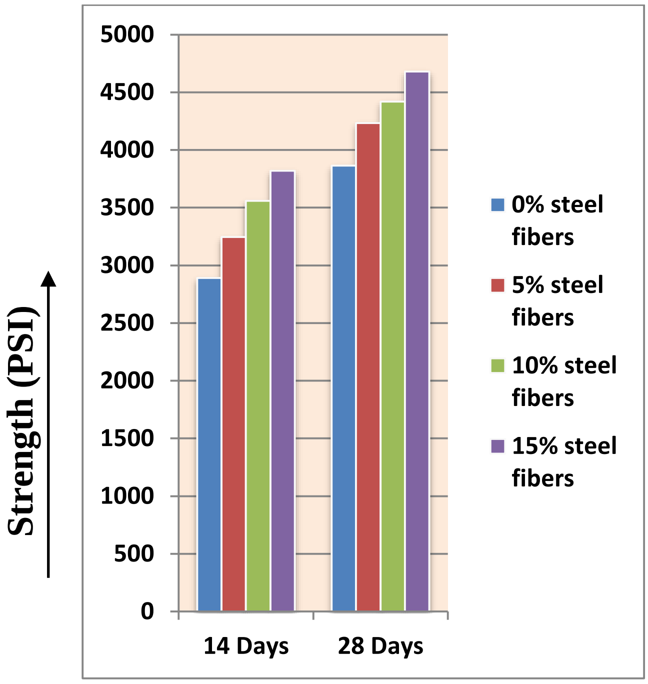

Figure 5Test Results – Compression:

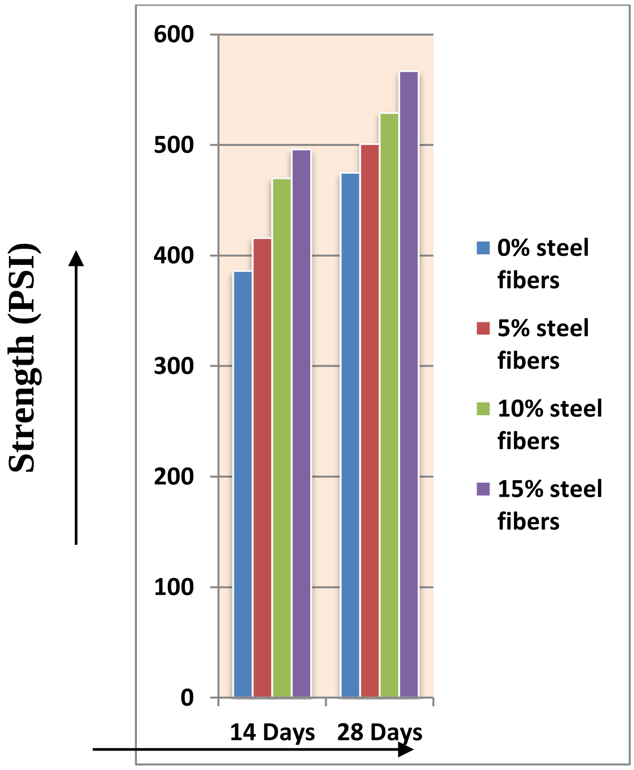

Figure 6 Test Results – Tensile (Split Cylinder)

7. CONCLUSIONS

Fibers plays a vibrant role for a definite load-bearing matrix fracture, which depends upon the location, orientation and embedded length. Results showed that the mechanical properties are improved in the form of STS (Splitting tensile strength) by the amalgamation of steel fibers in specimen. This improvement has been tracked down with increase percentage of the fibers contents.

The compressive strength of cylinders was directly proportional at all the ages with an increase in steel fiber. On 28th day, compressive strength of concrete having steel fiber reinforced concrete (SFRC) was found about 4700 Psi. However, on the same age the normal concrete showed a compressive strength lower than 3800 Psi.

Splitting tensile strength (STS) increased with addition of steel fibers. With raising quantity i.e. 0% up to 15%, STS raised from 475 Psi up to 567 Psi on 28th age. From these results it shows that from normal concrete to SFRC, the splitting tensile strength increases almost 16%.

SFRC specimens developed multiple cracking before failure and could resist loads even after failure. This was confirmed by the fluctuating dial gauge of testing machine. Incorporation of steel fibers to concrete changed the mode of failure from brittle to ductile.

The construction of ever long span bridges, tall buildings, deep off-shore structures, defense related infrastructure, roads, runways and other numerous mega structures are calling for construction materials with increasingly improved properties such as strength, stiffness, toughness, ductility and durability. In some cases, simultaneous improvements in a combination of properties are required. The steel fibers addition into concrete provides satisfactory results in response to the above mentioned properties.

Recommendations

During the course of investigation it was felt that
certain other aspects of fibers are under-taken for further studies. Following topics are recommended for detailed investigation for future research:-

The improved ductility due to incorporation of steel fibers need to be investigated. Presently steel fibers have been investigated. Other types of artificial fibers like carbon, glass and polymer fibers are to be investigated for their use in concrete. Also steel fibers with higher tensile strength are to be investigated for their use in concrete.

Corrosion of the exposed steel fibers in cementitious matrix due to the environmental affects has revealed that methods be developed to reduce / eliminate corrosion to enhance the serviceability of the structure.

The Fatigue and the impact resistance get increased by using SFRC.By using SFRC the wear and tear resistance of the concrete get increased.
SFRC used to increase joint spacing between the pavement spans.

The construction of thinner pavements for higher flexural strength.SFRC can be used for the thinner sections with easily handling and transportation.

From use of SFRC different size and shapes of pre-cast units can be made.SFRC can be used in hydraulic and marine structures to resist the cavitations and the damaging impacts of hydraulic heads and swirling water currents.
Use of SFRC highly efficiently and economical used in conventional shot Crete for mesh reinforcement.
SFRC can be used in seismic-resistance of buildings in joints & connections for their ductile behavior.

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