EXPERIMENTAL INVESTIGATION OF BOND STRENGTH IN STEEL FIBER REINFORCED CONCRETE

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ABSTRACT

Reinforced concrete is most successful material used in the construction industry. Also used in worldwide. Utility of reinforced concrete as structural material is derived from composite action of takes place between reinforcing bars and concrete at their interface known as bond. In recent years SFRC is widely used in the construction industry as it can improve durability of structural member if correctly mixed and casted. The properties of steel fiber such as aspect ratio, diameter of fiber etc. influences properties of concrete. Many researchers have found that steel fibers when added to the concrete in specific proportions increases its compressive strength and arrest concrete cracks. Many researcher effect of steel fiber on bond slip behavior of fiber reinforced concrete is not entirely implicit. There are insufficient guidelines for bond behavior of reinforcing steel bars to fiber reinforced concrete and this one of the reason limiting their use in the practice. The proposed work bond strength of steel fiber reinforced concrete is investigated for concrete mixes M30 and M40 with 0%,0.5%,1.0%,and 1.5% steel fibers in concrete and reinforcing bar of diameter 12 mm. hooked end steel fibers with aspect ratio 50 are used in the experimental investigation. A series of 24 cubes and 40 pullout specimens are casted and tested for compressive test and bond strength respectively. The result shows that for concrete mix compressive strength of concrete increases with the increase in the content of steel fibers in the concrete. Also it is observed that for a grade of concrete bond strength decreases with the increase in steel fibers percentage in concrete. Almost all the pullout specimens failed in splitting mode.

Keywords— *Steel Fibers, Aspect Ratio, Reinforced Concrete, Bond Strength*

INTRODUCTION

Reinforced concrete is the most successful material used in construction industry. It is accepted as a structural material worldwide. Utility of reinforced concrete as a construction material is derived from the composite action that takes place between reinforcing bar and concrete. Utility of reinforced concrete as a structural material is derived from the composite action that takes place between reinforcing bar and concrete at their interface known as bond. For composite action to take place effectively, the bond must be adequate and efficient. Stronger the bond more will be the load carrying capacity and hence strength, durability and life span of a structural element. Thus bond affects the structural performance of reinforced concrete buildings. Bond strength of reinforced concrete varies with many parameters like compressive and tensile strength of concrete, curing condition, material grade, material properties, type of fibers added, concrete cover, bar diameter, bar geometry, confining reinforcement, embedment length of reinforcing bar in concrete, etc. Many researchers have investigated on bond strength and found that bond strength and bond failure pattern is influenced by variation of steel fiber in reinforcing bar in concrete. It is found that very less investigation is done on effect of especially varying dosage of steel fibres on bond strength. Hence more research is required to be done. In the proposed work effect of varying proportion of steel fibers on bond strength is investigated.

LITREATURE REVIEW

Farnoud Rahimi Mansour (2011) experimentally investigated on mechanical properties of SFRC with varying volume of steel fiber. A series of 108 specimens (cube and cylinder) with four different steel fiber volume by ratio of 0.0, 0.7, 1.0 and 1.5 were casted. Hooked end steel fibers of length 30mm and diameter 0.75mm, aspect ratio 40 were used. The cube dimension was 150mm x 150mm x 150mm and cylinder 150mm diameter x 300mm height used. OPC was used for the concrete mixed of 25 Mpa. Maximum coarse aggregate size was 10 mm. The specimens were cured and tested at 7, 14 and 28 days. They concluded that addition of steel fibers marginally reduces compressive strength and marginally increases tensile strength but a significant increase in flexural strength. They also found that addition of 1% of steel fiber gives best results.

Vikrant S. Vairagade (2012) experimentally investigated on Steel Fiber Reinforced Concrete on Compressive and Tensile Strength. They have casted cube (150mm x 150mm x 150mm) tensile as well as compressive strength and cylindrical (length 200 mm x diameter 100 mm) for tensile strength containing fibers of 0% and 0.5% volume fraction of hook end and crimped round Steel fibers of aspect ratio 50 , 53.85, 62.50 were used without admixture. OPC was used for the concrete mixed of 25Mpa.The specimens were cured and tested at 7 and 28 days. It was observed that at maximum aspect ratio gives maximum compressive and maximum tensile strength.

Hasan Sahan Arel (2012) effect on steel fiber on bond between concrete and steel deformed fiber in SFRCs. Steel fibers with l/d ratios of 60 and 80 were added to concretes designed in C20, C40, C60 classes in 10, 20, 30, 40, 60 and 80 kg/m3amounts. S420 deformed steel bars with 14mm diameter were embedded at 70mm bond length to cubic specimens prepared from the concrete produced with and without steel fiber enabling the concrete cover to be 40 55 and 70mm. The specimens were subjected to pull out test. Moreover, 28-days mechanical tests of the concrete produced were defined. The pullout loads are found to be increased by 7-16% when the amount of steel fibers and aspect ratio in SFRC increased as compared to concrete without steel fiber. And also found that compressive and tensile strength increased more efficiently with the use of steel fiber of 80 l/d ratio when compared to use of the steel fiber of 40 l/d ratios.

D.B.Mohite (2013) have investigated the Compressive strength using concrete mix of M70 grade and casting 150 specimens (cubes) of 150mm x 150mm x 150mm size with 0.0% to 4.0% hooked, flat, waving steel fibers at the interval of 0.5% by weight of cement and water curing is done for 7 and 28 days Ordinary Portland cement of 53 grade and natural sand and coarse aggregates 10mm and 20mm .They found that compressive strength of concrete increase with increase in fiber content. The maximum increase in compressive strength in concrete at maximum fibre content for flat shape fiber than waving shape and for hook end is less compared with both.

Anwar A. Alnaki (2013) experimentally investigated on Behavior of High Performance Pull-out Bond Strength of SFRC with varying volume of steel fiber and aspect ratio. A series of 30 pull-out bond half-cylinder specimens by using aspect ratio of Hook end steel fiber having 30, 60, 90 with four different fiber volume by ratio 0%, 1.0%, 2.0% and 2.5% were casted. The cylinder dimension was 150mm diameter x 150mm height and cube dimension was 150mm x 150mm x 150mm used. The maximum size of coarse aggregate is 12.5 mm and a water-cement ratio of 0.47 used. The specimens were cured and tested at 28 days. They also investigated that by increasing both volume and aspect ratio of steel fibers compressive strength and bond strength of SFRC is increases.

OBJECTIVES

The study consists following objective:

1. To investigate experimentally bond strength of steel fiber reinforced concrete with varying proportions of steel fibers in concrete for M30 & M40 grade of concrete.
2. To compare result of bond strength of steel fiber reinforced concrete with that of conventional concrete.

STEEL FIBER

Fiber reinforced concrete is a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Although every type of fiber has been tried out in cement and concrete, not all of them can be effectively and economically used. Each type of fiber has its characteristics properties and limitations. Some of fibers that could be used are steel fibers, polypropylene, nylons, asbestos, coir, glass and carbon. Generally, steel fibers are most commonly used fiber. Because of the vast improvements achieved by the addition of fibers to concrete, there are several applications where Fibers Reinforced Concrete (FRC) can be intelligently and beneficially used. These fibers have already been used in many large projects involving the construction of industrial floors, pavements, highway-overlays, etc. in India. These fibers are also used in the production of continuous fibers and are used as a replacement to reinforcing steel. High percentages of steel fibers are used extensively in pavements and in tunneling. This invention uses Slurry Infiltrated Fiber Concrete (SIFCON).

About two decades back, steel fiber reinforced shotcrete (SFRS) and steel fiber reinforced concrete (SFRC) were considered a new technology for the construction industry. However today this technology has found wider acceptance among the construction industry, currently, steel fibers are used in varied segments in many application areas across different segments in the construction industry, especially in tunneling, airports, warehouses, etc.

Generally steel fibers are classified as hooked shaped fiber, waving shape fiber, flat shaped fiber, and continuously deformed fiber.

HOOKED END STEEL FIBER

Features and Benefits of Hooked End Steel Fiber:-

1) Provide multi-directional concrete reinforcement.
2) Increase crack resistance, ductility, energy absorption or toughness of concrete.
3) Improve impact resistance, fatigue endurance and shear strength of concrete.
4) High tensile strength steel fibber bridging joints and crack to provide tighter aggregate interlock resulting increase load carrying capacity.
5) Provides increase ultimate load carrying capacity which allows possible reduction in concrete section.
6) Required less labour to incorporate into concrete than conventional reinforcement

Physical Properties of Hooked End Steel Fiber

Fiber length: 10 - 70mm

Fiber diameter: 0.25 - 1.00mm

Aspect ratio: 30 - 250

STEEL FIBRE REINFORCED CONCRETE (SFRC)

Concrete is the most widely used structural material in the world with an annual production of over seven billion tons. It has also been proved by extensive research and field trials carried out over the past three of steel fibers to conventional plain or reinforced and prestressed concrete members at the time of mixing/production imparts improvements to several properties of concrete, particularly those related to strength, performance and durability.

The weak matrix in concrete, when reinforced with steel fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete.

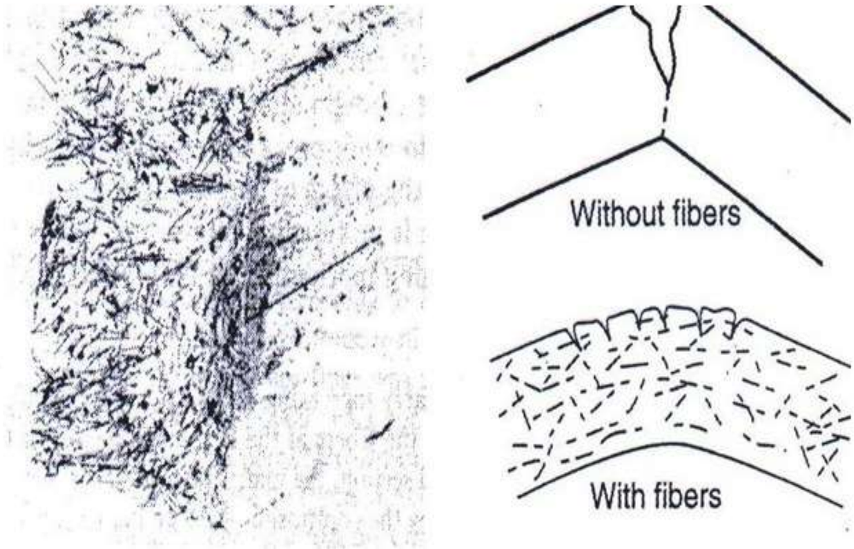


Fig. 1:Failure mechanism and the effect of fibers

Typical shapes of Fibers (Hooked Shaped Fiber) are given in Fig.2.

Fig. 2: Photograph of Typical shapes of fibers.

In general, SFRC is very ductile and particularly well suited for structures which are enquired to exhibit:-

i. Resistance to impact, blast and shock loads and high fatigue
ii. Shrinkage control of concrete (fissuration)
iii. Very high flexural, shear and tensile strength
iv. Resistance to splitting/spalling, erosion and abrasion
v. High thermal/ temperature resistance
vi. Resistance to seismic hazards.

The degree of improvement gained in any specific property exhibited by SFRC is dependent on a number of factors that include

a. Concrete mix and its age
b. Steel Fibre content
c. Fibre shape, its aspect ratio (length to diameter ratio) and bond characteristics.

Factors Controlling SFRC:-

a) Aspect ratio, l/d
b) Volume fraction, if
c) Balling of fibbers
d) Good mix design: more matrix, small aggregate, workable.

Advantages of SFRC over RCC:-

a. Fatigue and impact resistance increased.
b. Wear and tear resistance increased.
c. Joint spacing increased.
d. Thinner pavements possible due to higher flexural strength of SFRC.
e. Long service life with little or no maintenance.
f. Reduced consumption and savings in cost of materials makes pre-cast products competitive in price with cast iron or reinforced concrete products.
g. Products possess increased ductility and resistance to chipping and cracking.
h. Overall improvement in all structural properties.
i. Exhibits high ductile and toughness resulting in superior resistance to blast, impact and falling loads and missiles.

Applications of Steel Fiber

Steel Fiber Reinforced Concrete (SFRC) has been used in various applications throughout the world.

a. Overlays Roads, Airfields, Runways, Container, Movement and Storage Yards, Industrial Floors and Bridges
b. Pre-cast Concrete Products Manhole covers and Frames, Pipes, Break-Water Units , Building Floor and Walling Components, Acoustic Barriers, Kerbs, Impact Barriers, Blast Resistant Panels etc.
c. Hydraulic and Marine Structures Dams, Spillways, Aprons, Boats and Barges, Sea Protection Works
d. Defence and Military Structures Aircrafts Hangers, Missile and Weaponry Storage Structures, Blast Resistant Structure, Ammunition Production and Storage Depots, Underground Shelters, etc.
e. Shotcreting Applications Tunnel Linings, Domes, Mine Linings, Rock-Slope Stabilization, Repaint and Restoration Distresses Concrete Structures.

EXPERIMENTAL PROGRAM

The experimental program is designed to study bond strength of SFRC for varying percentage of steel fiber in concrete. The hooked end steel fibers with a constant aspect ratio of 50 are used. M30 and M40 concrete mixes are used in casting of the test specimens. Concentric pull-out specimens of 150 mm diameter and 200 mm height with 12 mm cast iron deformed bar embedded into the concrete for a length of 100 mm are casted and tested for bond strength. Cube specimens of 150 mm x 150 mm x 150 mm are casted for testing compressive strength of concrete.

MATERIALS

1. Reinforcing Steel:

12mm reinforcing TMT steel bars of yield strength 500 Mpa.

2. Cement:

Ordinary Portland cement of 53 Grade conforming to I.S- 8112-1989.

3. Sand:

Locally available natural sand conforming to IS: 383-1970

4. Coarse Aggregate:

Triangular, 20 mm and 10 mm conforming to IS: 2386 (Part III)-1963

5. Water:

Potable water is used for the experimentation.

6. Steel Fibres:

NOVOCON HE1050 Hook end Steel fibers are used.

PROPORTIONING OF PULLOUT SPECIMEN

The setup is prepared using a 25 mm-thick wooden base having thin metallic sheet which give smooth appearance to cylinder. Two holes are drilled in the wooden base to hold the wooden base to stool top by fixation of nut bolt system and one hole is drilled in wooden base with a diameter of 12 mm and the centre of gravity is coincident with the centre of gravity of the circular mould base. This hole is drilled in order to support the bar when casting the specimen and allowed the embedded bar to extend 100 mm in cylinder which is placed and fixed over the wooden base.

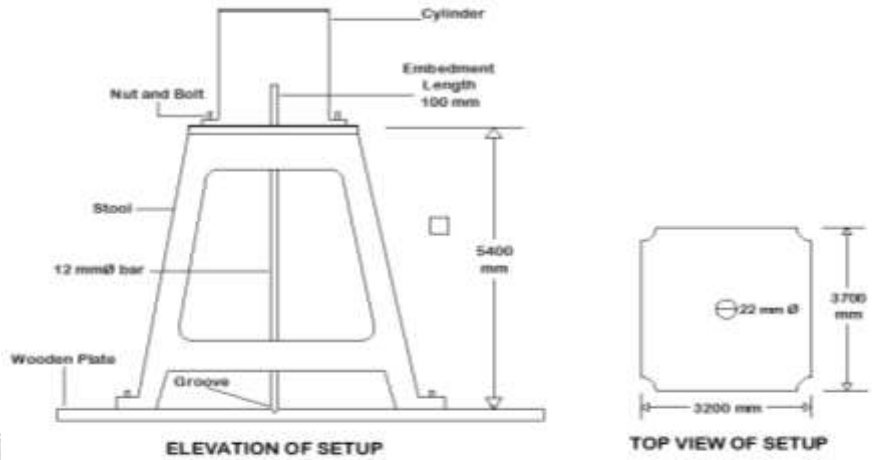


Fig.3 Dimensions of Pullout Setup

TESTING OF SPECIMENS

Pull out test:

The test specimen is mounted on a suitable testing machine means Universal Testing Machine in such a manner that the bar is pulled axially from the cylinder. The end of the bar at which the pull is applied shall be that which projects from the top fact of the cylinder as cast. The steel moulds of the control short cylinders are 200 mm in length and 150 mm in diameter. In assembling the testing apparatus on the specimen the distance between the face of the concrete and the point on the loaded end of the reinforcing bar at which the device for measuring slip is attached, shall be carefully measured so that the elongation of the bar over this distance may be calculated and deducted from the measured slip. The load shall be applied to the reinforcing bar at a rate 0.1KN/sec, depending on the type of testing machine used and the means provided for ascertaining or controlling speeds. The movement between the reinforcing bar and the concrete cube, as indicated by the digital micrometer is to be read a slip has occurred at the loaded end of the bar. The digital micrometer is to be read at the loaded and unloaded ends.

After 28 days curing, these cylinders are tested on Universal Testing Machine as per I.S: 2770 (Part I) – 1967. The failure load is noted. In each category, five cylinders are tested and their average value is reported.

The bond strength is calculated as follows:

Bond strength (MPa) = Failure load / cross sectional area.

RESULTS AND DISCUSSION

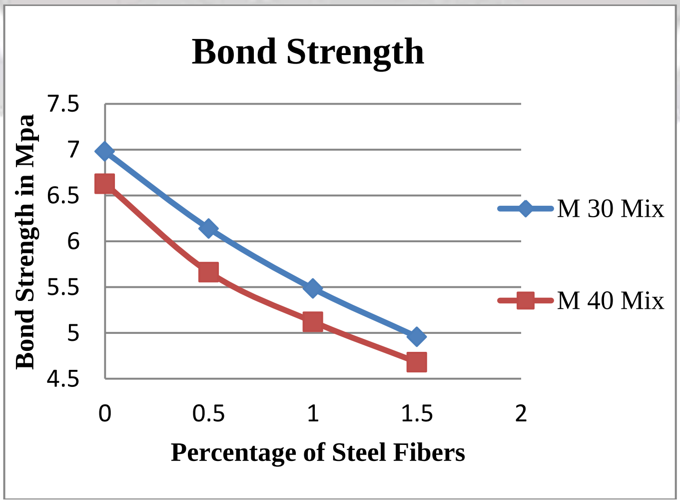
Results of Bond strength for M30 and M40 grade of concrete on pull-out specimen with 0%, 0.5%,1.0% and 1.5% steel fibers are shown in table 1and 2 and graph 1 below:

% of Steel Fibers	Bond Strength (Mpa)					
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Average
0	7.615	6.848	6.340	6.766	7.320	6.978
0.5	5.138	8.425	5.043	6.558	5.534	6.139
1.0	5.026	6.006	5.387	5.465	5.534	5.484
1.5	4.688	3.829	3.686	4.366	4.591	4.958

Table No. 1 Test results of Bond strength for M30 Concrete

% of Steel Fibers	Bond Strength (Mpa)					
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5	Average
0	5.543	6.041	7.159	8.156	6.226	6.628
0.5	5.606	5.273	6.059	5.694	5.701	5.662
1.0	5.116	5.118	5.121	5.126	5.128	5.122
1.5	4.468	4.938	4.342	4.788	4.868	4.681

Table No. 2 Test results of Bond strength for M40 Concrete



Graph No.1 Bond Strength for M30 and M40 Concrete

This graph indicates the comparison of result of bond strength using pull-out specimen of M30 and M40 grade of concrete. It is observed that for conventional concrete gives more bond strength than varying percentage of steel fibers at 28 days.

CONCLUSION

Following conclusions can be obtained from the present experimental work on effects of varying percentage of steel fibers to bond strength.

1. Addition of steel fibers reduces bonds strength of reinforced concrete.
2. The maximum decrease in bond strength compared with conventional concrete at 0.5%, 1.0% and 1.5% of fiber content are 12.02%, 21.41% and 28.95% respectively for M30 mix of concrete.
3. The maximum decrease in bond strength compared with conventional concrete at 0.5%, 1.0% and 1.5% of fiber content are 14.57%, 20.02% and 21.20% respectively for M40 mix of concrete.
4. Steel fibers enhanced the capacity of the matrix to hold together during post cracking stage, thus prevent spalling even at failure.
5. All the pullout specimens with SFRC failed in splitting mode.

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