Behavior of Bond Strength for Steel Fiber Reinforced Pavement

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Abstract-*Our project deals with an experimental and results obtained on the standard steel fiber reinforced concrete. The effects of these fibers on workability, density, and on various strengths of standard strength of concrete (M35 grade concrete) are studied. Present project emphasizes on the pullout strength of concrete. The fiber content varied from 0.5% to 2% by weight of cement at the interval of 0.5%. Concrete cubes of 150x150x150 mm with 20 mm bar embedded in concrete at the center of the cube were casted. All the specimens are water cured and tested at the age of 28 days. Workability of wet mix is found to be reduced with increased fiber content. Super plasticizer is used to increase the workability. Bond strength is determined.*

Key words- coarse aggregate, fine aggregate, cement, steel fiber, water.

1. INTRODUCTION

SFRC is a composite material made of cements, water, fine and coarse aggregate, and a dispersion of discontinuous, small fibers. These short discrete fibers are uniformly distributed and randomly oriented. They are mixed with concrete before pouring. The reinforced concrete structures are subjected to cyclic loads during dynamic loads such as earthquake shocks, traffic loads on the bridges, etc. It is well known that plain concrete is brittle and weak under flexural loads. To eliminate the disadvantages of plain concrete is added fibers into concrete mix. All admixtures meeting ASTM specifications for use in concrete are suitable for use in SFRC. Steel fiber-reinforced concrete (SFRC) has gained increased popularity in construction industries in recent years.

2. STEEL FIBER

Fibers are usually usedin concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types offibers produced greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to the concrete mix is expressed as a percentage of total volume of the composite (concrete and fibers), termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiberlength (l) by its diameter (d). fibers with a noncircular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fiber usually segments the flexural strength and the toughness of the matrix. However, fibers which are too long tend to the mix and create workability problems. Some recent research indicated that using fiber concrete has limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that the ductility increases when concrete is reinforced with fibers. The results also indicated out that the use of micro fibers offers better impact resistance compared with the longer fibers.Plain concrete pavements have low tensile strength and strain capacity, however these structural characteristics are improved by fiber addition, allowing reduction of the pavement layer thickness. This improvement can be significant and depends on fiber characteristics and dosage. The most significant influence of fiber reinforcement is to delay and control the tensile cracking of concrete. Therefore it is found to have significant impact on the pavement cost due to reduced thickness requirements, less maintenance costs and longer useful life. Comparing with the life cycle of an asphalt road, SFRC pavements have been reported to last twice as long.

The largest volume application of SFRC has been in airport pavements due to high and damaging loads. Steel fibers significantly improve the impact resistance of concrete making it a suitable material for structures subjected to impact loads. SFRC pavement eliminates spring load restrictions. It does not rut, washboard or shove as in asphalt roadways; and it provides fuel savings for heavy vehicles versus asphalt pavements . All the above factors suggest that SFRC pavements are the most beneficial pavement type from an engineering and economical prospective. On the other hand, the current high cost of steel fibers in many regions may not justify their use, despite the lower life cycle costs achieved due to reduced maintenance requirements. To facilitate the extended use of SFRC in pavement construction (especially in developing countries), it is necessary to develop alternative sources of low-cost steel fiber reinforcement.

- Fast and perfect mixable fibers and High performance

  and crack resistance
- Optimize costs with lower fiber dosages
- Steel fibers reinforced concrete against impact forces,

  Thereby improving the toughness characteristics

The different types of steel fibers based on their shapes are,

1. Straight
2. Hooked
3. Paddled
4. Deformed
5. Crimped
6. Irregular

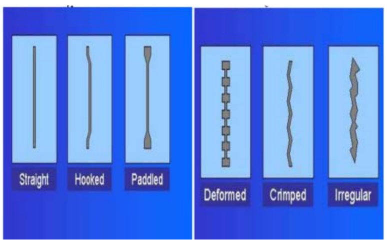

Fig 1: Types of Fiber

3. APPLICATION OF STEEL FIBER

- Highway and airfield pavements
- Hydraulic structures
- Fibershotcrete
- Refractory concrete
- Industrial floors
- Warehouses

4. METHODOLOGY

This chapter briefly explains the methodology adopted in this experimental work. The literature review is briefly studied related to our project and based on that the materials have been collected. In this first phase, the preliminary tests were conducted for various material properties, and using these properties, IS method was adopted for M35 grade concrete for computing control mix ratio. In these second phase, the mechanical characteristics of concrete such as bond strength behavior of reinforced concrete cubes by varying the length (30mm, 50mm)& percentage of steel fiber from 0%, 0.5%, 1.0%,1.5%, and 2.0% by weight of cement and fine aggregate for M35 grade concrete will be studied. Finally the results comparison and discussion has to be done for conclusion of our project.

5. MIX DESIGN

TABLE 1.STIPULATION FOR PROPORTIONING

1	Grade designation	M35
2	Types of Cement	OPC 53 grade
3	Maximum nominal size of aggregate	12.5 mm
4	Minimum cement content	280 kg/m^3
5	Maximum water cement ratio	0.50
6	Workability	100 mm (slump)
7	Exposure condition	Severe
8	Method of concrete placing	Normal pouring
9	Degree of supervision	Good
10	Types of aggregate	Crushed angular aggregate
11	Maximum cement content	450 kg/m^3

TABLE 2. TEST DATA FOR MATERIALS

1	Specific gravity of cement	3.09
2	Specific gravity of fine aggregate	2.604
3	Specific gravity of coarse aggregate	2.82
4	Water absorption of coarse aggregate	0.6%
5	Fine aggregate Zone	Zone II
6	Coarse aggregate	Aggregate conforming to IS 383:1970

TABLE 3. MIX PROPORTION FOR M35 GRADE CONCRETE

Cement	Fine aggregate	Coarse aggregate	water
1	2.02	2.34	0.4

6. TEST ON FRESH CONCRETE

A.General

To measure and ensure the workability of fresh concrete, tests have done on fresh concrete. Workability means degree of firmness and workability of fresh concrete is directly related to strength and durability of concrete. Every jobs requires a particular workability. Slump and compaction factor tests are most common tests to measure the workability of concrete.

B. Slump Value

Slump and compaction factor test are most common test used to measure the workability of concrete. Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 - 1959 is followed. The apparatus used for doing slump test are Slump cone and tamping rod. The slump test is the most widely, primarily because of the simplicity of the apparatus required and the test procedure. The slump test indicates the behavior of a compacted concrete cone under the action of gravitational forces. The test is carried out with a mould called the slump cone, and filled in three equal layers of fresh concrete, each layer being tamped 25 times with a standard tamping rod. The top layer is struck off level and the mould lifted vertically without disturbing the concrete cone. The slump measured should be recorded in mm of subsidence of the specimen during the test. Any slump specimen, whom collapses or shears off laterally, gives incorrect result and if this occurs, the test should be repeated with another.

The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould is then filled in four layers, each ~ 1/3 of the height of the mould, each layer being tamped 25 times with a standard tamping rod taking care to distribute the strokes evenly over the cross section. After top layer has been rodded, the concrete is struck off level with a trowel and tamping rod sample. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allowed concrete to subside. This subsidence is referred as slump of concrete. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. This difference in height in mm. and is taken as slump of concrete.

TABLE 4. SLUMP TEST VALUE

S.NO	Length of the fiber	Fiber content (%)	Slump value
1	No	0	7.8
2	30	0.5	7.7
3	30	1.0	7.3
4	30	1.5	7.1
5	30	2.0	6.9
6	50	0.5	7.6
7	50	1.0	7.5
8	50	1.5	7.3
9	50	2.0	7.0

7. COMPACTION FACTOR TEST

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete are in sensitive to slump test. Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 - 1959. The apparatus used is Compacting factor apparatus.

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap-door is opened so that the concrete falls into the lower hopper. Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. In the case of a dry-mix, it is likely that the concrete may not fall on opening the trap-door. In such a case, a slight poking by a rod may be required to set the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades supplied with the apparatus.

The outside of the cylinder is wiped clean. The concrete is filled up exactly up to the top level of the cylinder. It is weighted to the 10 grams. This weight is known as "weight of partially compacted concrete". The cylinder is emptied and then refilled with the concrete from the same sample in layers approximately 5cm deep. The layers are heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighted to the nearest 10gm. This weight is known as "weight of fully compacted concrete".

The Compacting factor = (Weight of partially Compacted concrete) / (Weight of fully Compacted concrete)

The weight of fully compacted concrete can also be calculated by knowing the proportion of materials, their respective specific gravities and the volume of cylinder. It is seen from experience, that it makes very little difference in Compaction factor value, whether the weight of fully compacted concrete is calculated theoretically or found out actually after 100 % compaction.

TABLE 5. COMPACTION FACTOR TEST VALUE

S.NO	Length of the fiber	Fiber content (%)	Compaction factor value
1	No	0	0.86
2	30	0.5	0.87
3	30	1.0	0.87
4	30	1.5	0.88
5	30	2.0	0.89
6	50	0.5	0.79
7	50	1.0	0.88
8	50	1.5	0.83
9	50	2.0	0.85

8. TEST ON HARDENED CONCRETE

A Bond Strength Test :

To study the effect of fibers on interfacial bond strength between the matrix and the reinforcing bar (rebar) was performed. The bond strength test was carried out on cubes of 150mm size with 20mm diameter of steel bar of length 1000mm was embedded in each test specimen on to a depth of 150mm at the center. The bar is pulled out with the help of Universal Testing Machine.

The pull-out tests were performed at a specimen age of 28days. All the specimens were tested up to failure of bar matrix interfacial bond. All the specimens failed with vertical crack along the embedded length of bar with cracking sound.

The bond strength and the pullout energy (maximum work done during de-bonding of bar and the matrix) have been calculated from the test data and are presented in the Table 8.1 and 8.2.The bond strength was calculated by dividing the applied load, by the surface area of the embedded length the bar over the nominal diameter of bar. The pullout work was calculated for the slip at peak load.

The bond strength has been computed from the following expression:

$$f_p = P / \pi D L_e \qquad (1)$$

where
f_p = Pullout Strength (N/mm^2)
P = load (N)
D = embedment length (mm) and
L_e= diameter of the rebar (mm)
Experimental results and results of regression analysis at 28 days are presented in Table 8.1 and 8.2. Expression for Pullout strength in terms of V_f (% fiber) at 28days from Journal comprehensive study of high strength fiber reinforced concrete under pull out strength, Prof. R.M. Sawant,
for 28 days

$$f_p=-0.298V_f^2+1.581V_f+12.58 \qquad (2)$$

Fig 2 : BOND STRENGTH TEST

TABLE 6.BOND STRENGTH VALUE FOR 30 mm FIBER

Length of the fiber	Fiber content (%)	Pull out strength in N/mm^2		
		Experimental value	From equation (2)	Average experimental value
		28 Days strength		
-	0	12.328	12.58	12.471
		12.456	12.58	
		12.629	12.58	
30	0.5	13.657	13.296	13.440
		13.154	13.296	
		13.521	13.296	
30	1.0	13.964	13.863	13.782
		13.638	13.863	
		13.745	13.863	
30	1.5	14.022	14.281	14.268
		14.294	14.281	
		14.489	14.281	
30	2.0	14.236	14.55	14.505
		14.547	14.55	
		14.734	14.55	

TABLE 7.BOND STRENGTH VALUE FOR 50 mm FIBER

Length of the fiber	Fiber content (%)	Pull out strength in N/mm^2		
		Experimental value	From equation (2)	Average experimental value
		28 Days strength		
-	0	12.328	12.58	12.471
		12.456	12.58	
		12.629	12.58	
50	0.5	12.835	13.296	12.686
		12.578	13.296	
		12.645	13.296	
50	1.0	13.329	13.863	13.362
		13.292	13.863	
		13.467	13.863	
50	1.5	13.835	14.281	13.759
		13.764	14.281	
		13.678	14.281	
50	2.0	14.425	14.55	14.280
		14.328	14.55	
		14.267	14.55	

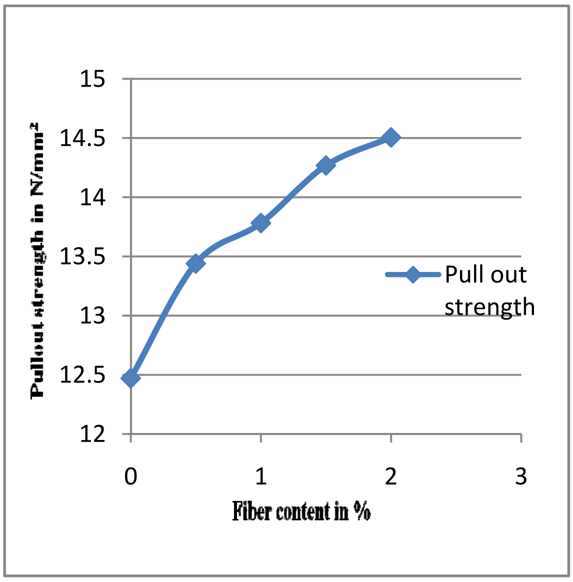

Fig 3: BOND STRENGTH VALUE FOR 30mm STEEL FIBER

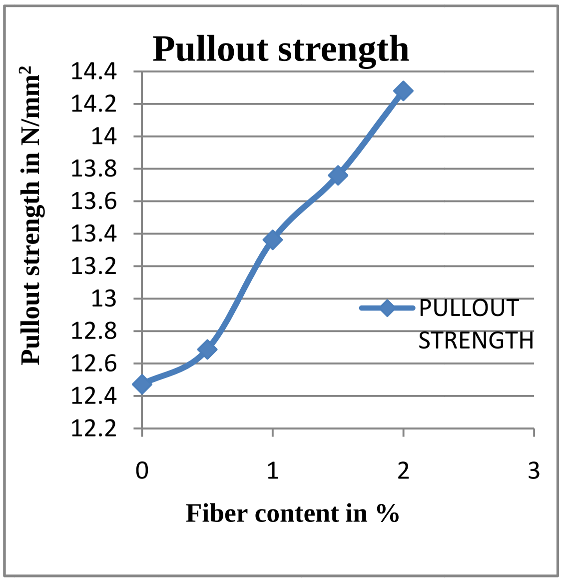

Fig 4 :BOND STRENGTH VALUE FOR 50mm STEEL FIBER

9. CONCLUSION

In this project, we used 30 mm and 50mm length undulated steel fiber of various proportions such as 0% ,0.5%,1%,1.5%,2%. The following conclusions are obtained

- The pullout strength increase for 30mm fiber (2% fiber content) more than 50mm fiber (2% fiber content)
- All the specimens failed with vertical crack along the embedded length of bar with cracking sound.
- While testing plain cement concrete cube, spalling of concrete is observed. However, it is not observed in SFRC cubes due to randomly distributed fibers.
- The vertical crack width of cracks is found to vary between 1.16mm and 2.48mm.
- In general, the significant improvement in Pullout Strengths is observed with the inclusion ofsteel fibers in the plain concrete. However, maximum gain in strength of concrete is found to be depend upon the amount of fiber content.

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