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EFFECT OF DIFFERENT POSITION OF STEEL FIBERS ON STRENGTH OF CONCRETE

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Abstract — Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at tension end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of creaks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail. The formation of cracks is the main reason for the failure of the concrete. To overcome this and to increase the strength of concrete many attempts have been made. One of the successful and most commonly used methods is providing steel reinforcement. Fiber reinforcement gives the solution for this problem. In this paper we have used steel fibers, which are straight and circular in shape and placed in different forms (i.e. Horizontal and vertical). The aim of paper is to steel fibers with different positions as fiber reinforcement to concrete. Our objective is to add the steel fibers of 1mm guage diameter to the concrete and to study the strength properties of concrete with the variation in fiber position. i.e., to study the strength properties of concrete (M20 Grade) for fiber content of 1.0% by weight at 7days and 28days. The compressive strength being studied in our paper. And then this compressive strength compared with plain concrete.

Keywords: Compressive Strength, Fiber Reinforced Concrete, Steel Fibers.

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INTRODUCTION

Concrete is composite material containing hydraulic cement, water coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at tension end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of creaks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail.

The formation of cracks is the main reason for the failure of the concrete. To overcome this and to increase the strength of concrete many attempts have been made. One of the successful and most commonly used methods is providing steel reinforcement. Fiber reinforcement gives the solution for this problem.

So to increase the strength of concrete a technique of introduction of fibers in concrete is being used. These fibers act as crack arrestors and prevent the propagation of the cracks. These fibers are uniformly distributed and randomly arranged. This concrete is named as fiber reinforced concrete. The main reasons for adding fibers to concrete matrix is to improve the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material. The initial researches combined with the larger volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of fiber Reinforced Concrete.

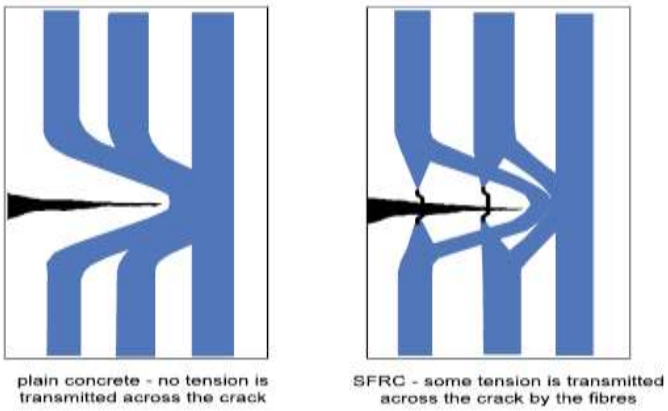


Fig 1.1: Stress Lines in concrete Under Tension

The main reason for incorporating steel fibers in concrete is to impart ductility to an otherwise brittle material. They enable concrete to continue to carry load after cracking has occurred, the so called post crack behavior, or toughness as shown in fig 1.1

LITERATURE REVIEW

B. Setti, M. Taazount, S. Hammoudi, F. Setti, M. Achit-Henni[1] (August 2013) This study relies on an experimental study conducted to examine compressive, flexural and abrasion resistance of steel fiber reinforced concrete specimens. The used Steel Fibers (S.F) are curved steel elements with a length to diameter ratio equal to 67. Concrete is made of local materials. The steel fiber contents examined are 0.5%, 1% and 1.5%. The purpose of this research is to investigate the mechanical performances of steel fibers reinforced concrete regarding compressive strength, flexural strength, mechanical abrasion and ductility according to the specimen age. The experimental results show a significant improvement in the mechanical behavior of the SFRC specimens in comparison with plain concrete without reinforcement. In this paper authors conclude that, Steel fibers also increase the abrasion resistance of SFRC materials. The optimal SF content to reduce the effect of abrasion is close to 1%.

Kavita S Kene, Vikrant S Vairagade and Satish Sathawane[2] (December 2012) In this research paper authors observed that, The addition of these fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and impact strength of concrete. FRC has found many applications in civil engineering field. Based on the laboratory experiment on fiber reinforced concrete (FRC), cube and cylinders specimens have been designed with steel fiber reinforced concrete (SFRC) containing fibers of 0% and 0.5% volume fraction of hook end Steel fibers of 53.85, 50 aspect ratio and alkali resistant glass fibers containing 0% and 0.25% by weight of cement of 12mm cut length were used without admixture. Comparing the result of FRC with plain M20 grade concrete, this paper validated the positive effect of different fibers with percentage increase in compression and splitting improvement of specimen at 7 and 28 days, analyzed the sensitivity of addition of fibers to concrete with different strength.

Vikrant S Vairagade, Kavita S. Kene, Tejas R Patil[3] (May 2012) This paper deals with Experimental investigation for M-20 grade of concrete to study the compressive strength, and tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0% and 0.5% volume fraction of hook end steel fibers. A result data obtained has been analyzed and compared with a control specimen (0% fiber). A relationship between Compressive strength vs. days, and tensile strength vs. days represented graphically. Result data clearly shows

percentage increase in7 and 28 days Compressive strength and Tensile strength for M-20 Grade of Concrete. It is observed that the compressive strength for M20 grade of concrete from two different dimensional fibers at same volume fraction shows nearly same results with minor increase. By addition of 0.5% hook end steel fibers increases compressive strength of concrete up to 10%.

Ashish Kumar Parashar, Rinku Parashar[4] (July- August 2012) This paper in essence present study revealed the effect of size of fibers on compressive strength of M-20 concrete mix design. In this study it was concluded that the 28 days compressive strength of concrete mixed (M20), containing Steel Fiber in varying percentage of steel Fiber (viz. 5% & 10%) was slightly less than the strength of Plain Cement Concrete. But it was possible to increase other properties of concrete like durability, cracking resistance, fire resistance property etc. The present study showed that compressive strength increased when we allow more than 10 % with size 30mm & 50mm long Steel Fibers were used. The present study indicates that to increase compressive strength of concrete when the steel fiber from bicycle spokes were used. For making higher strength at nominal mix proportion by allowing 25%, 50 mm long Steel Fiber in Plain M-M-20 grade of concrete & save the cement quantity.

FAISAL FOUAD WAFA[5] This paper describes the different types of fibers and the application of FRC in different areas. It also presents the result of research about the mechanical properties of FRC using straight as well as hooked steel fibers available in the region, No workability problem was encountered for the use of hooked fibers up to 1.5 percent in the concrete mix. The straight fibers produce balling at high fiber content and require special handling procedure. Use of fiber produces more closely spaced cracks and reduces crack width. Fibers bridge cracks to resist deformation. Fiber addition improves ductility of concrete and its post-cracking load-carrying capacity. The mechanical properties of FRC are much improved by the use of hooked fibers than straight fibers, the optimum volume content being 1.5 percent. While fibers addition does not increase the compressive strength, the use of 1.5 percent fiber increase the flexure strength by 67 percent, the splitting tensile strength by 57 percent, and the impact strength 25 times.

Jacek Katzer, Ph.D.[6] It is steel fiber which is mainly used to reinforce concrete and overcome the problem of brittleness. This paper describes the most interesting applications of steel fiber reinforced concretes (SFRC) all over the world. Firstly, the author presents the evolution of steel fibers and SFRC. Secondly, the paper covers the contemporary importance of SFRC in civil engineering. Over 40 years ago, Romualdi, Baston, and Mandel published the papers (Romualdi & Baston 1963, Romualdi & Mandel 1964) that brought SFRC to the attention of academic and industrial research scientists around the world. In the ensuing four decades, SFRC has been

constantly examined and its technology was continually developed. Today, SFRC is a commercially available and viable construction material.

EXPERIMENTALWORK

In order to study the interaction of Steel fibers (straight fiber) with concrete under compression 24 cubes were casted respectively. The experimental program was divided into four groups. Each group consists of 6 cubes of 15x15x15cm respectively, 3 cubes for 7 days testing and 3 cubes for 28 days testing.

a) The first group is the consists of Plain concrete with 0% fiber (PCC).

b) The second group consisted of 1% of Steel fibers (straight fiber), placed horizontally with aspect ratio 75, by weight.

c) The fourth group consisted of 1% of Steel fibers (straight fiber), placed vertically with

Aspect ratio - by weight.

MATERIALS =

- **CEMENT,** ordinary Portland cement

43 grades

- **FINE AGGREGATES,** Robo sand 0–4.75 mm
- **COARSE AGGREGATES,** retained on I.S Sieve No.480 4.75mm
- **WATER,** . In this experiment adopted 0.5 water-cement ratio.
- **FIBERS,** Steel Straight Fibers.

PROPERTY	VALUES
Steel fiber is used in	1% by weight
concrete	1mm
Steel fiber diameter (d)	130 mm
Fiber length (L)	75
Aspect ratio (L/d)	1.25gm
Weight of one steel bar	81 gm.
For one block, weight of steel	64 No’s

fiber	0.55 to 1 mm
No. of bar for 1 block	
diameters range	

➢ **FOR M20 GRADE OF CONCRETE (1:1.5:3)**

MATERIALS REQUIRED FOR A BATCH OF M20 GRADE

CONCRETE:

1- Weight Calculations:

Weight of one cube- =0.15×0.15×0.15×24 = 0.081 KN

= 81.00 N

=8.1 Kg

2- Quantity Calculations:

For one block-

Cement required = 1.5 Kg

Fine Aggregate = 2.25 Kg

Coarse Aggregate = 4.5 Kg

Water required = 0.5 x cement content

= 0.5 x 1.5

= 0.75 liters.

For three block-

Cement required = 4.5 Kg

Fine Aggregate = 6.75 Kg

Coarse Aggregate = 13.5Kg

Water required = 0.5 x cement content

= 0.5 x 4.5

= 2.25 liters.

3- Fiber Quantity Calculations:

In this experimental investigation straight steel fiber placed horizontally and vertically.

For one cube-

Steel fiber used- 1% by weight

Weight of one steel bar- 1.25 gm.

For one block, weight of steel- 81gm.

Fiber

No. of bar for 1 block- 64 No.

- **MIXING OF SPECIMEN:**

Hand mixing is adopted throughout the experimental work. First the materials cement, fine aggregate, coarse aggregate, steel (straight) fibers weighed accurately as per the above mentioned calculations. The sand is laid in a layer of approximately 10cm thick. Then cement is added to the sand and mixed thoroughly to get a uniform colour. The coarse aggregate is spread on the ground and then the cement-sand mixture is mixed with it to get a uniform matrix.

Fig 1.2 - Mixing of Specimen

- **CASTING OF SPECIMENS:**

In this experimental work the specimens casted in four types-

a) Conventional Concrete- For casting the cubes, moulds of size 150x150 cubes, are used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before the concrete is poured into the moulds. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Then the mould is placed on the table vibrator for a small period. Excess concrete is removed with trowel and top surface is finished to smooth level

b) Concrete with steel fiber placed horizontally-The above procedure is same for this type, only the difference is that after mixture is prepared for pouring into mould, firstly poured concrete layer up to 2.25cm of cube. Placed straight steel fiber in a horizontal way. Again pouring concrete layer up to 1.5cm above that. For whole cube kept spacing @1.5cm. In this way in one layer there is 8 steel fibers is used and total is 64 no.

Fig 1.3- Concrete with steel fiber placed horizontally

c) Concrete with steel fiber placed vertically- Concrete mixture is poured half of cube after that placed steel fiber vertically with the help of thread. Poured again concrete layer up to top of cube.

Fig 1.4 - Concrete with steel fiber placed vertically

Description of Horizontal and Vertical type-

For one block-

Spacing between fiber- 1.5cm

Spacing between layer- 1.5cm

No. of concrete layer- 9 no.

No. of steel fiber layer- 8 no.

- **CURING:**

After casting the molded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients. After this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 7days and for 28days in the present work.

Fig 1.5- Curing

- **TEST ON HARDENED CONCRETE:**

Compressive strength test:

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties concrete are qualitatively related to its compressive strength. In this experiment the compression test is carried out on specimens cubical in shape. For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm for M20 grade of concrete. The moulds were filled with conventional concrete and 1% steel fiber of three types. Vibration was given to the moulds using table vibrator. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7 days and 28 days. After 7 and 28 days curing, these cubes and cylinders were tested on digital compression testing machine

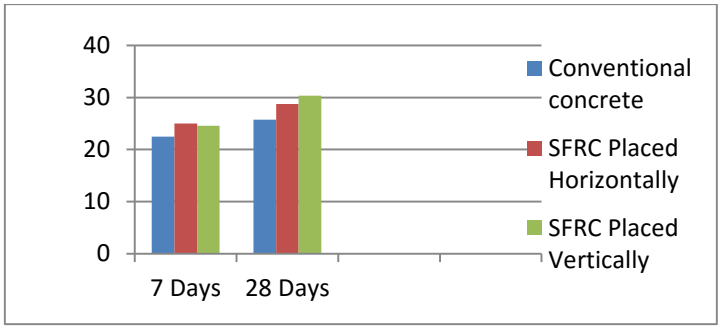
Compressive strength (MPa) = Failure load / cross sectional area.

Fig. 1.6 "Testing of compressive strength test specimen

RESULTS:

S.N	Type of Concrete	7 Days		28 Days	
		Average Load (KN)	Average Compressive Strength (N/mm²)	Average Load (KN)	Average Compressive Strength (N/mm²)
1.	Conventional Concrete	506.67	22.51	710	31.55
2.	SFRC Placed Horizontally	563.33	25.03	535	23.81
3	SFRC Placed Vertically	553.33	24.590	683.33	30.36

COMPRESSION TEST VALUES OF M20 GRADE



Graph 1- Comparison of convention concrete with SFRC Placed Horizontally and vertically.

DISCUSSIONS:

- Comparing the compressive strength of plain concrete and fiber reinforced concrete in which
- Steel fiber placed at different position after 7 days of curing.

Plain Concrete (N/mm²)	Steel Fiber Reinforced Concrete (N/mm²)	Percentage Increase in Strength
22.51	Placed Horizontally 25.03	11.195
	Placed Vertically 24.590	9.240

- Comparing the compressive strength of plain concrete and fiber reinforced concrete in which steel fiber placed at different position after 28 days of curing.

Plain Concrete (N/mm²)	Steel Fiber Reinforced Concrete (N/mm²)	Percentage Decrease in Strength
	Placed Horizontally	24.53

	23.81	
31.55	Placed Vertically 30.36	3.771

CONCLUSIONS

It is observed that after **7 days** –

- By placing steel fibers horizontally, the compressive strength of concrete increases by **11.19%**
- By placing steel fibers vertically, the compressive strength of concrete increases by **9.24%**

It is observed that after **28 days** –

- By placing steel fibers horizontally, the compressive strength of concrete increases by **11.48%**
- By placing steel fibers vertically, the compressive strength of concrete increases by **18.91%**

For above it has been concluded that, after 7 days steel fibers placed horizontally gives maximum compressive strength and after 28 days steel fibers placed vertically gives maximum compressive strength for concrete. So it is considered as optimistic.

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