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Experimental Study to Check Effectiveness of Stirrups and Steel Fibers as Shear Eeinforcement

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Abstract-The present study is carried out for evaluating the influence of steel fibers on cracking, deformation and shear strength of M_{20} grade reinforced concrete beams. This paper presents the results of compression test, split tensile test, shear test on beams which were casted with various percentage of steel fibers 0%, 1% and 3% and aspect ratio 30 and 50.Out of 48 beams sixteen beams were casted with nominal stirrups, sixteen without stirrups and remaining with maximum stirrups at the ends of beams. Results clearly indicated that with increase in % of steel fibers compressive strength, tensile strength and shear strength of beam increases and also crack width reduces.

Index Terms - *Shear* strength; Steel Fibers; Aspect Ratio.

1. INTRODUCTION AND LITERATURE REVIEW

Concrete is a composite material which mainly consists of aggregates, binding agents, additives, Admixtures etc. The Properties of hardened concrete is most important as far as load carrying capacity and deformation of structure is concerned. The properties in which concrete is weak can be improved by addition of steel fibers to concrete mix and such concrete is called steel fiber reinforced concrete. Various types of fibers like steel fibers, Polypropylene fiber, Glass fiber, Asbestos fiber, carbon fiber etc. are available in market for different kind of applications. There are many civil engineering applications in which the use of steel fiber reinforced concrete increased like precast members, transport tracks, industrial floor slabs, foundations under dynamic loading, concrete pipes, stabilization of banks and slopes, high security buildings like nuclear power plants, steel concrete columns etc. A method of predicting tension stiffening with the presence of steel fibers and the transfer of tension across the cracks after the yielding of reinforcing bars is proposed [1].After yielding of the reinforcing bars, only those specimens containing steel fibers showed increases in loads with increase strains. The experimental results of steel fiber reinforced concrete specimens subjected simultaneously to compressive and tensile stress indicated that there was a significant increase in uniaxial and biaxial tensile strength [2]. Impact and compression tests were carried out on concrete cylinders reinforced with 60, 75 and 83 aspect ratio of hooked end steel fiber with four different percentages of steel fibers (0.5%, 1%, 1.5%, 2%) by volume of concrete. Impact resistance of HSFRC with a fiber volume percentage of 2% and aspect ratio 83 increased about 74 times compared to that of plain concrete [3]. A study on properties of steel fiber reinforced shortcrete at early age indicated that three dimensionally distributed steel fibers can reinforce both shear failure and splitting failure greatly at early age while in long term steel fibers have no influence on the duration at peak load [4].An experimental program was conducted to obtain fatigue lives of SFRC at various stress levels on beams under four point load flexural fatigue loading. The coefficients of the fatigue equation have been determined corresponding to different survival probabilities so as to predict the flexural fatigue strength of SFRC for the desired level of survival probability [5].The effect of inclusion of steel fibers on the behavior of high strength concrete beams was investigated .The addition of steel fibers enhanced the strength and increases the ductility and flexural stiffness of tested beams[6].High strength fiber reinforced (singly reinforced) without shear reinforcement beams were subjected to combined shear and flexure. Based on the test results two modified equations were proposed to predict shear strength of high strength fiber reinforced beams without stirrups [7]. SFRC concept is well known in india. Some of the major projects carried out with positive contribution of SFRC are Uri Hydropower Project(river Jhelum in Jammu and Kashmir), Srisailam Project (river Krishna at Srisailam in Andhra Pradesh0, and Sardar Sarovar Project (river Narmada in Gujarat). There are many advantages of SFRC like Easy and simple to use, increases load bearing capacity of foundation, increases durability of structure, high fatigue and impact resistance, provides ductility, increases shear strength etc.

2. EXPERIMENTAL STUDY

2.1. *Material Used*

2.1.1. Cement

Ordinary Portland cement (Sanghi-53 Grade) Confirming IS 12269:1987[8] was used in present study with properties listed in Table 1

Table1.Properties of OPC 53 grade SANGHI cement

Sr. No.	Properties	Results
1	Loss of Ignition	1.56
2	$\%SiO_2$	19.70
3	% CaO	63.44
4	Specific Gravity	3.15
5	% Normal Consistency	29.5
6	Specific Surface(m^2/kg)	306
7	Initial Setting Time (minutes)	145
8	Final Setting Time (minutes)	185
9	Compressive Strength(MPa) 3days 7days 28days	 37.5 48.5 63.0

2.1.2. Coarse aggregate

Crushed angular aggregates confirming IS 383:1987[9] with maximum size of 20mm and 10mm was used having bulk density of 1600 kg/m^3.The specific gravity was found to be 2.87.

2.1.3. Fine aggregate

River sand from local sources confirming IS 383:1987[9] was used as fine aggregate. The fineness modulus and specific gravity were found to be 2.64, 2.84.

2.1.3. Water

Fresh potable water free from acid and organic substances was used for mixing and curing the concrete.

2.1.3. Steel Fibers

The steel fibers used in this study were DRAMIX. These fibers were made of hard drawn steel wires intended for concrete and mortar reinforcement which was purchased from NINA INDUSTRY, BOMBAY.

2.2. *Mix Proportion*

The Mix Proportion shown in Table 2 was made for a concrete with a compaction factor of 0.96 and M_{20} grade as per method given by IS 10262-1982 [10].

Table3.Mix Design Detail

W/C ratio	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate(kg)		Water (Litre)	% Steel Fiber
			20mm	10mm		
0.48	390	600	863	406	188.8	1% (24.48kg/m^3)
0.48	390	600	863	406	188.8	1% (73.36kg/m^3)

2.3. *Casting and Curing*

Mixing of ingredients was done according to specifications given in IS 516:1959[11] by machine mixing. The concrete was filled into the moulds in layers approximately 5cm deep and compacted by vibrator. The specimens were removed from mould after 24 hours and were kept submerged in curing tank. After curing for a period of 7 and 28 days, specimens were taken out and dried before testing.

2.4. *Testing*

Specimens were tested to ascertain properties at 7 and 28 days by performing following Tests.

2.4.1. Compression Test

Compression Test on cubes of size 150 mm was conducted on the compression testing machine (Aimil, 2000kN capacity). The load on cube was applied at a rate 5.2kN/s upto the failure of specimen. Average compressive strength of three cubes was taken after 7 and 28 days curing.

2.4.2. Split Tensile Test

Split tensile test on cylinders of size 150mm diameter and 300mm height was conducted on the compressive testing machine (Aimil,2000kN) as per specifications given in IS 5816:1999[12].The load was applied at a rate of 1.8kN/s upto failure of specimen. Average Split Tensile Strength of 3 cylinders was taken after 7 and days.

2.4.3. Shear Strength Test

Beams of size 110mm×110mm×500mm with HYSD bars as main reinforcement with varying diameter 8,10,12,16 and 20mm were loaded under a central point load[13]. Deflections were measured at mid span of each specimen using dial gauge.

3. RESULTS AND DISCUSSIONS

Table 4 Shows the results of compression and split tensile test. From the results it can be seen that compressive strength of concrete increases with increase in fiber content. It can be also seen that when aspect ratio changes 30 to 5, the compressive strength also increases. The maximum compressive strength is obtained with aspect ratio 50 with 3% fibers. There is an increasing trend in the splitting tensile strength with increase in fiber content. At the highest fiber content with highest aspect ratio there was maximum increase in splitting tensile strength. It was seen that increase in splitting tensile strength is much higher than increase in compressive strength because of higher tensile strength of steel fibers. From the results shown in Table 5,6 and 7, at ultimate load the plain concrete specimen had a sudden failure leading to breaking on beam into two halve in to the line of application of load. There is no difference between first crack and failure crack. In case of reinforced beam with shear reinforcement there was shear crack formed starting from support and continued to center until beam failed. The beams failed with one main shear crack which was at 45^0 with some minor crack. In case of steel fiber reinforced concrete beam with shear reinforcement the failure was marked by multiple cracking rather than formation of single hair line crack. The failure pattern was changed from pure shear cracks to flexure shear crack. The steel fibers became effective after shear crack formed and continued to resist the principal tensile stress until the complete pull out of all fibers occurred at one critical crack.

4. CONCLUSSIONS

The following are the conclusions from the present study.

- From load v/s deflection curve it can be concluded that as compare to RCC beam, the SFRC beam can take more load and because of higher percentage of steel fibers, the shear strength also increases. With steel fiber volume increased from 1% to3%, the failure mode changes to a combination of shear and flexure failure.
- The steel fibers became effective in delaying the formation of cracks.
- With addition of more volume of steel fibers splitting tensile strength increases more compare to increase in compressive strength.
- With the provision of steel fibers ,percentage of steel can be reduced and increase in strength is obtained.
- After addition of steel fibers, the width of cracks reduces.
- The steel fiber can modify the brittle shear mechanism into a ductile flexure mechanism. thus allowing a larger dissipation of energy.

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Table 4.Compressive Strength and Split Tensile Strength of concrete

Sr. No.	Aspect Ratio	% of Steel fibers	Grade of Concrete	Compressive Strength MPa	Split Tensile Strength MPa
1	--------	-------	M_{20}	28	3.2
2	30	1%	M_{20}	30	4.0
3	50	1%	M_{20}	32	4.5
4	30	3%	M_{20}	32	5.2
5	50	3%	M_{20}	35	6.0

Table 5. Beams with maximum stirrups at supports with various % of steel Fibers

Sr. No.	Aspect Ratio	% of Steel fibers	a/d	V_{cr} kN	V_u kN	σ_{cr} MPa	σ_u MPa	Failure Mode
Beam 5a	-------	-------	2	45	57.5	4.31	5.5	Shear
Beam 5b	-------	-------	2	42.5	55	4.07	5.26	Shear
Beam 5c	-------	-------	2	47.5	57.5	4.55	5.5	Shear
Beam 10a	50	1%	2	56	62.5	5.36	5.98	Flexure/Shear
Beam 10b	50	1%	2	52.5	60	5.02	5.74	Flexure/Shear
Beam 10c	50	1%	2	57.5	62.5	5.5	5.98	Flexure/Shear
Beam 11a	30	1%	2	55	60.5	5.26	5.79	Flexure/Shear
Beam 11b	30	1%	2	53	57.5	5.07	5.5	Flexure/Shear
Beam 11c	30	1%	2	57.5	62	5.5	5.93	Flexure/Shear
Beam 16a	30	3%	2	60.5	64	5.79	6.12	Flexure/Shear
Beam 16b	30	3%	2	60	64	5.74	6.12	Flexure/Shear
Beam 16c	30	3%	2	60	65	5.74	6.22	Flexure/Shear
Beam 17a	50	3%	2	62.5	70	5.98	6.70	Flexure/Shear
Beam 17b	50	3%	2	60	67.5	5.74	6.46	Flexure/Shear
Beam 17c	50	3%	2	65	70	6.22	6.70	Flexure/Shear

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Table 6. Beams with nominal stirrups at supports with various % of steel Fibers

Sr. No.	Aspect Ratio	% of Steel fibers	a/d	V_{cr} kN	V_u kN	σ_{cr} MPa	σ_u MPa	Failure Mode
Beam 4a	-------	-------	2	42.5	52.5	4.07	5.02	Shear
Beam 4b	-------	-------	2	40	50	3.83	4.78	Shear
Beam 4c	-------	-------	2	45	52.5	4.31	5.02	Shear
Beam 8a	50	1%	2	55	64	5.26	6.12	Flexure/Shear
Beam 8b	50	1%	2	55	62.5	5.26	5.98	Flexure/Shear
Beam 8c	50	1%	2	57.5	65	5.5	6.22	Flexure/Shear
Beam 9a	30	1%	2	52.5	60	5.02	5.74	Flexure/Shear
Beam 9b	30	1%	2	53	62.5	5.07	5.98	Flexure/Shear
Beam 9c	30	1%	2	55	60	5.26	5.74	Flexure/Shear
Beam 14a	30	3%	2	56.5	63.5	5.41	6.08	Flexure/Shear
Beam 14b	30	3%	2	55	63.5	5.26	6.08	Flexure/Shear
Beam 14c	30	3%	2	57.5	60.5	5.50	5.79	Flexure/Shear
Beam 15a	50	3%	2	60.5	67.5	5.79	6.46	Flexure/Shear
Beam 15b	50	3%	2	57.5	65	5.50	6.22	Flexure/Shear
Beam 15c	50	3%	2	62.5	67.5	5.98	6.46	Flexure/Shear

Table 6. Beams without stirrups at supports with various % of steel Fibers

Sr. No.	Aspect Ratio	% of Steel fibers	a/d	V_{cr} kN	V_u kN	σ_{cr} MPa	σ_u MPa	Failure Mode
Beam 3a	-------	-------	2	40	47.5	3.83	4.55	Shear
Beam 3b	-------	-------	2	42.5	47.5	4.07	4.55	Shear
Beam 3c	-------	-------	2	40	45	3.83	3.83	Shear
Beam 6a	50	1%	2	52.5	60	5.02	5.74	Flexure/Shear
Beam 6b	50	1%	2	50	57.5	4.78	5.50	Flexure/Shear
Beam 6c	50	1%	2	55	62.5	5.26	5.98	Flexure/Shear
Beam 7a	30	1%	2	47.5	55	4.55	5.26	Flexure/Shear
Beam 7b	30	1%	2	45	55	3.83	5.26	Flexure/Shear
Beam 7c	30	1%	2	50	55	4.78	5.26	Flexure/Shear
Beam 12a	30	3%	2	55	60	5.26	5.74	Flexure/Shear
Beam 12b	30	3%	2	57.5	60.5	5.50	5.79	Flexure/Shear
Beam 12c	30	3%	2	52.5	60	5.02	5.74	Flexure/Shear
Beam 13a	50	3%	2	57.5	65	5.50	6.22	Flexure/Shear
Beam 13b	50	3%	2	60	65	5.74	6.22	Flexure/Shear
Beam 13c	50	3%	2	56	62.5	5.36	5.98	Flexure/Shear