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Experimental Investigation and Strength Improvement of Concrete by Using Steel Fibers

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ABSTRACT:

Concrete is the one of the world's most widely used construction material. When the concrete is weak in tension and brittle in nature which results in sudden tensile failure without warning. These failures can be reduced by using the steel fibers in concrete. These fibers are thin, short and distributed randomly throughout theconcrete member of different aspect ratios (L/d ratio). In this experiment an attempt is made in order to increase the strength and properties by adding steel fibers of different proportions 0%, 0.5%, 1.5%, 2.5% and 3.5%. In order to identify the mechanical properties of concrete various tests have been conducted like compressive strength, split tensile strength & flexural strength for M30 grade of concrete.

INTRODUCTION:

Portland cement concrete is made with coarse aggregate, fine aggregate, Portland cement, water and in some cases selected admixtures (mineral & chemical). In the last decade, construction industry has been conducting research on enhancing the properties of concrete; each additive product has its own specific effect on properties of fresh and hard concrete. So, we have to search for different fibers to increase the strength of concrete mix with changing the mix design procedure and considerations. We are adding the crimped steel fiber to the concrete in percentage wise. There are some research were done on crimped steel fibers which are very near to use them in concrete mix along with basic natural aggregates. In those researches we observed that these materials can be used in some extent percentages.

For analyzing this drawback, first we add the 0.5% of crimped steel fiber to the concrete later that we add 1.5% of crimped steel fiber and then 2.5% and 3.5% of crimped steel fiber respectively to know the optimum percentage which is to be added to the concrete. When mixing the concrete, observed that there is a proper bonding of crimped steel fiber materials with cement and other aggregates in concrete mix. And when compressive strength test, split tensile strength test& flexural strength test conducted after 28 days curing period on these cube, cylinder & prism samples, observed that there is increment in compressive strength, split tensile strength& flexural strength when compared to the conventional mix. The compressive strength test results of the cube, split tensile strength cylinder & flexural strength of prism samples having crimped steel fiber material and the conventional mix are as follows.

Table 1.1 Compressive, split tensile & flexural strength results when crimped steel fiber material used

S.No	Concrete mix	Average Compressive Strength (MPa)	Average split tensile strength (MPa)	Average flexural strength (MPa)
1	Conventional mix	38.34	3.22	6.26
2	Mix with 0.5% of steel Fiber	41.3	3.85	7.12

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1.1 Objective of the project:

The main objective of the project is reduce the cracks in the concrete structures like precast beams, columns, pipes and many other concrete structures. By increasing the tensile strength, we can reduce the cracks. Thereby, we can increase the strength in the concrete structures. By avoiding the cracks in buildings, they appear to be more appealing.

1.2 Scope of the project:

The main scope of project is the use of steel fibers in concrete where the usage of normal steel reinforcement will be reduced. In uneven settlement of cement concrete roads the bottom portion will subjected to tension, but it is plain concrete so it can't tolerate these stresses therefore they may give cracks and finally it leads to the entire road failure. In that case we can increase the tensile strength of concrete by introducing steel fiber reinforced concrete. Economical and easily available.

LITERATURE REVIEW

A.M Shende (2012):

In this experiment critical investigation for M-40 Grade of concrete having mix proportion 1:1.43:3.04 with water cement ratio 0.35. To study the compressive strength, flexural strength, split tensile strength of steel fibers reinforced concrete (SFRC) containing fibers of 0%, 1%, 2% and 3% volume of fraction of hooked train. The steel fibers of 50,60 and 67 aspect ratio were used. The result data obtained has been analyzed and compared with a control specimen (0% fibers). The optimum compressive, flexural and split tensile strengths obtained for the 3% of steel fibers added. Compared to 0%, 1%, and 2%. All the strength properties are observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 and 67, compressive strength increases from 11 % to 24% with addition of steel fibers. The flexural strength and split tensile strength increases for the 12 to 49%, 3 to 41% with addition of steel fibers [1].

Deepthi, Dumpa, Venatateswarulu (2016):

In this paper delay with the study of the effect of addition of wood waste ash (WWA) and crimped steel fiber (CSF) in concrete. The crimped steel fibers are various % will be used 0.1%, 0.5% 1.0% 1.5% on the addition of wood waste in concrete. The test would be conducted for compressive strength split tensile strength and flexural strength-for various proportions adding of crimped steel fibers and wood waste. In this experiment investigation was made to understand the behavior of concrete with addition of varying quantities of wood waste and crimped steel fibers. The compressive, split tensile strength & flexural strength will be increases to level 20% of wood waste and 0.75% of the crimped steel fibers and beyond these limits which its starts decreasing strengths [2].

Vijay M. M Shake, Rahul D. Pandit (2016):

This experimental study was carried out to assessment of mechanical properties of High Strength Fiber Reinforced concrete (HSFRC) for M90 grade High Strength Concrete (HSC) is made with appropriate cementations materials i.e. cement, fly ash, and silica by dot mix design method the crimped steel fiber volume fraction is used 0 to 4% of 0.5% internal. To investigate the strength properties of high strength fiber reinforced concrete composite with various volume fraction. Such as compressive strength, split tensile strength and bond strength. To compare the properties of these special controlled concrete with that of normal concrete. The experimental study and results are obtained. The maximum percentage increase in compressive strength at 3.5% of fiber volume fractions and split tensile strength is achieved at 3% of fibers volume fraction [3].

Mr. Vikram Vijay SinhBalgude (2014):

The experimental work is carried out to evaluate the shear strength of steel reinforced concrete deep beams without stirrups. The fiber fraction is varied as 0%, 1.5%, & 3.5%. The experimental results are compared with theoretical results obtained for empirical equations and design loads. In this test will be

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conducted for the steel fibers in concrete deep beams provides better crack is control and deformation characteristics of beams and effective shear resistance in deep beams [4].

AswaniSabu, Thomas Paul (2016):
Accordingly, it has been found that steel fibers give the maximum strength in comparison to glass and poly propylene fibers. In this experimental study two type of steel fibers namely hooked and crimped fibers are used. The volume of fractions is taken as 0.75%, 1.0%, & 1.25% and M30 grade is adopted. Cement has replaced with 25% of class F fly-ash. The primary focus is to compare the mechanical properties of concrete using both fibers. Various tests have been conducted for compressive test & flexural strength based on after 28th days and 56th days curing period studied. The compressive strength of hooked fiber increased by 5% with the addition of steel fibers 1.25% was found to be optimum and crimped fibers shaved little effect on compressive strength and 1% was found to be optimum. The split tensile strength for hooked fiber improved by about 10% and optimum was at 1.25% and crimped fibers also shaved an increase of about 9% till 1% and a gradual decrease after that. Flexural strength of hooked fibers at maximum is 1.25% and crimped fibers are at 1% [5].

MATERIAL AND THEIR PROPERTIES

Cement:
Cement is a fine material powder manufactured with very precise processes mixed with water. This powder transforms into a paste that binds and hardens when submerged in water. Cement is made by grinding together a mixture of lime Stone and clay which is heated at a temperature of 1450 ºc [6].

Calculation:
W1=Weight of cement =100gm
W2=Weight of residue on the sieve =7gm
Fineness of cement=

$$\frac{(W1-W2)}{100}\times 100\ \%$$

$$= \left(\frac{100-7}{100}\right)\times 100\ \%$$

$$= 93\%$$

Result:
The fineness of cement obtained after sieve = 93%.

Table 3. 1 Consistency of a cement test observations

Trail	Percentage of water by weight of cement	Penetration value
1	25%	3.7mm
2	26%	3.9mm
3	27%	4.2mm
4	28%	4.8mm
5	29%	5mm
6	30%	5.6mm

Table 3.2 Properties of cement

S.No.	Description	Test Result / Specifications
1	Grade used	53
2	Fineness of the cement	93%
3	Consistency	30%
4	Initial setting time	60min
5	Final setting time	240min
6	Specific gravity	3.15
7	Soundness	1mm

Coarse aggregate
Material which retained on 4.75 mm size classified as a coarse aggregate. For most works, 20 mm aggregate is suitable. The locally available aggregate having nominal size of 20mm was used.

Calculation:
Weight of saturated aggregate suspended in water with the basket=W1
Weight of basket suspended in water=W2
Weight of saturated surface dry aggregate in air =W3

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Weight of the oven dried aggregate=W4
Specific gravity=dry weight of aggregate /weight of equal volume of water = W4/W3-(W1-W2)

Result: Specific gravity of coarse aggregate = 2.86

Table 3.3 Properties of Coarse aggregate

S.No	Description	Test Results
1	Nominal size used	20mm
2	Specific gravity	2.86
3	Impact value	13.12%
4	Water absorption	0.2%

Fine aggregates:

Fine aggregate is a material such as sand, crushed stones or crushed gravel passing through 4.75 mm size. Locally available sand is used as fine aggregate in the concrete mix.

Table 3.4 Sieve analysis of fine aggregate test observation table

S.No	IS sieve no	Particle size	Weight Retained	% of retained	% of cumulative weights	% of finer
1	4.75 mm	4.75	15	1.5	1.5	98.5
2	2.36 mm	2.36	26	2.6	4.1	95.9
3	1.18 mm	1.18	33	3.3	7.4	92.6
4	600μ	0.6	126	12.6	20	80
5	300μ	0.3	493	49.3	69.3	30.7
6	150μ	0.15	280	28	97.3	2.7
7	75μ	0.075	19	1.9	99.2	0.8
8	Pan	Pan	8	0.8	100	0

Table 3.5 Properties fine aggregate

S.No	Description	Test Result
1	Sand zone	Zone- II
2	Specific gravity	2.62
3	Water absorption	0.8%

3.4 Addition of material (Crimped steel fibers):

Table 3. 6 Properties of steel fibers

S.NO	PROPERTY	VALUES
1	Equivalent Diameter, mm	0.15 to 1.00
2	Specific Gravity, kg/m3	7840
3	Tensile Strength, MPa	345 to 3000
4	Young's Modulus, GPa	200
5	Ultimate Elongation, %	4 to 10
6	Thermal Conductivity,1%	2.74
7	Aspect Ratio	50 to 100

MIX DESGIN

4.1 Design procedure:

The Bureau of Indian Standards recommended a set of procedure for design of concrete mix mainly based on the work done in national laboratories. The mix design procedure as per the Indian standard recommended method of Concrete Mix Design (IS 10262: 2009) as follows

4.1.1 Target Mean Strength:

The target mean strength at 28 days is given by
fck = fck + (t ×S)

Table 4.1 Assumed Standard Deviation (IS10262:2009 Table 1)

Grade of concrete	Standard Deviation
M 10	3.5
M 15	
M 20	4.0
M 25	

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Water - Cement Ratio (W/C):

Table 4.2 Maximum Water-Cement Ratio for different exposure conditions

Exposure Conditions	Maximum W/C ratio Plain concrete)	Maximum W/C ratio (Reinforced Concrete)
Mild	0.6	0.55
Moderate	0.6	0.50
Severe	0.5	0.45
Very Severe	0.45	0.45
Extreme	0.40	0.40

Table 4.3 Table for selection of water content

S.No	Nominal Max size of aggregate(mm)	Maximum Water content (W) (Kg)
1	10	208
2	20	186
3	30	165

Table 4.4 Minimum Cement Contents for different exposure Condition

Exposure Conditions	Minimum Cement Content (Kg per cum) (Plain concrete)	Minimum Cement Content (Kg per cum) (Reinforced Concrete)
Mild	220	300
Moderate	240	300
Severe	250	320
Very Severe	260	340
Extreme	280	360

Table 4.5 Volume of coarse aggregates per unit volume of total aggregates

Nominal Maximum size of Aggregates	Volume of Coarse aggregate per unit volume of total aggregate for different zones of fine aggregates			
	Zone IV	Zone III	Zone II	Zone I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

METHODOLOGY AND WORKABILITY

Types of mixes prepared:

Mix design was prepared for M30 grade. 20 mm nominal size of coarse aggregate and Zone – II sand is used for preparing conventional mix. Crimped steel fiber was taken and mixed with concrete. Different types of mixes were prepared by changing the percentage of addition of crimped steel fiber to the concrete with cement, coarse aggregate and fine aggregate. Total 5 types of mixes ware prepared along with conventional mix. 0%, 0.5%, 1.5%, 2.5%,and 3.5%, of crimped steel fiber is added to the concrete mix individually. The details of mix designations are as follows.

Table 5.1 Material percentages for different mixes

S no	Mix code	Cement (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Fiber	Description of concrete
			Sand	Coarse aggregate		
1	A_0	425.73	643.40	1214.41	0%	Normal Concrete
2	A_1	425.73	643.40	1214.41	0.5%	Additional with steel fiber concrete
3	A_2	425.73	643.40	1214.41	1.5%	
4	A_3	425.73	643.40	1214.41	2.5%	
5	A4	425.73	643.40	1214.41	3.5%	

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5.2 No. of specimens prepared:

Total 5 types of mixes are prepared as mentioned on above table and are decided to do compressive strength test for 7,14 and 28 days curing period. For each mix type 3 trails of cubes having dimension 150 x 150 x 150 mm are repared. Total no. of specimens prepared is 45. Total Cubes =5 (types of mixes) x 3 (curing periods) x 3 (cubes for each trail) = 45 cubes

Table 5.2 Specimens details for each mix

S.No.	Mix code	No. of cubes prepared for the curing period of		
		3 days	7days	28days
1	A_0	3	3	3
2	A_1	3	3	3
3	A_2	3	3	3
4	A_3	3	3	3
5	A_4	3	3	3
Total cubes prepared		15	15	15

Mixing Process:

All materials are weighed according to mix design and according to the different mix proportions. The aggregate were added into the mixer and mixed thoroughly till the aggregates mixed properly. Cement was added into the mixer and mixed until the mix was uniform. Water was added into the mixer slowly after the cement was placed. The concrete was mixed around 3 minutes. The concrete in the mixer was poured out and the fully mixed concrete is ready for the workability test.

5.5.1 Slump Test (IS 1199: 1959):

This test is performed on fresh concrete to know the workability of concrete i.e. to measure the flow of the concrete. Slump should be ranges from 25-120mm. For pumping and placing of concrete, slump should be range from 80-120mm. In order to increase the slump admixtures can be added.

FIG 5.6 Slump Test Apparatus

Slump Test results:

Table Slump values for different mixes

S.No	Mix Type	Slump (mm)
1	A0 (0%)	100
2	A1 (0.5%)	90
3	A2 (1.5%)	70
4	A3 (2.5%)	55
5	A4 (3.5%)	43

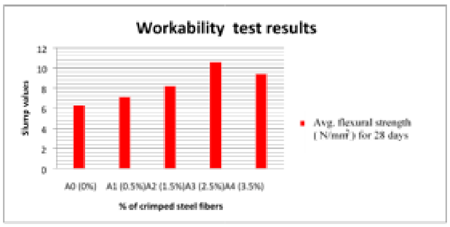

Chart: Slump values for different mixes

EXPERIMENTAL PROGRAMME

Compressive Strength Test (IS516:1959):

This test is a destructive method of testing to measure the compressive strength of the concrete. These tests are performing on hardened concrete cubes under CTM. Compressive strength test was conducted on concrete cubes of size 150 x 150 x 150 mm cast from concrete of each series, to check quality by obtaining the 7-days and 28-days compressive strength. The maximum compressive load on the specimen was recorded as the load at which the specimen failed to take any further increase in the load. The average of three samples was taken as the representative value of compressive strength.

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The compressive strength was calculated by dividing the maximum compressive load by the cross-sectional area of the cube specimen.

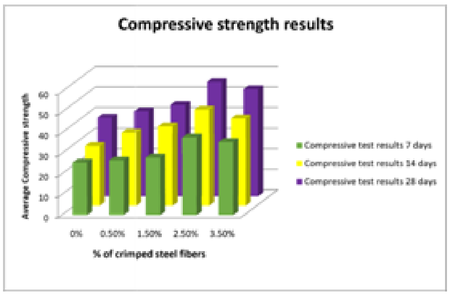

Chart 6.1 Compressive strength variations for different concrete mixes

Table: compressive strength test result

Mix type	TRAIL	Peak Load (KN)			Compressive Strength (N/mm²)			Avg Compressive Strength (N/mm²)		
		7 days	14 days	28 days	7 days	14 days	28 days	7 days	14 days	28days
A0	1	570	641	855	25.33	28.48	38	25.56	29.11	38.34
	2	573.7	655.9	862	25.49	29.15	38.31			
	3	582	668	877.8	25.86	29.86	39.01			
A1	1	595	786	919	26.44	34.93	40.84	26.67	35.55	41.3
	2	600	795	926	26.66	35.33	41.16			
	3	607	818.6	942.8	26.97	36.38	41.90			
A2	1	615	850	982	27.34	37.78	43.64	28.01	38.65	44.5
	2	633.8	875	1006	28.16	38.88	44.71			
	3	642	884	1015.8	28.53	39.28	45.14			
A3	1	832	1040	1240	36.97	46.22	55.12	37.78	46.76	55.67
	2	853	1051	1254	37.91	46.72	55.73			
	3	865	1065	1264	38.44	47.34	56.17			
A4	1	790	943	1163	35.12	41.91	51.68	35.56	42.47	52.12
	2	801	955	1173	35.6	42.44	52.14			
	3	810	969	1182	36	43.06	52.53			

6.2 Split tensile strength test: (IS 5816-1999)

For split tensile test, cylinder specimens of dimension 150mm diameter & 300mm length were cast. The specimens were de-moulded after 24 hours of casting and where transferred to curing tank wherein they were allowed to cure for 7,14 & 28 days. These specimens were tested under compressing testing machine. In each category 3 cylinders were tested and their average value is reported. Split tensile strength was calculated as follows as split tensile strength: Split tensile strength (MPa) = 2P/π DL, Where P= failure load, D= diameter of cylinder & L= Length of cylinder.

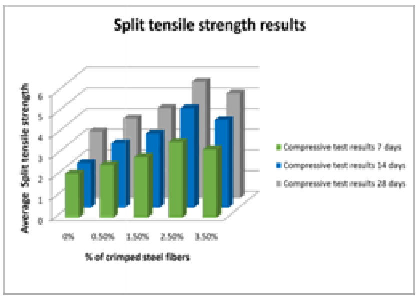

Chart 6.3 Split tensile strength variations for different concrete mixes

Table 6.2 split tensile strength test results

Mix type	T R A I L	Peak Load (KN)			Split tensile Strength (N/mm²)			Avg Split tensile Strength (N/mm²)		
		7days	14days	28days	7days	14days	28 days	7 days	14days	28 days
A0	1	140	170	214	1.98	2.40	3.02	2.12	2.16	3.22
	2	149	185	229	2.10	2.61	3.23			
	3	160	199	240	2.26	2.81	3.39			
A1	1	172	210	250	2.43	2.97	3.53	2.54	3.12	3.85
	2	178	219	278	2.51	3.09	3.93			
	3	189	233	289	2.67	3.29	4.08			
A2	1	195	241	294	2.75	3.40	4.15	2.92	3.58	4.35
	2	208	255	308	2.94	3.60	4.35			
	3	216	263	320	3.05	3.72	4.52			
A3	1	244	328	385	3.45	4.64	5.44	3.65	4.81	5.62
	2	260	339	397	3.67	4.79	5.61			
	3	270	353	410	3.81	4.99	5.80			
A4	1	225	282	340	3.18	3.98	4.81	3.29	4.24	5.06
	2	230	300	358	3.25	4.24	5.06			
	3	243	318	375	3.43	4.49	5.30			

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Flexural strength test: (IS 516-1959):

For flexural strength test prisms of dimension 100x100x500 mm were cast. The specimens were de-moulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 7,14 & 28 days. These flexural strength specimens were tested under two-point loading as per I.S 516-1959, over an effective span of 400mm on flexural testing machine. Load and corresponding deflections were noted up to failure. In each category three prism were tested and their average value is reported. The flexural strength was calculated as follows.

Flexurlal strength (MPa) = $(P \times L) / (b \times d^2)$
Where, P= Failure load, L = Centre to centre distance between the support = 400mm, b= width of specimen = 100 mm, d= depth of specimen = 100mm.

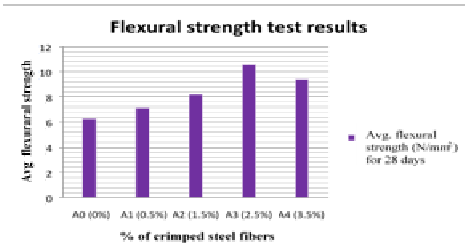

Chart 6.5 Flexural strength variations for different concrete mixes

Table 6.3 Flexural strength test results

Mix Type	Trail	Peak Load (KN)	Flexural Strength (N/mm^2) for 28 days	Avg Flexural Strength(N/mm^2)
	1	2075	6.22	
	2	2085	6.26	
A0 (0%)	3	2100	6.30	6.26
	1	2355	7.06	
	2	2375	7.12	
A1 (0.5%)	3	2390	7.17	7.12
	1	2720	8.16	
	2	2735	8.20	
A2 (1.5%)	3	2755	8.26	8.21
	1	3505	10.51	
	2	3520	10.56	
A3 (2.5%)	3	3535	10.60	10.56
	1	3115	9.34	
	2	3126	9.37	
A4 (3.5%)	3	3139	9.41	9.38

CONCLUSION:

After completion of total experimental methodology, from the above investigations and from the test results some variations observed in workability and compressive, split tensile & flexural strengths of different concrete mixes having different percentages of adding crimped steel fibers. It is observed that compressive, split tensile & flexural strengths are on higher side for 2.5% fibers compared to that produced from 0%, 0.5%, 1.5% & 3.5%. It is observed that compressive strength increases from 8% to 46% with addition of crimped steel fibers. It is observed that split tensile strength increases from 19% to 75% with addition of crimped steel fibers. It is observed that flexural strength increases from 13% to 69% with addition of crimped steel fibers. In this experiment it is observed that all the strengths are increased compared to normal concrete.

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