RESEARCH ARTICLE OPEN ACCESS

Strength Evaluation of Steel-Nylon Hybrid Fibre Reinforced Concrete

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ABSTRACT
When fibres like steel, glass, polypropylene, nylon, carbon, aramid, polyester, jute, etc are mixed with concrete known as fibre reinforced concrete. To overcome the deficiencies of concrete; fibres are added to improve the performance of concrete. In this research hybrid reinforced concrete is made by using steel and nylon 6 fibres. The inclusion of both steel and nylon 6 fibres are used in order to combine the benefits of both fibers; structural improvements provided by steel fibers and the resistance to plastic shrinkage improvements provided by nylon fibers. So the aim of this project is to investigate the mechanical properties (compressive strength, flexure strength and split tensile strength) of hybrid fiber reinforced concrete under compression, flexure & tension. The total volume of fibre was taken 0.75 % of total volume of concrete. In this experimental work, four different concrete mix proportions were casted with fibres and one mix without fibres. Four different mix combinations of steel- nylon 6 fibres were 100-00%, 75-25%, 50-50% and 25-75%. Superplasticizer was used in all mixes to make concrete more workable.
The results shown that compressive, split tensile and flexural strength of hybrid fibre reinforced concrete increase by increasing quantity of steel and nylon 6 fibres. The increase in compressive and tensile strength due to incorporation of steel fibre is greater than that of using nylon fibre. For the nylon 6 fibres, adding more fibres into the concrete has a limited improvement on splitting tensile strength. Inclusion of nylon 6 fibres along with steel fibres results in considerable improvement in flexural strength as compared to solo steel fibre.
***Keywords*-** Hybrid reinforced concrete, steel, nylon 6, Compressive strength, Split tensile strength, flexural strength

I. INTRODUCTION

Plain cement concrete has some shortcomings like low tensile, limited ductility, little resistance to cracking, high brittleness poor toughness, and so on that restrict its application. [1] The cracking of concrete may be due to economic structural, environmental factors, but most of the cracks are formed due to inherent internal micro cracks and the inherent weakness of the material to resist tensile forces. Drying shrinkage in the concrete may also results in the formation of cracks. To overcome these deficiencies, extra materials are added to improve the performance of concrete. Fibre reinforced concrete provides solutions for these shortcomings. Inclusion of fibres as reinforcement to concrete results as crack arrestor and improves its static and dynamic properties by preventing the propagation of cracks as well as increases tensile strength of concrete. Extensive research work on FRC during the last two decades has established that combination of two or more types of fibres such as metallic and non-metallic fibers increase overall performances of concrete. It is obvious that the behavior of HFRC depends on the aspect ratios, orientations, geometrical shapes, distributions and mechanical properties of fibres in concrete mixtures. Fibre-reinforced concrete are mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations etc) either alone or with hand-tied rebars [2]. In this research, therefore, an attempt has been made to study the feasibility of using two kinds of fibres for making FRC.

The beneficial effects of non-metallic fibres like nylon 6 is to arrest the propagation of micro cracks in the plastic stage of concrete due to their lower stiffness and increased fibre availability (because of lower density as compared to steel) at a given volume fraction. It is important to have a combination of low modulus (nylon 6) and high modulus fibres (steel) to arrest the micro and macro cracks, respectively. [3]

II. Materials and Experimental Methods

2.1 Materials:

In this experimental study cement, sand, coarse aggregate, water, steel and nylon 6 fibres were used.

Cement: Ordinary Portland cement of 43 grade confirming to IS 8112-1989 manufactured by Ultratech Company was used in this experimental work. Cement with specific gravity 3.12 was used for the preparation of test specimens.

Coarse aggregates: Broken stone from the local quarry of size 20 mm and 10 mm in the ratio of 60:40 respectively confirming to IS: 383-1970 was used as coarse aggregate. The specific gravity of 10 mm and 20 mm coarse aggregate were taken as 2.72 and 2.74 respectively. Water absorption for 10 mm and 20 mm aggregate were 0.17 and 0.15 % respectively. Fineness modulus of 10 mm and 20 mm were 2.31 and 2.65 respectively.

Sand: Locally available river sand of zone II conforming to IS 383-1970 with specific gravity 2.69, water absorption 1.82 % and fineness modulus 2.86.

Water: Fresh, clean and portable water from tape was used for mixing and curing the concrete as per IS: 456-2000 in the entire experimental programme.

Superplaticizer: A commercially available super-plasticizer (SIKA 150) was used in all mixes. The super plasticizer was added 0.6 % by weight of cement to all mixes conforming to IS 9103:1999. The specific gravity of SIKAMAN superplasticizer was 1.18.

Steel fibres: End hook steel fibres (NOVOCON HE0630) with length 12 mm, filament diameter 0.6 mm and density 7850 kg/m^3 having the aspect ratio of 50 were used in this research work.

Nylon fibres: nylon 6 fibres with length 45 mm, filament diameter 0.3 mm and density 1130 kg/m^3 having the aspect ratio of 200 were used in this research work. Nylon fibres were taken from fish net made of nylon 6 monofilament.

Table: 1Different proportions of fibres used

Mix	Fibre by % of volume	% contribution of Steel-nylon
MS0N0	0	0-0
MS100N0	0.75	100-0
MS75N25	0.75	75-25
MS50N50	0.75	50-50
MS25N75	0.75	25-75

Figure 1: Steel fibre

Figure 2: Nylon 6 fibre

2.2 Mix design

Concrete for M25 grade were prepared as per I.S.10262:2009 with w/c 0.43. Mix proportion for M25 grade concrete for material was as follows:

Table 2: Quantities of materials

Material	Quantity
Cement	380.91 Kg/ m3
Sand	701.29 Kg/ m3
Coarse Aggregates	1237.37 Kg/ m3
Water	163.71 Kg/ m3

2.3Mixing, casting and curing

Concrete was mixed along with steel, nylon 6 and superplasticizer. Concrete was placed uniformly over the length of the standard steel mould in three layers and compacted satisfactorily. Demoulding was done after 24 hours and the specimens were cured under water. After 7days and 28days, the specimens were removed from curing tank and taken for testing.

2.4 Testing

2.4.1 Workability

Slump cone test was performed to determine the workability using standard sizes of Slump Moulds as per IS: 1199 – 1999.

2.4.2 Compressive strength

30 cube moulds of size 150 x 150 x 150 mm were casted and allowed for curing in a curing tank for 28 days and they were tested at 7 days and 28 days. These cubes were tested on compression testing machine as per I.S. 516-1959.

Cube compressive strength (fck) in MPa = P/A

Where, P= cube compression load, A= area of the cube

2.4.3 Split tensile strength

30 cylindrical specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank for 7 and 28 days for curing. The test was conducted as per IS 5816:1999.

Split tensile strength =$2P/\pi Ld$.

Where, P is the compressive load on the cylinder

L & d are the length & diameter of the cylinder.

2.4.4 Flexural strength

30 beams of size 500 x 100 x 100 mm were cast. The specimens were demoulded after 24 hours of casting and transferred to curing tank for 28 days. It is calculated by loading beam at 7 and 28 days in flexural testing machine conforming IS: 9399:1979. The modulus of rupture is calculated using the formula.

$\sigma = 3PL/2bd^2$, where,
P = load in N applied to the specimen
L= length of the support span (mm)
b = width in mm of the specimen
d = depth in mm of the specimen

III. Results and discussion

3.1 Workability

The results of slump test are plotted in figure no. 3. It states that slump decreases with adding fibre in concrete with respect to reference mix. Maximum slump loss was obtained for mix $MS_{50}N_{50}$. Superplasticizer was added to reduce the slump loss.

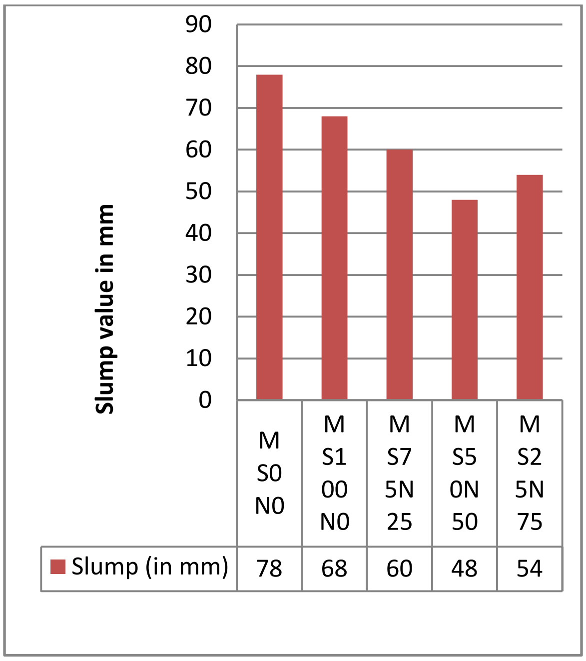

Figure: 3 Slump value for all mixes

3.2 Compressive strength

The results of compressive strength test at 7 days & 28 days are given in table no. 3 and are plotted in figure no. 4. The maximum compressive strength obtained from mix (MS100N0) made with steel only. The compressive strength made with solo steel fibre increases by 37.09 % and made with mix MS75N25 (75-25%) increases by 28.52 % with respect to reference mix without fibre. It is observed that compressive strength of all hybrid fibre reinforced concrete mixes is more than compressive strength of reference mix (without fibre). Compressive strength is directly influenced by steel fibre and increases by increasing quantity of steel fibre. Because of high strength, stiffness and modulus of elasticity of steel fibres, metallic fibers (steel) are more capable to arrest the macro cracks hence provide ductility to the concrete.

Mix	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
MS0N0	21.33	31.70	2.03	2.83	5.36	6.40
MS100N0	31.93	43.26	2.64	3.42	6.20	7.40
MS75N25	28.00	40.74	2.47	3.20	6.70	7.70
MS50N50	26.96	38.00	2.38	3.11	5.90	7.00
MS25N75	24.45	33.04	2.12	3.02	5.70	6.90

Table 3: Test results at 7 days & 28 days

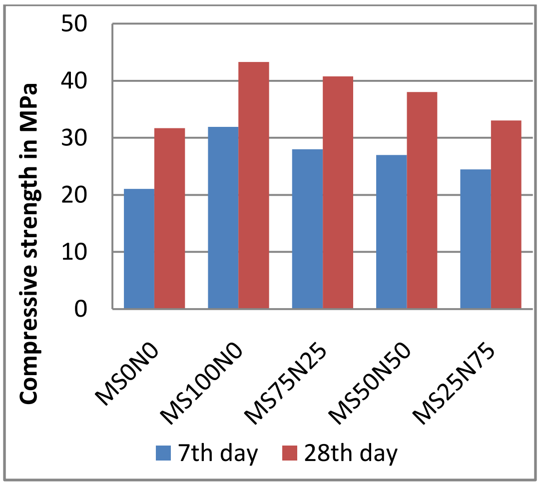

Figure 4: Compressive strength at 7 & 28 days

3.3 Split tensile strength

The results of split tensile strength test at 7 days & 28 days are given in table no. 1 and are plotted in figure no. 5. It can be seen from figure no. 5 that the maximum increase in split tensile strength is by 20.84% for mix (MS100N0) having 100-0% (steel-nylon). The increase in split tensile strength with respect to the control mix (MS0N0) is observed for the all mixes. In case of hybrid fibre reinforced concrete maximum tensile strength is observed by 13.07 % for mix MS75N25 with 75-25% (steel-nylon)**.** When first crack occurred, the nylon restricts growth of crack. When stress continuously damaged the specimen, bridging effect of nylon fibres would gradually transfer to the steel fibres to make the concrete more resistant to the stress, further increasing the splitting tensile strength.

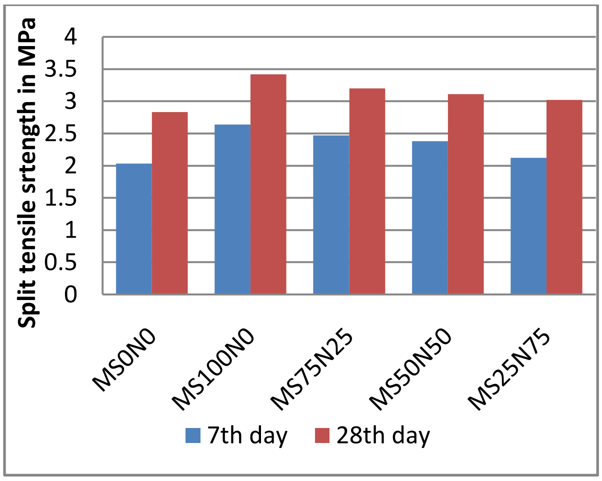

Figure 5: Split tensile strength at 7 & 28 days

3.4 Flexural strength

The results of flexural strength are tabulated in table no. 1 and Figure 6 shows the graphical presentation of flexure strength. Figure no. 6 states that maximum flexural strength is obtained for mix MS75N25 having 75-25% (steel-nylon). Flexural strength of all mixes (MS100N0, MS75N25, and MS50N50 & MS25N75) increases with respect to reference mix MS_0N_0. Maximum increment of flexural strength is observed by 20.31 % for mix MS75N25 with respect to reference mix. It is also seen that the addition of nylon fibres increase the flexural strength. The modulus of rupture of steel fibers is more as compare to nylon fibers. Therefore steel fibers are effective to arrest the macro cracks and undergo ductile failure while nylon fibers are only effective to arrest the micro cracks and undergoes brittle failure. Therefore steel-nylon combination also shows better performance during flexural strength test. Figure 6 states that combination of steel and nylon fibres are beneficial for increasing flexural strength.

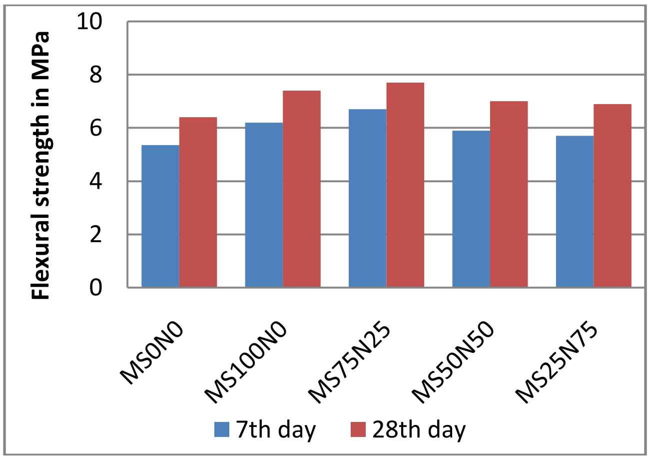

Figure 6: Flexural strength at 7 & 28 days

IV. Conclusions

From the experimental study conducted on steel-nylon hybrid fibre reinforced concrete, the following conclusions are drawn.

1. Slump decreases with adding fibres in concrete. Maximum slump loss was obtained for mix $MS_{50}N_{50.}$
2. The maximum compressive strength obtained from mix (MS100N0) made with steel only. Compressive strength is directly influenced by steel fibre and increases by increasing quantity of steel fibre.
3. Maximum increase in split tensile strength is by 20.84% for mix (MS100N0) having 100-0% (steel-nylon). Alike compressive strength, Split tensile strength is also more influenced by steel fibre. The increase in split tensile strength with respect to the control mix (MS0N0) is observed for the all mixes.
4. Maximum increment of flexural strength is observed by 20.31 % for mix MS75N25 with respect to reference mix. It is also observed that the addition of nylon 6 along with steel fibres increase the flexural strength.

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