International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.3, Issue.3, May-June. 2013 pp-1279-1282 ISSN: 2249-6645

Structural Behaviour of Fibrous Concrete Using Polypropylene Fibres

Parveen,[1] Ankit Sharma[2]

[12]Department of Civil Engineering DCRUST, Sonepat, Haryana, India

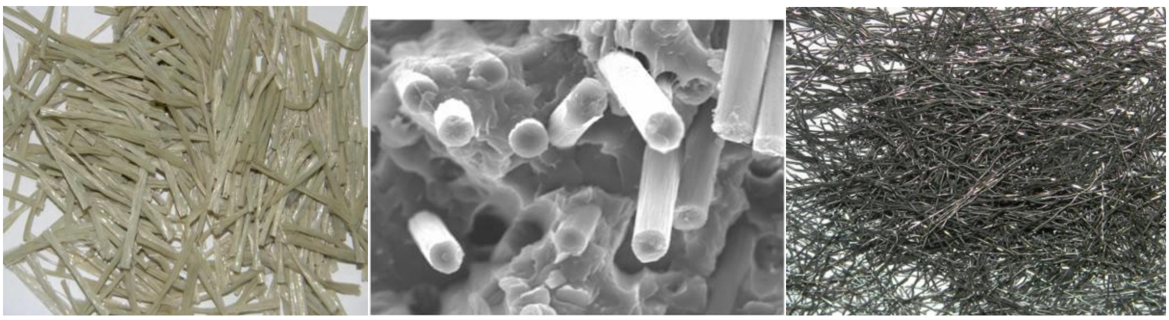
Abstract: *The aim of the present study is to investigate the effect of variation of polypropylene fibres ranging from 0.1% to 0.4% along with 0.8% steel fibres on the behaviour of fibrous concrete. The mechanical properties of the concrete such as compressive and tensile strength have been investigated. The result shows that addition of polypropylene fibre has a little effect on the compressive strength, but there was significant increase in the tensile strength with increase in fibre volume fraction. The present investigation shows an increase of 47% of split tensile strength and 50% of flexural strength. The result shows that ultimate load mainly depended on percentage volume fraction of fibre.*

Keywords: *Ppf, Gfrp, Sfrc, Fbc, Pfrc*

I. Introduction

Concrete is known to be a brittle material when subjected to tensile stresses and impact loads; tensile strength of the concrete is approximately one tenth of its compressive strength. As a result of this, concrete members are unable to withstand such loads and stress that are usually encountered by concrete structural members. Usually, concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses and to compensate for the lack of ductility and strength. The addition of steel reinforcement to concrete significantly increases its strength, but to produce a concrete with homogenous tensile properties and better micro cracking behaviour, fibres are advantageous. The introduction of fibres in concrete has brought a solution to develop a concrete having enhanced flexural and tensile strength, which are a new form of composite material. At the micro-level, fibres inhibit the initiation and growth of cracks, and after the micro-cracks coalesce into macro-cracks, fibres provide mechanisms that abate their unstable propagation, provide effective bridging, and impart sources of strength gain, toughness and ductility. Fibres are mostly discontinuous, randomly distributed throughout the cement matrices.

The randomly distributed short fibres are generally introduced into concrete to enhance its control crack system and mechanical properties such as toughness, impact resistance, ductility (post cracking), tensile strength etc. of basic matrix. There are many kinds of fibres, such as metallic, synthetic, natural etc which are being used in normal concrete as shown in Fig 1. The term fibre based concrete (FBC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Different type of fibres in concrete changes the character of fibre based concrete. Further properties of fibre based concrete changes with varying concrete, fibre materials geometries, distribution, orientation and densities. When fibre is added to a concrete mix, each and every individual fibre receives a coating of cement paste. Modification of synthetic fibre geometry includes monofilaments, fibrillated fibres, fibre mesh, wave cut fibre large end fibres etc. This increases bonding with cement matrices without increasing in its length and minimized chemical interaction between fibres and the cement matrices. Fibres also modifies and enhances the mechanical properties and behaviour of concrete during its application. Fibre can be used with admixture such as super plasticizer, air entraining, retarding, accelerating etc and all type of cement and concrete mixtures. These produce a special type of concrete with desired properties in fresh and hardened concrete. In present study polypropylene and steel fibres have been used. Polypropylene fibre having low modulus, light density, small monofilament diameter and not susceptible to corrosion and steel fibre increases its ductility, toughness, and impact resistance. Polypropylene and steel fibre is



(a) (b) (c)

Figure 1. (a) polypropylene fiber (b) glass fiber (c) steel fiber

Considered to be an effective method for improving the shrinkage, cracking characteristics, toughness and impact resistance of concrete material Almost all FRCs used today commercially involve the use of a single fibre type. Clearly, a given type of fibre can only be effective in a limited range of crack opening and deflection. The benefits of combining organic (polypropylene and nylon) and inorganic fibres (glass, asbestos and carbon) to achieve superior tensile strength and fracture toughness were recognized about 30 years back. Thereafter much research was not undertaken, recently again there is renewed interest in this field. In present study the structural behaviour of the fibre based concrete using hybrid fibres has been conducted.

II. EXPERIMENT AND RESULT

To achieve the objectives of research programme, an experimental investigation has been carried out on FBC. The cubes, cylinders & beams have been cast with varying percentages of fibre volume fraction. This chapter outlines the experimental program plan, properties of the constituent materials, concrete mix, casting of specimen and testing of specimen. The focus of experimental investigation is to assess the structural behaviour of fibre based concrete. To attain the aim of present study experimental investigation is carried out on 60 Nos. of fibre based reinforced concrete cubes, 60 nos. of fibre based reinforced concrete cylinder & 60 Nos. of fibre based reinforced concrete beams, having overall dimensions (L x B x D) as 150 x 150 x 150 mm for cubes, for cylinder (L x D) as (300 x 150 mm) & for beams (L x B x D) as 500 x 100 x 100 mm.

(a) (b) (c)

Figure 2. (a) Setup for compressive strength (b) Setup for Split Tensile strength (c) Setup for Flexural strength

A. Compressive Strength –

From the results it observed that the addition of the polypropylene fibre in the control mix has a little effect on the compressive strength. It is observed that the use of fibres increases the compressive strength of concrete when the polypropylene fibres were up to 0.2% and then reduction in compressive strength is observed. An increase in 7.5% in compressive strength occurs when the percentage of polypropylene fibre increases up to 0.2%. The decrease in compressive strength is observed when percentage of fibres increases beyond 0.2%. The increase in the compressive strength is due to the increase in bonding effect of fibre with matrix. With the increase in percentage volume of fibre beyond its optimum value (which is 0.2% in present case) compressive strength decreases, this is due to the increase in interference of fibre with each other. This will produce internal voids in concrete mix which leads to decrease the total density of mix and thereby decrease the compressive strength of the mix.

Table -1 Compressive Strength

Sr. No.	Percentage of polypropylene fibre along with 0.8% steel fibre	Compressive strength(N/mm2) After 7 Days	Compressive strength(N/mm2) After 28 Days
1	0%	27.86	39.84
2	0%+0.8%	28.40	40.50
3	0.1%+0.8%	28.54	40.90
4	0.2%+0.8%	29.92	42.82
5	0.3%+0.8%	27.90	40.02
6	0.4%+0.8%	27.08	39.58

B. Flexural Strength–

It is observed that with the increase in polypropylene fibre, the flexural strength increases. However, it is noticed that the rate of increase of flexural strength is more as compared to compressive strength. The results show that optimum dosage for flexure is 0.3% of polypropylene fibre along with 0.8% of steel fibre. The above results show that flexural strength increases with increase in fibre volume fraction; this is due to the additional load taken by the fibres present in the matrix. However, after increasing the volume percentage of polypropylene fibre beyond the optimum value (0.3%) improper mixing of fibres with the matrix takes place due to balling effect of fibre, this increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases flexural strength of the mix. The failure pattern of plain and hybrid fibrous concrete in flexural strength test shows that fibrous concrete are more ductile as compared to plain concrete. This is because when the matrix cracked, the load was transferred from the composite to the fibres at the crack surfaces, which prevents the brittle failure of the composite.

Table -2 Flexural Strength

Sr. No.	Percentage of polypropylene fibre along with 0.8% steel fibre	Flexural strength(N/mm2) After 7 Days	Flexural strength(N/mm2) After 28 Days
1	0%	3.63	4.67
2	0%+0.8%	3.73	4.80
3	0.1%+0.8%	3.92	5.57
4	0.2%+0.8%	4.40	6.19
5	0.3%+0.8%	5.01	7.20
6	0.4%+0.8%	4.15	5.92

C. Split Tensile Strength–

For studying the split tensile behaviour, cylinders of fibrous concrete were tested. The failure load was observed and the strength was calculated which is shown in Table 3. The figures show the effects of volume variation of polypropylene fibre and split tensile strength of concrete. It is noted that with the increase in the polypropylene fibres upto 0.3% the split tension strength increases. The above results shows that split tensile strength increases with increase in fibre volume fraction, because of the holding capacity of the fibres which helps in preventing the splitting of concrete. However, after increasing the volume percentage of polypropylene fibre beyond the optimum value (0.3%) improper mixing of fibres with the matrix takes place due to balling effect of fibre, this increases the amount of vibrations required to remove air voids from the mix which in turn causes the problem of bleeding and decreases split tensile strength of the mix.

Table -3 Split Tensile Strength

Sr. No.	Percentage of polypropylene fibre along with 0.8% steel fibre	Split tensile strength(N/mm2) After 7 Days	Split tensile strength(N/mm2) After 28 Days
1	0%	2.14	3.10
2	0%+0.8%	2.25	3.35
3	0.1%+0.8%	2.59	3.72
4	0.2%+0.8%	2.83	4.09
5	0.3%+0.8%	3.50	4.95
6	0.4%+0.8%	2.70	3.85

D. Stress Strain Response–

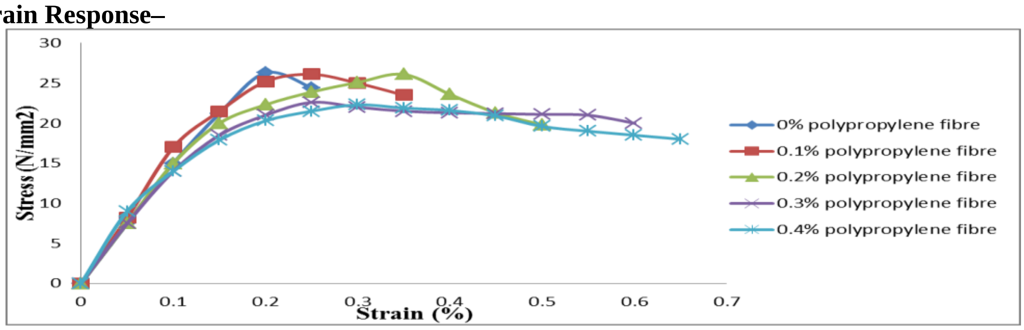


Figure 3. Stress strain response of FBC at different volume fraction of polypropylene fibre

Above figure shows there is significant change in strain of the concrete due to addition of fibres. Descending portion of the curve becomes more and more flatten as the fibre volume fraction increases. The relationship with different volume fraction of polypropylene fibre is shown in Fig. 3. Two different behaviour patterns are obtained as shown in stress strain curve. The stress-strain behaviour of the specimens containing polypropylene fibre upto 0.1% behaves in a similar trend to the control specimen. For these cases which contains 0% and 0.1% polypropylene fibre behaves like a brittle material of which the total energy is generated is elastic energy. However, non linear behaviour is seen for the other specimens which contains more than 0.1% of polypropylene fibre. Here, once the peak stress is reached the specimens continues to yield as shown in figure 3. Therefore it can be stated that concrete with higher percentage of polypropylene fibre possess higher toughness, since the generated energy is mainly plastic. Also it was found that as fibre volume increase failure strain also increases, which leads to more area under the curve, thus enhancing the toughness of the concrete.

III. Conclusion

Based on experimental investigation and analysis of results obtained, the following conclusions may be drawn broadly:

1. Steel-polypropylene mix shows a slight increase in the compressive strength as compared with the plain concrete. Hybrid (steel + polypropylene) fibre showed about 5.7% increase in compressive strength.
2. It is observed that polypropylene fibre have not contributed significantly towards compressive strength.
3. The maximum gain in compressive strength was achieved for 0.2% polypropylene fibre. Thereafter increase in fibre content has marginally reduced the compressive strength.
4. Hybrid FRC (steel + polypropylene) shows an increase in split tensile strength as compared to the plain concrete. Fibre reinforced concrete mix showed a considerable increase of about 47% in split tensile strength.

5. The maximum gain in split tensile strength was achieved for 0.3% polypropylene fibre. Thereafter increase in fibre content has marginally reduced the split tensile strength.
6. Steel-polypropylene fibre reinforced concrete showed increase in flexural strength when compared with steel fibre reinforced concrete.
7. The maximum gain in flexural strength was achieved for 0.3% polypropylene fibre. Thereafter increase in fibre content has marginally reduced the flexural strength.
8. From the present study it is observed that the optimum dosage of polypropylene fibre fraction is 0.3%.
9. Stress-Strain relationship showed that there was marginal increase in strain. Stress-Strain relationship shows that strain increases as the percentage of polypropylene fibre increases. As fibre volume increases failure strain also increases, which leads to more area under the curve, thus enhancing the toughness of concrete.

Reference

[1] A. Sivakumar, Manu Santhanam, "Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibre", cement and concrete composite 29 (2007) 603-608.

[2] ASTM A820, "Steel fibre-reinforced concrete design consideration", (1997).

[3] Balaguru, P., and Ramakrishnan, V., Properties of Fiber Reinforced Concrete: Workability Behavior under Long Term Loading and Air-Void Characteristics", ACI Materials Journal, May-Jun, Vol. 85, No. 3, pp. 189-196,1988.

[4] Chote Soranakom, Bazin Mobasher, "flexure design of fibre reinforced concrete", ACI Material Journal (September 2009).

[5] C.D. Johnston, "Steel fibre reinforced mortar and concrete", A review of mechanical properties in fibre reinforced concrete ACI- SP 44- Detroit (1974).

[6] F.Puertas, T.Amat, Fernandez-Jimenez, T.Vazquez, "Mechanical and durable behavior of alkaline cement mortars reinforced with polypropylene fibres", Cement and Concrete Research 33 (2003) 2031-2036.

[7] Giuseppe Campione, Maria Letizia Mangiavillano, "fibrous reinforced concrete beam in flexure: experimental investigation, analytical modeling and design considerations" Engineering structures journal 30 (2008) 2970-2980.

[8] G.Ramakrishna, T.Sundararajan, " Impact strength of a few natural fibre reinforced cement mortar slabs: a comparative study", Cement and Concrete Composites 27 (2005) 547-553.

[9] G.R. Williamson, "The effect of steel fibres on compressive strength of the concrete," Fibre Reinforced Concrete, American Concrete Institude, Detroit, MI, (1974) pp. 195-207 (ACI).

[10] H. Krenchel, S.P. Shah, Restrained shrinkage tests with polypropylene fibre reinforced concrete, in: S.P. Shah, G.B. Baston (Eds.), Fibre Reinforced Concrete and Applications, American Concrete Institute SP-105, Detroit, 1987, pp. 141–158

[11] Indian Standard Code of practices for plain and reinforced concrete IS: 456:2000.

[12] Indian Standard methods of physical test for hydraulic cement. IS: 4031 (Part 6)-1988.

[13] Indian Standard methods of test for aggregates for concrete. IS: 2386 (Part-6)-2007.

[14] Indian Standard methods of chemical analysis of hydraulic cement. IS: 4032 (1985).

[15] Indian Standard recommended guidelines for concrete mix design. IS: 10262-1982.

[16] Indian Standard methods of tests for strength of concrete. IS: 516 (1991).

[17] LI Bei-xing, Chen Ming-xiang Cheng Fang Liu Lu-ping. " The mechanical properties of Fibre Reinforced concrete", Journal of Wuhan University of Technology (May 2004) vol. 19 No.3

[18] Lars Kutzign, Gert Konig, "Design Principals of steel fibre reinforced concrete- A Fracture Mechanics Approach", Leipzig Annual Civil Engineering Report LACER, vol.3 (1999).

[19] Machine Hsiea, Chijen Tua, P.S.Song, "Mechanical properties of polypropylene hybrid fibre-reinforced concrete", Material Science and Engineering A 494 (2008) 153-157.

[20] Menon and Pillai, "Reinforced concrete design", published by Tata McGraw-Hill Company (2007).

[21] Nguyen Van Chanh, "Steel fibre reinforced concrete", Advances in concrete technology volume 3- Gordon and Breach Science publishes.

[22] Naaman, A.E and Najm, "bond sleep mechanism of steel fibre in concrete", ACI material journal (1992), vol. 88 pp. 135-145.

[23] T. Budi Aulia, "Effect of polypropylene Fibres on the properties of high strength concretes", Institutes for Massivbau and Baustoffechnologi, University Leipzig, Lacer No. 7 (2002).

[24] T.S.Lok and J.R.Xiao, "Flexural strength assessment of steel fibre reinforced concrete," Journal of material in civil engineering, vol.11, No.3 (1999).

[25] Tantary, M.A.Ramajan, B.Upadhyay A and Prasad, J, "Mechanical properties of steel fibre based concrete", second national conference on recent Advances in Civil Engineering, Kochi, India (2006), pp.27-33.

[26] V M Malhortra, Carette, A Bilodeaue, "Mechanical properties and durability of Polypropylene fibre reinforced high-volume fly ash concrete for shotcrete applications", ACI Materials Journal,1994,91(5) 478-486.

[27] Waheeb Ahmed Al-Khaja. "Mechanical properties and time dependant deformation of polypropylene fibre concrete." J.King Univ, Vol. 7 Eng Sci. (1) pp 67-76.

[28] Yeol Choia, Robert L. Yuan, "Experimental relationship between splitting tensile strength and compressive strength of GFRC and PFRC", Cement and Concrete Research 35 (2005) 1587-1591.

[29] Youjiang Wang, "modeling of fibre pull-out from a cement matrix", International journal of cement composites and light weight concrete, Volume 10 No.3.