



International Journal of Engineering, Business and Enterprise Applications (IJEBA)

www.iasir.net

EXPERIMENTAL STUDY OF NON-DESTRUCTIVE TEST ON STEEL FIBRE REINFORCED CONCRETE

Mandeep Singh Saroe¹, Inderpreet Kaur²

Guru Nanak Dev Engg. College, Ludhiana (Punjab)

Punjab Technical University, Jalandhar (Punjab)

W.No.9, Vijay colony, Khamano, Distt. Fatehgarh Sahib (Punjab)

INDIA

Abstract: Steel fibres are widely used in concrete as additional industrial materials for concrete products. Because of its huge application areas it keeps its popularity to be an academic research on developing the usage of them. As concrete is naturally weak in tension, steel fibres added will improve tensile strength of concrete. A convenient parameter describing the fibre is its aspect ratio which is defined as the fibre length divided by its equivalent diameter. The equivalent fibre diameter is the diameter of a circle having an area equal to the cross-sectional area of the fibre. Hooked steel fibres are used in the present study. This study investigates the effect of adding steel fibres with aspect ratio 80 and length 60mm on concrete properties in fresh and hardened states. The concrete are produced by fibres with varying volume percentages i.e., 0.5%, 1.0% and 1.5% by volume. At the end of the study, the effects of the mixes with the plain concrete and the correlation curve are obtained for compressive strength, flexural strength, rebound hammer and ultrasonic pulse velocity. The results have shown that the adding fibres to the concrete increase the compressive strength, flexural strength and rebound number on the other hand adding fibres decreases the workability and ultrasonic pulse velocity of concrete.

Keyword: Steel fibres, Compressive strength, Flexural strength, Rebound hammer, Ultrasonic pulse velocity, Workability.

I. INTRODUCTION

Steel fibre reinforced concrete (SFRC) may be defined as a composite materials made with Portland cement, fine and coarse aggregate, and incorporating discrete discontinuous fibres. When steel fibres are added to a concrete mix, they are randomly distributed and act as crack arrestors. Debonding and pulling out of fibres require more energy, giving a substantial increase in toughness and resistance to dynamic loads. SFRC has been used for a wide variety of applications, namely, pavements and overlays, industrial floors, hydraulic and marine structures, repairing and rehabilitation works.

Steel fibres may be of different types i.e., straight steel fibre, hooked steel fibre, paddled steel fibre, crimped steel fibre, etc. In this research, mainly hooked steel fibres were used. In fresh state, high percentage of steel fibres reduces workability of concrete but increases the hardened properties of concrete i.e., compressive strength, flexural strength. So admixtures are added in SFRC for high workability.

Non-destructive test are those in which there is no damage to the concrete. These tests are used to check the quality control or the resolution of doubts about the quality of materials. These tests are done on both old and new structures of concrete. This test also saves time and money. In this research mainly Schmidt rebound hammer test and Ultrasonic pulse velocity test were done.

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. And, the ultrasonic pulse velocity test is a pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test.

According to [1], SFRC is used to improve the strength of concrete. And it has been recognizes that adding steel fibres to the concrete develops the mechanical properties of it. According to [2], proposed an equation to quantify the effect of fibre on compressive strength of concrete in terms of fibre reinforcing parameter. In their model, the compressive strength ranging from 30 to 50 MPa, with fibre volume fraction of 0%, 0.5%, 0.75% and 1% and aspect ratio of 55 and 82 were used.

According to [3], were carried out a slump tests to determine the workability and consistency of fresh concrete. In their research slump changed due to different types of fibre content and form. According to [4], when the amount of steel fibres increased, i.e., more than 2%, the workability of concrete is decreased and for 0.5% steel fibres the workability is increased.

According to [5], using steel fibres in concrete increases the rebound number. Although, adding two or three different sizes of steel fibres increase the rebound number. Increasing the amount of steel fibres increases the rebound number. According to [6], there is a relation between the rebound number and the quality of concrete

which says that when rebound number is more than 40 the quality of concrete is very good, between 30 to 40 it is good, between 20 to 30 it is fair, less than 20 it is poor and when it is 0 it is very poor.

According to [7], states that adding steel fibres in concrete reduces the pulse velocity, the higher the amount of fibre the lessens the pulse velocity. According to [8], there is a relation between UPV and quality of concrete which says that when UPV (km/s) is more than 4.5 the quality of concrete is excellent, between 3.5 to 4.5 it is good, between 3.0 to 3.5 it is doubtful, between 2.0 to 3.0 it is poor and less than 2.0 it is very poor.

II. EXPERIMENTAL WORKS

A. MATERIALS

Cement: Ordinary Portland cement (O.P.C.) of 43 grade manufactured by Shree Ultra

Fine Aggregates: crushed stone sand

Coarse Aggregates: Coarse aggregates (angular type of 10mm size

Steel Fibres: Hooked steel fibres were of 0.75mm diameter and 60mm in length and aspect ratio of 80.

Water: Potable water

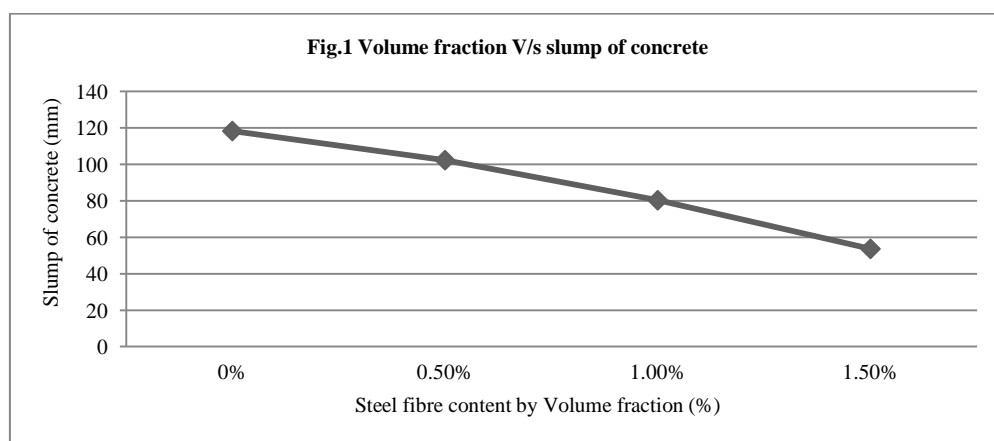
Superplasticizer: CONPLAST SP-430 manufactured by FOSROC Chemicals (India)

Methodology: The effect of hooked steel fibres on the compressive strength, flexural strength and workability of concrete was studied on M20 concrete mix. For compressive strength test, concrete cubes of size 100mm were casted and three samples of each proportion were tested after 3, 7 and 28 days. For flexural strength test, beam specimens of size 100mm x 100mm x 500mm were casted two samples at each proportion were tested after 3, 7 and 28 days. Workability of concrete mix at each proportion was tested by using slump test. After casting of these specimens it will be remove from moulds after 24 hours and it is cured for 3, 7 and 28 days in a storage tank of water. Different dosages (0.5%, 1.0% and 1.5% by volume fraction) were used for hooked steel fibres for all the above three types of tests. Non destructive test (NDT), i.e., Schmidt rebound hammer test and Ultrasonic pulse velocity test were performed on cubes and beams before the compressive strength and flexural strength were tested after 3, 7 and 28 days.

III. RESULTS AND DISCUSSION

The Effect of Steel Fiber on the Fresh Properties of SFRC: Workability of concrete decreases considerably by the use of steel fibres because the reason of lower slump is that adding SF can form a network structure in concrete, which restrain mixture from segregation and flow. For dosage of 0.5% of SF there is decrease in workability by 14%. For addition of 1.0% of SF there is decrease in workability by 32% and for addition of 1.5% of SF there is decrease in workability by 55%.

Volume fraction (in %)	Slump (mm)			Average Slump (mm)
	1 st	2 nd	3 rd	
0	120	115	120	118.33
0.5	105	100	102	102.33
1.0	80	82	79	80.33
1.5	55	50	56	53.67



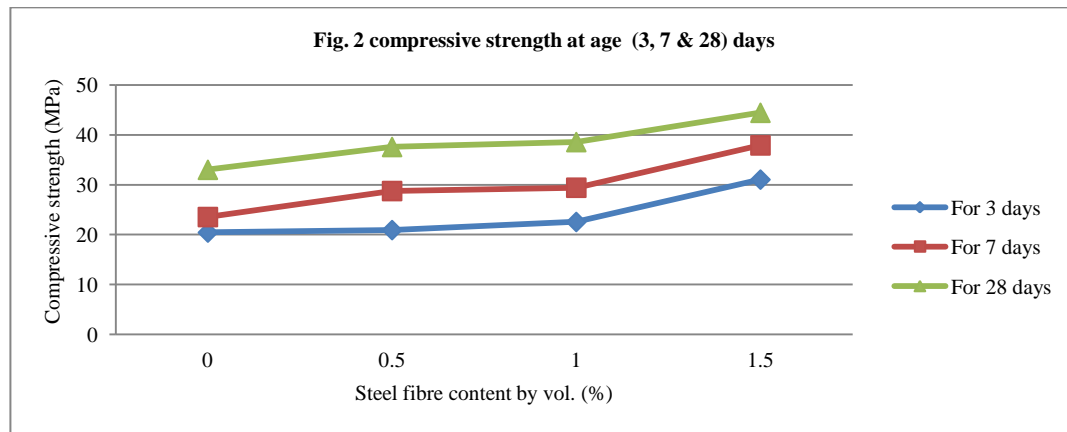
The Effect of Steel Fiber on the Hardened Properties of SFRC:

Compressive strength: The compressive strength is one of the most important properties of hardened concrete. Table (1) and Figure (2) show the compressive strength test at 3, 7 and 28 days. The results indicate that all specimens exhibited a continuous increase in compressive strength with progress in age. This increase in compressive strength with age is due to the continuity of hydration process which forms a new hydration product within the concrete mass. For dosages of 0.5% of hooked steel fibres there is gain in compressive

strength of concrete by 13%. For addition of 1.0% there is gain in compressive strength by 15%. And for addition of 1.5% there is gain in compressive strength by 27%.

Table 1 Compressive strength of all specimens

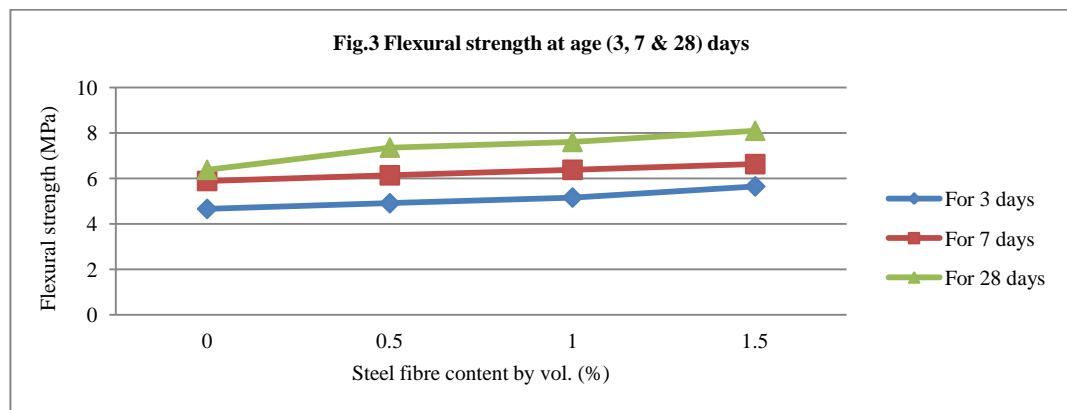
Fibre content (%)	Compressive strength (MPa)		
	3 days	7 days	28 days
0	20.44	23.55	33.03
0.5	20.93	28.77	37.61
1.0	22.56	29.43	38.59
1.5	31.06	37.93	44.47



Flexural strength: The results indicate that all specimens exhibited a continuous increase in flexural strength with progress in age as shown in Table (2) and Figure (3). The result showed that the benefit of steel fibers to improve of flexural strength. For dosage of 0.5% of hooked steel fibres there is gain in flexural strength by 8%. For addition of 1.0% there is gain in flexural strength by 13%. And for addition of 1.5% there is gain in flexural strength by 20%.

Table 2 Flexural strength of all specimens

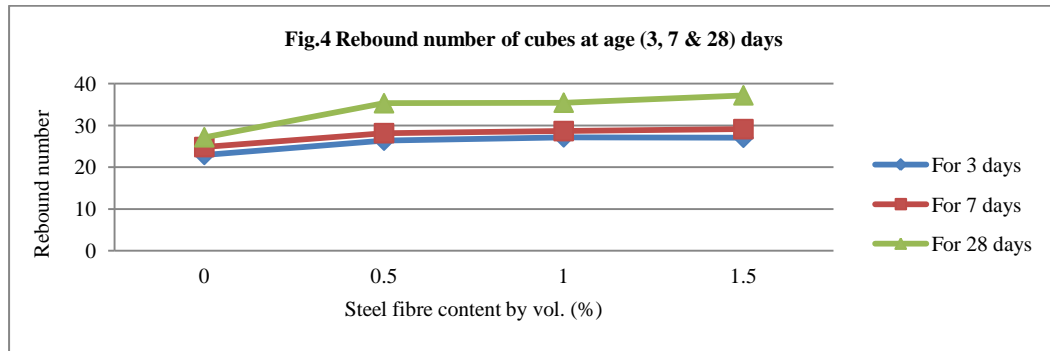
Fibre content (%)	Flexural strength (MPa)		
	3 days	7 days	28 days
0	4.66	5.89	6.38
0.5	4.91	6.14	7.36
1.0	5.16	6.38	7.61
1.5	5.65	6.63	8.10



Rebound number: The results indicate that all specimens exhibited a continuous increase in compressive strength with progress in age as shown in Table (3) and Figure (4). This increase is due to the fibre-matrix bond between the concrete and the steel fibres. Although According to Kamran keikhaei (2012), using steel fibres in concrete increases the rebound number.

Table 3 Rebound number of all cube specimens

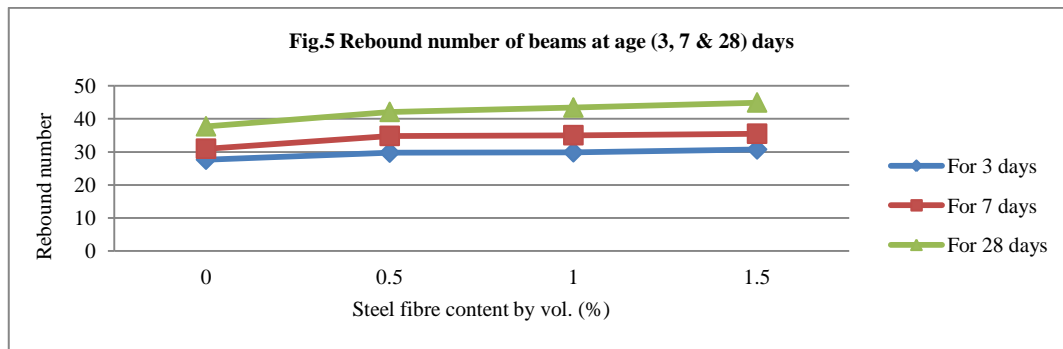
Fibre content (%)	Rebound number			Quality of concrete (Mishra 2012)
	3 days	7 days	28 days	
0	22.95	24.82	27.17	Fair
0.5	26.36	28.15	35.32	Fair
1.0	27.15	28.65	35.45	Good
1.5	27.06	29.11	37.21	Good



The results indicate that all specimens exhibited a continuous increase in flexural strength with progress in age as shown in Table (4) and Figure (5). This increase is due to the fibre-matrix bond between the concrete and the steel fibres.

Table 4 Rebound number of all beams specimens

Fibre content (%)	Rebound number			Quality of concrete (Mishra 2012)
	3 days	7 days	28 days	
0	27.62	30.94	37.73	Good
0.5	29.75	34.82	42.09	Good
1.0	29.86	35.04	43.42	Good
1.5	30.73	35.48	44.94	Good



Ultrasonic pulse velocity: Ultrasonic pulse velocity increased with the increase in curing age of SFRC mixes. The results of ultrasonic pulse velocity at (3, 7 and 28 days) are presented in Table (5), (6) and Figure (6), (7). It can be seen that introducing steel fibers negatively affected the ultrasonic pulse velocity. This might be attributed to the increase of the amount of entrapped air voids due to incorporation of fibers into the mixes. Besides, the fibers inside cube were randomly oriented, when the wave pass through the fibers the wave maybe deflected to other directions rather than pass straight forward to the end of the cube.

Table 5 UPV of all cubes specimens

Fibre content (%)	Ultrasonic pulse velocity (km/s)			Quality of concrete (IS:13311_1-1992)
	3 days	7 days	28 days	
0	4.65	5.53	5.98	Excellent
0.5	4.43	4.84	5.41	Excellent
1.0	4.36	4.66	5.29	Excellent
1.5	4.32	4.48	5.27	Excellent

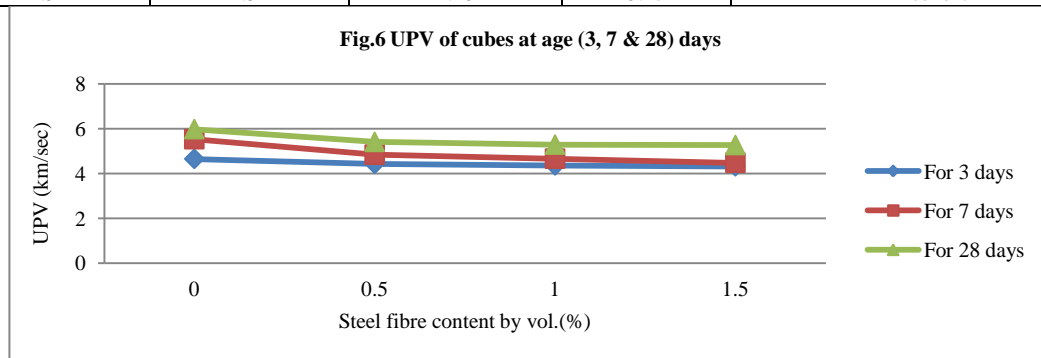
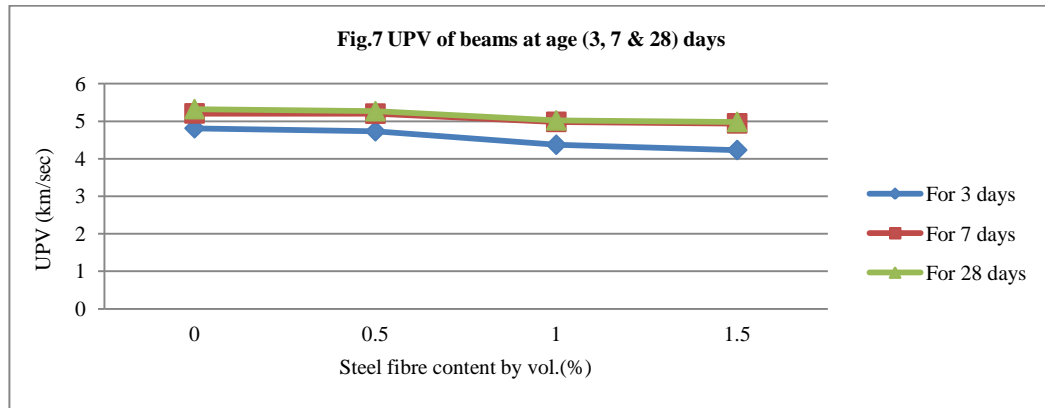
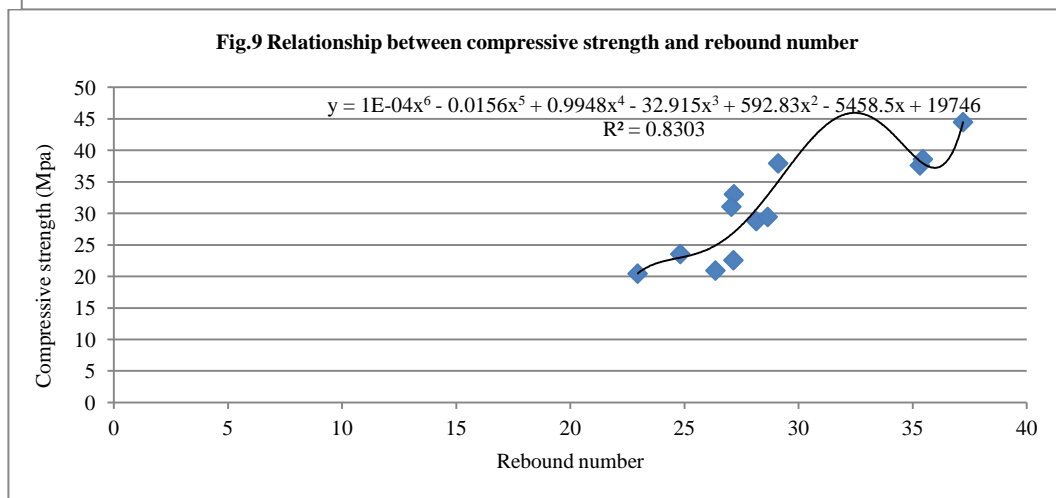
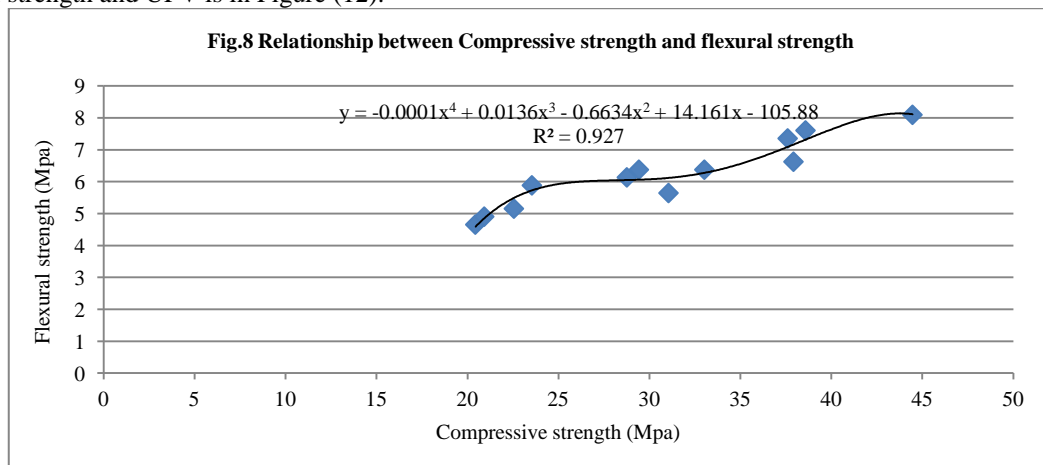


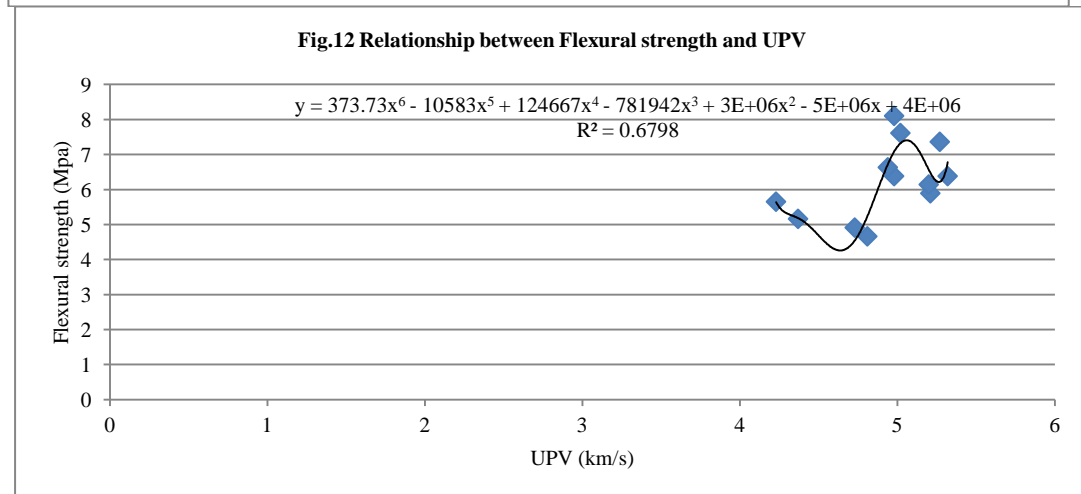
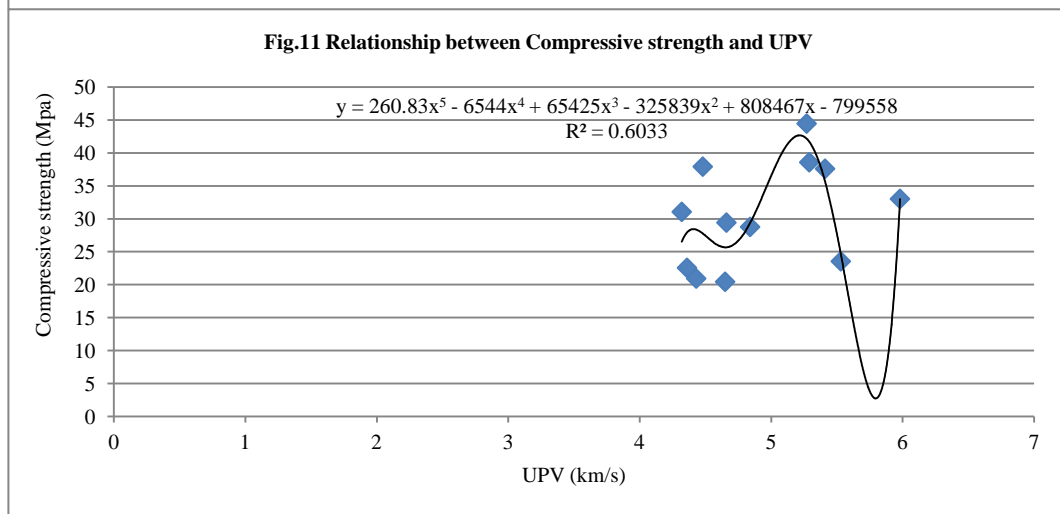
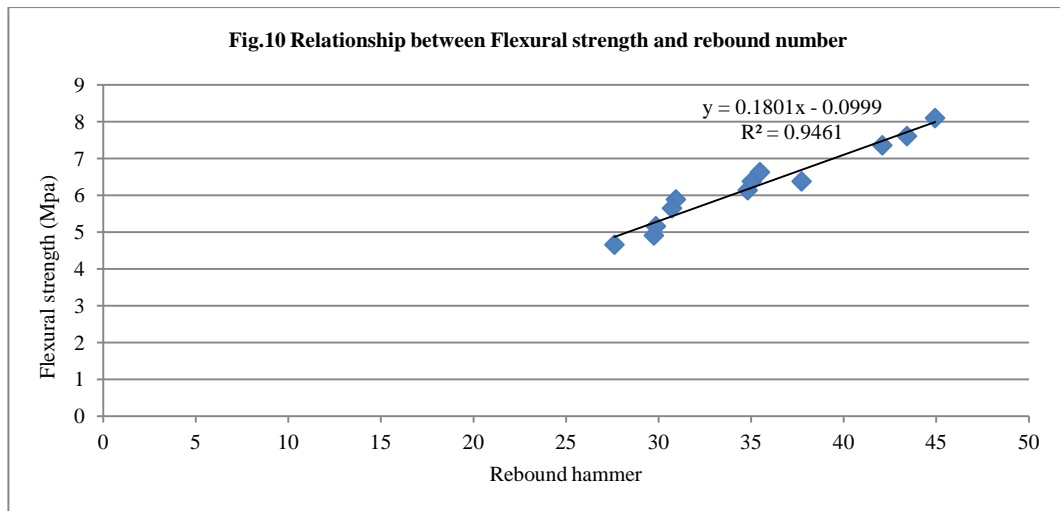
Table 6 UPV of all beams specimens

Fibre content (%)	Ultrasonic pulse velocity (km/s)			Quality of concrete (IS:13311_1-1992)
	3 days	7 days	28 days	
0	4.81	5.21	5.32	Excellent
0.5	4.73	5.20	5.27	Excellent
1.0	4.37	4.98	5.02	Excellent
1.5	4.23	4.94	4.98	Excellent



Relationship curves: The relationship curve between compressive strength and flexural strength is pooled together for all results in Figure (8). The relationship curve between compressive strength and rebound number is in Figure (9). The relationship curve between flexural strength and rebound number is in Figure (10). The relationship curve between compressive strength and UPV is in Figure (11). And the relationship curve between flexural strength and UPV is in Figure (12).





The statistical analysis of the regression models are mentioned below:

1. Relationship between compressive strength and flexural strength

$$y = -0.0001x^4 + 0.0136x^3 - 0.6634x^2 + 14.161x - 105.88$$

$$R^2 = 0.927$$

2. Relationship between compressive strength and rebound hammer

$$y = 1E-04x^6 - 0.0156x^5 + 0.9948x^4 - 32.915x^3 + 592.83x^2 - 5458.5x + 19746$$

$$R^2 = 0.8303$$

3. Relationship between flexural strength and rebound hammer

$$y = 0.1801x - 0.0999$$

$$R^2 = 0.9461$$

4. Relationship between compressive strength and UPV

$$y = 260.83x^5 - 6544x^4 + 65425x^3 - 325839x^2 + 808467x - 799558$$

$$R^2 = 0.6033$$

5. Relationship between flexural strength and UPV

$$y = 373.73x^6 - 10583x^5 + 124667x^4 - 781942x^3 + 3E+06x^2 - 5E+06x + 4E+06$$

$$R^2 = 0.6798$$

From these regression models the correlation coefficient R^2 i.e., 0.927, 0.8303 and 0.9461 are very good polynomial relations and they give the almost accurate results. Whereas, the correlation coefficient R^2 i.e., 0.6033 and 0.6798 are the highest degree order polynomial relations but they are not giving the accurate results as compared to the R^2 i.e., 0.927, 0.8303 and 0.9461 because the UPV results are decreasing due to the steel fibres in concrete because it reflects the waves to the opposite direction rather than passing through the concrete.

IV. CONCLUSION:

- The slump decreases with the increase in SF content of the concrete mixtures with respect to plain concrete mixtures by 55%.
- The addition of 1.5% SF, the maximum increase in compressive strength and flexural strength was observed to be around 27% and 20% with the SF compared to the reference concrete.
- Rebound number of concrete increases up to 20% by increasing the percentage of steel fibre by 1.5%.
- UPV decreased with including SF in concrete by 10%.

REFERENCES:

- [1] Chalioris, C.E. & Sifri, E.F., 2011. "Shear Performance of Steel Fibrous Concrete Beams". In *The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction*. China, 2011.
- [2] Nataraja M.C., Dhang, N. and Gupta, A. P. (1999), "Stress-strain curve for steel fibre reinforced concrete in compression", *Cement and Concrete Composites*, 21(5/6), pp 383- 390.
- [3] Chen B, Liu J (2000), "Contribution of hybrid fibres on the properties of the control concrete hybrid fibres. *Cem. Con. Comp*". 22(4): 343-351.
- [4] Tayfun, U., 2010. Effect of fibre type and content on bleeding of steel fibre reinforced concrete. *Construction and Building Materials*, pp.766-772.
- [5] Kamran Keikhaei, 2012, Properties of concretes produced by single and combined hooked end discontinuous discrete steel fibres.
- [6] Mishra, G. (2012). Rebound Hammer Test. Retrieved May 10, 2012. From World Wide.
- [7] Abbas AL-Ameeri (2013), "The effect of steel fibre on some mechanical properties of self compacting concrete", *American Journal of Civil Engineering*, Vol. 1, No. 3, 2013, pp. 102-110.
- [8] Whitehurst E.A. (1951). Soniscope tests concrete structures. *J. Am. Concr. Inst.* 47. pp 443-444.