Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 04 – Issue 01, February 2016

Interpretation of Modulus of Elasticity of Normal Strength Concrete with Hook-end Steel Fibres

L. K. Rex[1,*], P. N. Raghunath[2]

[1] Research Scholar, Department of Civil & Structural Engineering,
Annamalai University, Annamalainagar, Tamilnadu, India

[2] Professor, Department of Civil & Structural Engineering,
Annamalai University, Annamalainagar, Tamilnadu, India

[*] *Corresponding author's email: lkrphd1 [AT] gmail.com*

ABSTRACT--- ***The brittleness characteristic of a plain concrete or the concrete embedded with longitudinal ferrous reinforcements possess a low tensile strength, limited ductility and little resistance in cracking. This inherent deficit in the property of concrete can be overcome by the addition of multidirectional and closely spaced short discontinuous steel fibres distributed randomly. Short, discrete steel fibres provide discontinuous three-dimensional reinforcement that picks up load and transfer stresses at micro-crack level. This fibre reinforcement provides tensile capacity and crack control to the concrete section prior to the establishment of visible macro-cracks thereby promoting ductility or toughness. Addition of fibres plays an important role in the improvement of the mechanical properties of concrete like increase in elastic modulus, decrease in brittleness, increases tensile strength, energy absorption and control of crack initiation and propagation. In the present study, the effect of steel fibres on the modulus of elasticity of Normal Strength Concrete (NSC) is evaluated. Hook-end steel fibres of diameter 0.75mm and with an aspect ratio of 80 were used at different fibre volume fractions of 0%, 0.5%,1.0% and 1.5%.Cylinder specimens of standard size 150mm diameter x 300mm height were prepared and then subjected to uniaxial compression. From the test results, it was shown that Steel Fibre Reinforced Concrete (SFRC) specimens exhibited ductile behavior after reaching their compressive strength. Further, it was shown that the compressive strength generally increased along with an increased in fibre volumetric ratio, while the elastic modulus decreased.***

Keywords--- modulus of elasticity, fibre volume fraction, aspect ratio, uniaxial compression, non-linear, stress-strain curve, initial tangent modulus

---

1. INTRODUCTION

The brittle failure of plain concrete can be avoided by incorporating randomly distributed short fibres in concrete mix which make the concrete more tensile and absorb more energy. Even the tensile nature in reinforced concrete is not sufficient since there is no significant inherent tensile strength in the concrete itself. Hence cracks in reinforced concrete members extend freely deep into the proximity of the reinforcing bar resulting in the need for multidirectional and closely spaced reinforcement for concrete. The strengthening mechanism of the fibre involves transfer of stress from the matrix to the fibre by interfacial shear or by interlock between the fibre and matrix if the fibre surface is deformed. Stress is shared by the fibre and matrix in tension until the matrix cracks and then the total stress is progressively transferred to fibres. Debonding and pull out of the fibre requires more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the material to cyclic and dynamic loads. The use of SFRC is thus suitable for structures in particular subjected to loads beyond the serviceability limit state in bending and shear when exposed to impact or dynamic forces propagated during seismic activity.

The modulus of elasticity of concrete is a very important parameter reflecting the ability of concrete to deform elastically. The modulus of elasticity is essentially a measurement of the stiffness of a material. It is a key factor for evaluating the deformation of buildings and members, as well as a fundamental factor for determining modular ratio 'm' used in structural design of flexural members. The modulus of elasticity of concrete is often used in sizing structural members and substantial quantity of reinforcement. The modulus of elasticity determines the elastic behaviour of concrete and is influenced by density, porosity, mix proportion, moduli of elasticity of the ingredients, characteristics of the transition zone and morphology of gel structure. The most important factor affecting the modulus of elasticity of concrete is the strength of concrete which is represented as the relationship between ratio of mix or water-cement ratio. It also depends upon the state of wetness of concrete. Wet concrete shows higher modulus of elasticity than dry concrete.

The modulus of elasticity may be measured in tension, compression or shear. The modulus in tension is usually equal to the modulus in compression. The modulus of elasticity of conventional strength concrete generally increases proportionally to the square root of the compressive strength. The procedure adopted to determine modulus of elasticity for concrete as per IS 516-1959 are:

*Determination of the modulus of Elasticity by means of an extensometer
*Determination of the modulus of Elasticity by electrodynamic method

J. Mater (2007) worked on the mechanical properties of steel fibre-reinforced concrete. The study indicates that the fibre matrix interaction contributes significantly to the enhancement of mechanical properties caused by the introduction of fibres. Osman Gencel et al. studied the workability and mechanical performance of steel fibre-reinforced self-compacting concrete with fly ash. The modulus of elasticity was improved only to a little extent with increasing fibre content. Er. Prashant Y. Pawade et al. studied the effect of steel fibres on modulus of elasticity of concrete and concluded crimped steel fibres when added to concrete changed the basic characteristics of its stress-strain response. The modulus of elasticity increased with an increase in fibre volume fraction or fibre reinforcing index. . Natraja C. Dhang N. and Gupta A.P. investigated the effect of stress-strain curve of steel fibre reinforced concrete under compression. They have proposed an equation to quantify the effect of fibre on compressive strength of concrete in terms of fibre reinforcing parameter.

The battle between strength and ductility of concrete always persist. The strength behaves against ductility of concrete by inviting brittleness pronouncedly. To improve the ductility in concrete, the strategy of random addition of short discontinuous steel fibres in concrete being referred to as Steel Fibre Reinforced Concrete (SFRC) results in development of near isotropic material. This SFRC concrete greatly improves the static and dynamic properties of concrete in terms of reasonable tensile strength and high toughness which prevents the initiation and propagation of cracks.

In this experimental study, the effect of random distribution of steel fibre on modulus of elasticity of concrete through compressive strength test was carried out. Studies on effect of volume fraction of fibres on modulus of elasticity of concrete in particular have been considered as an important aspect of this experimental investigation.

2. EXPERIMENTAL PROGRAMME

The mix proportion used in this study is given in Table 1. The mixing sequence followed for normal strength SFRC was different from that of control concrete. The concrete mixes were prepared by hand mixing on a non-absorbing platform. The mixing procedure was as follows: sand and coarse aggregates were homogenized together and mixed with half the total water content to reach a saturated surface-dry condition. Cement and the remaining mixing water were then added. The fibres were gradually sprinkled by hand and care was taken to obtain homogeneous and workable mixtures. The concrete batch was filled into each mould and compacted on a vibrating table.

Table 1. Concrete Mix Proportions

Grade of Concrete	M_{20}
Water cement ratio	0.50
Cement	383 Kg
Fine Aggregate	836Kg
Coarse Aggregate 20mm	981 Kg
Water @ 0.50 w/c ratio	192 Litres
Steel fibre @ 0.5%,1.0%,1.5% by weight of cement	0.5% = 1.915 kg 1.0% = 3.83 kg 1.5% = 5.745 kg
Design Mix Proportions	1: 2.18: 2.56

2.1 Materials

Steel fibre is one of the most commonly used fibre and number of steel-fibre types are available as reinforcement. Generally round steel fibres produced from cutting or chopping round wires into short lengths with diameters varying from 0.25mm to 0.75mm are used. For improving the mechanical bond between the fibre and matrix, indented, crimped, machined and hook-ended fibres are normally produced. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of the fibres takes place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete. It has been extensively used in various types of structures, particularly for overlays of roads, hydraulic structures, refractory concrete, precast applications, rock slope stabilization, tunnel lining, thin shells & plates, airfield pavements and bridge decks. The properties of steel fibre (Figure 1.) are given in Table 2.

Table 2. Properties of Steel Fibre

1.	Material	Low Carbon Drawn wire
2.	Aspect ratio (L/D)	80
3.	Length, L	60 mm
4.	Diameter, D	0.75 mm
5.	Tensile strength	> 1100 Mpa
6.	Elastic modulus	200 Gpa
7.	Elongation at breaking point	3.5%
8.	Specific gravity	7.86
9.	Appearance	Clear, Bright, Glued/Loose fibres with Hook End anchorage
10.	Product commercial name	DURA flex

Figure 1. Hook-end Steel Fibre

2.2 Workability

The concrete mix proportion of normal concrete without fibres are difficult to apply for SFRC since steel fibres reduce the workability for a given mix design. Therefore, finer aggregate and cement should replace a portion of the coarse aggregate to guarantee both workability and target compressive strength. Before mixing the concrete, the coarse aggregate was dried for one day after being submerged in water so that surface saturation could be achieved when the concrete was mixed.

2.3 Test conducted

The modulus of elasticity is determined by subjecting cylinder specimen to uniaxial compression and measuring the deformations by means of compressometer fixed between certain guage lengths as shown in Figure 2. The guage length of compressometer is 200mm. The test was conducted as per IS 516-1959. The cylinders of size 300mm height and 150 diameter were used to find out the modulus of elasticity. Specimens were placed in CTM of 2000kN capacity without eccentricity and uniform load was applied till the failure of target load of the cylinder specimen. The target load and deformations were noted. The deformation readings observed from the compressometer were calculated as strain.

Diameter of the cylinder, D = 150mm

Height of the cylinder, H = 300mm

Cross-sectional area, A = 17671mm^2

Capacity of CTM = 2000kN

Figure 2. Compression Test on Cylinder Specimens

3. RESULTS AND DISCUSSIONS

The modulus of elasticity of concrete is generally related to compressive strength. The modulus of concrete under static loading conditions is generally known as its static modulus. The value of the static modulus 'E' for concrete is determined on the basis of the uniaxial stress-strain curve obtained from a standard test cylinder. The stress-strain characteristics of concrete are non-linear from the beginning. Strain was computed as the ratio of change in length obtained from the dial readings of compressometer at incremental load levels to the initially marked guage length. The stress was obtained for every incremental load to the specimen cross-sectional area. For finding out elasticity modulus of concrete, the strain deformations for incremental loads were graphically plotted against the stress variations. Using the stress-strain curves, modulus of elasticity values was determined. The initial tangent to the stress-strain curve is regarded as the initial tangent modulus. The modulus of elasticity is determined from the slope (dy/dx) of initial tangent drawn. The elasticity modulus varies with the load level, as well as with the rate of loading and the values of specimens is shown in Table 3 to 6. The stress-strain relationship of specimens is shown in Figure 3 to 6.

Table 3. Test Results of Specimen-1 (Vf=0%)

Load	Dial guage reading	Strain	Stress	Modulus of Elasticity (E)
kN	mm	mm/mm	N/mm^2	N/mm^2
0	0	0.0E+00	0	0
50	0.01	4.9E-05	2.83	5.80E+04
100	0.03	1.5E-04	5.66	3.87E+04
150	0.05	2.4E-04	8.49	3.48E+04
200	0.08	3.9E-04	11.32	2.90E+04
250	0.15	7.3E-04	14.15	1.93E+04
300	0.24	1.2E-03	16.98	1.45E+04
350	0.3	1.5E-03	19.81	1.35E+04
400	0.35	1.7E-03	22.64	1.33E+04
450	0.39	1.9E-03	25.46	1.34E+04
500	0.42	2.0E-03	28.29	1.38E+04

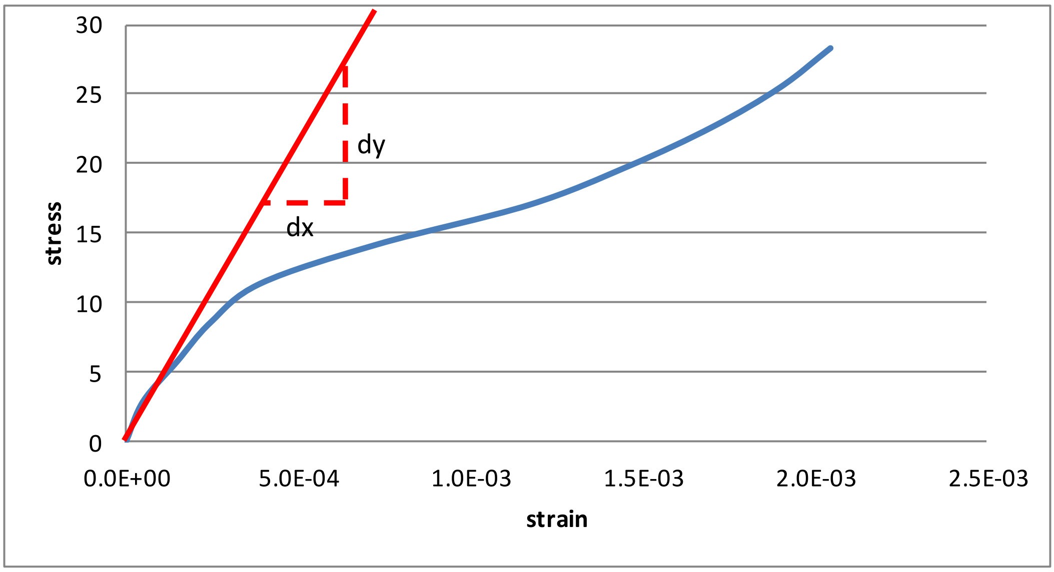

Figure 3. Stress-Strain curve for Specimen-1 (Vf=0%)

Table 4. Test Results of Specimen-2 (Vf=0.5%)

Load	Dial guage reading	Strain	Stress	Modulus of Elasticity (E)
kN	mm	mm/mm	N/mm^2	N/mm^2
0	0	0.00E+00	0	0
50	0.01	4.88E-05	2.83	5.80E+04
100	0.03	1.46E-04	5.66	3.87E+04
150	0.05	2.44E-04	8.49	3.48E+04
200	0.08	3.90E-04	11.32	2.90E+04
250	0.13	6.34E-04	14.15	2.23E+04
300	0.2	9.76E-04	16.98	1.74E+04
350	0.27	1.32E-03	19.81	1.50E+04
400	0.34	1.66E-03	22.64	1.36E+04
450	0.39	1.90E-03	25.46	1.34E+04
500	0.43	2.10E-03	28.29	1.35E+04
510	0.46	2.24E-03	28.86	1.29E+04

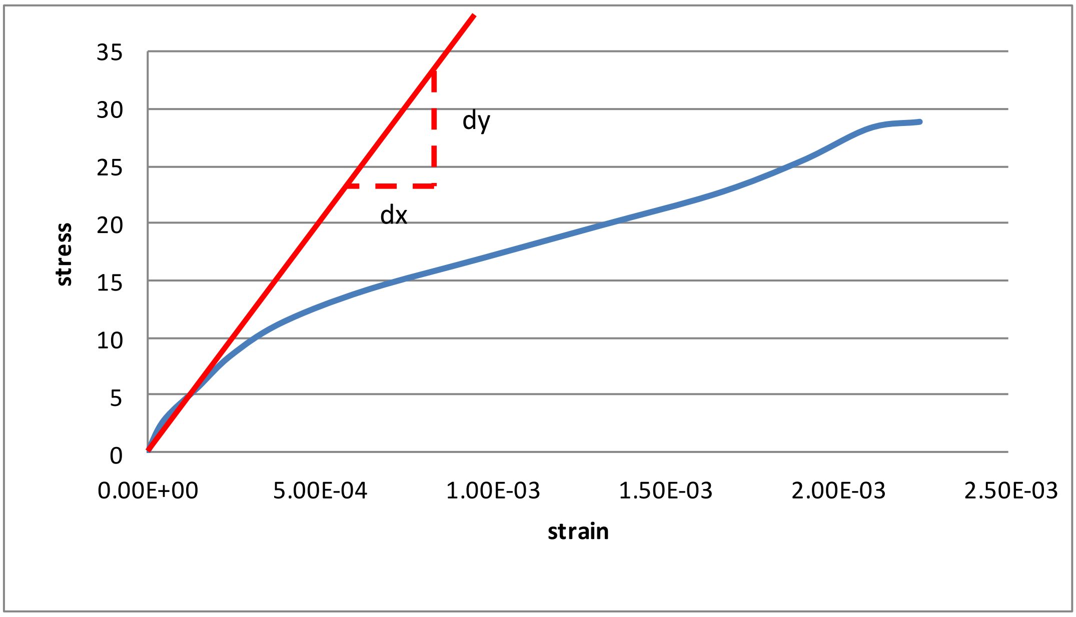

Figure 4. Stress-Strain curve for Specimen-2 (Vf=0.5%)

Table 5. Test Results of Specimen-3 (Vf=1.0%)

Load	Dial guage reading	Strain	Stress	Modulus of Elasticity (E)
kN	mm	mm/mm	N/mm^2	N/mm^2
0	0	0.00E+00	0	0
50	0.01	4.88E-05	2.83	5.80E+04
100	0.03	1.46E-04	5.66	3.87E+04
150	0.05	2.44E-04	8.49	3.48E+04
200	0.08	3.90E-04	11.32	2.90E+04
250	0.16	7.80E-04	14.15	1.81E+04
300	0.23	1.12E-03	16.98	1.51E+04
350	0.29	1.41E-03	19.81	1.40E+04
400	0.34	1.66E-03	22.64	1.36E+04
450	0.39	1.90E-03	25.46	1.34E+04
490	0.45	2.20E-03	27.73	1.26E+04

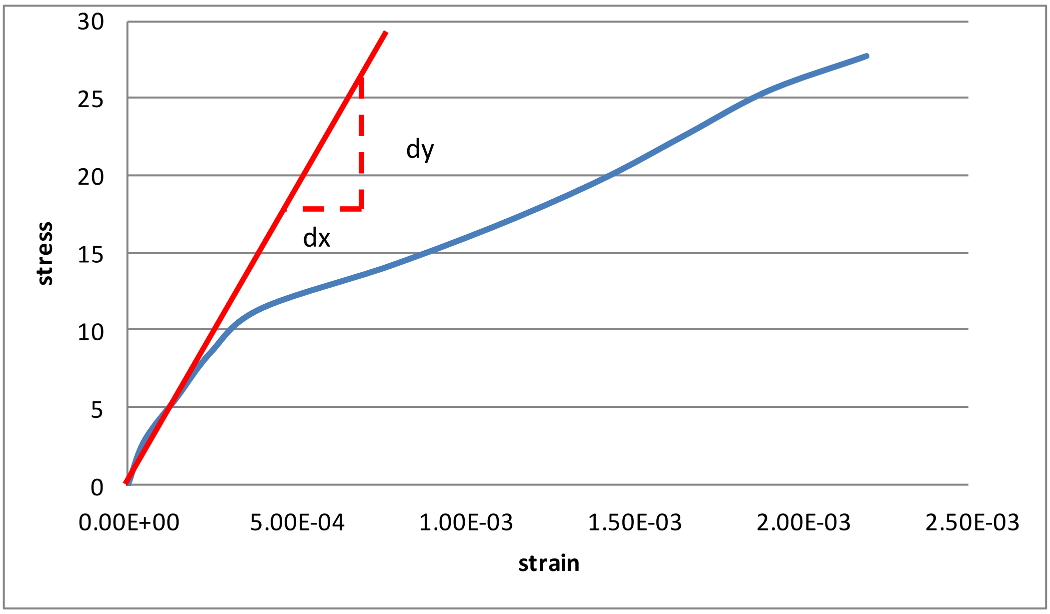

Figure 5. Stress-Strain curve for Specimen-3 (Vf=1.0%)

Table 6. Test Results of Specimen-4 (Vf=1.5%)

Load	Dial guage reading	Strain	Stress	Modulus of Elasticity (E)
kN	mm	mm/mm	N/mm^2	N/mm^2
0	0	0.00E+00	0	0
50	0.01	4.88E-05	2.83	5.80E+04
100	0.03	1.46E-04	5.66	3.87E+04
150	0.05	2.44E-04	8.49	3.48E+04
200	0.08	3.90E-04	11.32	2.90E+04
250	0.15	7.32E-04	14.15	1.93E+04
300	0.21	1.02E-03	16.98	1.66E+04
350	0.28	1.37E-03	19.81	1.45E+04
400	0.33	1.61E-03	22.64	1.41E+04
450	0.38	1.85E-03	25.46	1.37E+04

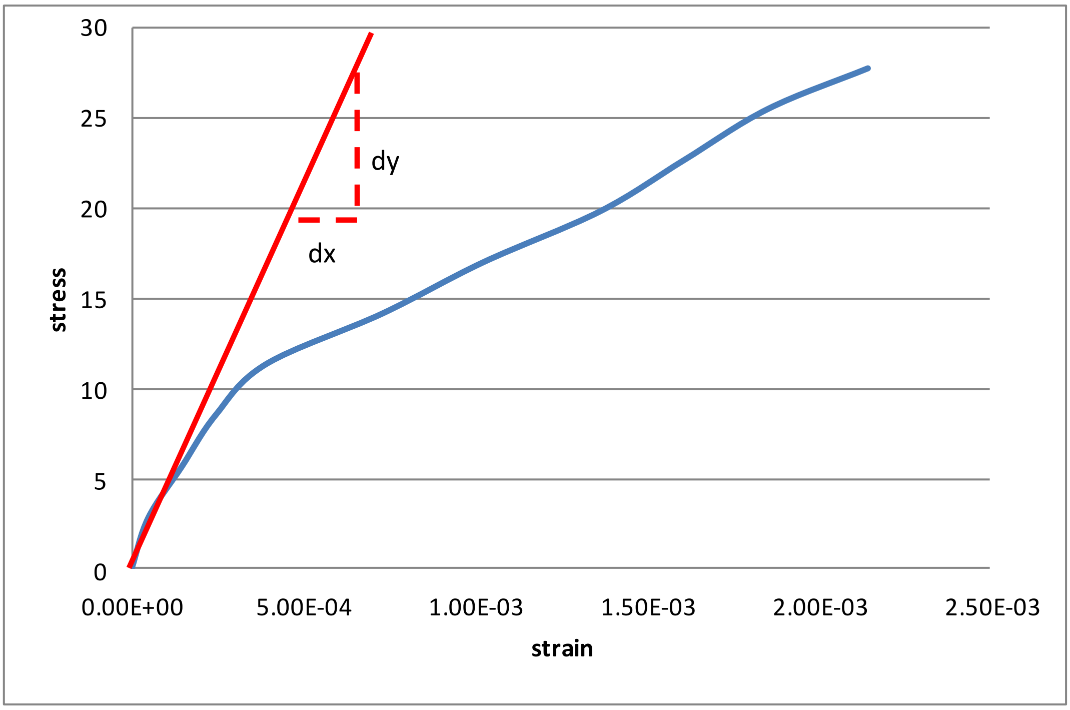

Figure 6. Stress-Strain curve for Specimen-4 (Vf=1.5%)

The modulus of elasticity for different values for fibre volume fractions, Vf = 0%, 0.5%, 1.0% and 1.5% were computed. From the stress-strain curves, taking slope (dy/dx) from the initial tangent modulus plotted, the values for modulus of elasticity are determined and tabulated in Table 7.

Table 7. Modulus of Elasticity of Specimens

Specimen No.	Fibre Volume fraction 'Vf'	Modulus of Elasticity 'E'	Average Modulus of Elasticity 'E'
	%	**N/mm^2**	**N/mm^2**
1	0	25.55×10^3	27.35×10^3
2	0.5	26.97×10^3	
3	1.0	28.75×10^3	
4	1.5	28.12×10^3	

From the above test results of the specimens, it was observed that the stress-strain variation is non-linear. The modulus of elasticity E of specimen ranges from 25 to 28 MPa for M20 grade concrete which is correlated with the theoretical modulus of elasticity $E=22.36 \times 10^3$ N/mm^2 as per IS 456-2000. The variation of modulus of elasticity with respect to fibre volume fraction is shown in Figure 7.

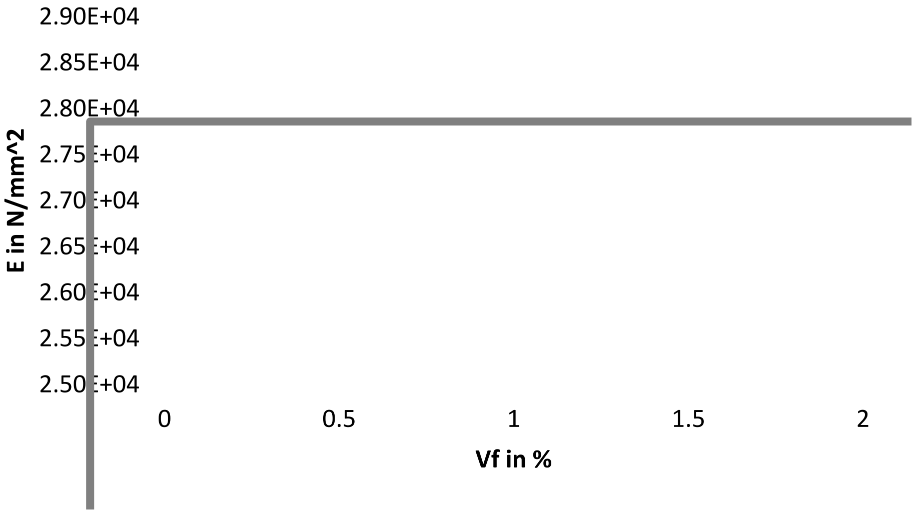

Figure 7. Modulus of Elasticity vs Fibre Volume fraction

4. CONCLUSION

Based on the results presented, the following conclusions are drawn:

- For the mix proportion of 1: 2.18: 2.56 and with a w/c ratio of 0.50 a desirable slump of 55mm has been achieved.
- The stress-strain relationship for the normal strength steel fibre reinforced concrete indicates a non-linear variation which gives an average modulus of elasticity value as 27.35×10^3 N/mm^2
- With a constant aspect ratio of steel fibre, the modulus of elasticity increases with the increase in fibre volume fraction from 0% to 1.0% and decreases for 1.5%.
- The compressive strength increases with increase in steel fibre volume fraction.
- The density of concrete increase with the addition steel fibre content.

5. REFERENCES

[1] IS: 456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete", ISI, New Delhi.

[2] IS: 516-2004, "Methods for Tests for Strength of Concrete", ISI, New Delhi.

[3] IS: 10262-1982, "Recommended guidelines for concrete mix design", ISI, New Delhi.

[4] BS 1881: Part 121:1983," Testing concrete Method for determination of static modulus of elasticity in compression".

[5] ASTM C 469-94" Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression"

[6] Shetty, M. S., "Concrete Technology Theory and Practices", Reprint 2008.

[7] Chen, S, 2004. "Strength of Steel Fibre Reinforced Concrete Ground Slabs". Proceedings of the Institute of Civil Engineers, Structures and Buildings (157), Issue SB2, pp. 157-163

[8] Banthia,N, Chokri,K, and Trottier,JF,1995. Impact tests on Cement-Based Fibre Reinforced Composites. ACI Publications, Detroit, USA, SP, 155-9, pp.171-188

[9] Khaloo, A R and Kim, N, 1997. "Influence of Concrete and Fibre Characteristics on Behaviour of Steel Fibre Reinforced Concrete under Direct Shear". ACI Materials Journal, 94, No. 4,pp. 592-601.

[10] Johnston, CD, and Zemp, WR, 1991. "Flexural Fatigue performance of Steel Fibre reinforced concrete- Influence of Fibre Content, Aspect Ratio, and Type". ACI Material Journal, 88, No.4, pp. 374-383.

[11] Elsaigh,WA and Kearsley,EP,2002."Effect of Steel Fibre Content on Properties of Concrete". Journal of Concrete/Beton, South Africa, No 102, pp. 8-12.

[12] Johnston Gopalaratnam, V.S. and S. Shah, 1987. “Failure mechanism and Fracture of fibre reinforced concrete, Fibre reinforced concrete – Properties and Application”, American Concrete Institute, Detroit, pp: 1-25

[13] A.M Shende et al.. “Comparative Study on Steel Fibre Reinforced cum Control Concrete” International Journal of Advanced Engineering Sciences and Technologies Vol. No. 6, Issue No. 1, 116 – 120

[14] Mohammed Alias Yusof et al., “Mechanical Properties of Hybrid Steel Fibre Reinforced Concrete with Different Aspect Ratio.” Australian Journal of Basic and Applied Sciences, 5(7): 159-166, 2011

[15] Er Prashant Y.Pawade et al. “Effect of Steel Fibres on Modulus of Elasticity of Concrete” (IJAEST) International Journal Of Advanced Engineering Sciences And Technologies Vol No. 7,Issue No. 2, 169 – 177

[16] Osman Gencel et al. “Workability and Mechanical Performance of Steel Fibre-Reinforced Self-Compacting Concrete with Fly Ash” Composite Interfaces 18 (2011)169–184

[17] Saravana Raja Mohan. K, Parthiban. K “Strength and behaviour of Fly Ash based Steel Fibre Reinforced Concrete Composite.

[18] J. Mater. “Mechanical Properties of Steel Fibre Reinforced Concrete”, Journal of Materials in Civil Engineering ,Volume 19 , Issue 5, 2007.