Experimental study of modulus of elasticity due to change in steel fiber reinforced concrete (SFRC) and size of aggregates

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Abstract— This paper presents a experimental study considers the effect of aggregate size &steel fibers on the modulus of elasticity of concrete. The modulus of elasticity of concrete is a very important parameter reflecting the ability of concrete to deform elastically. Modulus of elasticity of high strength concrete is very important in avoiding excessive deformation, providing satisfactory serviceability, and avoiding the most cost-effective designs. The present experimental study considers the effect of aggregate size and steel fibers on the modulus of elasticity of concrete. Crimped steel fibers at volume fraction of 0%.0.5%, 1.0% and 1.5% were used. Study on effect of volume fraction of fibers and change of aggregate size on the modulus of elasticity of concrete was also deemed as an important part of present experimental investigation. This work aims in studying the mechanical behavior of concrete in terms of modulus of elasticity with the change of aggregate size reinforced with steel fibers of different series for M30 and M50 grade concretes.

Index Terms— steel fibers, different size of aggregates, compressive test, split tensile test, cement, water, vibrator, weighing machine

1 Introduction

The concept of using fibers to improve the mechanical properties of concrete is known for many decades. It has been increasingly used in structural engineering applications. Adding fibers enhances the compressive, tensile and shear strengths, flexural toughness, durability and resistance to impact. The mechanical properties of fiber reinforced concrete depend on the type and the content of the added fibers.[1] SFRC is being increasingly used to improve static and dynamic tensile strength, energy absorbing capacity and better fatigue strength. Janesan, P. V. Indira and S. Rajendra Prasad reported the effect of steel fiber on the strength and behaviour of reinforced concrete is two-way action.[2] fiber volume fraction used in producing steel fiber reinforced concrete should be within 0.5% to 1.5% as the addition of fiber may reduce the workability of the mix and will cause balling or mat which will be extremely difficult to separate by vibration. According to ACI 544, 3R-08, aspect ratio is referred to the ratio of fiber length over the diameter. The normal range of aspect ratio for steel fiber is from 20 to 100. Aspect ratio of steel fiber greater than 100 is not recommended, as it will cause in adequate workability, formation of mat in the mix and also non uniform distribution of fiber in the mix. the percentage of volume of fiber in the concrete up to 1.5%. There results indicates that the addition fibers to concrete enhances its toughness and strength and peak stress, but can slightly reduced young's modulus. Steel fibers can reliably inhibit cracking and improve resistance to material deterioration as a result of fatigue, impact, and shrinkage, or thermal stresses[3]. A conservative but justifiable approach in structural members where flexural or tensile loads occur, such as in beams, columns, or elevated slabs , is that reinforcing bars must be used to support the total tensile load. In applications where the presence of continuous reinforcement is not essential to the safety and integrity of the structure, e.g., floors on grade, pavements, overlays, and concrete linings, the improvements in flexural strength, impact resistance, and fatigue performance associated with the fibers can be used to reduce section thickness, improve performance, or both. From this work it is observed that with increase in % volume of fibers the young's modulus decreases with an increase in strain fraction. The main advantages of these fibers fast& perfect mixable fibers & high performance and crack resistance, optimization costs with lower fiber dosages, steel fibers reduces the permeability & wa

migration in concrete.

2 .METHODOLOGY

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage[4]e. They also reduce the permeability of Concrete and thus reduce bleeding of water. Some types of fibers produced greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to the concrete mix is expressed as a percentage of total volume of the composite (concrete and Fibers), termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%[5]. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). This is an experimental set up of casting SFRC cylindrical specimens standard size with change of aggregate sizes such as 20mm,16mm,10mm and with varying percentages of fibers such as 0%,0.5%,1% &1.5% to study the stress-strain relationship in tension & compression aspect ratios of steel fibers used in concrete mix are varied between 50 and 100.

The experimental program was designed to determine the modulus of elasticity of M30 & M50 grade concrete standard cylinders for M30/20 mix proportion 0.46:1:1.26:3.12 and M50/20 mix proportion 0.39:1:0.74:3.08[6] under the compression and split tensile tests[7].

This experimental program consists of twenty four standard size of cylinders for each grade namely M30/20mm/0 % ,M30/20mm/0.5%,M30/20mm/1%,M30/20mm/1.5%,M30/16mm /0%M30/16mm/0.5%,M30/16mm/1%,M30/16mm/1.5%,M30/10 mm/0%,M30/10mm/0.5%,M30/10mm/1%,M30/10mm/1.5%for M30gradeandM50/20mm/0%,M50/20mm/0.5%,M50/20mm/10% ,M50/20mm/1.5%,M50/16mm/0%,M50/16mm/0.5%,M50/16mm /1%,M50/16mm/1.5%,and0/10mm/0%,M50/10mm/0.5%,M50/10 mm/1% ,M50/10mm/1.5% for M50 grade concrete. The arrangement of the cylindrical specimen subjected to split tensile loading and compressive loading [8].

Compression test: Then place the cylinder in test setup and apply the load continuously without any After 28 days curing, the cylindrical specimens were tested in the compression testing machine of capacity of 200 tons. An extensometer of gauge length 200mm and a least count of 0.002mm has been used to note the deformation values. So a cylinder mounted with an extensometer was used to find out the deformation values during loading. The vertical strips of extensometer were removed before placing the cylinder in test setup so as to avoid the damage of extensometer during loading shock to note the deformation values. And stop the applying of the load after the specimen has failed.[9] The compressive strength of the specimen can be calculated by using Compressive strength (MPa) = Failure load / cross sectional area

Split tensile test: In Split tensile strength test, cylinder 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 where in they were allowed to cure for 28 days.[10] The strain gauges of 350Ω resistance capacity and a gauge factor of 2.1 have been used to note the strain values.[11] After the strain gauges have been attached to the specimens, they were tested under compression testing machine of Capacity 200 tons[12]. Split Tensile strength was calculated [13]:

$$\text{SplitTensilestrength(MPa)} = 2P/\pi DL$$

Where ,P=failure load, D=diameter of cylinder,

L = length of cylinder.

3. RESULTS AND DISCUSSION

3.1 Modulus of elasticity in compression: the failure stress values increases with the increase of steel fiber content. And the percentage increase in failure stresses were 51.8%, 45.8% and 57.14% for M30 grade and 38.5%, 40% and 35.71% for M50 grade concrete. The following are the graphs showing the relationship between stress and strain of casted specimens after testing in compression.

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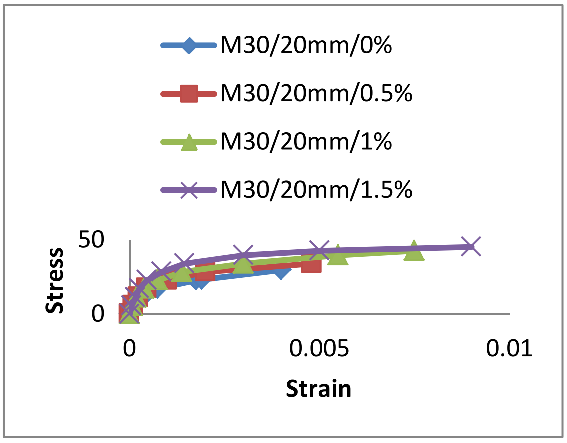

Fig1:StressVsstraingraphforM30/20m

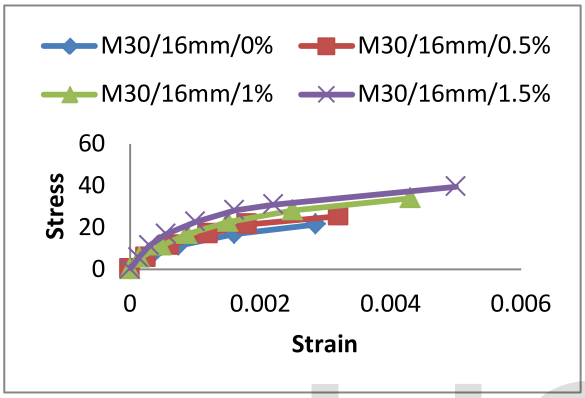

Fig2:Stress Vs strain graph for M30/16mm

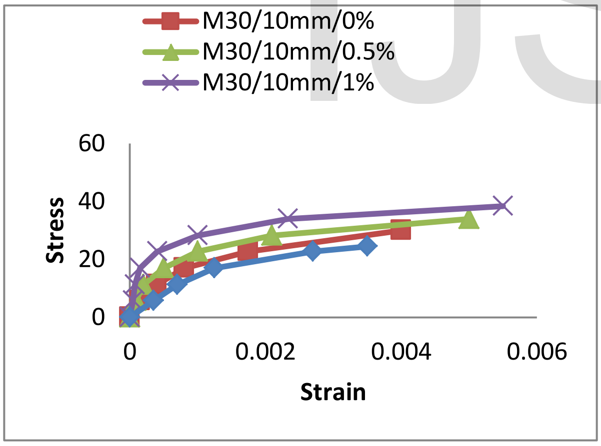

Fig 3 Stress Vs strain graph for M30/10mm

Percentage increase in modulus of elasticity of steel fiber based concrete mixes were 118.36%, 117.42% and 326.2% for M30 grade and 140%, 92.76%and 120.6% for M50 grade concrete.

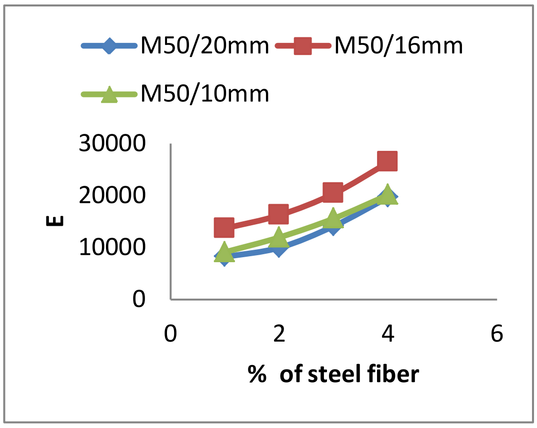

Fig4:EVs%offiberforM50

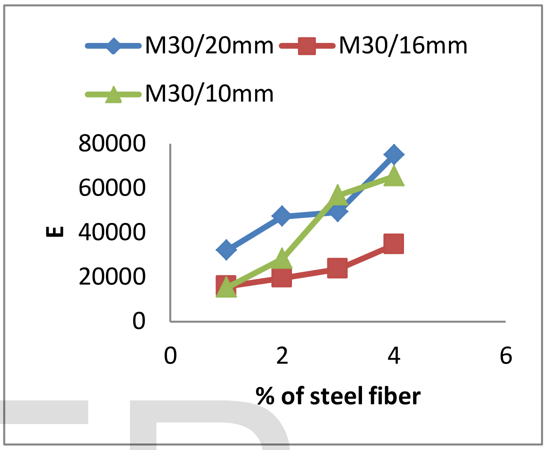

Fig5:EVs%offiberforM30

The percentage increase in modulus of elasticity of steel fiber reinforced concrete at 33% of the percentage increase in modulus of elasticity of steel fiber reinforced concrete at 33% of the maximum stresses were 45.8%,60% and 60% for M30 grade, and 38.83% ,50% and 43.32% for M50 grade concrete.

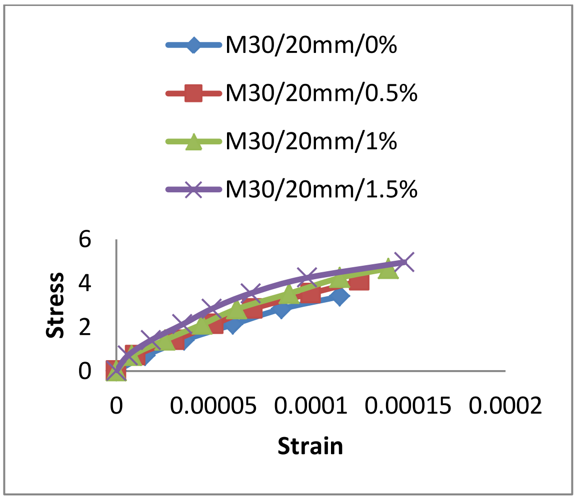

Fig 6:Stress strain graph for M30/20

Maximum stresses were 45.8%,60% and 60% for M30 grade, and 38.83% ,50% and 43.32% for M50 grade concrete.

3.2 Modulus of elasticity in tension: It is observed that the failure stresses were increased with the increase of steel fiber content. And the percentage increase in failure stresses were 45.8%, 60% and 60% for M30 grade and 38.72%, 50% and 50% for M50 grade concrete. The following are the graphs showing the relationship between stress and strain of casted specimens after testing in tension.

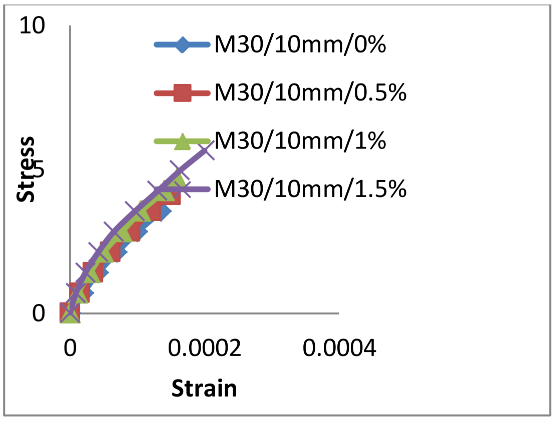

Fig 7:Stress strain graph for M30/10

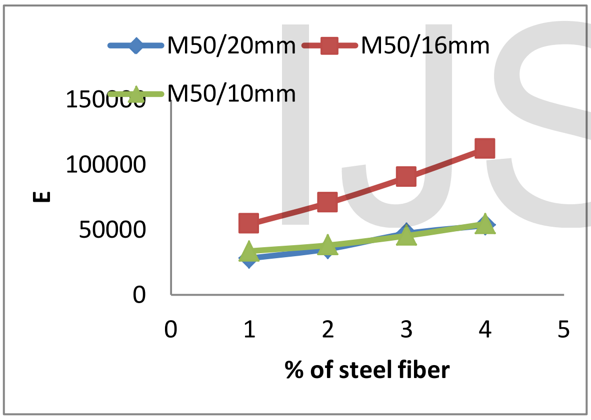

Fig8: EVs%of steel fiberforM50

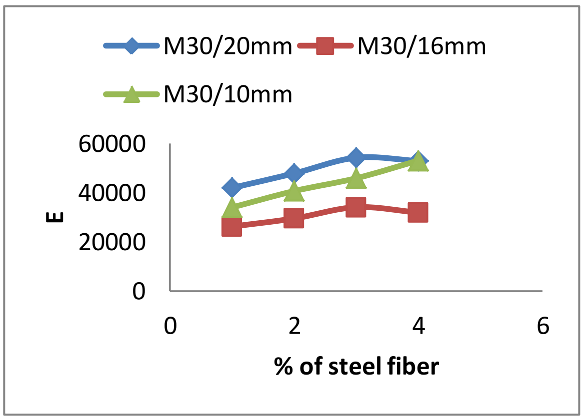

Fig 9:EVs%of steel fiberforM30

The relationship between ultimate stress (σ_U) and % of steel fiber content and the percentage increase in the ultimate stress were 45.8%, 60% and 60% for M30 grade, and 38.72% ,50% and 50% for M50 grade concrete.

The results of modulus of elasticity for plain concrete and Steel Fiber Reinforced Concrete in compression and tension are shown in Table 1, Table 2& Table3 And the percentage increase in modulus of elasticity of steel fibre reinforced concrete at 33% of the maximum stresses were 51.7%, 45.82% and 56.8% for M30 grade, and 3.5%,38.5% and 35.7% for M50 grade concrete.

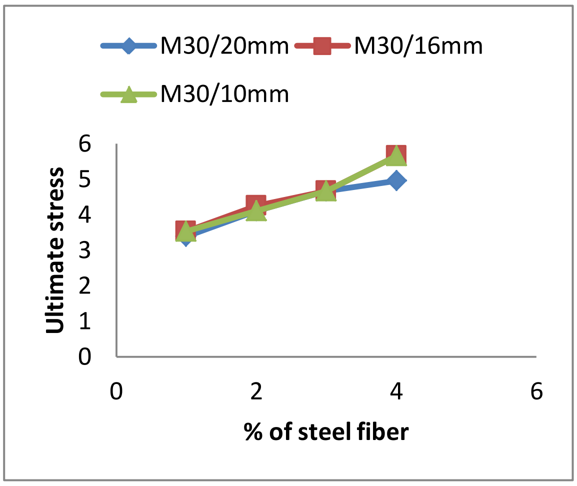

Fig 10:σ_U Vs%ofsteelfiberforM50

SPECIMEN ID	σ_U	E_U (%)	σ	E(%)	$E_{33\%}$
M30/20 /0%	29.837	0.004	9.846	0.000307	31986
M30/20 /0.5%	34.026	0.0048	11.228	0.000237	47245.8
M30/20 /1%	42.462	0.0075	14.012	0.000284	49167.7
M30/20 /1.5%	45.293	0.009	14.946	0.000054	276685
M30/16 /0%	27.1762	0.0033	8.968	0.0006	15934
M30/16 /0.5%	27.742	0.0035	9.154	0.0005	19647
M30/16 /1%	33.970	0.0043	11.21	0.0005	23679
M30/16 /1.5%	39.632	0.005	13.078	0.0004	34645
M30/10 /0%	24.572	0.0035	8.108	0.000529	15308.7
M30/10 /0.5%	30.007	0.004	9.902	0.000349	28307.1
M30/10 /1%	33.97	0.005	11.21	0.000198	56614.9
M30/10	38.5	0.0055	12.705	0.0001	6525

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/1.5%				090	0
M50/20/0%	39.631	0.0099	13.078	0.0016	8202.1
M50/20/0.5%	47.558	0.0106	15.694	0.0016	9983.5
M50/20/1%	51.521	0.0102	17.001	0.0012	14141
M50/20/1.5%	54.918	0.0105	18.122	0.0009	19687
M50/16/0%	39.631	0.0043	13.078	0.001	13695
M50/16/0.5%	45.293	0.0047	14.947	0.0009	16246
M50/16/1%	53.220	0.0055	17.562	0.0009	20394
M50/16/1.5%	55.484	0.0053	18.309	0.0007	26399
M50/10/0%	39.632	0.0059	13.078	0.0014	9129.7
M50/10/0.5%	45.294	0.0061	14.947	0.0012	11976
M50/10/1%	50.389	0.0062	16.628	0.0011	15608
M50/10/1.5%	53.786	0.0065	17.749	0.0009	20147

σU= Ultimate stress of cylindrical specimens (N/mm2)
stress
of σ
E33%= Elastic Modulus at a stress corresponding to 33% of Ultimate strength.*E*U = Ultimate strain of cylindrical specimens (%)
σ = Stress at 33% of the ultimate strength (N/mm2)
E = Strain of cylindrical specimens corresponding to

Table 1 Details of modulus of elasticity in compression

SPECIMEN ID	σ_U	E_U (%)	σ	E (%)	$E_{33\%}$
M30/20/0%	3.3970	0.000115	1.1210	0.00002668	42006
M30/20/0.5%	4.1047	0.000125	1.354	0.00002827	47887
M30/20/1%	4.670	0.00014	1.541	0.00002838	54296
M30/20/1.5%	4.953	0.000148	1.634	0.00003086	52932
M30/16/0%	3.5386	0.0002	1.167	0.00004447	26242.3
M30/16/0.5%	4.246	0.0003	1.401	0.00004743	29538.1
M30/16/1%	4.670	0.0003	1.541	0.00004516	34122.3
M30/16/1.5%	5.6617	0.0003	1.868	0.00005855	31901.6
M30/10/0%	3.538	0.000135	1.167	0.00003427	34045
M30/10/0.5%	4.104	0.00015	1.354	0.00003326	40704
M30/10/1%	4.670	0.000159	1.541	0.00003355	45931
M30/10/1.5%	5.6617	0.0002	1.8681	0.00003515	53133
M50/20/0%	4.387	0.0002	1.447	0.00005126	28225.6
M50/20/0.5%	4.953	0.00021	1.634	0.00004618	35378.3
M50/20/1%	5.520	0.00023	1.821	0.00003860	47174.1
M50/20/1.5%	6.086	0.00025	2.008	0.00003756	53456.1
M50/16/0%	4.246	0.00015	1.401	0.00002574	54422.693
M50/16/0.5%	4.954	0.00017	1.634	0.00002309	70756.697
M50/16/1%	5.661	0.0002	1.868	0.00002067	90337.705
M50/16/1.5%	6.369	0.00024	2.101	0.00001875	112044.89
M50/10/0%	4.246	0.0002	1.401	0.00004152	33739
M50/10/0.5%	4.954	0.0002	1.634	0.00004273	38237
M50/10/1%	5.6617	0.0002	1.868	0.00004099	45566
M50/10/1.5%	6.086	0.0003	2.008	0.00003675	54637

Table 2 Details of modulus of elasticity in tension

C	E_c	E_t	E_t/E_C
M30/20/0%	31986	42006	1.313
M30/20/0.5%	47245.8	47887	1.013
M30/20/1%	49167.7	54296	1.104
M30/20/1.5%	276685	52932	0.191
M30/16/0%	15934	26242.3	1.646
M30/16/0.5%	19647	29538.1	1.503
M30/16/1%	23679	34122.3	1.441
M30/16/1.5%	34645	31901.6	0.920
M30/10/0%	15308.7	34045	2.223
M30/10/0.5%	28307.1	40704	1.437
M30/10/1%	56614.9	45931	0.811
M30/10/1.5%	65250	53133	0.814
M50/20/0%	8202.1	28225.6	3.441
M50/20/0.5%	9983.5	35378.3	3.543
M50/20/1%	14141	47174.1	3.335
M50/20/1.5%	19687	53456.1	2.715
M50/16/0%	13695	54422.693	3.973
M50/16/0.5%	16246	70756.697	4.355
M50/16/1%	20394	90337.705	4.429
M50/16/1.5%	26399	112044.89	4.244

M50/10/0%	9129.7	33739	3.695
M50/10/0.5%	11976	38237	3.192
M50/10/1%	15608	45566	2.919
M50/10/1.5%	20147	54637	2.711

Table 3 Details of modulus of elasticity in compression and tension

4. Conclusion

It is observed that,the failure stresses increased with the increase of steel fiber content [i.e.0-1.5%] as 51.8%,45.8% and 57.14% for M30 grade and 38.5% ,40% and 35.71% for M50 grade concrete in compression and 45.8%,60% and 60% for M30 grade and 38.72%, 50% and 50% for M50 grade concrete in tension. It is also observed that,the modulus of elasticity (E) value increases with the increase of steel fiber content.It is also observed that,the ultimate stress and modulus of elasticity (E) value were increased with the decrease of aggregate size From the comparisions of compression and tension reults,it was cleared that the ultimate stress values in tension were higher than those in compression.i.e,5 times for M30 and 14 times for M50 grade concretes.

The modulus of elasticity (E) values in tension were higher than those in compression. i.e,94 times for M30 and 55 times for M50 grade concretes.

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