A Elastic Properties of Fibrous Triple Blended Concrete with Flyash and Silica Fume

M. Bhasker, P. Sreenivasa Rao, B.L.P. Swami

Abstract— **In the present experimental investigation, standard cylinders are cast with M60 grade concrete. Upto 35% of cement is replaced by a combination of flyash and silica fume in different proportions and fibres are added to these combinations in different percentages. Elastic properties of these fibrous triple blended concrete, in terms of Young's Modulus and Poisson's ratio are studied. It is found that concrete mix with 15% silica fume and 1.5% fibres is giving the highest Young's Modulus and lowest Poisson's ratio. In almost all the mixes tried in the investigation, it is observed that the elastic properties are fairly good.**

Index Terms— Flyash, HPC, Silica Fume, Fibres, Young's Modulus, Poisson's ratio, Triple Blending.

1. INTRODUCTION

A. Requirements of Concrete

Concrete is one of the versatile heterogeneous materials civil engineering has ever known. With the advent of concrete, civil engineering has touched highest peak of technology. Concrete is a material with which any shape can be cast and with equal strength or rather more strength than the conventional building stones. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required.

B.High Strength Concrete and High Performance Concrete

Technology for producing high strength concrete has sufficiently advanced that concrete with compressive strength greater than 40 Mpa are commercially available and strength much higher than that can be produced in laboratories. High-performance concrete (HPC) offers significantly better structural engineering properties, such as higher compressive and tensile strengths, higher stiffness, better durability, when compared to the conventional normal strength concrete (NSC). Concrete of very high strength entered the field of construction of high rise buildings and long span bridges. In India high strength concrete is being used for pre-stressed concrete bridges. Concrete being used for important construction projects should possess not only high strength but also workability and durability. High Performance Concrete (HPC) possessing all these qualities has become the need of the hour.

Manuscript received July 02, 2014

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C. Admixtures for HPC

Admixture is defined as a material, other than cement, water and aggregates and is added to the batch immediately before or during mixing. Mineral admixtures like fly ash, condensed silica fume (CSF), Ground Granulated Blast Furnace Slag (GGBS) etc. are being added as part replacement of cement in the production of HPC. In addition, high range water reducing admixtures like superplasticizers are being employed to maintain workability without affecting the strength.

D. Necessity of Triple Blended Mixes

While silica fume is compatible with pulverized fly ash, it is a pozzolonic material and hence will gave differing results depending on the mix design used. If present in high proportions the reactivity of fly ash will be affected by the ability of the microsilica to rapidly consume the calcium hydroxide. High levels of fly ash can cause problems with high water contents leading to segregation and bleeding, not only on the surface of the concrete but also within the matrix itself. Silica fume will virtually eliminate this bleeding and hence maintain the integrity of the concrete. With normal levels of fly ash (say 10-30%) silica fume can be added to give enhanced performance.

E. Role of Fibre Reinforcement

When the loads imposed on concrete approach that for failure, cracks propagate, sometimes rapidly. Fibres in concrete provide a means of arresting the crack growth. Reinforcing steel bars in concrete have, the same beneficial effect because they act as long continuous fibres. Short discontinuous fibres have the advantage however of being uniform. If the modulus of elasticity of the fibre is high with respect to the modulus of elasticity of the concrete or mortar binder, the fibres help to carry the load, thereby increasing the tensile strength of the material. Increases in the length, diameter ratio of the fibres usually augment the flexural strength and toughness of the concrete. The values of aspect ratio are usually restricted to between 100 and 200 since fibres which are too long tend to "ball" in the mix and create workability problems. Fibres are generally randomly distributed in the concrete.

F. Brief Review of Previous Work

Bharat Kumar et at[2] discussed the details like mix proportioning for HPC, cement content, admixtures etc. Myers [6] studied the procedure for obtaining higher modulus of elasticity of concrete. Setunge et al[5] studied the static modulus of very high strength concretes.

G. Details of the Present Paper

The present investigation is to study the elastic properties of HPC of M60 grade, with a partial replacement of cement with silica fume and fly ash. The study includes the concept of triple blending of cement with silica fume and fly ash. The triple blended cements exploit the beneficial characteristics of both pozzolonic materials in producing a better concrete. The elastic properties of triple blended concrete composites with and without steel fibre reinforcement are studied.

II. EXPERIMENTAL INVESTIGATION

A. Experimental Programme

An experimental study is conducted to find out the young's modulus and poisons ratio of the composite at the age of 28 days. In concrete the partial replacement of cement by silica fume and fly ash are varied as (15%+0%), (0%+10%), (15%+10%), (0%+20%), (15%+20%), (0%+30%) and (15%+30%) by weight.
M-60 grade of concrete is designed according to DOE method.
The effect of partial replacement of cement by silica fume (% by weight) on strength and workability of concrete are investigated.
The following gives the details of materials used and the experiments conducted.

B. Cement

Ordinary Portland cement 53 grade brand conforming to I.S. specifications is used in the present investigation. The cement is tested for its various properties as per IS code.

C. Fine Aggregate

The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clayey matter, salt and organic impurities. The sand is tested for various properties like specific gravity, bulk density etc., in accordance with IS 2386-1963(28).

D. Coarse Aggregate

Machine crushed angular granite metal from local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is also tested for its various properties.

E. Flyash

It was obtained from Ramagundam Thermal Power Station, Andhra Pradesh.

F. Silicafume

Condensed Silica Fume (CSF) was obtained from M/s. V.B. Ferro Alloys Ltd., Rudraram, Medak Dist., A.P.

G. Steel Fibre

Steel fibres with an aspect ratio of 55 are (diameter 0.9mm and length 50mm) mixed with concrete uniformly to produce fibrous concrete mix. Steel fibres were added at percentages of 0.0, 0.5, 1.0 and 1.5 by volume of concrete.

H. Superplasticizer

A small percentage (less than 0.5) of superplasticizer (Conplast 430 of M/s. Fosrock India ltd.) was added to fresh concrete to obtain sufficient workability.

I. Concrete Mix

In the present investigation, M-60 concrete is designed by the D.O.E. methods as per British code. The various proportions of the materials are given in table.1.

Table.1 Mix Proportions by weight of M-60 grade concrete

	Cement	Fine Aggregate	Coarse Aggregate	Water	Remarks
Proportions	1.00	1.01	1.72	0.33	
Quantities required for 1cm. of concrete	590.94 kg.	597.21 Kg.	1016.88 kg.	195 lit.	Superplasti-cizer was not employed as sufficient workability was available for the basic mix.

J. Mixing, Casting and Curing

All the ingredients were mixed uniformly to produce a homogenious and cohensive concrete matrix. Four percentage of flyash 0, 10, 20 and 30 were adopted. Two percentages of CSF 0 and 15 were used. The mineral admixtures were used as replacement to cement. Four percentages of fibre by volume of concrete, 0, 0.5, 1.0 and 1.5 were incorporated. In total 28 combinations of fibrous triple blended concrete composites were tried. Superplasticizer was added in small percentages wherever necessary. All the mixes were cast in standard cylinder moulds, and cured for 7 days and 28 days. For mixing, casting and curing standard procedures were followed, and sufficient number of standard cylinder specimens were prepared.

K. Workability Test

All the mixes with various combinations were tested for workability in the fresh state using compacting factor apparatus. The workability was maintained almost at medium level with a compacting factor of 0.85 to 0.92. This was possible with the addition of superplasticizer particularly in mixes with high percentage of fibres.

L. Testing of Specimens

The cylinder specimens cured as explained above are tested as per standard procedure after removal from curing tank and allowed to dry under shade. The cure specimens are tested for
Young's modulus
Poisons ratio

M. Determination of Young's modulus and Poisson's Ratio

The longitudinal extensometer is used for determination of the strain and deformation characteristics of high strength fibrous cement concrete cylindrical specimens of 150mm dia x 300mm length. Poisson's ratio was found by testing the specimens using lateral extensometer. Standard digital compression testing machine was used for applying the loads on the specimens.

III. PRESENTATION OF RESULTS

Typical results are given in the following.

Table.2 gives the values of young's modulus computed for reference mix with 0% fly ash, 0% CSF and 0% fibres. Table.3 shows the results of young's modulus for 1% fibres with admixtures (0% fly ash and 0% CSF). Typical tables from 4 to 8 show the results obtained for various other combinations. Typical results of Poisson's ratio are shown in tables 9 to 12. Typical stress-strain relation is plotted and shown in fig. 1. Fig.2 shows the influence of fly ash percentage on young's modulus for 15% CSF and 0.5% fibres.

IV. DISCUSSION OF RESULTS

The results obtained on basis of experimentation conducted in the present research work are discussed herein.

A. Triple Blended Concrete Mixes

Triple blending of cement by partially replacing cement with pozzolonas like flyash and condensed silica fume contributes to the enhanced properties of the concrete mix. By replacing the cement with readily and cheaply available pozzolonas considerable economy is achieved.
Internal Micro cracks are inherently present in the concrete and its poor tensile strength is due to the

B. Use of Fibres in Concrete

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking propagation of such micro cracks, eventually leading to brittle fracture of the concrete.
It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties and does not notably increase the mechanical properties before failure but governs the post failure behaviour. The addition of fibres contribute to the enhanced properties in tensile strength and flexural strength of the concrete.

C. Influence of Fly ash on Young's Modulus and Poisson's ratio

Keeping the percentage of silica fume and steel fibre percentage zero in the concrete mix, the increase in fly ash content has considerably decreased the Young's modulus and has shown an increase in the Poisson's ratio as shown in tables and figures. Keeping the steel fibre percentage zero and silica fume content equal to 15 percent, with increase in fly ash content in the concrete mix, young's modulus increased initially and decreased with the increase in fly ash content as shown.The poisson's ratio has initially decreased, but with the increase in fly ash content it has increased as shown. Keeping the silica fume percentage 15 and fibre percentage 1.0 in the concrete mix, with increase in fly ash content, the young's modulus has a gradual increase initially and a gradual decrease later due to the increase in fly ash content and the Poisson's ratio has initially decreased and later increased due to the same reason.

D. Influence of Silica fume on Young's Modulus and Poisson's Ratio

With an increase in silica fume content upto 15 percent in the concrete mix and fly ash content kept constant, the young's moduli of the mixes have a gradual increase. The poisson's ratio shows a gradual decrease. With an increase in silica fume content upto 15 percent in the concrete mix and fly ash content varying upto 30 percent, the young's modulus has increased initially but the values have come down with an increase in fly ash content as shown in tables and graphs.

E. Influence of Fibres on Young's Modulus

The increase in fibre content in concrete mixes and keeping the silica fume and fly ash contents constant has shown a gradual increase in young's modulus as shown.

Table.2 Young's modulus for (Fly ash=0% CSF=0% Fibres=0%)

Load (KN)	Longitudinal Extensometer Reading	ReadingxL.C. LC=0.002mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	4.5	0.009	0.0000	1.131	50297.	
40	9	0.018	0.0000	2.263	50288.	
60	14	0.028	0.0000	3.395	48504.	
80	19	0.038	0.0000	4.527	47652.	
100	24	0.048	0.0001	5.658	47156.	
120	29	0.058	0.0001	6.790	46831.	
140	35	0.07	0.0001	7.923	45276	
160	41	0.082	0.0002	9.054	44166.	Avg.
180	46	0.092	0.0002	10.18	44286.	42607.
200	51	0.102	0.0002	11.31	44382.	
220	56	0.112	0.0002	12.44	44462.	
240	61	0.122	0.0003	13.58	44527.	
260	67	0.134	0.0003	14.71	43919.	
280	72	0.144	0.0003	15.84	44013.	
300	78	0.156	0.0003	16.97	43529.	
320	85	0.17	0.0004	18.10	42607.	
340	92	0.184	0.0004	19.24	41826.	
360	100	0.2	0.0005	20.37	40740	
380	107	0.214	0.0005	21.50	40192.	
400	115	0.23	0.0005	22.65	39396.	
420	121	0.242	0.0006	23.76	39284.	

Table.3 Young's modulus for fly ash =0% CSF=0% Fibres=1.0%

Load (KN)	Longitudinal Extensometer Reading	ReadingxL.C. LC=0.002 mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	5.5	0.011	0.0000275	1.1317	41152.73	
40	9.5	0.019	0.0000475	2.263	47642.11	
60	14	0.028	0.00007	3.3953	48504.29	
80	19	0.038	0.000095	4.527	47652.63	
100	24	0.048	0.00012	5.6588	47156.67	
120	30	0.06	0.00015	6.7906	45270.67	
140	35	0.07	0.000175	7.9233	45276	
160	41	0.082	0.000205	9.0541	44166.34	Avg. Ec= 39365 N/m
180	47	0.094	0.000235	10.1859	43344.26	
200	54	0.108	0.00027	11.3176	41917.04	
220	61	0.122	0.000305	12.4494	40817.7	
240	67	0.134	0.000335	13.581	40540.3	
260	74	0.148	0.00037	14.7129	39764.59	
280	81	0.162	0.000405	15.8447	39122.72	
300	86	0.172	0.00043	16.9765	39480.23	
320	92	0.184	0.00046	18.108	39365.22	
340	99	0.198	0.000495	19.24	38868.69	
360	107	0.214	0.000535	20.37	38074.77	
380	114	0.228	0.00057	21.503	37724.56	
400	122	0.244	0.00061	22.653	37136.07	
420	130	0.26	0.00065	23.7671	36564.77	

Table.4 Young's modulus for Flyash=0% CSF=0% Fibres=1.5%

Load (KN)	Longitudinal Extensometer Reading	ReadingxL.C. LC=0.002mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	5	0.01	0.0000	1.131	45268	
40	10	0.02	0.0000	2.263	45260	
60	14	0.028	0.0000	3.395	48504.	
80	20	0.04	0.0001	4.527	45270	
100	25	0.05	0.0001	5.658	45270.	
120	29	0.058	0.0001	6.790	46831.	
140	34	0.068	0.0001	7.923	46607.	
160	40	0.08	0.0002	9.054	45270.	Avg.
180	45	0.09	0.0002	10.18	45270.	42285.
200	51	0.102	0.0002	11.31	44382.	71
220	56	0.112	0.0002	12.44	44462.	
240	61	0.122	0.0003	13.58	44527.	
260	67	0.134	0.0003	14.71	43919.	
280	72	0.144	0.0003	15.84	44013.	
300	78	0.156	0.0003	16.97	43529.	
320	85	0.17	0.0004	18.10	42607.	
340	91	0.182	0.0004	19.24	42285.	
360	96	0.192	0.0004	20.37	42437.	
380	102	0.204	0.0005	21.50	42162.	
400	110	0.22	0.0005	22.65	41187.	
420	117	0.234	0.0005	23.76	40627.	

Table.5Young's modulus for Flyash=0% CSF=15% Fibres=1.0%

Load (KN)	Longitudinal Extensometer Reading	Readingx L.C. LC= 0.002 mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	5	0.01	0.000025	1.1317	45268	
40	10	0.02	0.00005	2.263	45260	
60	16	0.032	0.00008	3.3953	42441.25	
80	22	0.044	0.00011	4.527	41154.55	
100	30	0.06	0.00015	5.6588	37725.33	
120	39	0.078	0.000195	6.7906	34823.59	
140	48	0.096	0.00024	7.9233	33013.75	
160	57	0.114	0.000285	9.0541	31768.77	Avg.
180	66	0.132	0.00033	10.1859	30866.36	45843.0
200	68	0.136	0.00034	11.3176	33287.06	
220	69	0.138	0.000345	12.4494	36085.22	
240	70	0.14	0.00035	13.581	38802.86	
260	72	0.144	0.00036	14.7129	40869.17	
280	73	0.146	0.000365	15.8447	43410.14	
300	76	0.152	0.00038	16.9765	44675	
320	79	0.158	0.000395	18.108	45843.04	
340	84.5	0.169	0.000423	19.24	45538.46	
360	88	0.176	0.00044	20.37	46295.45	
380	88.5	0.177	0.000443	21.503	48594.35	
400	81	0.162	0.000405	22.653	55933.33	

Table.6 Young's modulus for Flyash=10% CSF=15% Fibres=0%

Load (KN)	Longitudinal Extensometer Reading	ReadingxL.C. LC= 0.002 mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	5	0.01	0.000025	1.1317	45268	
40	10	0.02	0.00005	2.263	45260	
60	15	0.03	0.000075	3.3953	45270.67	
80	20	0.04	0.0001	4.527	45270	
100	27	0.054	0.000135	5.6588	41917.04	
120	30	0.06	0.00015	6.7906	45270.67	
140	35	0.07	0.000175	7.9233	45276	
160	40	0.08	0.0002	9.0541	45270.5	Avg. Ec=
180	44	0.088	0.00022	10.1859	46299.55	46510.96
200	49	0.098	0.000245	11.3176	46194.29	N/mm^2
220	54	0.108	0.00027	12.4494	46108.89	
240	59	0.118	0.000295	13.581	46037.29	
260	63	0.126	0.000315	14.7129	46707.62	
280	68	0.136	0.00034	15.8447	46602.06	
300	73	0.146	0.000365	16.9765	46510.96	
320	77	0.154	0.000385	18.108	47033.77	
340	85	0.17	0.000425	19.24	45270.59	
360	90	0.18	0.00045	20.37	45266.67	
380	98	0.196	0.00049	21.503	43883.67	

Table.7 Young's modulus for Flyash=10% CSF=15% Fibres=1.0%

Load (KN)	Longitudinal Extensometer Reading	Readingx L.C. LC= 0.002mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	6	0.012	0.00003	1.1317	37723.33	
40	12	0.024	0.00006	2.263	37716.67	
60	18	0.036	0.00009	3.3953	37725.56	
80	24	0.048	0.00012	4.527	37725	
100	30	0.06	0.00015	5.6588	37725.33	
120	36	0.072	0.00018	6.7906	37725.56	
140	41	0.082	0.000205	7.9233	38650.24	
160	46	0.092	0.00023	9.0541	39365.65	Avg. Ec=
180	52	0.104	0.00026	10.1859	39176.54	34404.8
200	58	0.116	0.00029	11.3176	39026.21	N/mm^2
220	65	0.13	0.000325	12.4494	38305.85	
240	71	0.142	0.000355	13.581	38256.34	
260	77	0.154	0.000385	14.7129	38215.32	
280	84	0.168	0.00042	15.8447	37725.48	
300	88	0.176	0.00044	16.9765	38582.95	
320	96	0.192	0.00048	18.108	37725	
340	109	0.218	0.000545	19.24	35302.75	
360	116	0.232	0.00058	20.37	35120.69	
380	125	0.25	0.000625	21.503	34404.8	
400	133	0.266	0.000665	22.653	34064.66	

Table.8 Young's modulus for Fly ash=20% CSF=15% Fibres=1.0%

Load (KN)	Longitudinal Extensometer Reading	Readingx L.C. LC= 0.002 mm	Compressive Strain	Stress (N/mm^2)	Ec (N/mm^2)	Remarks
20	5	0.01	0.000025	1.1317	45268	
40	11	0.022	0.000055	2.263	41145.45	
60	17	0.034	0.000085	3.3953	39944.71	
80	24	0.048	0.00012	4.527	37725	
100	30	0.06	0.00015	5.6588	37725.33	
120	37	0.074	0.000185	6.7906	36705.95	
140	42	0.084	0.00021	7.9233	37730	
160	50	0.1	0.00025	9.0541	36216.4	Avg. Ec=
180	57	0.114	0.000285	10.1859	35740	36120.21
200	63	0.126	0.000315	11.3176	35928.89	N/mm^2
220	70	0.14	0.00035	12.4494	35569.71	
240	74	0.148	0.00037	13.581	36705.41	
260	79	0.158	0.000395	14.7129	37247.85	
280	85	0.17	0.000425	15.8447	37281.65	
300	94	0.188	0.00047	16.9765	36120.21	
320	101	0.202	0.000505	18.108	35857.43	
340	108	0.216	0.00054	19.24	35629.63	
360	115	0.23	0.000575	20.37	35426.09	
380	121	0.242	0.000605	21.503	35542.15	
400	127	0.254	0.000635	22.653	35674.02	
420	133	0.266	0.000665	23.7671	35740	

Table.9 Poisson's ratio Cement: 100% Flyash: 0% Silica Fume: 0%

Load	Extensometer Reading	Read-ing *LC	Lateral Strain	Longitud-inal Strain	VC	Remarks
280	5	0.01	0.0000333	0.00036	0.092593	Typical values are given
300	6	0.012	0.00004	0.00039	0.102564	
320	7	0.014	0.0000466	0.000425	0.109804	

Table.10 Poisson's ratio Cement: 100% Flyash: 0% Silica Fume: 0%

Load	Extensometer Read-ing	Read-ing *LC	Lateral Strain	Longitudinal Strain	VC	Remarks
290	8	0.016	0.00005	0.00034	0.147059	Typical values are give
300	9	0.018	0.00006	0.000365	0.164384	
310	9	0.018	0.00006	0.000385	0.155844	

Table.11 Poisson's ratio Cement: 65% Flyash: 20% Silica Fume: 15%

Load	Extensometer Read-ing	Read-ing *LC	Lateral Strain	Longitudinal Strain	VC	Stress	Re-marks
360	12	0.024	0.00008	0.000575	0.13913		
400	15	0.03	0.0001	0.000605	0.165289		
420	19	0.038	0.000126667	0.000635	0.199475		

Table.12 Poisson's ratio Cement: 70% Flyash: 30% Silica Fume: 0%

Load	Extensometer Read-ing	Read-ing *LC	Lateral Strain	Longitudinal Strain	VC	Stress	Re-marks
380	9	0.018	0.00006	0.000575	0.104348		
400	13	0.026	0.0000867	0.000575	0.144444		
420	16	0.032	0.000107	0.000575	0.164103		

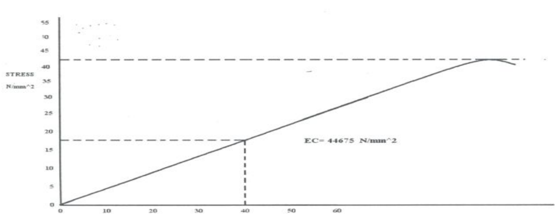

Fig.1 Stress-Strain relationship of concrete with Fly ash=0% CSF=0% Fibres=0.5%

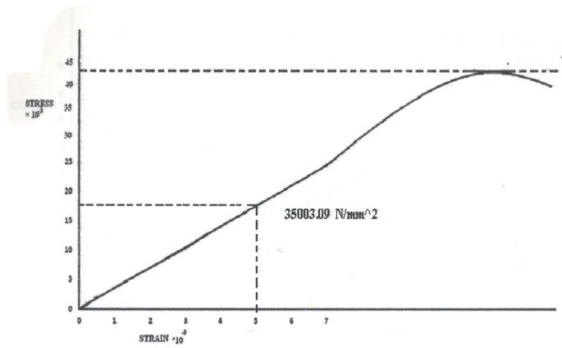

Fig.2 Stress-Strain relationship of concrete with Fly ash=0% CSF=15% Fibres=0%

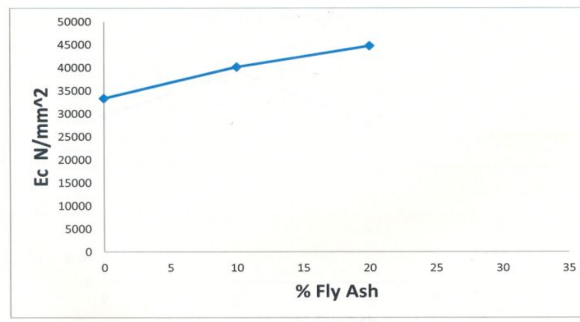

Fig.3 Variation of young's modulus against fly ash percentage with CSF=15% and fibres=0.5%

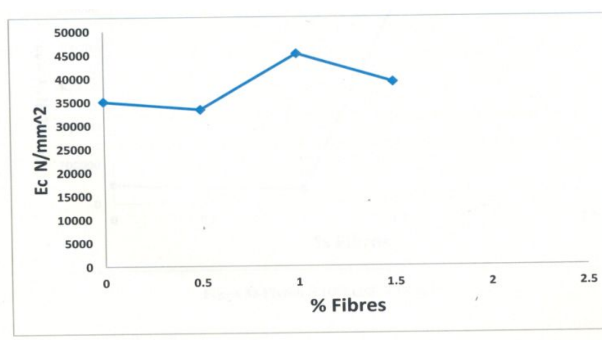

Fig.4 Variation of young's modulus against fibre percentage with fly ash=0% and CSF=15%

V. CONCLUSIONS

Based on the experimental investigation conducted in the present research work, the following conclusions are drawn.

In the case of high strength concrete mixes as the water cement ratio is low, super plasticizers are to be added to maintain the required workability.

By using triple blended cements, a better concrete mix possessing higher strength and elastic properties can be produced.
Steel fibres in the concrete mix help in graining tensile strength and flexural strength in addition to improving its elastic properties as well as crack resistance.

On increasing the fly ash content from 0 to 30 percentage and with no silica fume, compressive strength is reduced as such elastic properties have reduced.

When fly ash is used along with silica fume in triple blended concrete mixes, the strength and elastic properties can be maintained without reduction in Young's modulus.

The presence of silica fume in the concrete mix helps in the strength gain. As the silica fume percentage added is increased upto 15 percent, there is maximum strength gain. Elastic modulus is increased and Poisson's ratio is decreased. The presence of silica fume compensates for the loss of strength which occurs when higher percentages of fly ash are used.

Steel fibres in the concrete mix contribute towards higher compressive strength, higher elastic modulus and lesser Poisson's ratio.

Triple blended concrete mix with 15 percent silica fume and zero percent fly ash and 1.5 percent fibres is giving the highest young's modulus and lowest poisson's ratio.

On the whole, in almost all the mixes tried in the investigation the elastic properties are fairly good when compared to the reference mix (fly ash=0%, silica fume=0%, fibre=0%).

Triple blended concrete mixes with suitable percentages of steel fibres serve all the requirements and hence provide the best answer to the production of high performance concrete for structural use.

ACKNOWLEDGEMENTS

The authors express this deep sense of gratitude to the authorities of Vasavi College of Engineering, Ibrahimbagh, Hyderabad, for the facilities provided in carrying out the present research programme

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