International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

EFFECT OF TERNARY BLENDS ON PROPERTIES OF HARDENED CONCRETE

K Raja Sekhar[1], Ravulaparti Rama Rao[2]

[1]*PG Student, Civil Engineering, Pydah College of Engg &Tech*

[2]*Senior Professor, Civil Engineering, Pydah College of Engg &Tech*

ABSTRACT

This research focused on study of the effect of different supplementary cementitious materials (silica fume and fly ash) on various properties of concrete, because combinations of cement additions may provide more benefit for concrete than a single one. In present study concrete with ternary blends of Portland cement, silica fume and fly ash were produced to investigate their effects on compressive strength at 7,28 and 90 days curing, split tensile strength and modulus of elasticity at 28 days curing. Portland cement is partially replaced by silica fume and fly ash by keeping silica fume constant at15% and increasing percentage of fly ash from 0% to 60% of total cementitious material. Compressive strength at 7,28 & 90 days and split tensile strength at 28 days shows same variation but variations of modulus of elasticity were different. Compressive strength and split tensile strength were found maximum at 45% replacement but modulus of elasticity was found maximum at 30% total replacement of cement by silica fume and fly ash. The test results indicate that combination of fly ash and silica fume can be used to increase compressive strength and to increase the modulus of elasticity of concrete.

Keywords: Cementitious Material, Super Plasticizer, Silica Fume, Fly Ash Cement.

I. INTRODUCTION

High performance concrete prepared from ordinary Portland cement and various supplementary cementitious materials are increasingly finding their use in construction worldwide. High performance concrete (HPC) is in general, cement-based concrete which meets special performance requirements with regard to workability, strength, and durability, that cannot always be obtained with techniques and materials adopted for producing conventional cement concrete.

1.1 Why Ternary Blends?

A number of reports have demonstrated that concretes containing combinations of fly ash and silica fume with Portland cement are superior in certain respects to concretes containing Portland cement only. Studies at the Virginia Transportation Research Council have also demonstrated that silica fume added in relatively small amounts to fly ash concrete significantly improves early resistance of the concrete to penetration by chloride ions when tested in accordance with ASTM C1202.4, 5 The type and source of the cement, characteristics and amounts of fly ash, and silica fume affected the results.

The chemical binding of chlorides by fly ash due to its content of aluminum works together with the pore refinement due to silica fume to give excellent performance in a chloride environment, Due to low reaction rate, fly ash has often been used in HPC to reduce the heat of hydration and will also give good flow in fresh concrete. However, this gives a problem in fly ash concrete is the early age, what to do until the fly ash has hydrated sufficiently to have strength and to protect against aggressive. In a triple blend, the silica fume takes care of properties in the early age, while fly ash adds its contribution at later ages. Many reinforced concrete structures have suffered from premature chlorides induced corrosion damage and the specification of concrete to prevent this has proven to be difficult. Benefits, in terms of improved resistance to chloride ingress, through the use of additional materials in ternary blends, such as silica fume (SF) and fly ash (FA) are now well established.

A. Effect on fresh concrete

a. Increase cohesion

b. Reduced bleeding

B. Effect on hardened concrete

a. Enhanced mechanical properties

b. Reduced permeability

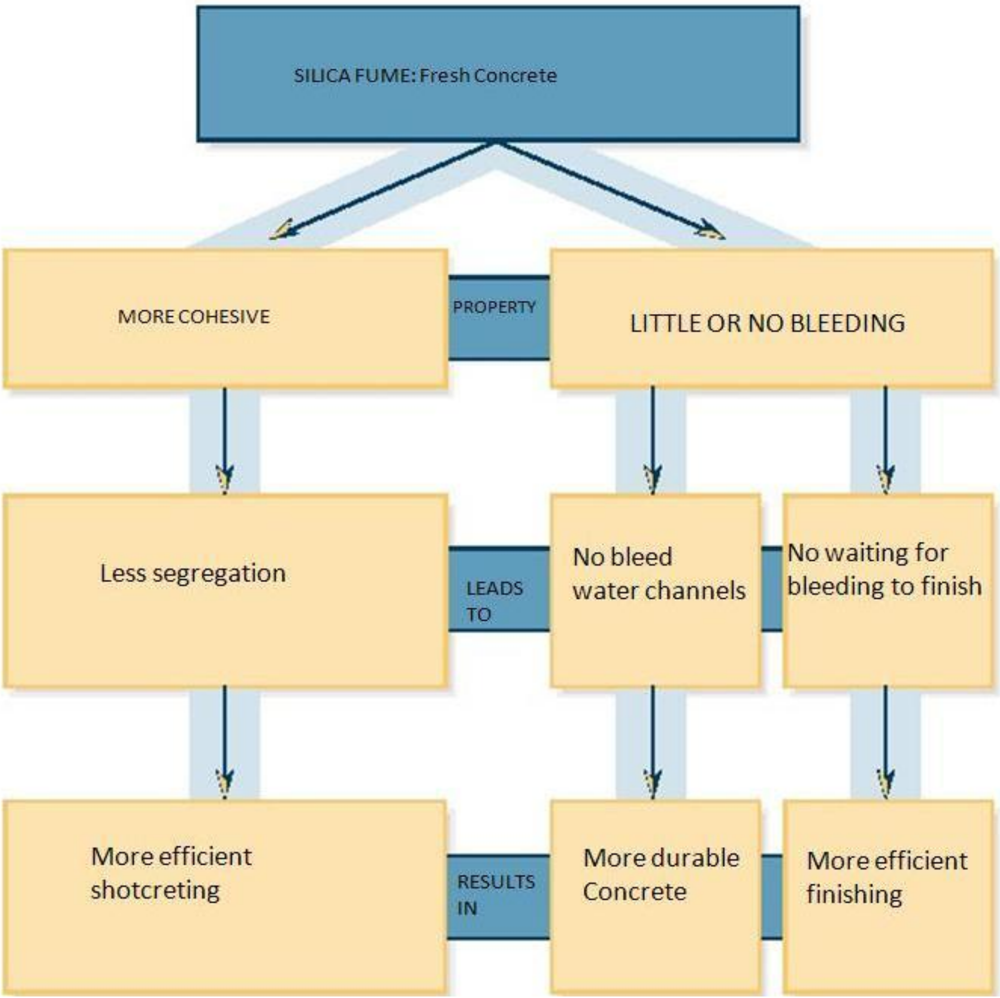

Fig.1.1 effect of silica fume on properties of fresh concrete (source: silica fume user manual "US department Triple blends have characterized several major projects done with micro silica.

1. Great Belt, Denmark
2. Øresund, Denmark/Sweden
3. Confederation Bridge, Canada
4. Tsing Ma, Hong Kong
5. Bandra Worli in Mumbai

1.2 Bandra Worli in Mumbai

As an example, these are performance data from pile-caps in the Bandra Worli project Concrete specification

Cement (53 Grade)
Micro silica
Fly ash
Coarse aggregate 20mm
Coarse aggregate 10mm
Natural Sand
Crushed Sand
Free water (liters)
Water Binder ratio
Admixture (liters)

Chloride Ion penetration- ASTM C 1202:	600 Coulombs
Water Permeability (DIN 1048):	Nil
Maximum temperature at the core:	**6**8 C.
Max. Temperature difference	< 20^{o} C

Concrete structures made up of silica fume and OPC concrete-

Fig.1.2High bridge great belt, Denmark (source- Elkem micro silica)

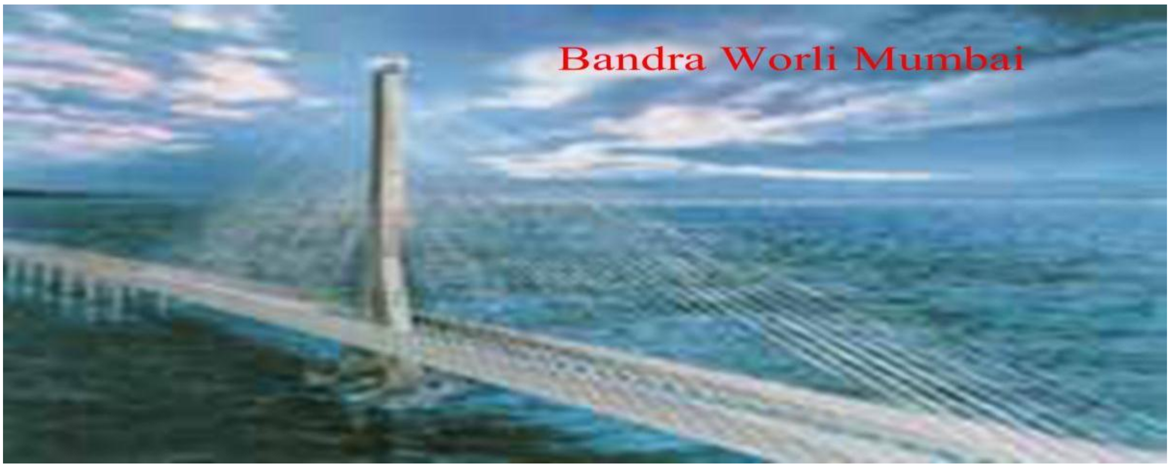

Fig.1.3Bandra worli bridge, Mumbai(source- Elkem micro silica)

II. REACTIONS OF SILICA FUME AND FLY ASH

2.1 Silica fume

The benefits seen from adding silica fume are the result of changes to the microstructure of the concrete. These changes result from two different but equally important processes. The first of these is the physical aspect of silica fume and the second is its chemical contribution. Here is a brief description of both of these aspects.

(a)Physical contributions

Adding silica fume brings millions and millions of very small particles to a concrete mixture. Just like fine aggregate fills in the spaces between coarse aggregate particles, silica fume fills in the spaces between cement grains. This phenomenon is frequently referred to as particle packing or micro-filling.fig (2.6) shows the basic concept of particle packing - filling the spaces between cement grains with silica fume particles.

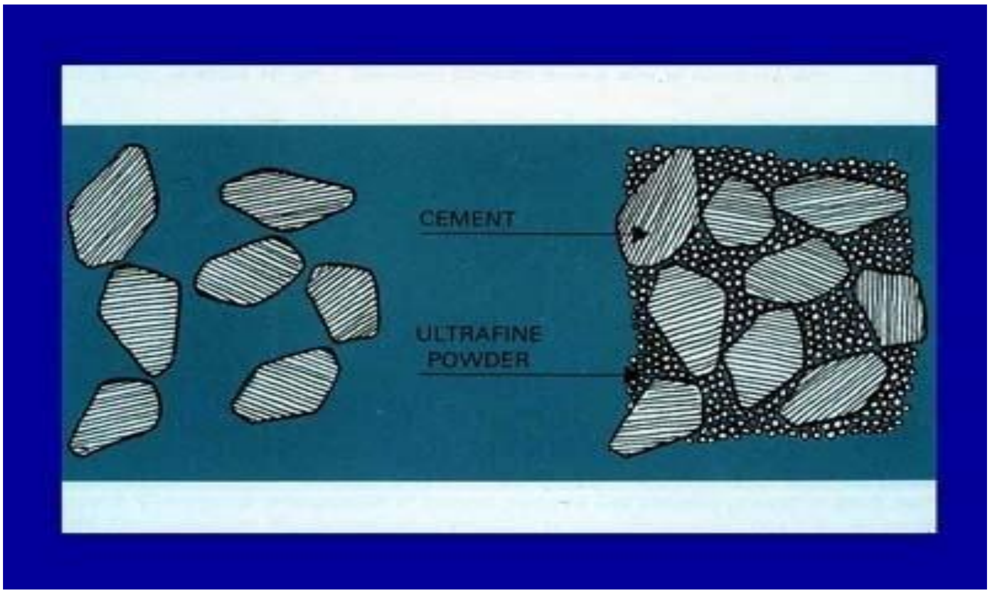

Fig.2.1 concept of particle packing - filling the spaces between cement grains with silica fume particles (source: silica fume user manual "US department of transportation)

(b)Chemical contributions

The reaction of cement with water causes a series of complex chemical reactions. The main compounds in cement are two calcium silicates (i.e., di-calcium silicate and tri-calcium silicate), and the physical behavior of these compounds is similar to that of cement during hydration. Highly crystalline portlandite [$Ca(OH)_2$] and amorphous calcium-silicate-hydrate (C-S-H) are formed in the hydration of Portland cement (PC). The hydrated cement paste consists of approximately 70% C-S-H, 20% CH, 7% sulfo-aluminate, and 3% secondary phases [10].

Calcium hydroxide, which is formed as a result of chemical reaction, is soluble in water and has low strength. These properties affect the quality of concrete negatively. Adding mineral admixtures (silica fume and fly ash) to cement decreases the amount of $Ca(OH)_2$. According to **M. Lessard et al(1992)**, cement paste containing silica fume (SF) produces amorphous C-S-H gel with high density and low Ca/Si ratio. The benefits of this reaction can be seen in the crucial interfacial zone increasing the bond strength between concrete paste and aggregates, yielding greatly increased compressive strengths and a concrete that is more resistant to attack from aggressive chemicals than the weaker calcium hydroxide found in ordinary Portland cement concretes.

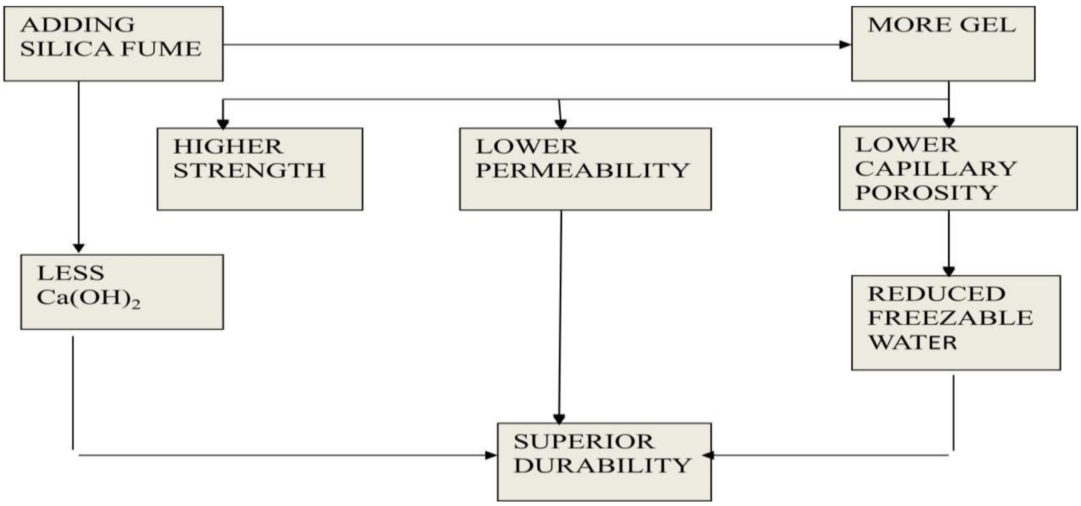

Fig.2.2 effects of adding silica fume to concrete

2.2 Fly Ash

In similar manner like silica fume fly ash also contribute as physical and chemical contribution.

(a) Physical aspect

Main influence of fly ash is on water demand and workability. For a constant workability, reduction in water demand due to fly ash is usually between 5 to 15 percent by comparison with a Portland cement only.

A concrete mix containing fly ash is cohesive and has a reduced blending capacity. Reduction in water demand of concrete caused by presence of fly ash is usually ascribed to their spherical shape, which-bearing is called **Neville** effect **AM (2005)** ball However, other mechanisms are also involved and may well be dominant. In particular, in consequence of electric charge, the finer fly ash particles become adsorbed on the surface of cement particles. If enough fine fly ash particles are present to cover the surface of the cement particles, which thus become deflocculated, the water demand for a given workability is reduced.

(b) Chemical contributions

Like silica fume, in fly ash product of reaction closely resemble C-S-H product by hydration of Portland cement. However reaction does not start until some time after mixing. Because glass material of fly ash is broken down only when the PH value of pore water is more than 13 and this increase in alkalinity of pore water require that a certain amount of hydration of Portland cement in the mix has taken place. Moreover reaction products of Portland cement participate on the surface of fly ash particle, which acts as nuclei.

Class C fly ash which has high lime content reacts, to some extent, direct with water; in particular, some C_2S may be present in fly ash and this compound reacts to form C-S-H. Also, crystalline C_3A and aluminates are reactive. In addition to this with class F fly ash, there is a reaction of silica with calcium hydroxide produced by hydration of Portland cement. Thus, class C fly ash reacts earlier than class F fly ash. As the reaction of class F fly ash required a high alkalinity of pore water and this alkalinity is reduced when silica fume is used in the mix. So in the ternary mix of fly ash and silica fume, class C fly ash is used.

2.3 Testing Procedure and experimental setup

After the specified period of curing the specimens were taken out of the curing tank and their surfaces were wiped off. The various tests were performed as described below.

1. Compressive Strength of cubes at 7, 28 & 90 days.
2. Split Tensile Strength of cylinders at 28 days.
3. Modulus of elasticity at 28 days.

III. COMPRESSIVE STRENGTH

The specimens were tested at the age of 7, 28 and 90 days. The cubes were tested on compression testing machine after drying at room temperature according to IS 516- 1959. The load was applied continuously without impacts and uniformly @140kg/cm²/minute. Load was continued until the specimen failed and maximum load carried by the specimen was recorded. The cube compressive strength was obtained by considering the average of three specimens at each age.

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

Fig.3.1 Compression testing machine

3.1 Split Tensile Strength

The splitting tests are well known indirect tests used for determining the tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive plates. due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of loaded diameter as obtained from an elastic analysis. Due to this tensile stress a vertical crack is appeared in the cylinder at the failure. The magnitude of$_{sp}$ (actingthisin a tensi perpendicular to the line of action of applied loading) is given by the formula(IS : 5816-1970) :

$\sigma_{sp} = 2P/\pi dl$

Fig. 3.2 Tensile testing of cylinder in CTM

Fig.3.3 Specimen failed in tension (vertical crack is appeared)

3.2 Modulus of elasticity

Three cylindrical specimens are prepared for each mix type to find the modulus of elasticity by means of an extensometer. After removing the cylinder from water and while it is in wet condition, extensometer is attached at ends, parallel to its axis, in such a way that the gauge points are symmetrical about center of specimen and not nearer to either end of specimen than a distance equal to half the diameter of the specimen.

The load is applied continuously and without shock at the rate of 5 KN/Sec until an average stress of (C+5)kg/cm^2 is reached, where C is one third of average compressive strength of the cubes calculated to the nearest 5 kg/cm^2. After drawing a stress-strain curve, modulus of elasticity is found from this curve. An average value is found foe the three specimens..

Fig.3.4 Set to draw stress strain curve by CTM using LVD

ijates
ISSN 2348 - 7550

Fig3.5 Failure of sample under compression

Fig 3.6 Failure pattern of samples under compression

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

IV. RESULT & DISCUSSION

Table 4.1 Variation of 7, 28 and 90 days compressive strength

S.no.	Mix designation	7 days Compressive strength (MPa)	28 days Compressive strength (MPa)	90 days compressive strength (MPa)
1	R-0	18.88	34	37.33
2	R-30	18.67	33.33	37.11
3	R-45	17.77	38.44	42.89
4	R-60	16.88	31.11	36.67
5	R-75	12.44	20.88	32.44

Table: 4.1

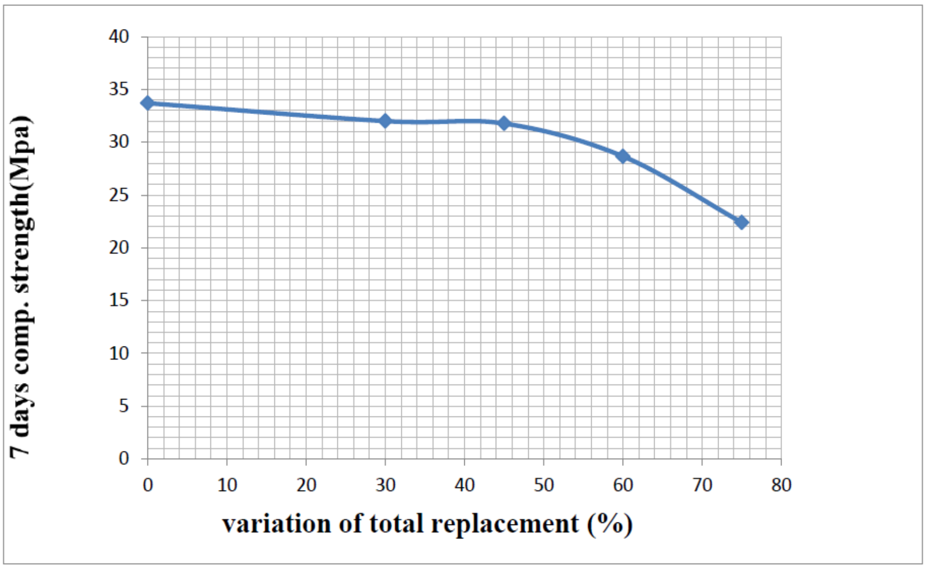

Fig.4.1 variation of 7 day compressive strength

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

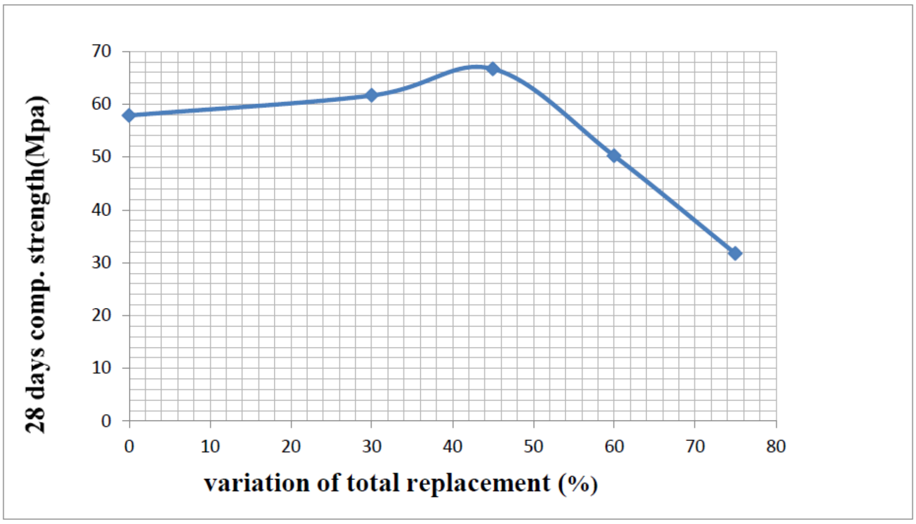

Fig.4.2 Variation of 28 days compressive strength

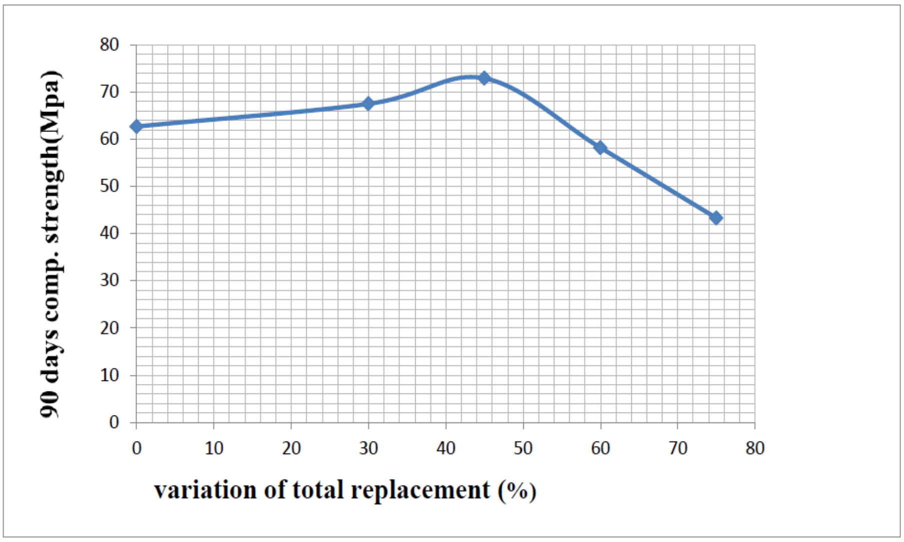

Fig.4.3 Variation of 90 days compressive strength

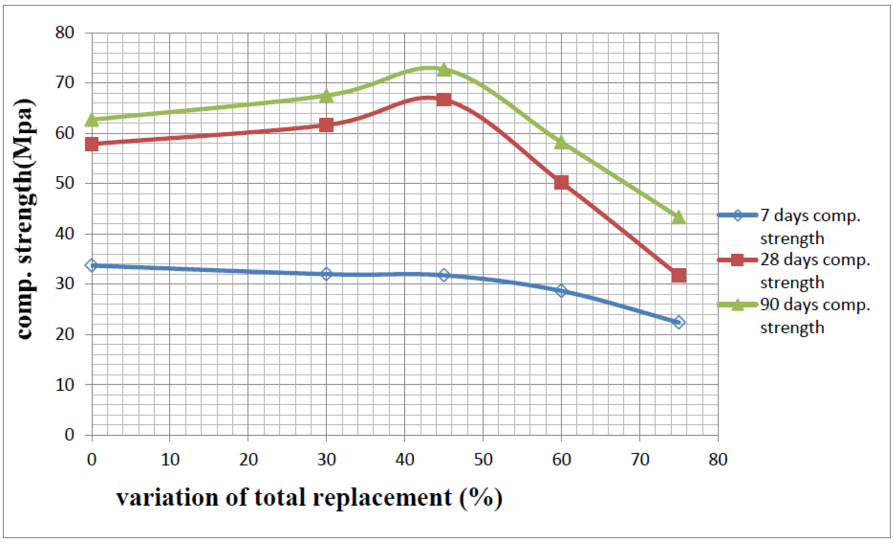

Fig.4.4 Comparison of compressive strength at 7, 28 and 90 days of curing

4.4 Variation of split tensile strength

150mmX300mm cylinders were casted to calculate split tensile strength. Specimens were tested for split tensile strength after 28 days of curing in compressive testing machine. Results obtained are shown in Table 4.2 and Fig 4.5 below-

Table 4.2 Variation of 28 days split tensile strength

S.no.	Mix designation	28 days split tensile strength(MPa)
1	R-0	3.52
2	R-30	3.61
3	R-45	3.71
4	R-60	3.23
5	R-75	2.61

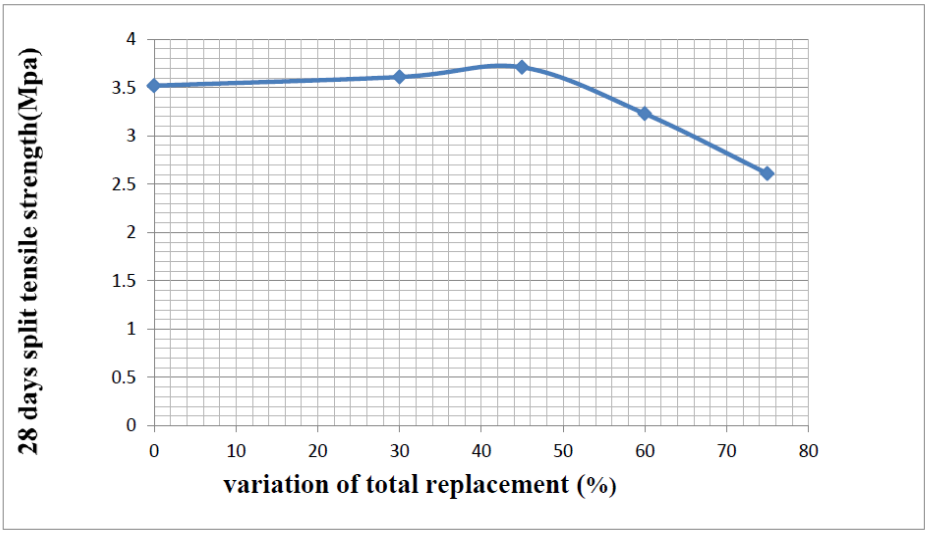

Fig.4.5 Variation of 28 days split tensile strength

4.5 Discussion

The variation in 28 days split tensile strength is very similar to the 28 days compressive strength, it increases from R-0 mix to R-45 mix and then deceases from R-45 mix to R-75 mix. The increment from R-0 mix to R-30 mix is 2.55% and from R-30 mix to R-45 mix is 2.77%. The decrement from R-45 mix to R-60 mix is 12.93% and from R-60 mix to R-75 mix is 19.19%.

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

4.6 Variation of modulus of elasticity at 28 days

Stress-strain curves for various mixes are shown in Figures from 4.6 to 4.10 and values of Stress-strain are shown in Table 4.3. Modulus of elasticity for various mixes were calculated from these curves. Variation of modulus of elasticity is shown in Table4.4 and Fig. 4.11 below

STRESS-STRAIN CURVES

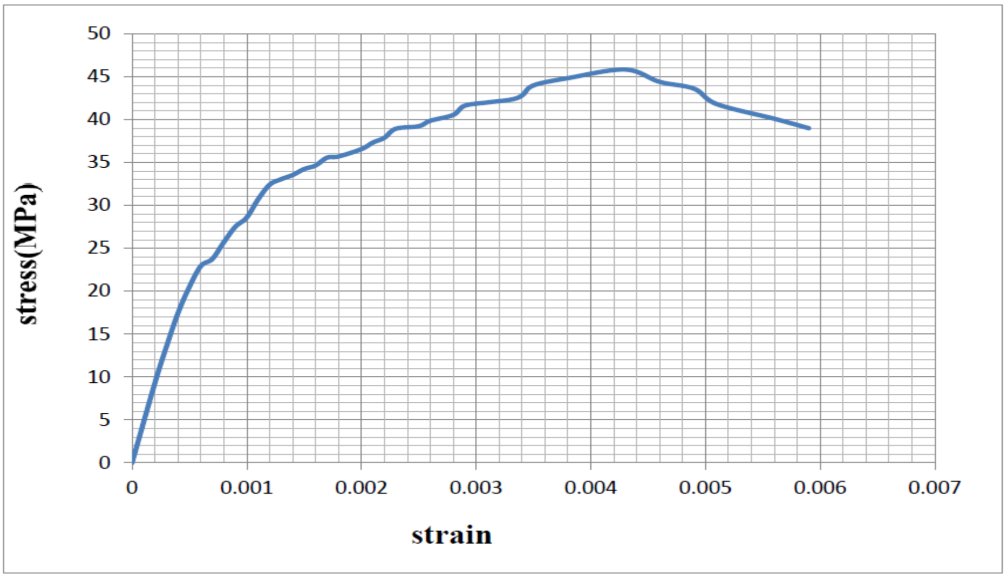

Fig.4.6 Stress-strain curve for control mix

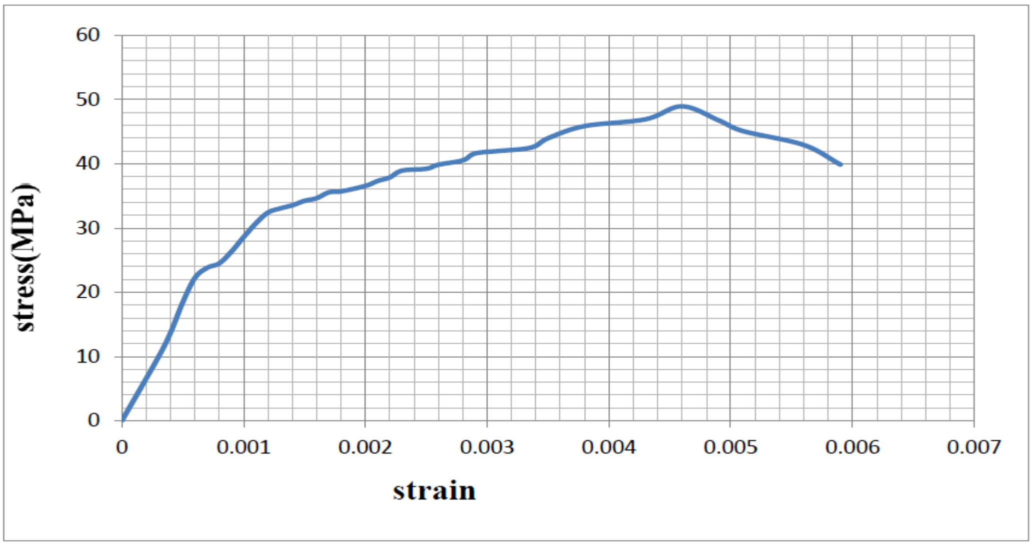

Fig.4.7 Stress-strain curve for 30% replacement

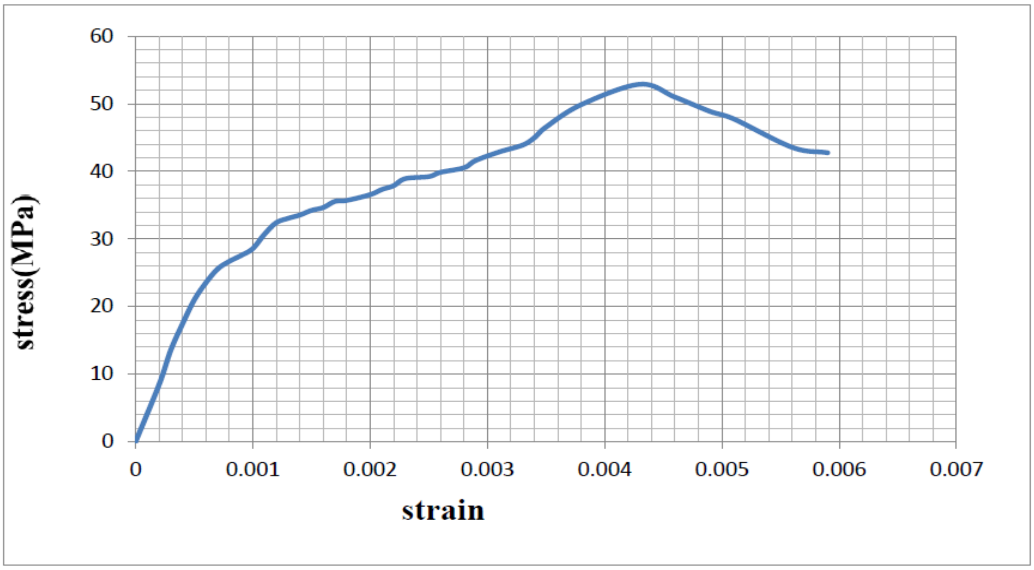

Fig.4.8 Stress-strain curve for 45% replacement

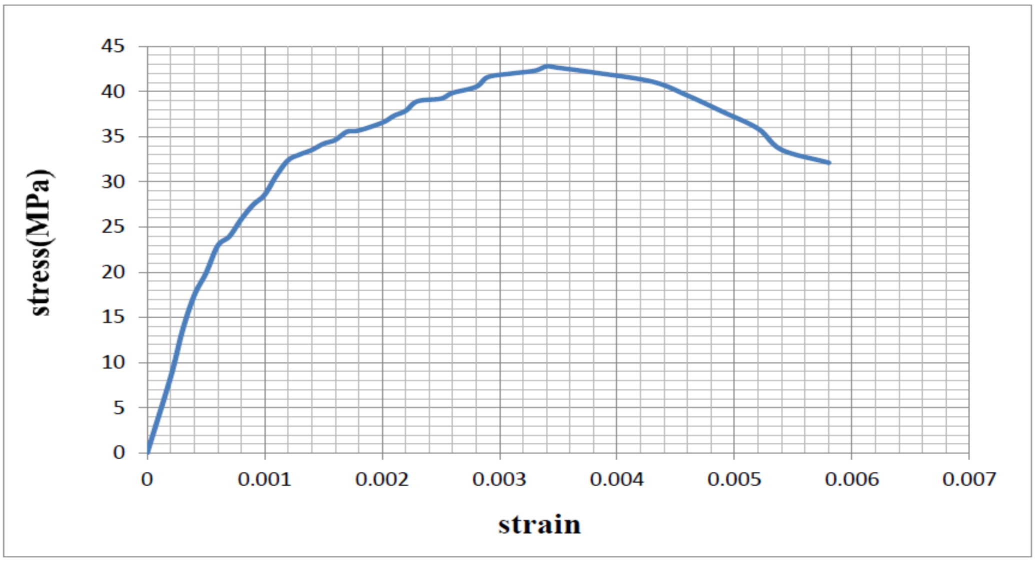

Fig.4.9 Stress-strain curve for 60% replacement

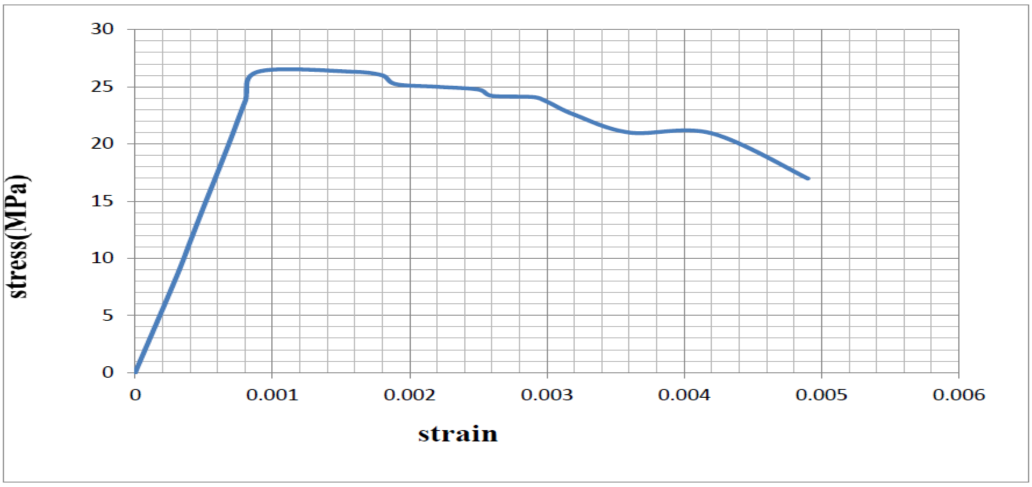

Fig.4.10 Stress-strain curve for 75% replacement

Table 4.4 variation of modulus of elasticity at 28 days

S.no.	Mix designation	Modulus of elasticity at 28 days(Gpa)
1	R-0	33.943
2	R-30	37.066
3	R-45	36.515
4	R-60	34.257
5	R-75	29.255

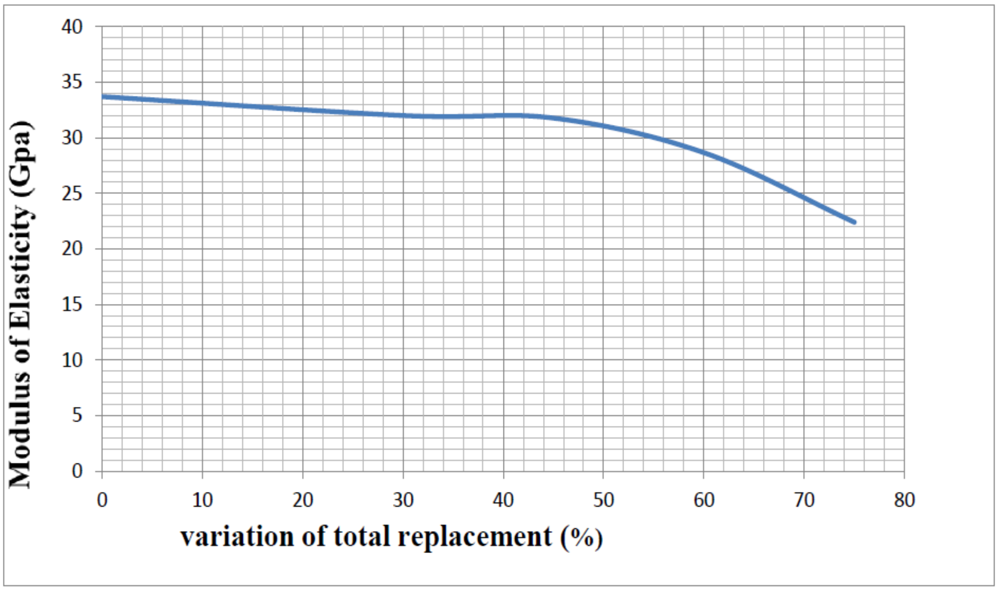

Fig.4.11 variation of Modulus of Elasticity at 28 days

4.7 Discussion

The variation in 28 days modulus of elasticity is different from the variation of 28 days compressive strength, it increases from R-0 mix to R-30 mix and then deceases from R-30 mix to R-75 mix. The increment from R-0 mix to R-30 mix is 9.20%. The decrement from R-30 mix to R-45 mix is 1.48%, from R-45 mix to R-60 mix is 6.18% and from R-60 mix to R-75 mix is 14.60%.

V. CONCLUSION

Following conclusions have been drawn based on the results obtained:

1. Compressive strength for 7 days for control mix was found as 33.70 MPa. generally it should be the about 43 MPa (70% of target mean strength). It may be due to the effect of temperature of curing water as the temperature of curing water was less than normal temperature required. Compressive strength was consciously decreases from R-0 to R-75. Decrease from R-0 to R-45 is very less but it was more for R-45 to R-75. it may be due to the increased content of fly ash. as reaction of silica fume and fly ash starts after some days.
2. Compressive strength at 28 days curing period was found maximum for 45% total replacement (15% silica fume and 30% fly ash). It may be due to the decrease in porosity and due to the change of calcium hydroxide in to CSH gel by silica fume and fly ash. On further addition of fly ash, compressive strength starts decreasing. This decrement is due to the decrease in quantity of CSH gel due to the decrease in quantity of cement in mixture.
3. Variation of 90 days compressive strength is very similar to the 28 days compressive strength. It is also found maximum at 45% total replacement.
4. Increase in 7,28 & 90 days compressive strength and 28 days split tensile strength up to 45% is due to decrease in permeability by the finer particles of silica fume and due to the conversion of $Ca(OH)_2$ in to C-S-H gel by the fly ash, which(C-S-H gel) is responsible for the strength of concrete.
5. Decrease in 7,28& 90 days compressive strength and 28 days split tensile strength after total replacement of 45%, is due to increase in fly ash content. Because due to the addition of fly ash after 45% total replacement, percentage of cement is very less due to which formation of C-S-H gel decreases, same time formation of $Ca(OH)_2$ is also decreases. Due to decrease in $Ca(OH)_2$ and increase in fly ash quantity most of the fly ash remains useless and strength decreases.
6. Variation of modulus of elasticity is different from the variation of compressive strength and split tensile strength. Modulus of elasticity at 28 days curing is found maximum for total replacement 30%.

5.2 SCOPE FOR FUTURE WORK

Properties of concrete discussed above can be further studied by taking in to account the following parameters:

1. By varying the percentage replacement of fly ash with 5% instead of 15% between 30% and 60%, more exact variations can be found and more accurate value of percentage replacement, which gives the strength values equals to strength values for control mix can be found.
2. With the different percentage of silica fume.

ijates
ISSN 2348 - 7550

3. Using different grade of cement i.e 33 grade and 53 grade.
4. Using recycled aggregate.
5. Using fiber concrete in place of plain concrete.

REFERENCES

[1] Baoyu, L.; Angi, L.; and Pengfei, X., "Application of concre condensed silica fume and fly ash at fancuo hydropower station,"flyash,silica fume, slag, and natural pozzolans in concrete— proceedings, third international conference, SP-114, American concrete institute, Detroit, 1989, V. 1, pp. 593-606.

[2] D.S. Lane, C. Ozyildirim Virginia Transportation Research Council, 530 Edgemont Rd., Charlottesville, VA 22903, USA:1998

[3] Elkem microsilica, "Triplewithblendfly-03 applicationash": 2002CS

[4] G.G. Bye, "Portland cement composition production and properties"Pergamon, Oxford, UK, 1983.

[5] G. J. Lynsdale and M. I. Khan, "Chloride and oxygen permeability of concrete incorporating fly ash and silica fume in ternary systems"SP 192-45

[6] Isaia GC, Gastaldini ALG, Moraes R. "Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete".Cem Concr Comp 2003;25(1):69–76.

[7] IS-383, "Specification for coarse and fine aggregate from natural source for concrete" ; 1970

[8] IS-456, "Plain and reinforced-codeofpractice"concrete ;2000

[9] IS-516, "Methods of tests for strength of concrete" ; 1959

[10] IS-3812, "Pulverized fuel ash-specification(part-1) for use as pozzolana in cement, cement mortar and concrete" ; 2003

[11] IS-3812, "Pulverized fuel ash-specification(part-2) for use as admixture in cement mortar and concrete" ; 2003

[12] IS-4031, "Methods of physical test for hydraulic cement" ; 1996

[13] IS-5813, "Splitting tensile strength of concrete-method of test"; 1999

[14] IS-6491, "Methods of sampling fly ash" ; 1972

[15] IS-9013,"Method of making, determining compressive curing strength and of accelerated curing concrete test specimens" ;1999

[16] IS-9103, "Concrete-admixtures specification" ; 1999

[17] IS-10262, "Concrete mix-guidelines" proportioning; 2009

[18] IS-15388, "Silica-specification" fume ; 2003

[19] Li G, Zhao X. "Properties of concrete incorporating fly ash and Ground granulated blast-furnace slag".Cem Concr Comp 2003;25(3):293–9.

[20] M. Lessard, S.L. Sarkar, D.V. Ksinsik, P.C. Aı¨tcin,ongtermbehaviorl of silica fume concrete, Concr. Int. (1992) 25–30 (April).

[21] Mehta, P. K., and Gjørv, O. E., "Properties of Portland cement concrete containing fly ash and condensed silica fume,"Cement and Concrete Research, V. 12, 1982, pp. 587-595.

[22] Medhat H. Shehata, Michael D.A. Thomas, Department of Civil Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario, Canada M5S 1A4

[23] M.R. Jones, R.K. Dhir and B.J. Magee Concrete Technology Unit Department of Civil Engineering, University of Dundee Dundee, DDl4HN, Scotland, UK

[24] M. Sharfuddin Ahmed; Obada Kayali; and Wendy Anderson, Civil and Mechanical Engineering, Univ. of New South Wales at the Australian

[25] Defence Force Academy, Canberra, ACT 2600, Australia. Ozyildirim C, Halstead WJ. Improved concrete quality with combinations of fly ash and silica fume.

[26] ACI Mater J 1994;91(6): 587–94. Ronne, M., "Effect of Condensed Silica Fume a Development FlyofAsh, Concrete,"SilicaFume,Slag,and Natural Pozzolans in Concrete— Proceedings, Third International Conference, SP-114, American Concrete Institute, Detroit, 1989, V. 1, pp. 175-189.