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EFFECT OF TERNARY BLENDS ON PROPERTIES OF HARDENED CONCRETE

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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. Supplementary cementitious material (SCM) such as fly ash, ground granulated blast furnace slag (slag) and silica fume are extensively used in construction. A partial replacement of cement by mineral admixtures (MA), such as, flies ash, GGBFS, silica fume (SF) in concrete mixes would help to overcome these problems and lead to improvement in the durability of concrete. The primary advantage of concrete prepared from these materials and Portland cement is in the enhancement of fresh and hardened properties of the concrete and ecological benefits resulting from industrial by-products utilization ratios this would also lead additional benefits in terms of energy savings, promoting ecological balance and conservation of natural resources etc. however the degree to which particular property is improved or the rate at which a property is improved is dependent on the type and amount of supplementary cementitious material/s used. Among the various minerals additives used in concrete mortars, silica fume is highly favored for its superior concrete durability properties. Concrete is composed of fine as well as coarse aggregates as fillers, and hydrated cement paste (HCP) as a binder resulting from reaction of cementitious materials with water. The structure of cement hydration products is greatly influenced by the rate of hydration reaction, type of hydration products

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formed, and their distribution in the HCP

1.1 Effect on Fresh Concrete

- **a.** Increase cohesion
- **b.** Reduced bleeding

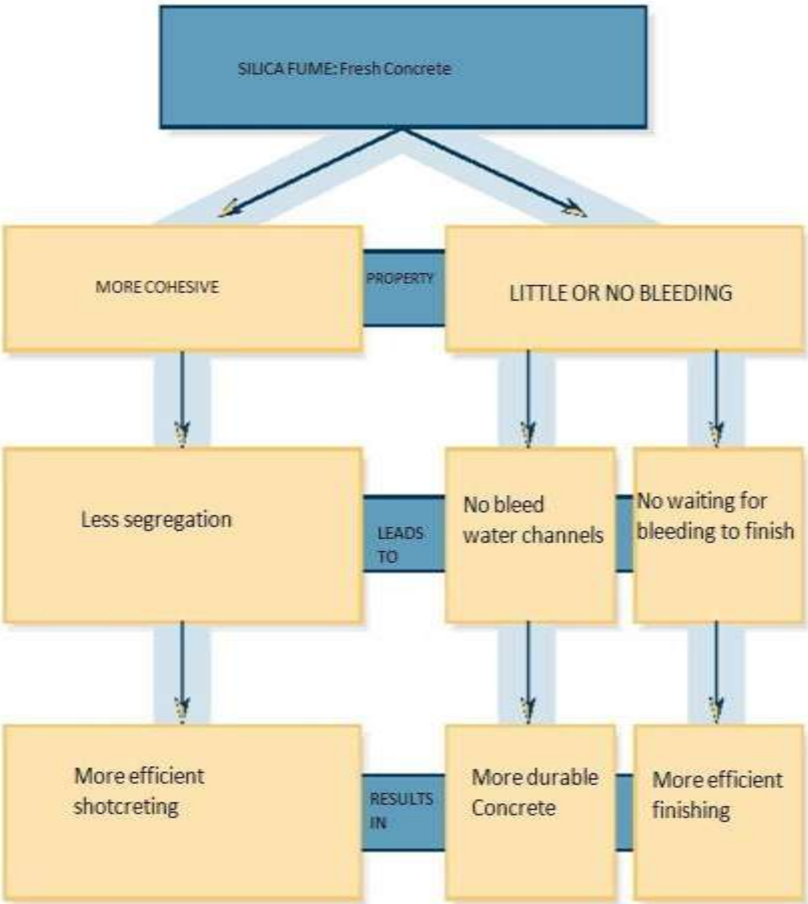

Fig.1 Effect of Silica Fume on Properties of Fresh Concrete

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.

2.2 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.

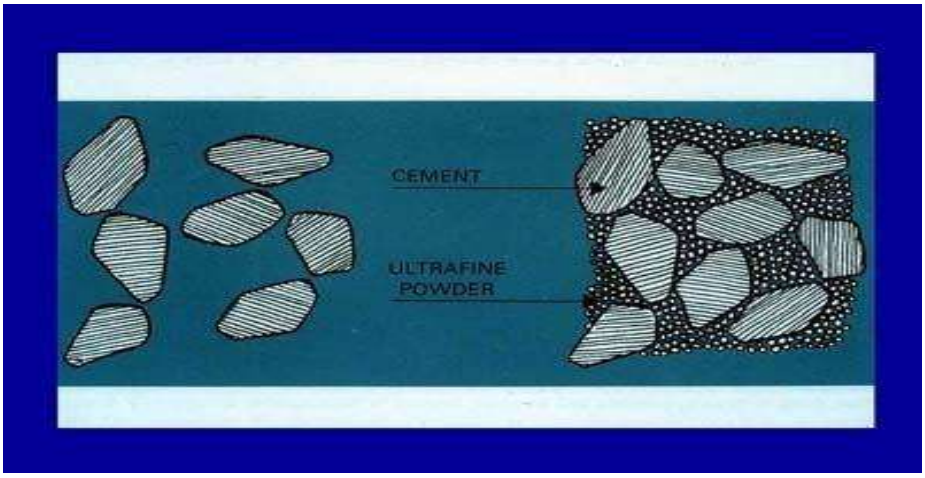

Fig.2 Concept of Particle Packing - Filling the Spaces Between Cement Grains with Silica Fume Particles

2.3 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].

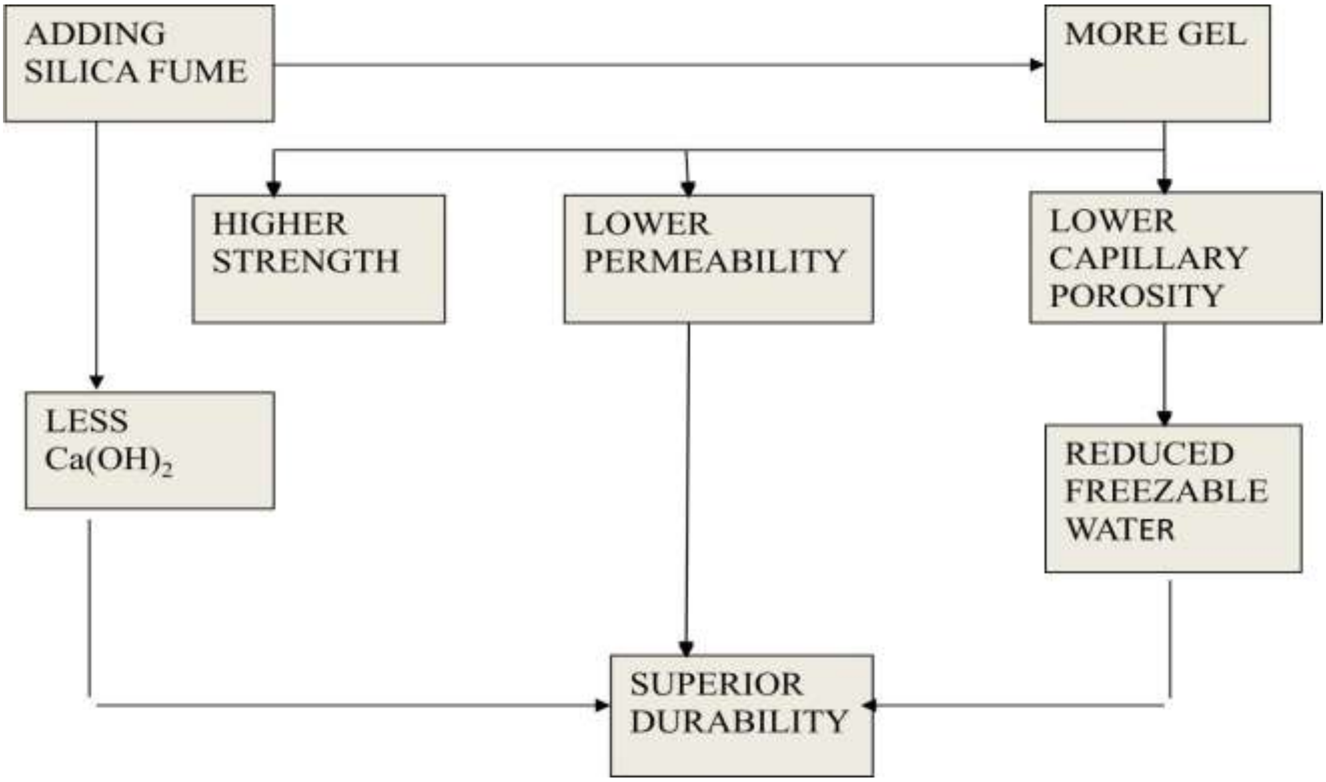

Fig.3 Effects of Adding Silica Fume to Concrete

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

2.4 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.

2.5 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.

Reactions of cement- fly ash blend	Reaction of Portland cement
$2S + 3CH \rightarrow C_3S_2H_3$	$2C_3S + 6H \rightarrow C_3S_2H_3 + 3CH$
$A + CSH_2 + 3CH + 7H \rightarrow C_4ASH_{12}$	$2C_2S + 4H \rightarrow C_3S_2H_3 + CH$
$A + 4CH + 9H \rightarrow C_4AH_{13}$	$C_3A + CSH_2 + 10H \rightarrow C_4ASH_{12}$
	$C_4AF + 2CH + 10H \rightarrow C_6AFH_{12}$

Finally reaction of silica fume and fly ash can be summarized by the following equation-

PORTLAND CEMENT + WATER = CALCIUM SILICATE HYDRATE + CALCIUM HYDROXIDE

POZZOLANA + CALCIUM HYDROXIDE + WATER = CALCIUM SILICATE HYDRATE

Fig.4 Reactions of Pozzolanic Material in Cement

2.6 Mix Proportion

Five mixtures were prepared by using ternary system of OPC, silica fume, and fly ash. One is control mix and other five mixes are made by replacing cement by silica fume as 15% in all mixtures and fly ash varying from 15% to 60%.detailing of these mixtures is given in table 3.12

Materials used are as follows-

Total cementitious material=430 kg/m3

Water= 150 lit/m3

Fine aggregate= 623 kg/m3

Coarse aggregate =1255 kg/m3

Superplasticizer = 4.229 lit./m3

W/c ratio = .35

Cement: F.A:C.A = 1:1.4488:2.9186

Mix proportioning for a concrete of M 30 grade as per IS 10262:2009

2.7 Casting of Specimens

The five mixes were prepared using ratio (total cementatious material: fine aggregate: coarse aggregate) as 1:1.4488:2.9186 with w/c=0.35. Concrete mixes were prepared using 10mm & 20mm natural coarse aggregate. The test specimens were 150mmX150mm cubes for compressive strength, 150mmX 300mm cylinders for split tensile strength and modulus of elasticity. The specimens were cast according to IS: 516-1959. The specimens were tested at the age of 7, 28 and 90 days for compressive strength and 28 days for split tensile strength and modulus of elasticity. The aggregates used were in saturated surface-dry condition. The test procedures were followed as per relevant Indian standard specifications. The batching was done by weight.

Table 1 Size of Moulds

S.No	Moulds	Size	Specimen Casted For
1.	Cube	150mmx150mmx150mm	Compressive strength
2.	Cylinder	300mmx150mm	Modulus of elasticity
3.	Cylinder	300mmx150mm	Split tensile strength

2.8 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.

2.9 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.

Fig.5 Compression testing machine

2.10 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) :σ_{sp} = 2P/πdl

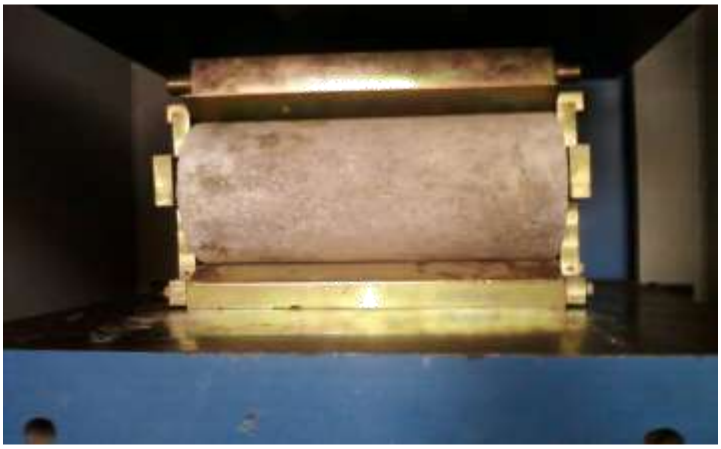

Fig. 6 Tensile Testing of Cylinder in CTM

Fig.7 Specimen Failed in Tension (vertical crack is appeared)

2.11 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.

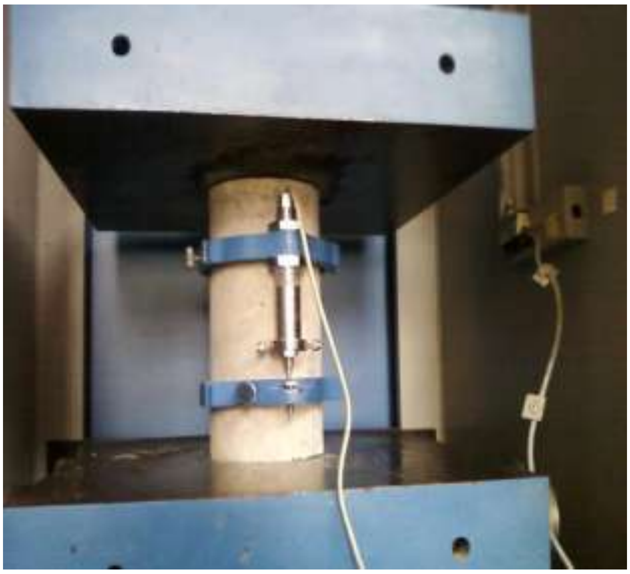

Fig.8 Set to Draw Stress Strain Curve by CTM Using LVD

III. RESULT

The results of 7, 28 & 90 days compressive strength, split tensile strength and modulus of elasticity are shown in Table 4.1 to 4.3 and in Fig. 4.1 to 4.11. These results are discussed in the following sections under-

3.1 Variation of 7, 28 and 90 Days Compressive Strength

150mmX150mmX150mm size cubes were casted to calculate compressive strength. Cubes were tested after 7, 28 and 90 days curing in compression testing machine. Results obtained are tabulated in Table 4.1 and in Fig.4.1 to 4.3 and compared in Fig. 4.4 as shown below.

Table 2 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

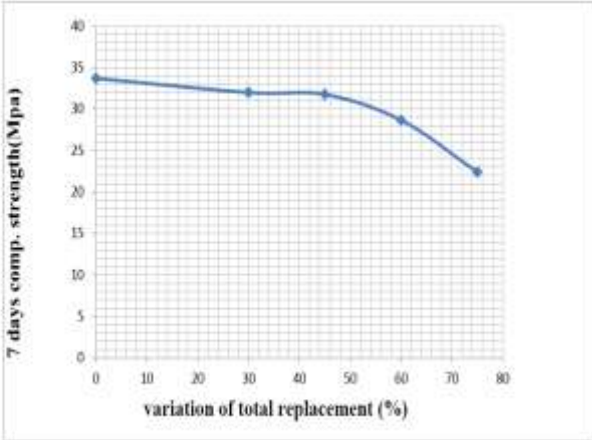

Fig.9 variation of 7 day compressive strength

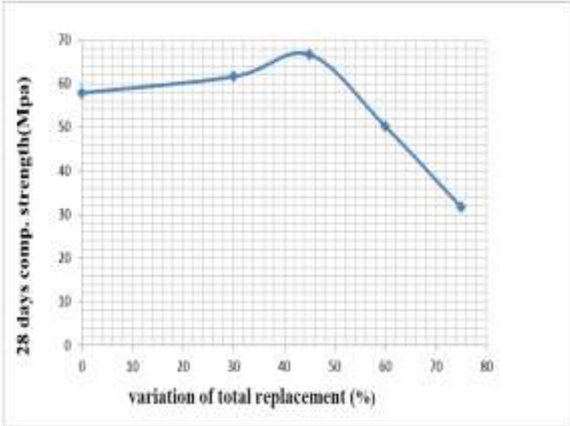

Fig.10 Variation of 28 days compressive strength

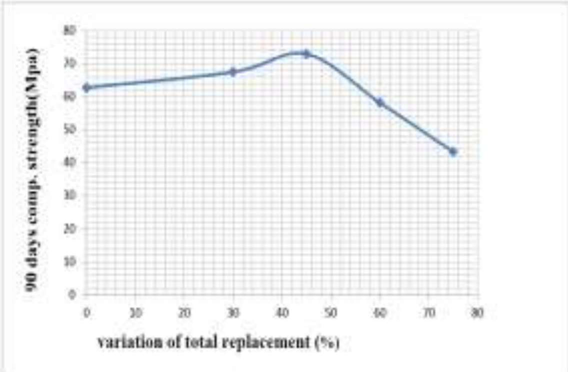

Fig.11 Variation of 90 days compressive strength

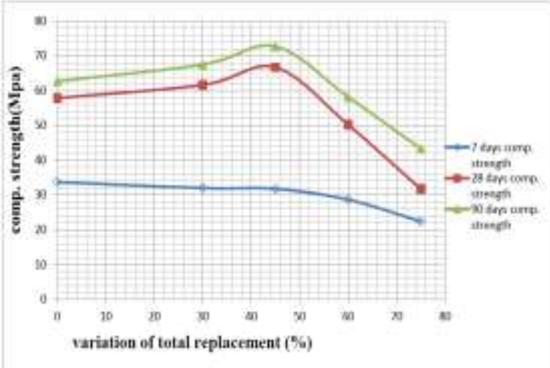

Fig.12 Comparison of compressive strength at 7, 28 and 90 days of curing

The compressive strength of any mix increases with curing time. The percentage increase in compressive strength of control mix from 7 days to 28 days is71.69%. This percentage increment increases up to 45% replacement and, after 45% replacement this increment starts decreasing and minimum at 75% replacement. The percentage increase in compressive strength of control mix from 28 days to 90 days is 8.36%.This percentage increase in compressive strength from 28 days to 90 days, continuously increases from control mix to 75% replacement and equals to 36.59%. The compressive strength for 7 days curing period, continuously decreases from control mix to, mix for replacement of 75%, whereas for 28 days curing period, it increases from control mix to, mix for 45% replacement, the increment is 6.53% from R-0 mix (control mix) to R-30 mix (total variation is 30%) and 8.14% from R-30 mix to R-45 mix(total variation is 45%), after this compressive strength suddenly decreases, this decrement is 24.69% from R-45 mix to R-60 mix(total variation 60%) and 36.85% from R-60 mix to R-75 mix(total variation 75%). For 90 days curing period variation is same as 28 days curing period. The increment from R-0 mix to R-30 mix is 7.56% and from R-30 mix to R-45 mix is 7.70%. The decrement from R-45 mix to R-60 mix is 19.944% and from R-60 mix to R-75 mix is 35.6%.

IV. 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.
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.

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