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# EXPERMENTAL INVESTIGATION ON EFFECT OF TERNARY BLENDS ON HARDENED CONCRETE PROPERTIES

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**ABSTRACT**

*This research focused on study of the effect of different supplementary cementations 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.

## II REVIEW OF LITERATURE

In order to fulfill the aims and objectives of the present study following literatures have been reviewed.

### 2.1 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 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

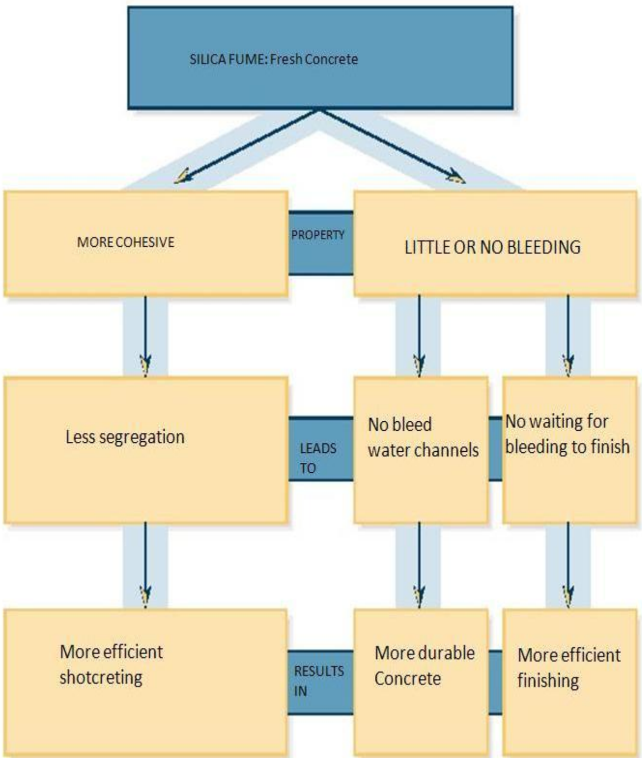
**b.** Reduced bleeding

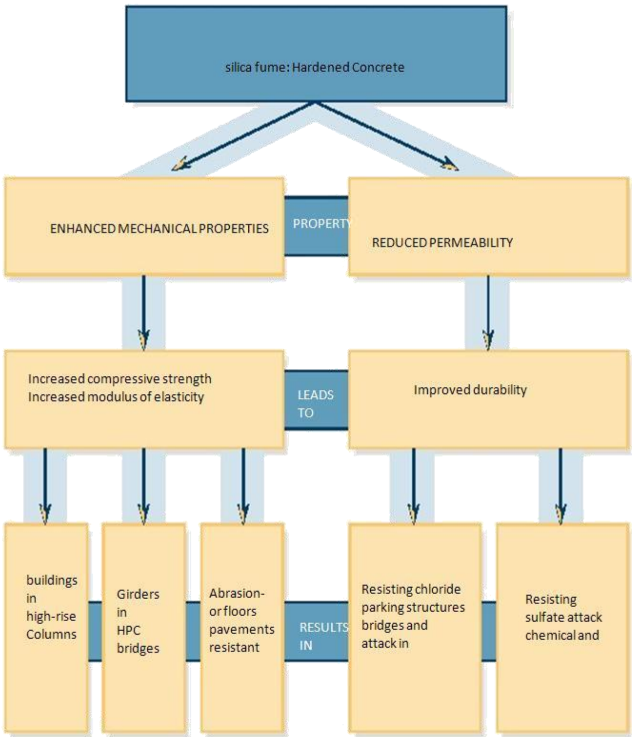
B. **Effect on hardened concrete**

**a.** Enhanced mechanical properties

b. Reduced permeability

c. Both of these effect can be explain as-



### 2.2 Reactions of Silica Fume and Fly Ash

### 2.2.1 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 referredtoasparticle packing or micro-filling.fig (2.6) shows the basic concept of particle packing - filling thespaces between cement grains with silica fume particles.

Even if silica fume did not react chemically, the micro-filler effect would bring about significant Improvements in the nature of the concrete. Figure (2.7) present a comparison of the size of silica-fume particles to other concrete ingredients to help understand how small these particles actually are.

**(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-Hgel 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.

### 2.2.2 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.

A hydration model for cement blended with fly ash given by **Yong Wang, Han-Seung Lee et al(2009)** shows that Fly ash is a complex material that consists of a wide range of glass and crystalline compounds. In reaction form, there is the aluminosilicate (A-S) glass with a high content of silicate (S). The hydration product of an aluminosilicate glass/ hydrated lime mixture should be a CSH gel incorporating significant amounts of aluminum (A). The S of A-S glass is proposed to react with CH without additional water binding and to form a calcium silicate hydrate described by the simplified formula of C3S2H3, as shown by using almost pure vitreous silica. The silicon presented as quartz or in crystalline aluminosilicate phases is inert. Based on the experimental results of the reaction stoichiometry among FL, chemically bound water, and calcium hydroxide, **Papadakis V. G(1999)** Proposed the pozzolanic reaction in cement-FA blends that is written as follows

**Fig.2.8 Reactions of pozzolanic material in cement**

| 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

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### 3.2 Material properties

The chemical and physical properties of different materials used are determined as per related standards.

### 3.2.1Cement

Ordinary Portland cement of 43 grade (Source: Ultra tech Cement) conforming to IS:8112-1989 was used. The cement was tested as per IS 4031-1986. The test results of the cement are given in the Table 3.1

**Table 3.1 Physical properties of 43-grade cement**

| S.No | PROPERTIES | OBSERVED VALUES | VALUES SPECIFIED BY IS: 8112-1989 |
|---|---|---|---|
| 1. | Normal Consistency (%)) | 31.5 | ------- |
| 2. | Soundness (mm) | 1.8 | Not more than 10 |
| 3. | Fineness % (90um I.S. Sieve) | 4 | Not more than 10 |
| 4. | Initial Setting Time (minutes) | 58 | >=30 |
| 5. | Final Setting Time (minutes) | 280 | <=600 |
| 6. | Compressive Strength (MPa) | | |
| | i) 3 days | 26.07 | >23 |
| | ii) 7 days | 34.40 | >33 |
| 7 | Specific gravity | 3.15 | |

### 3.2.2 Fly Ash

Class C Fly ash supplied by "**POZZOCRETE FLY ASH"** Mumbai was used. This was finer than cement. The physical and chemical properties of fly ash are shown in Table 3.2

**Table 3.2 Physical properties of Fly Ash**

| Physical properties | Observed properties | Requirement as per is-3812 (part1):2003 |
|---|---|---|
| Fineness-specific surface in $m^2$/kg | 460 | 320(min.) |
| Specific gravity | 2.23 | ------ |
| Lime reactivity –Average compressive strength in MPa | 4.10 | 4.5(min.) |

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**Table 3.3 Chemical properties of fly Ash**

| Chemical properties (% by mass) | Observed properties | Requirement as per is-3812(part1):2003 |
|---|---|---|
| $SiO_2$ | 37.3 | 35(min.) |
| $Fe_2O_3$ | 4.8 | ------- |
| CaO | 29.2 | ------- |
| MgO | 2.5 | 5(max.) |
| $Na_2O$ | 0.5 | 1.5(max.) |
| $SO_3$ | 2.4 | 3(max.) |
| LOI | 0.2 | 5(max.) |
| Total chlorides | 0.0 | .05(max.) |

### 3.2.3 Silica Fume

Silica fume supplied by "**HIND AGENCIES**" packed in 20Kgs Bags was used. Properties of which is given in Table 3.4

**Table 3.4 Physical properties of silica fume**

| Physical properties | Observed properties | Requirement as per is-15388:2003 | Requirement as per astmc 1240-03a |
|---|---|---|---|
| Fineness-specific surface | 20300 | 15000 | 15000 |
| Specific gravity | 2.23 | ------ | ------ |
| Size greater 45 µ | 0.5% | ------ | 10(max.) |
| Pozzoloan Activity Index | 146.60% | ------ | 105(max) |
| Bulk density(kg/$m^3$) | 520 | ------ | 500-700 |

**Table 3.5 Chemical properties of silica fume**

| Chemical properties (% by mass) | Observed properties | Requirement as per is-15388:2003 | Requirement as per astmc 1240-03a |
|---|---|---|---|
| $SiO_2$ | 88.1 | 85 | 85 |
| $Fe_2O_3$ | 1.8 | ------ | ----- |
| CaO | < 0.4 | ------ | ----- |

| | | | |
|---|---|---|---|
| $Na_2O$ | 0.6 | 1.5(max.) | ----- |
| LOI | 2.6 | 4(max.) | 6 |
| Moisture content | 0.7 | 3(max.) | 3(max.) |

### 3.2.4 Aggregate

The aggregates provide about 75 percent of the body of the concrete and hence its influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable and economical. The aggregate must be of proper shape (either rounded or approximately cubical), clean, hard, strong and well graded. The mere fact that the aggregate occupy70-80 percent of volume of concrete. The characteristics of aggregate affect the properties of concrete.

#### 3.2.4.1 Fine Aggregate

For the present study locally available sand (Badarpur sand) was used as fine aggregate. its sieve analysis and physical properties are shown in Table 3.7

**Table 3.7 Physical properties of fine aggregate**

| S.No | Property | Observed Values |
|---|---|---|
| **1.** | Bulk Density (Loose), kg/m³ | 1930 |
| **2.** | Bulk Density ( Compacted), kg/m³ | 1740 |
| **3.** | Specific Gravity | 2.5 |
| **4.** | Fineness modulus | 2.336 |
| **5.** | Water Absorption% | 3.5 |

#### 3.2.4.2 Coarse aggregate

Crushed stone of 10mm and 20mm confirming to IS:383-1970was used as coarse aggregate. Its sieve analysis and physical properties are shown in 3.9 respectively

**Table 3.9 Physical properties of coarse aggregate (20 mm)**

| S.No | Property | Observed Values |
|---|---|---|
| 1. | Bulk Density ( Loose), kg/m³ | 1500 |
| 2. | Bulk Density ( Compacted), kg/m³ | 1550 |
| 3. | Specific Gravity | 2.70 |
| 4. | Free Moisture% | 0.3 |
| 5. | Water Absorption% | 0.1 |

**Technical Data for Muraplast FK:**

**Table**

| Characteristic | Unit | Value | Comments |
|---|---|---|---|
| Density | kg/dm³ | approx. 1.18 | ± 0.03 |
| Recommended Dosage | g | 2 - 30 | per kg of cement |
| Max. Chloride Content | % | < 0.10 | per weight |
| Max. Alkali Content | % | < 4.5 | per weight |

**3.10Specification of superplasticizer**

**Table 3.12 Mix Designation**

| S. N | Mix desg | Cement (kg/m³) | S.F (% of total cementitious material) | S.F (kg/m³) | F.A (% of total cementitious material) | F.A (kg/m³) | w/c Ratio |
|---|---|---|---|---|---|---|---|
| 1 | R-0 | 430 | 0 | 0 | 0 | 0 | .35 |
| 2 | R-30 | 301 | 15 | 64.5 | 15 | 64.5 | .35 |
| 3 | R-45 | 236.5 | 15 | 64.5 | 30 | 129 | .35 |
| 4 | R-60 | 172 | 15 | 64.5 | 45 | 193.5 | .35 |
| 5 | R-75 | 107.5 | 15 | 64.5 | 60 | 258 | .35 |

**Physical Properties of Muralplast :**

Some physical properties are given below-

- ❖ Type of Admixture- Retarder/Super plasticizer
- ❖ Color- Brown
- ❖ Consistency- Liquid

**3.5 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.

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**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.3.1 Compression testing machine**

## 3.5.2 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) : $\sigma_{sp} = 2P/\pi dl$

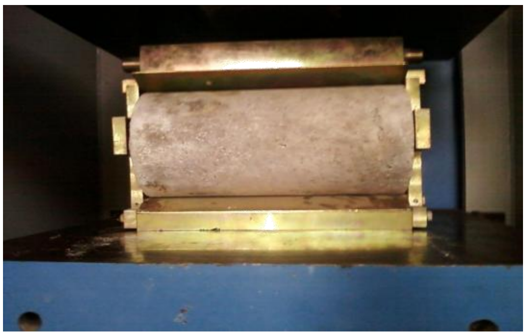

**Fig. 3.2 Tensile testing of cylinder in CTM** **Fig.3.3 Specimen failed in tension**

**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 |

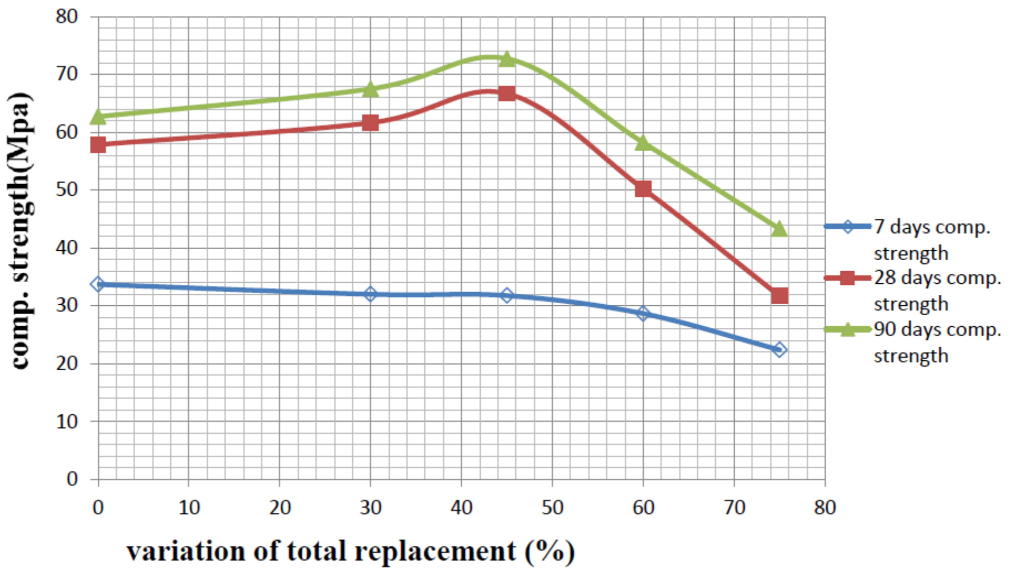


**Fig.4.4 Comparison of comp. strength at 7, 28 and 90 days**

## 4.4 Variation of split tensile strength

**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 |

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

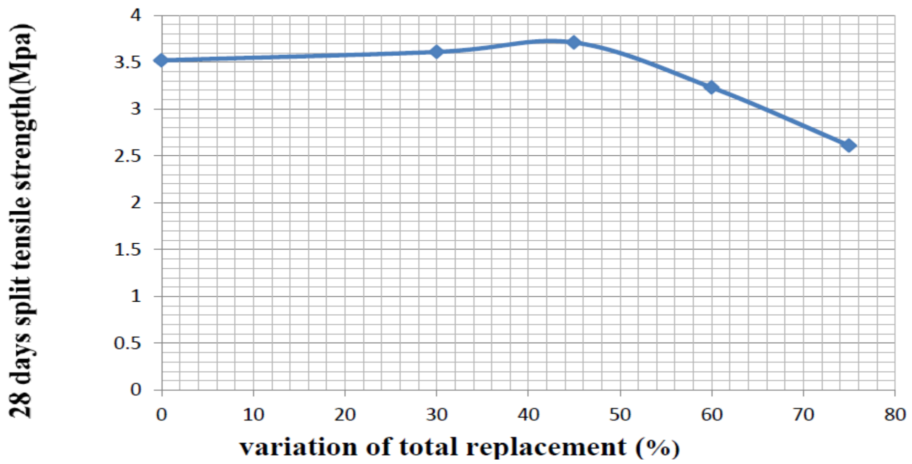


**Fig.4.5 Variation of 28 days split tensile strength**

## 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.
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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