A
MAJOR PROJECT
ON

EFFECT OF TERNARY BLENDS ON PROPERTIES OF HARDENED CONCRETE

Submitted in partial fulfillment of the requirement
for the award of degree

MASTER OF ENGINEERING

In

CIVIL ENGINEERING
(Structural Engineering)

Submitted by
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DELHI COLLEGE OF ENGINEERING
UNIVERSITY OF DELHI
2011

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DECLARATION

I hereby declare that the work embodied in this major project entitled "EFFECT OF TERNARY BLENDS ON PROPERTIES OF HARDENED CONCRETE" is authentic record of my own, carried out in partial fulfillment of the requirement for the award of Master of Civil Engineering (Structural Engineering) under the guidance and supervision of Dr. A.K Sahu, Associate Professor, Department of Civil & Environment Engineering, Delhi College of Engineering, Delhi.

The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

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Enroll No. 11/str./09
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This is to certify that the above statement made by Mr. SURESH KUMAR NAGAR bearing roll no.9081 is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

It is distinct pleasure to express my deep sense of gratitude and indebtedness to my supervisor **Dr. A.K SAHU** Associate Professor, Department of Civil and Environmental Engineering, Delhi College of Engineering, for his invaluable guidance, encouragement and patient reviews. His continuous inspiration only has made me complete this dissertation. Without his help and guidance, this dissertation would have been impossible. He remained a pillar of help throughout the project.

I am also grateful to Prof. **A.K. GUPTA** Head Department of Civil Engineering, for providing the experimental facilities in various labs of the Department.

I am also thankful to the Shri G.C Bhatt, Shri Miraj and Mr. Pushkal of concrete technology laboratory of the department to help me.

I express my sincere gratitude to the faculty and non teaching staff of Civil and Environmental engineering department and the library of Delhi College of Engineering for providing the relevant information and help when needed during the course of my this project work.

I am also thankful to my classmates and my friends for their unconditional support and motivation during this work

(SURESH KR. NAGAR)

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.

List of Notations

A- Aggregate

ACI - American concrete institute

AS- Alumino silicate

ASTM- American society of testing materials

ASR- Alkali silica reaction

BIS- Bureau of Indian standard

C- Cement

CA- Coarse aggregate ratio

C/A- Cement aggregate ratio

C.F. - Compaction factor

CSH- Calcium-silicate-hydrate

CTM- Compression testing machine

DCE- Delhi College of engineering

FA- Fly ash

HAPC- High-alkali Portland cement

HCP- Hydrated cement paste

HPC - High performance concrete

GGBS- Ground granulated blast furnace slag

MA - Minerals additives

NCA- Natural coarse aggregate

OPC- Ordinary portland cement

RCC- Reinforced cement concrete

SCM- Supplementary cementitious material

SF- Silica fume

VTRC- Virginia transportation research council

W- Water

W/C- Water cement ratio

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Chapter-1

INTRODUCTION

1.1 GENERAL

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 formed, and their distribution in the HCP. The rate of hydration reaction and the resulting hydration products can be substantially modified by addition of mineral and chemical admixtures. It has been well established that in cement-rich mixtures, the rate of hydration reaction is high enough to cause plastic shrinkage cracks as well as non-homogeneity in microstructure of concrete. The accelerated hydration results significantly from evolution of high level of heat due to hydration reaction in the mixture. Consequently, long and thin cementing C-S-II crystals are formed during the hydration process under such a condition. Such crystals occupy less space compared to that formed during normal hydration process, leading to a less dense concrete microstructure. As a result, concrete strength and durability properties are adversely affected. To avoid these, low-heat cement as well as mineral and chemical admixtures are added. Class C fly ash and silica fume can be added to concrete to control rate of hydration reaction and to improve its microstructure. The improvement in microstructure occurs due to grain as well as pore refinements, especially in the interface region between the aggregates and HCP. Inclusion of a Class C fly ash, up to a certain level, can exhibit hydration reaction similar to that of concrete made with portland cement alone. Therefore, a blend of Class C fly ash and silica fume should produce an improved rate of hydration reaction with a favorable microstructure compared to a concrete mixture without the addition of Class C fly ash and silica fume. Considering this, it was postulated that a blend of Class C fly ash and silica fume will result in improved concrete structure due to modification of rate of hydration reaction as well as other benefits that are derived when Class C fly ash and silica fume are added to concrete. This, in turn, will help enhance mechanical and durability properties of the concrete. This research was undertaken primarily to verify this hypothesis in improving concrete mechanical properties.

1.2 AIMS AND OBJECTIVES OF STUDY

Long term durability, high strength and good workability are paramount concern of high performance concrete(HPC).hence it is desired to produce a concrete having very low permeability, high strength(in flexure, compressive and split), and high modulus of elasticity to make it a high performance. As various literatures are available on the permeability and compressive strength but limited data are available on the variation of modulus of elasticity. Hence the Aim of this study are-

I. To prepare the concrete cubes & cylinders using cement partly replaced by silica fume and fly ash.
II. To determine compressive strength of hardened concrete at 7, 28 and 90 days of curing & compare various mixes.
III. To determine split tensile strength at 28 days of curing & compare various mixes

IV. To determine modulus of elasticity of concrete at 28 days curing & compare various mixes.

V. Utilization of ternary blends of fly ash and silica fume.

Chapter-2

LITERATURE REVIEW

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.

OzkanSengul and Mehmet Ali Tasdemir(2009), have concluded that for the improvement of strength, the pozzolanas were more effective in the low water/binder ratio i.e. for high strength concrete.

M. Sharfuddin Ahmed, Obada Kayali et al. (2009) observed the use of ternary blend in chloride ion penetration by using rapid chloride permeability test. They concluded that the ternary blend comprising 25% fly ash and 10% silica fume showed a significant decrease in average charge compared to the corresponding binary blend.

Tahir Kemal Erdem and OnderKırca(2009), used the ternary blend of silica fume and fly ash to obtain high strength concrete mix. They have shown that Ternary blends almost always made it possible to obtain higher strengths than PC + SF mixtures at all ages provided that the replacement level by FA/ F or FA/C or S was chosen properly. They also showed that the improvements in strengths by ternary blends were more significant at 7 and 28 days than at 3 days.

Isaia GC, Gastaldini ALG et al. (2003), observed the physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete. Particle packing is one reason. In the case of fly ash, the particle is often finer that the cement, this means that the small silica fume particles can perform better in particle packing since the intermediate particle space, slightly smaller than cement, is filled by the fly ash.

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.

M.R. Jones, R.K. Dhir et al (2003), have shown resistance to chloride ingress and carbonation by concrete containing ternary blended binders. **Lynsdale and Khan** studied chloride and oxygen permeability of Triple blends. Their main conclusion is the ternary blends enabled negligible chloride transport even at early ages, both fly ash and silica fume contributing. At low w/b with 10% silica fume, 15-20% fly ash gave the lowest chloride transport of the tests. Studies at the Virginia Transportation Research Council (**VTRC**) 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 and also **D.S. Lane and C. Ozyildirim(1994)** from VTRC.

Medhat H. Shehata and Michael D.A. Thomas (2001) have shown use of ternary blend (silica fume and fly ash) to suppress expansion due to alkali–silica reaction **(ASR)** in concrete. They concluded that Practical levels of silica fume and fly ash introduced into high-alkali Portland cement **(HAPC)** systems were found to be effective in reducing the expansion due to ASR to levels < 0.04% after 3 years.

The results of a study by **Shannag(2000)** suggest that certain natural pozzolan-SF combinations can improve the compressive and splitting tensile strengths, workability, and elastic modulus of concretes, more than natural pozzolan or SF alone.

Nassim and Suksawang(2003) in their very comprehensive study have a main conclusion:"Combining silica fume and fly ash enhances the durability and mechanical properties of HPC. In fact, it is highly recommended that a minimum of 5 percent silica fume beaded to fly ash concrete to improve its durability. Moreover, the ductility of concrete increases when comparing to ACI recommendation".

Similarly, according to **Li and Zhao(2003)**, blending FA and S presents an excellent behavior in both short- and long-term compressive strengths and in resistance to H_2SO_4 attack; and improves the microstructure and hydration rate. The achievement of these advantages becomes more important for HSC proportioning since HSC requires high amounts of cementitious materials.

So as summarily ternary blend of silica fume and fly ash can be use for the following purposes.

I. To conserve cement
II. To produce high strength concrete
III. To control alkali-silica reaction
IV. To reduce chloride associated corrosion and Sulphate attack
V. To increase modulus of elasticity

Individual effects of silica fume on fresh and hardened concrete are as

A. Effect on fresh concrete

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

B. Effect on hardened concrete

- **a.** Enhanced mechanical properties
- **b.** Reduced permeability

Both of these effect can be explain as-

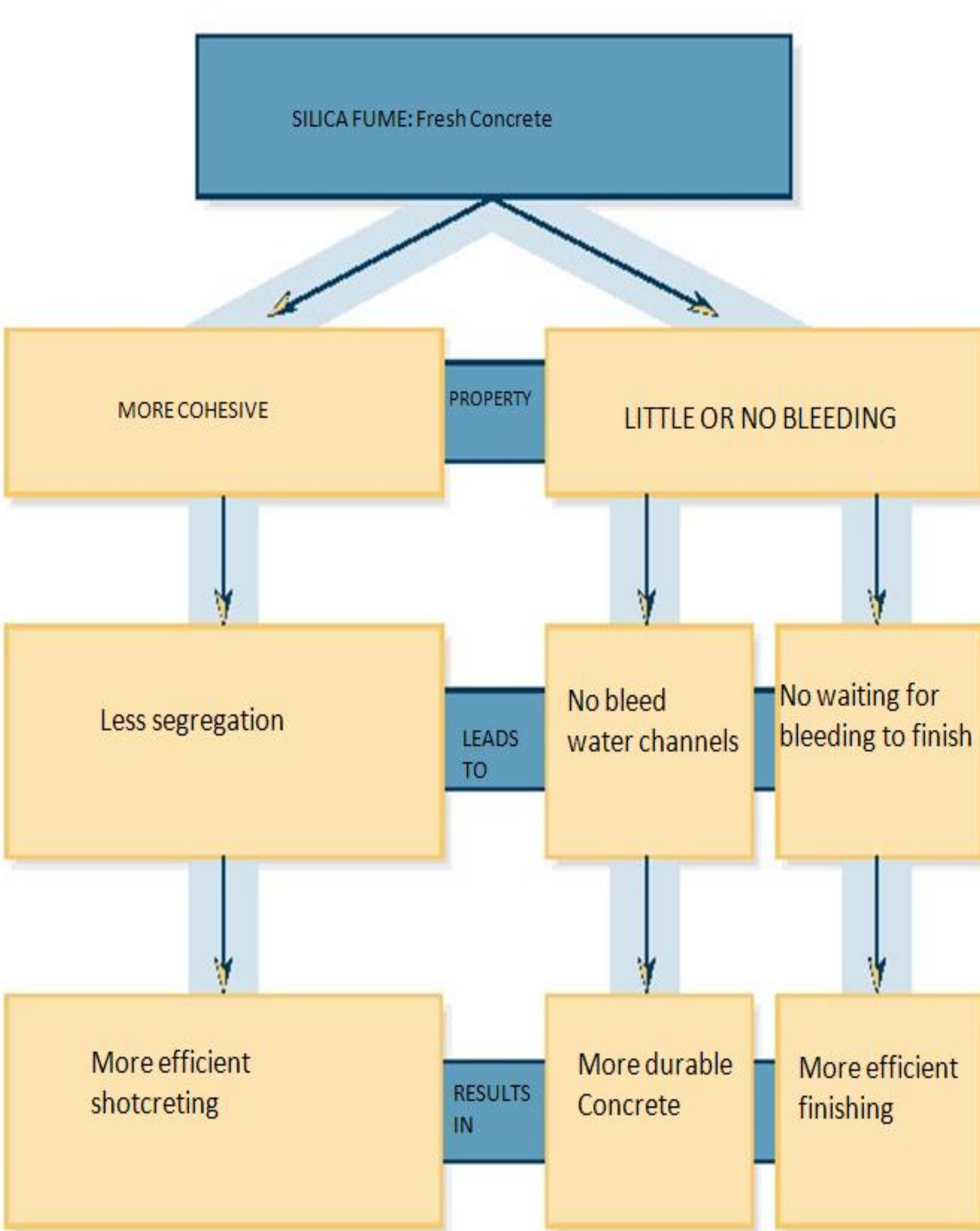


Fig.2.1 effect of silica fume on properties of fresh concrete (source: silica fume user manual "US department of transportation)

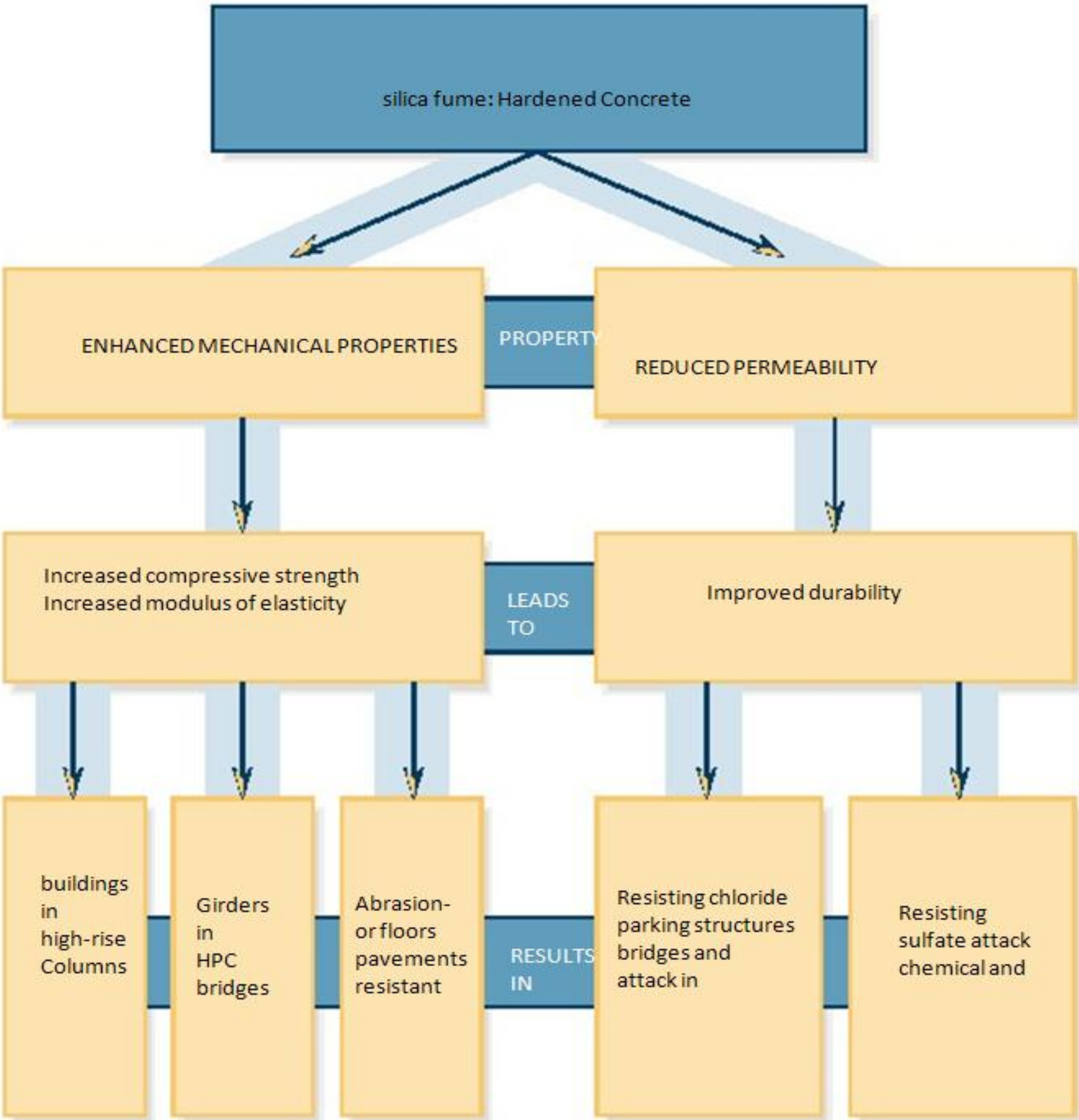


Fig.2.2 effect of silica fume on properties of hardened concrete (source: silica fume user manual "US department of transportation)

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

Bandra Worli in Mumbai

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

	Kg/m^3
Cement (53 Grade)	300
Micro silica	40
Fly ash	196
Coarse aggregate 20mm	577
Coarse aggregate 10mm	500
Natural Sand	423
Crushed Sand	327
Free water (liters)	134
Water Binder ratio	0.25
Admixture (liters)	13.4

Chloride Ion penetration- ASTM C 1202:	600 Coulombs
Water Permeability (DIN 1048):	Nil
Maximum temperature at the core:	68 C.
Max. Temperature difference	$< 20^{o}$ C

Concrete structures made up of silica fume and OPC concrete-

Fig.2.3High bridge great belt, denmark(source- Elkem microsilica)

Fig.2.4 Bandra worli bridge, mumbai(source- Elkem microsilica)

Fig2.5 Tsing Ma , Hong Kong(source- Elkem microsilica)

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 referred to as

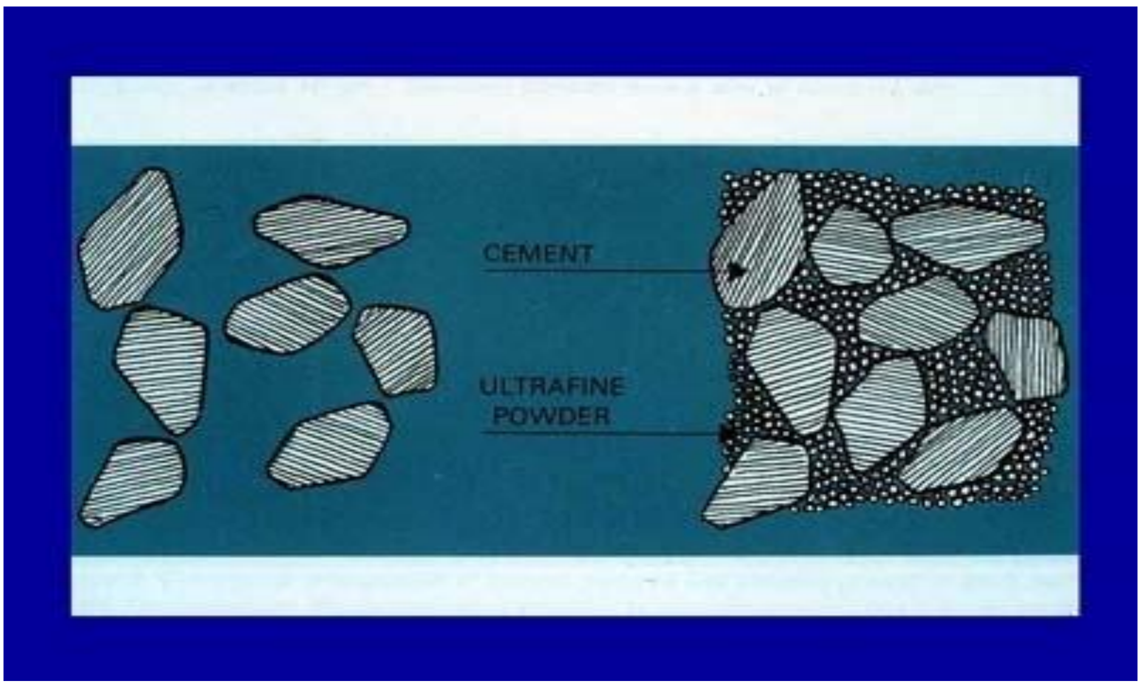
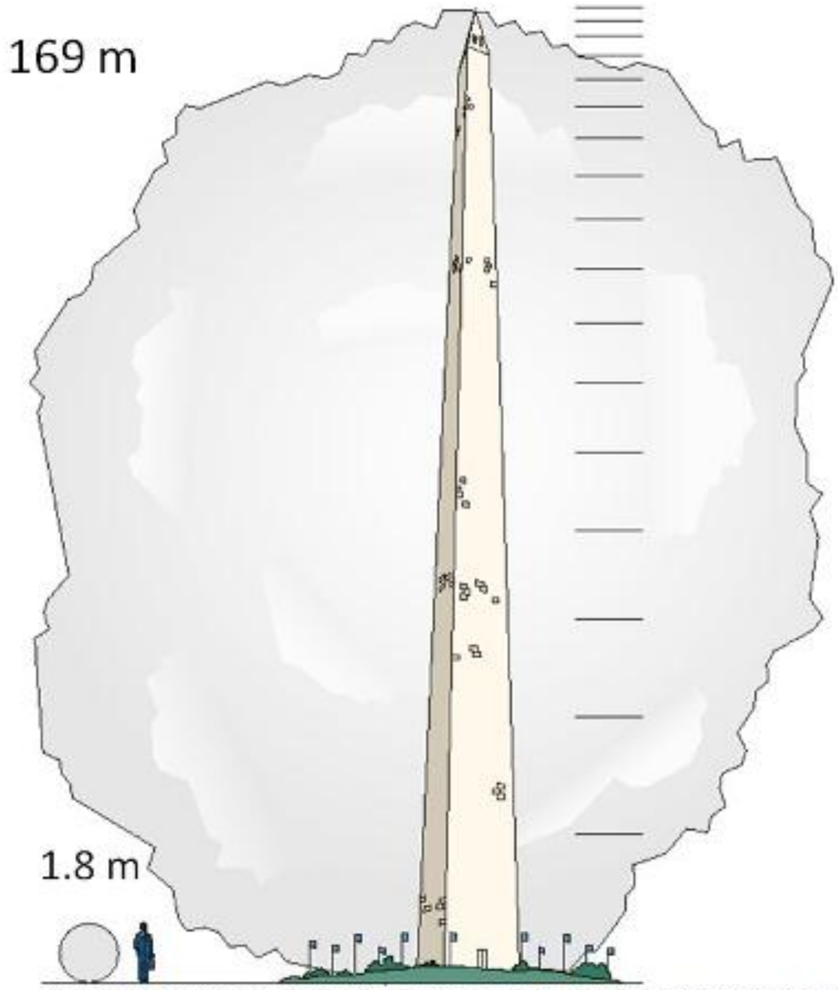


Fig.2.6 concept of particle packing - filling the spaces between cement grains with silica fume particles (source: silica fume user manual "US department of transportation)

partic

le packing or micro-filling.fig (2.6) shows the basic concept of particle packing - filling the spaces 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.



General size comparison of silica-fume particles. If a person (1.8 m) were the size of a silica-fume particle, then a cement grain would be approximately the size of the Washington Monument (169 m).

ource:

(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.

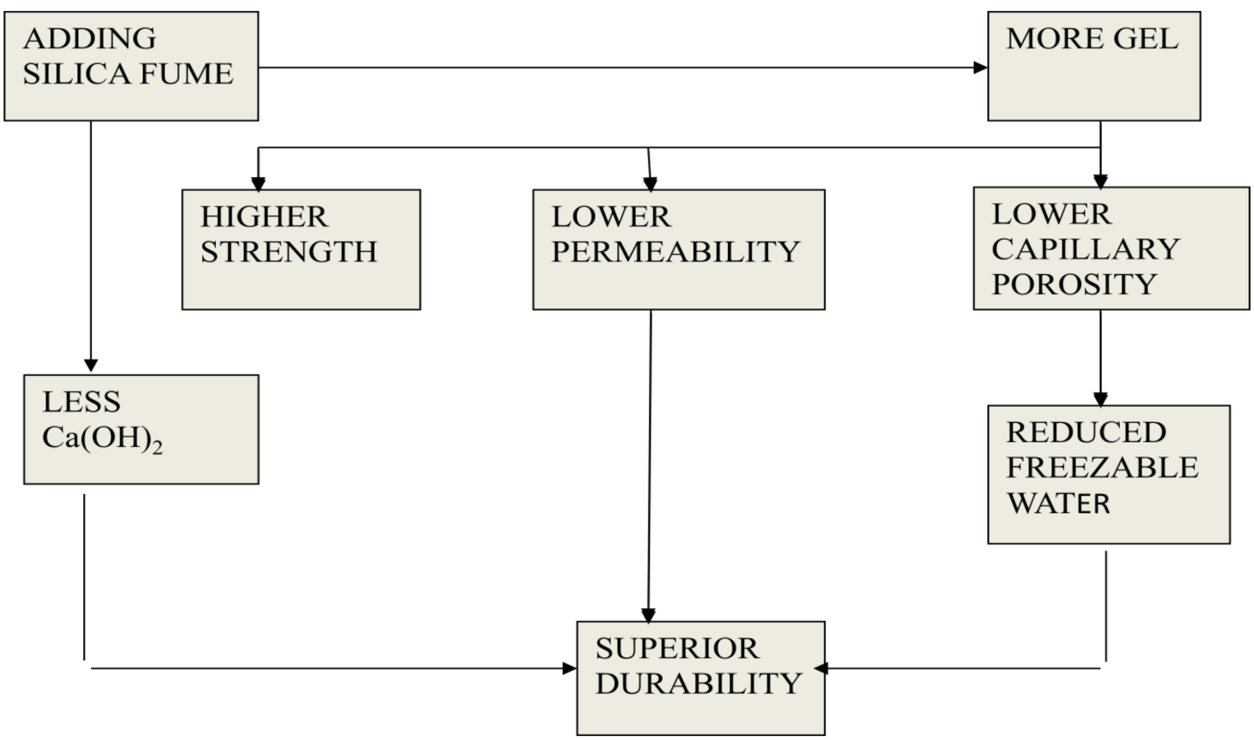


Fig.2.8 effects of adding silica fume to concrete

2.2.2 <u>Fly Ash</u>

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 is called "ball-bearing effect" **Neville AM(2005)** 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 $C_3S_2H_3$, 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

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.2.9 reactions of pozzolanic material in cement

2.2.3

On the basis of literature reviewed with respect to “EFFECT OF TERNARY BLENDS ON PROPERTIES OF CONCRETE” the experiments were carried out, which is reflected in the succeeding chapter 3.

Chapter-3

MATERIALS AND METHODS

3.1 GENERAL

The selection of mix materials and their required proportion is done through a process called mix design. There are number of methods for determining concrete mix design. The methods used in India are in compliance with the BIS (Bureau of Indian Standards). The objective of concrete mix is to find the proportion in which concrete ingredients-cement water fine aggregate and coarse aggregate should be combined in order to provide the specified strength workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2000. The specification of a concrete mix must therefore define the materials and strength work and durability to be attained. IS:10262-2009 given the guidelines for concrete mix designs. In this study three design mixes are calculated using w/c ratios as 0.34, 0.35, and 0.36. And nearest results are obtained for mix (1:1.4488:2.9186, w/c = 0.35). Five mixtures are prepared by replacing silica fume as 15% of total cementitious material in all mixtures and 15% variation of class-C fly ash(recommended by BIS) from 15% to 60 % (total replacement is from 0% to 75%)

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 ii) 7 days	 26.07 34.40	 >23 >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.)

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 "**ELKEM MICROSILICA**" as 920-D grade packed in 25 Kgs 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 (m^2/kg)	20300	15000	15000
Specific gravity	2.23	------	------

Size greater 45 μ	0.5%	------	10(max.)
Pozzoloan Activity Index (7days)	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 3.6 and 3.7 respectively

Table 3.6 Sieve analysis of fine aggregate

Weight of sample taken= 2.0 kg

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained	Cumulative% Retained	Percentage Passing
10.0	0.00	0.00	0.00	100
4.75	.068	3.40	3.40	96.6
2.36	.080	4.00	7.40	92.6
1.18	.147	7.35	14.75	85.25
600µ	.162	8.10	22.85	77.15
300µ	1.095	54.75	77.60	22.4
150µ	.335	16.75	94.35	5.65
Pan	.113	-	-	-
Total	∑=2.0		∑=220.35	

Fineness modulus = 220.35/100 =2.2035 (sand conferming to grading zone III as per IS:383-1970)

Table 3.7 Physical properties of fine aggregate

S.No	Property	Observed Values
1.	Bulk Density (Loose), kg/m³	1682
2.	Bulk Density (Compacted), kg/m³	1886
3.	Specific Gravity	2.66
4.	Fineness modulus	2.2035
5.	Water Absorption%	1.2

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 Table 3.8 and 3.9 respectively

Table 3.8(a) Sieve analysis of coarse aggregate (10mm)

Weight of sample taken= 2.0 kg

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weigh Retained (gm)	Cumulative percentage of Weight retained	Percentage Passing
25	0	0	0	100

20	0	0	0	100
12.5	8	8	0.4	99.6
10	541	549	27.45	72.55
4.75	1414	1963	98.15	1.85
2.36	32	1995	99.75	0.25
Pan	-	-	-	-

Table 3.8 (b) Physical properties of coarse aggregate (10 mm)

S.No.	Property	Observed Values
1.	Bulk Density (Loose), kg/m³	1307
2.	Bulk Density (Compacted), kg/m³	1469
3.	Specific Gravity	2.64
4.	Free moistures%	0
5.	Water Absorption	0.5

Table 3.9 (a) Sieve analysis of coarse aggregate (20 mm)

Weight of Sample Taken = 2.0kg

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage of Weight Retained	Percentage Passing
25	0	0	0	100
20	72	72	3.6	96.4
16	240	312	15.6	84.4
12.5	577	1389	44.45	55.55
10	546	1935	71.75	28.25
4.75	54	1989	74.45	25.55
Pan	-	-	-	-

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

S.No	Property	Observed Values

1.	Bulk Density (Loose), kg/m³	1477
2.	Bulk Density (Compacted), kg/m³	1554
3.	Specific Gravity	2.67
4.	Free Moisture%	0
5.	Water Absorption%	0.5

3.2.5 Superplasticizer

Conplast SP430 based on Sulphonated Naphthalene Polymers complies with IS: 9103:1999 was used as a high range water reducing Admixture. Properties are given in Table 3.10

Table 3.10 Specification of superplasticizer

Particulars	Properties
pH	7.54
Specific gravity	1.205
Chloride content	Nil
Alkali content	Less than 1.5 g Na_2O equivalent per liter of admixture
Optimum dosage	0.5 to 2.0 liters per 100kg of cementitious material

3.2.6 Water

Water used for mixing and curing was free from deleterious materials as per clause no. 5.4 of IS 456-2000. Potable water is generally considered satisfactory for mixing and curing of concrete. Properties are given in Table 3.11

Table 3.11 Specification of water

Sr.No	Property	observed value	Permissible value (max.)
1	Organic matters	140 mg/l	200 mg/l
2	In-organic matters	507 mg/l	3000 mg/l
3	Sulphate (as SO_3)	102 mg/l	400 mg/l
4	Chloride (CL)	120 mg/l	2000 mg/l for concrete work containing embedded steel and 500 mg/l for reinforced concrete work
5	PH	7	6 to 8
6	Total Suspended Solids	850mg/l	2000 mg/l

3.3 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 M55 grade as per IS 10262:2009

A-1 Simulation for mix proportioning

Grade designation	M-55
Type of cement	OPC 43 grade confirming to IS:8112
Maximum nominal size of the aggregate	20 mm
Type of aggregate	Angular (crushed) granite
Minimum cement	320 kg/m^3
Max. cement content	450 kg/m^3
Max. w/c ratio	0.45
Degree of workability	Medium (80 mm slump)
Degree of quality control	Good
Degree of exposure	severe
Chemical admixture used	superplasticizer

A-2 Test Data on material

Cement used	Ordinary Portland cement of Grade-43
Specific gravity	3.15
Chemical admixture	superplasticizer (confirming to IS: 9103)
Fine aggregate	Natural river sand conforming to zone III.
Specific gravity	2.66
Water absorption (%)	1.20

Fineness modulus	2.20	
Coarse aggregate	10mm	20mm
Specific gravity	2.64	2.67
Water absorption (%)	0.50	0.50
Fineness modulus	6.20	6.99
Surface moisture		
a. Coarse aggregate	Nil	
b. Fine aggregate	Nil	

CA: 20 and 10mm mixed in the ratio 60:40

A-3Target strength for mix proportioning

Pick the Standard deviation, SD=5

Target mean strength(Ft)

Ft = fck +k x S

= 55+ (1.65) x (5)

Ft = 63.25Mpa

A-4 Selection of Water cement ratio

From table-5 of IS456:2000 max. water- cement ratio =0.45

Adopt water cement- ratio = 0.35 < 0.45, hence ok

A-5 Selection of Water content

From table no. 2 of IS 10262:2009 max. Water

Content for 20mm aggregate =186 ltr. (25mm to 50mm slump range)

Estimate water content for 80mm slump =186+(3/25)x30x186/100=193ltr.

As superplasticizer is used water content can be reduced up 25% and above

Based on trial superplasticizer can reduce the water content up to 22% .

Hence arrived water content = 0.78x193=150ltr.

A-6 Calculation of Cement content

water cement- ratio = 0.35

cement content = 150/0.35=430kg.>320kg minimum cement content as per table 5 of IS456

A-7 proportioning of Volume of coarse aggregat*e*

From table-3 of IS10262:2009 for nominal size of 20mm & fine sand of zone-III for W/C ratio 0.50=0.64

In present case W/C ratio is 0.35. Therefore volume of coarse aggregate is needed to increase to decrease fine aggregate. As w/c ratio is decreased by 0.05, the proportion of volume of aggregate is increased by 0.01.

The corrected value proportion of volume of coarse aggregate = 0.67

Volume of fine aggregate = 1.0 -0.67=0.33

A-8Mix calculation

Mix calculation per unit volume of concrete as follows

a). Volume of concrete = $1m^3$

b). Volume of cement $=430/_{3.15}$ x1/1000=$0.136m^3$

c).Volume of water content $=150/_{1}$ x 1/1000=0.150

d).Volume of admixture (1.2% of wt. of cement) $=4.30/_{1.205}$ x 1/1000=$0.004229m^3$

e).Volume of all in aggregate = {a-(b+c+d)}

= 1-(0.136+0.150+0.004220)

=0.709771

f).Mass of coarse aggregate =e X volume of coarse agg. X sp. Gravity of coarse agg.x1000

= 0.709771x0.67x2.67x1000=1255kg

g).Mass of fine aggregate = e X volume of fine agg. X sp. Gravity of fine agg.x1000

= 0.709771x.33x2.66x1000=623kg

Finally, Keeping in view the workability properties, the W/C was increased to 0.44 from 0.38

Mix	W/C	Cement	FA	CA	Admix.
M-55	.35	1	1.1.4488	2.9186	0.012

Table 3.12 Mix Designation

S. N	Mix desg.	Cement (kg/m^3)	S.F (% of total cementitious material)	S.F (kg/m^3)	F.A (% of total cementitious material)	F.A (kg/m^3)	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

The properties which are to be evaluated are 7, 28 and 90 day compressive strengths, split tensile strength and modulus of elasticity.

3.4 <u>Casting of Specimens</u>

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 3.13 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

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.

3.5.1 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/cm^2/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.

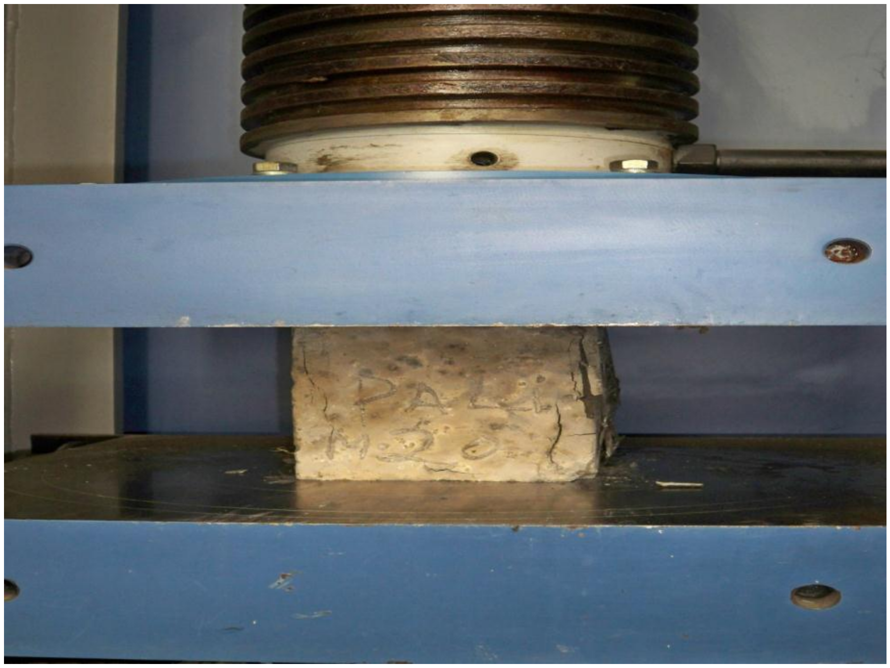


Fig.3.1 Compression testing machine

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 this tensile stress σ_{sp} (acting in a 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)

3.5.3 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.

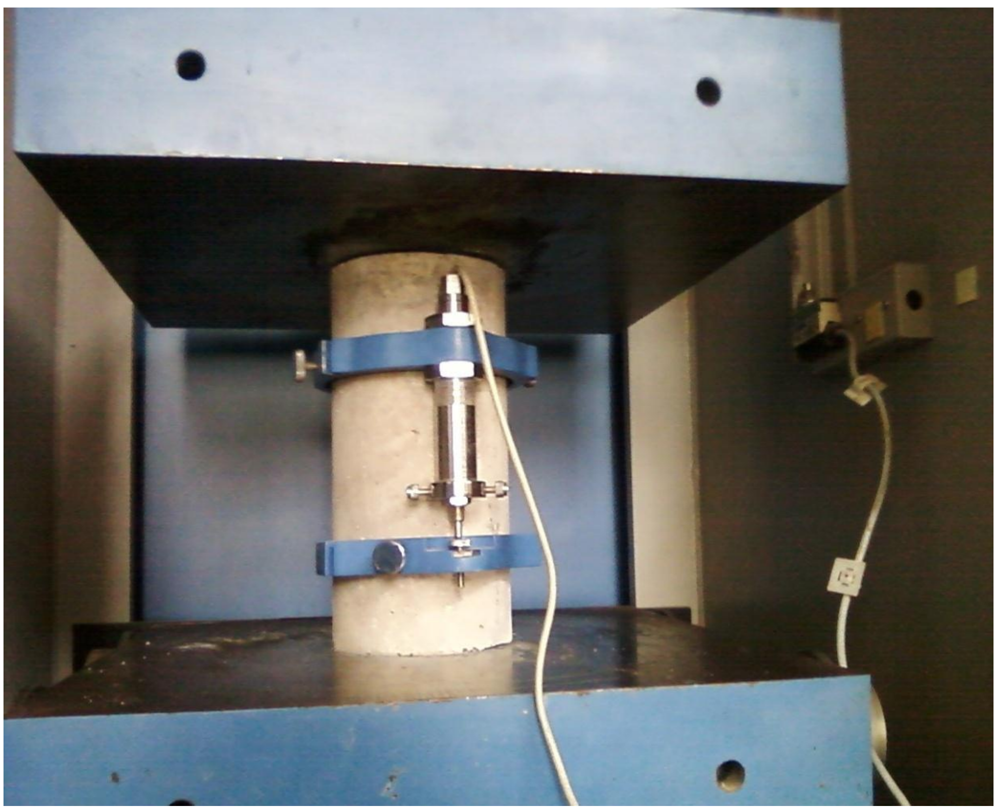


Fig.3.4 Set to draw stress strain curve by CTM using LVDT

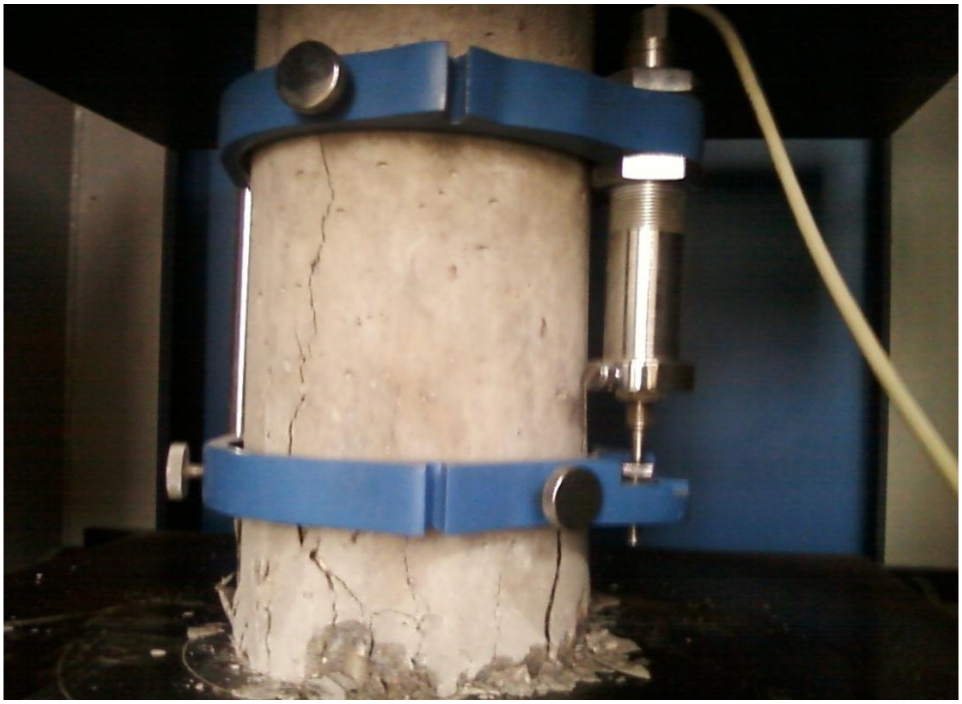


Fig3.5 Failure of sample under compression

Fig 3.6 Failure pattern of samples under compression

Chapter -4
RESULTS AND DISCUSSION

4.1 GENERAL

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-

4.2 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 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	33.70	57.86	62.7
2	R-30	32.00	61.64	67.5
3	R-45	31.77	66.66	72.7
4	R-60	28.66	50.2	58.2
5	R-75	22.40	31.7	43.3

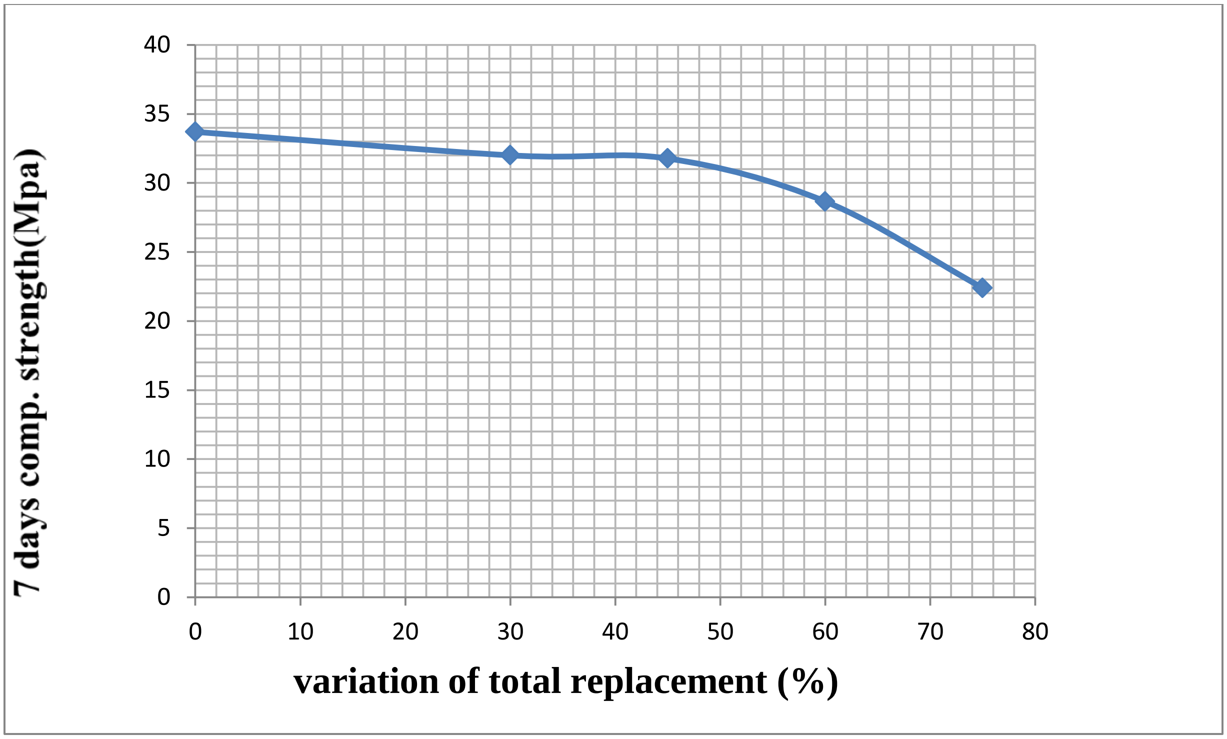


Fig.4.1 variation of 7 day compressive strength

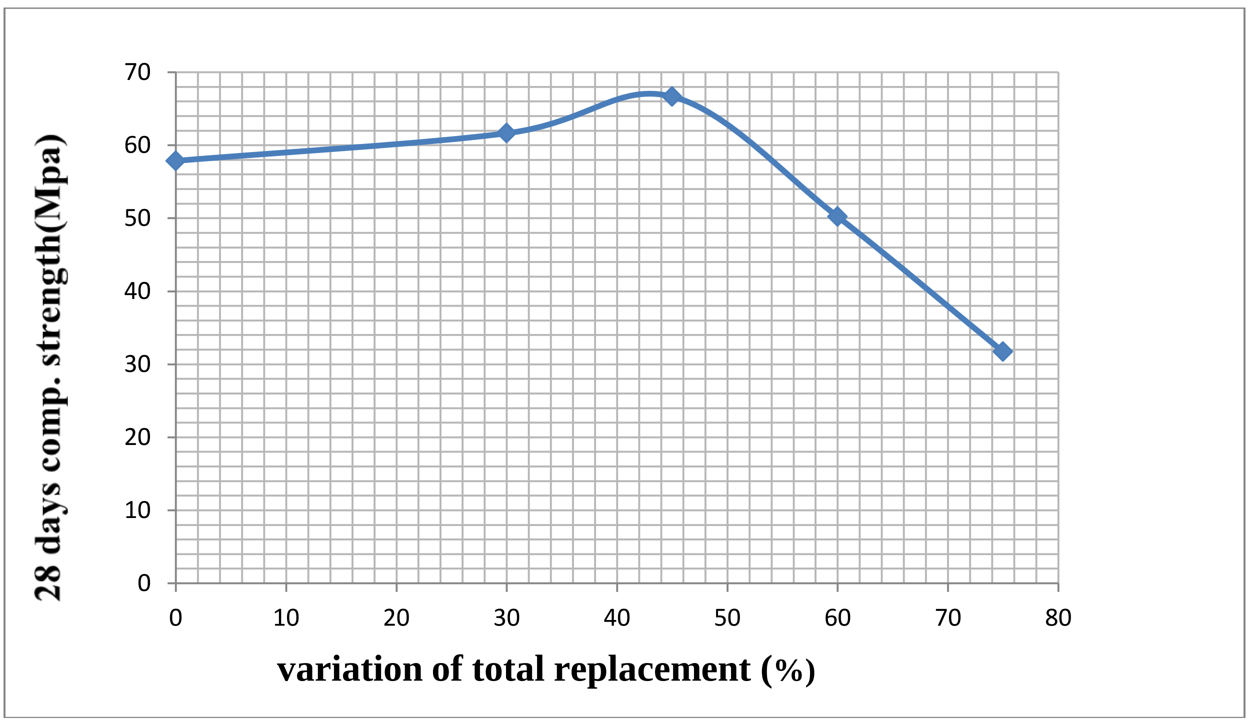


Fig.4.2 Variation of 28 days compressive strength

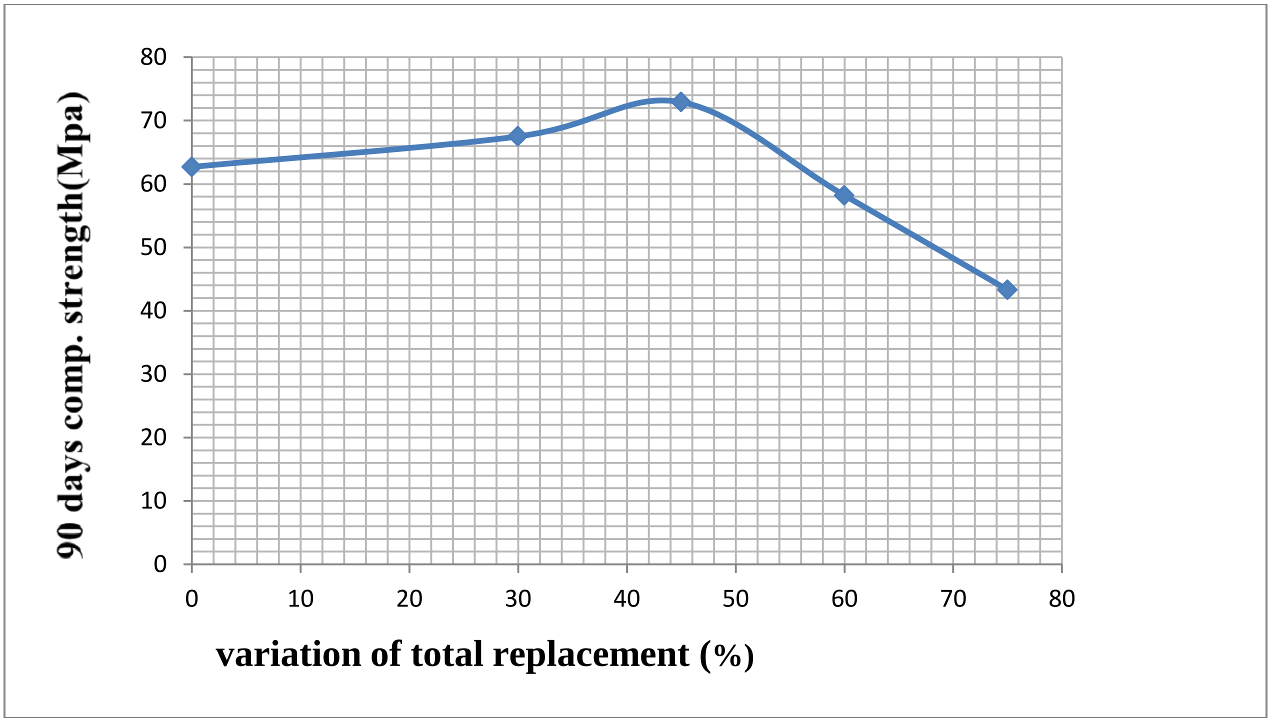


Fig.4.3 Variation of 90 days compressive strength

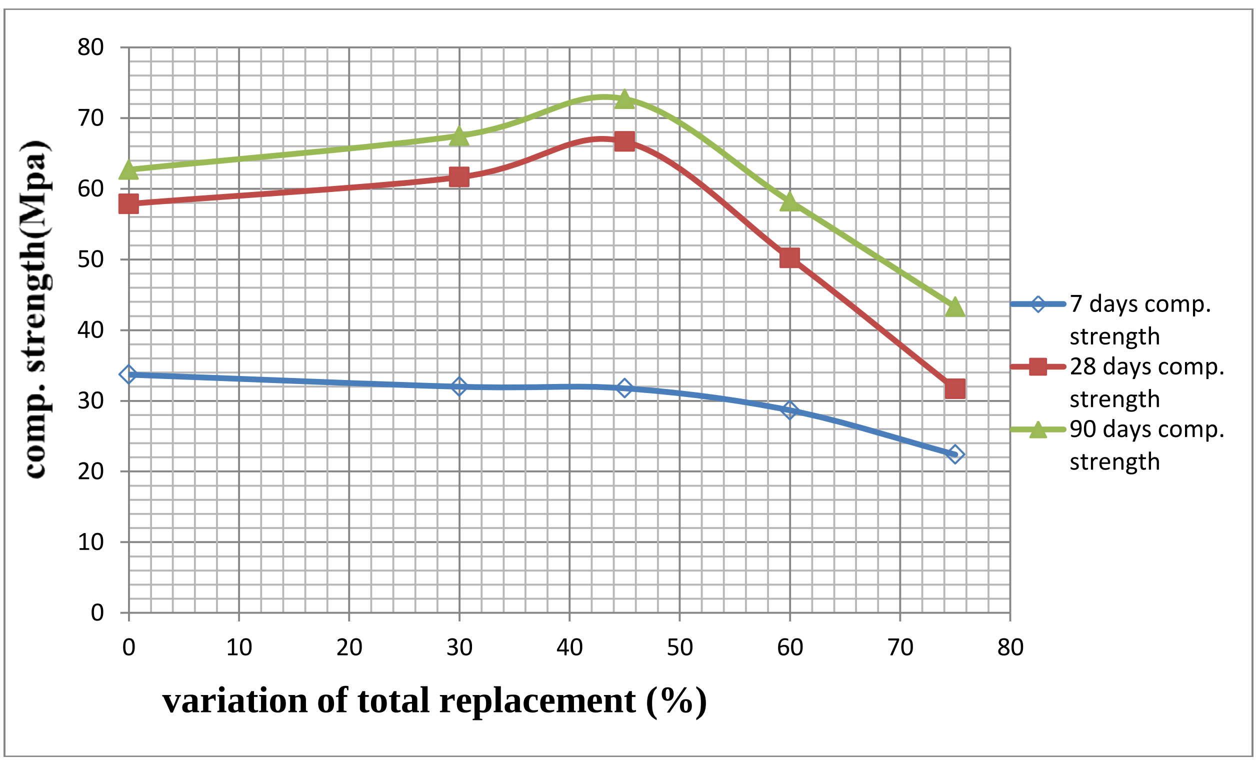


Fig.4.4 Comparison of compressive strength at 7, 28 and 90 days of curing

4.3 **Discussion**

1. 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.
2. 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%.
3. 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%.

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

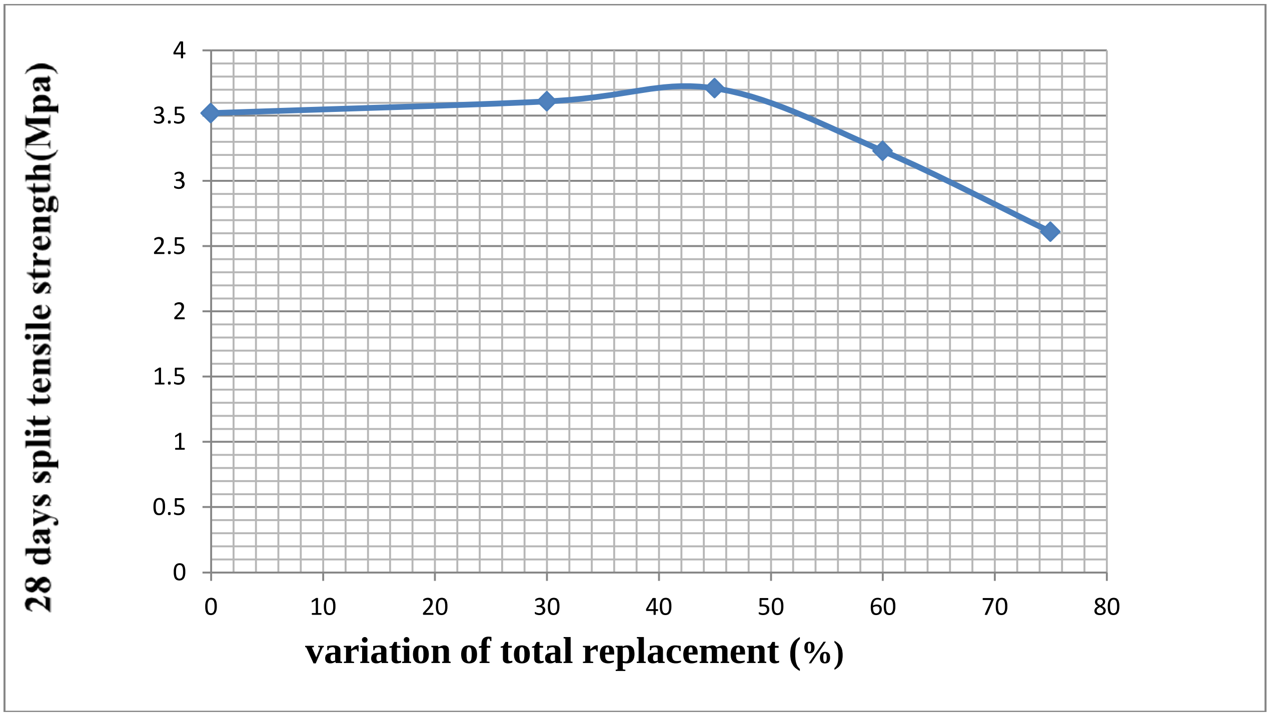


Fig.4.5 Variation of 28 days split tensile strength

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%.

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-

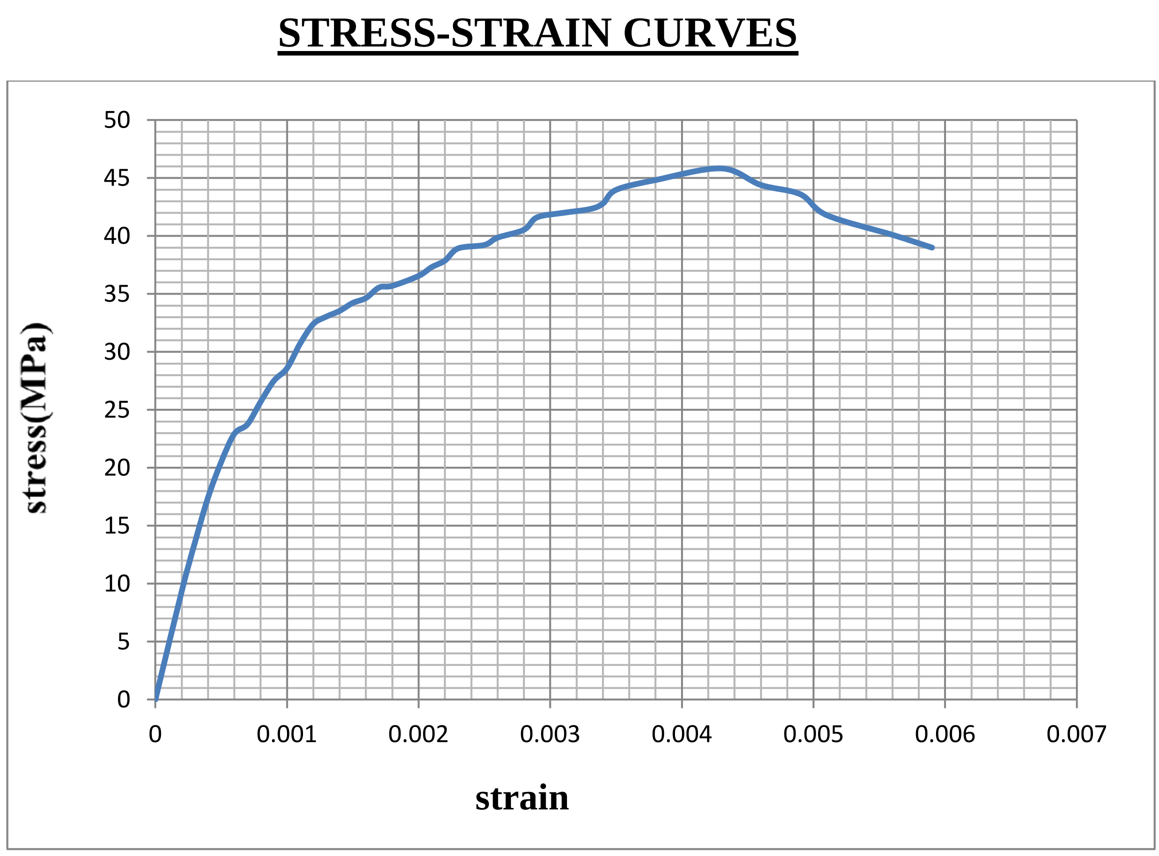


Fig.4.6 Stress-strain curve for control mix

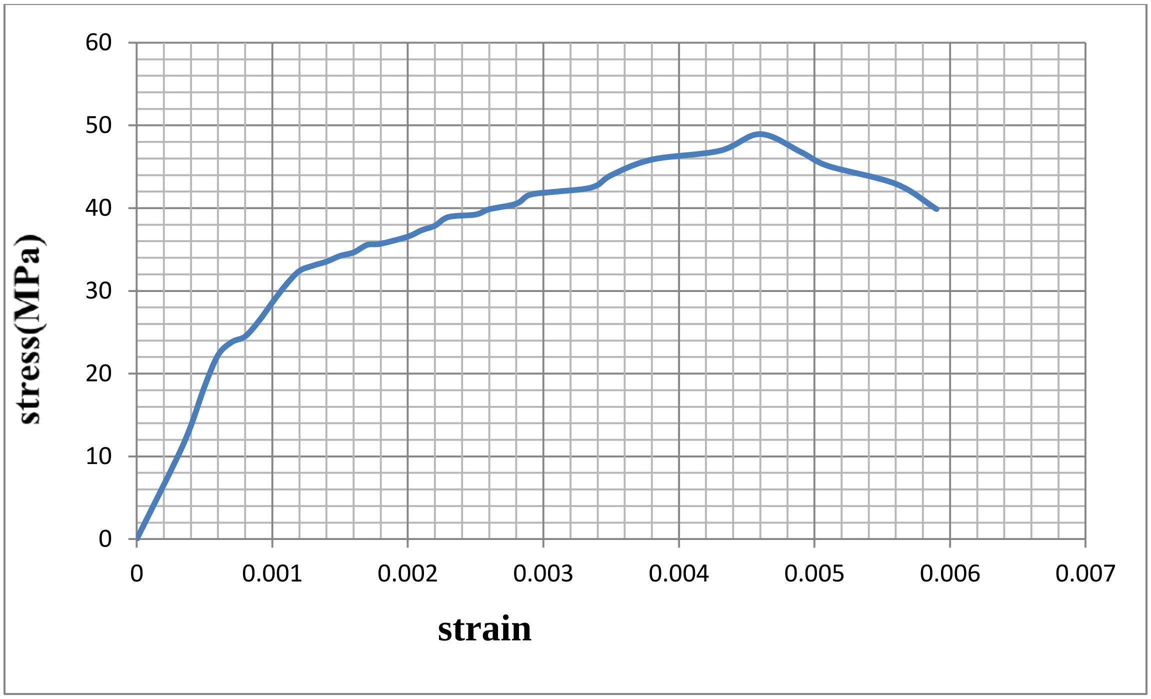


Fig.4.7 Stress-strain curve for 30% replacement

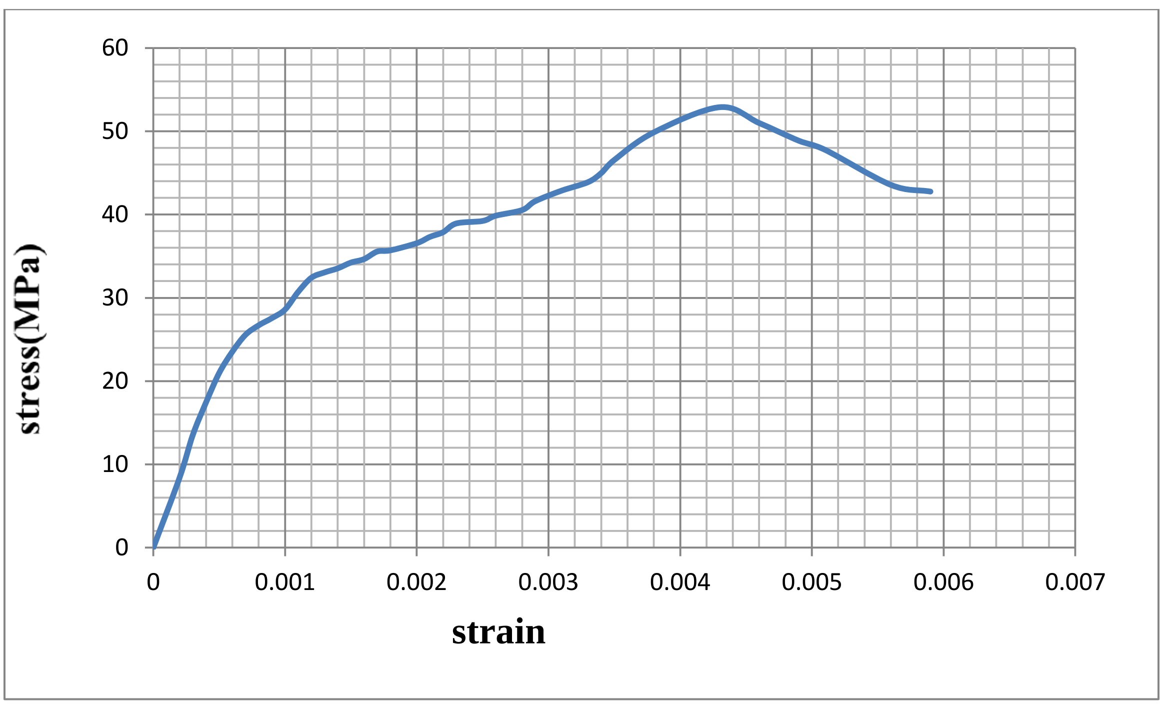


Fig.4.8 Stress-strain curve for 45% replacement

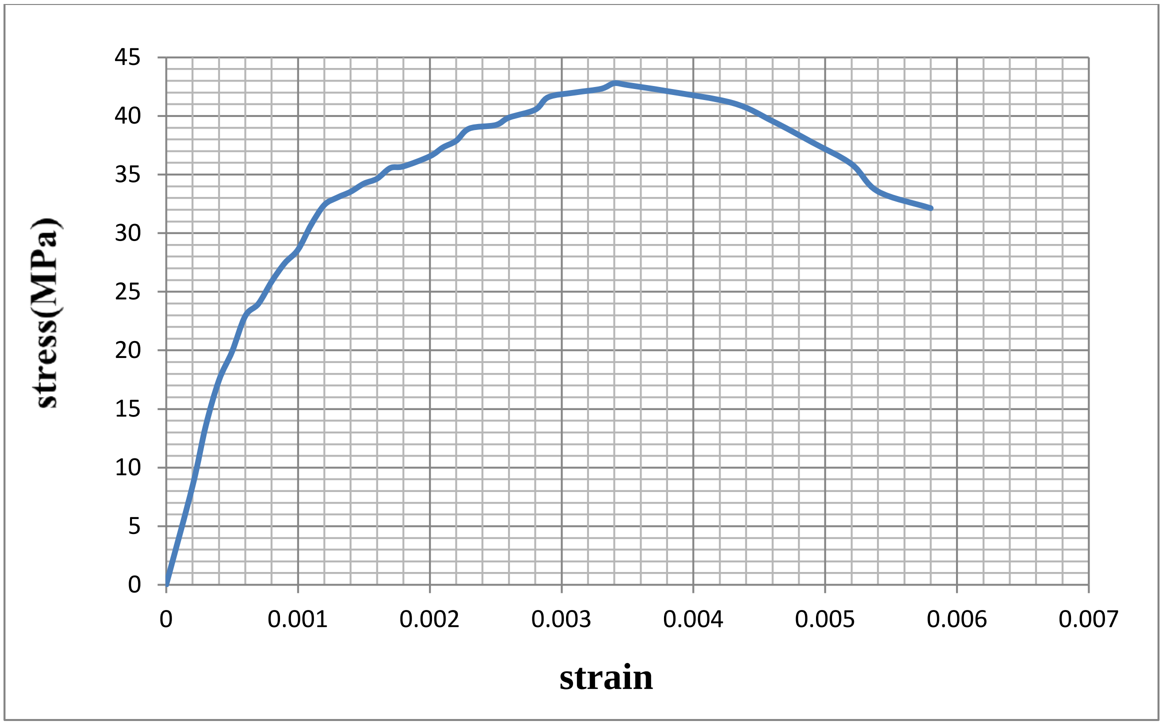


Fig.4.9 Stress-strain curve for 60% replacement

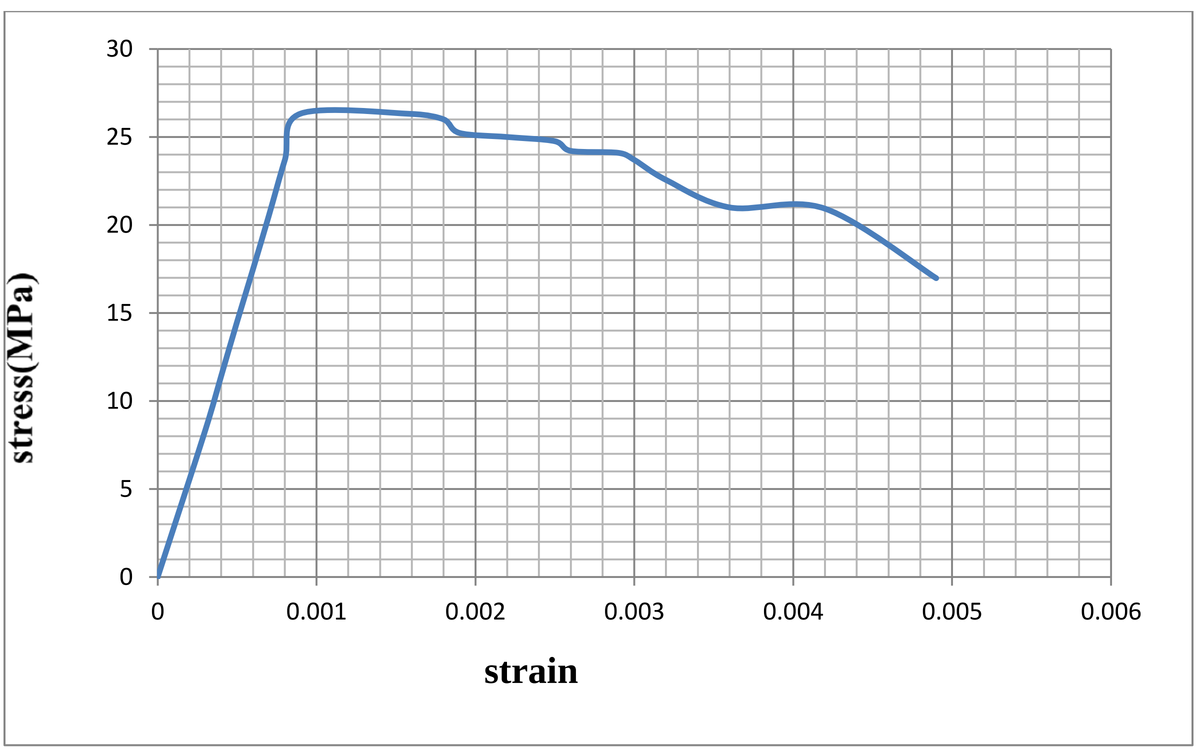


Fig.4.10 Stress-strain curve for 75% replacement

Table 4.3

STRESS-STRAIN VALUES

a) For control		b) For 30% rep.		c) For 45% rep.		d) For 60% rep.		e) For 75% rep.	
stress	**strain**	**stress**	**strain**	**stress**	**strain**	**stress**	**strain**	**stress**	**strain**
0	0	0	0	0	0	0	0	0	0
0.0002	09.34	0.0003	09.91	0.0002	08.43	0.0002	08.43	0.0003	08.35
0.0003	13.54	0.0004	13.72	0.0003	13.54	0.0003	13.54	0.0004	11.43
0.0004	17.43	0.0005	18.43	0.0004	17.43	0.0004	17.43	0.0005	14.51
0.0005	20.50	0.0006	22.24	0.0005	20.97	0.0005	19.90	0.0006	17.49
0.0006	22.93	0.0007	23.80	0.0006	23.53	0.0006	22.93	0.0007	20.54
0.0007	23.76	0.0008	24.50	0.0007	25.56	0.0007	23.98	0.0008	23.68
0.0008	25.70	0.0009	26.33	0.0008	26.70	0.0008	25.87	0.0009	26.33
0.0009	27.50	0.001	28.61	0.0009	27.56	0.0009	27.45	0.0016	26.31
0.001	28.59	0.0011	30.75	0.001	28.59	0.001	28.59	0.0018	26.00
0.0011	30.72	0.0012	32.45	0.0011	30.70	0.0011	30.72	0.0019	25.23
0.0012	32.41	0.0013	33.00	0.0012	32.42	0.0012	32.41	0.0022	25.00
0.0013	33.05	0.0014	33.57	0.0013	33.10	0.0013	33.05	0.0025	24.76
0.0014	33.54	0.0015	34.22	0.0014	33.52	0.0014	33.54	0.0026	24.21
0.0015	34.23	0.0016	34.63	0.0015	34.23	0.0015	34.23	0.0029	24.10
0.0016	34.65	0.0017	35.59	0.0016	34.66	0.0016	34.65	0.003	23.70
0.0017	35.56	0.0018	35.72	0.0017	35.52	0.0017	35.56	0.0032	22.56
0.0018	35.70	0.002	36.56	0.0018	35.71	0.0018	35.73	0.0036	21.00
0.002	36.56	0.0021	37.35	0.002	36.56	0.002	36.58	0.0042	20.93
0.0021	37.32	0.0022	37.78	0.0021	37.32	0.0021	37.32	0.0049	16.98
0.0022	37.88	0.0023	38.98	0.0022	37.85	0.0022	37.92		
0.0023	38.93	0.0025	39.20	0.0023	38.90	0.0023	38.99		
0.0025	39.23	0.0026	39.81	0.0025	39.25	0.0025	39.21		
0.0026	39.86	0.0028	40.55	0.0026	39.89	0.0026	40.00		
0.0028	40.54	0.0029	41.63	0.0028	40.59	0.0028	40.50		
0.0029	41.61	0.0031	42.20	0.0029	41.65	0.0029	41.61		
0.0031	42.00	0.0033	42.32	0.0031	42.87	0.0031	42.10		
0.0033	42.32	0.0034	42.81	0.0033	43.89	0.0033	42.36		
0.0034	42.80	0.0035	43.98	0.0034	44.97	0.0034	42.83		
0.0035	43.98	0.0038	45.87	0.0035	46.56	0.0035	42.64		
0.0038	44.83	0.0043	46.93	0.0038	49.87	0.0038	42.12		
0.0043	45.83	0.0046	48.95	0.0043	52.89	0.0043	41.10		
0.0046	44.40	0.0049	46.78	0.0046	50.99	0.0046	39.56		
0.0049	43.60	0.0051	45.1o	0.0049	48.87	0.0049	37.76		

0.0051	41.80	0.0056	42.93	0.0051	47.77	0.0052	35.89
0.0056	40.10	0.0059	39.89	0.0056	43.56	0.0054	33.56
0.0059	39.00			0.0059	42.76	0.0058	32.13
				0.0061	41.00		
				0.0064	39.13		

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

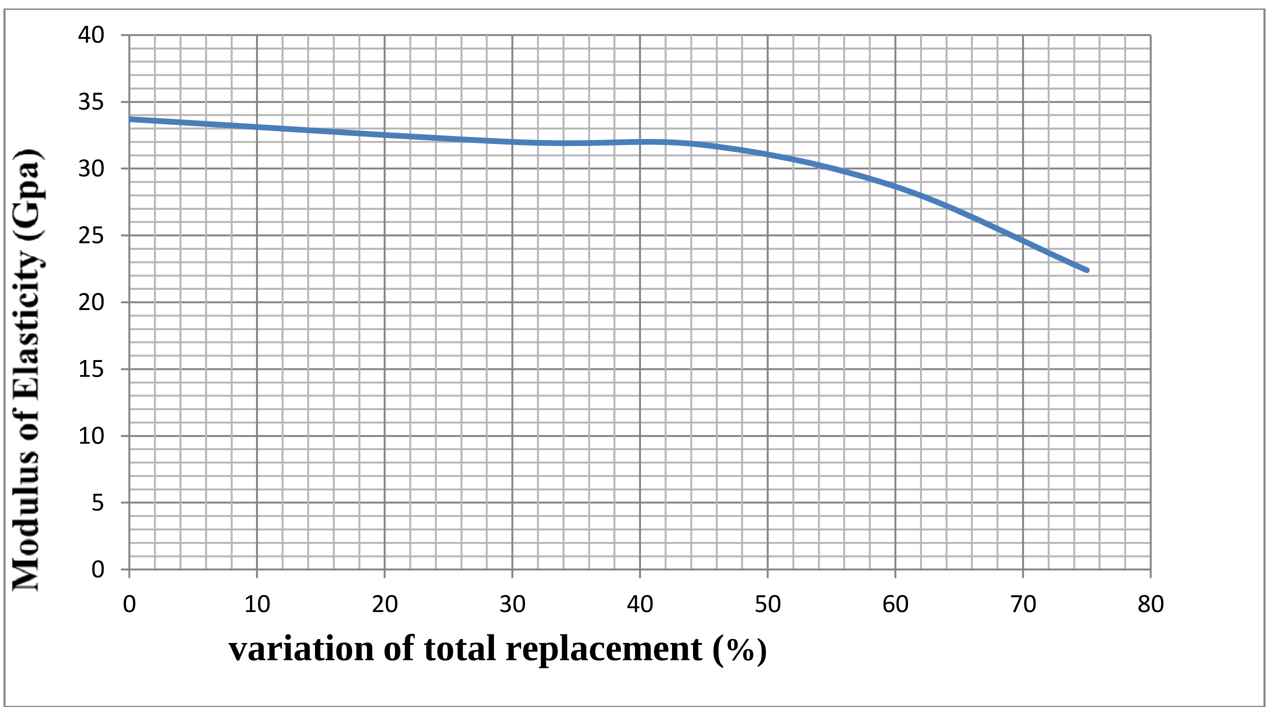


Fig.4.11 variation of Modulus of Elasticity at 28 days

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%.

Chapter-5
CONCLUSION AND RECOMMENDATION FOR THE FUTURE WORK

5.1 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%.
7. By using fly ash and silica fume, we can make a concrete with higher strength as per Indian standards which cannot be possible by using ordinary portland cement alone. Also by replacing cement with silica fume and fly ash mix we can reduce the use of cement and by this emission of CO_2, which forms during the formation of cement.
8. Use of fly ash in making concrete, results in ecological benefits as now a days Fly ash is a major solid industrial waste. It occupies a considerable amount of land and pollutes air and water sources. The disposal of fly ash is an environmental problem, as fly ash discharged on land may quickly spread far.

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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