ENHANCING CONCRETE PROPERTIES BY ADDING SILICA FUMES
(Compressive Strength)

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENT FOR THE AWARD OF DEGREE
OF

MASTER OF TECHNOLOGY
IN
STRUCTURAL ENGINEERING

Submitted by
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DECLARATION

I, Chitrank, 2K16/STE/06, student of M.Tech (Structural Engineering) hereby declare that the project Dissertation titled "ENHANCING CONCRETE PROPERTIES BY ADDING SILICA FUMES (Compressive Strength)" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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Date

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CERTIFICATE

I hereby certify that the project Dissertation titled "ENHANCING CONCRETE PROPERTIES BY ADDING SILICA FUMES (Compressive Strength)" which is submitted by Chitrank, 2K16/STE/06, to Civil engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi
Date

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ABSTRACT

Due to over increasing population and limited resources of land we have to look to the sky to accommodate this increasing population and for that we are so much focused on making high rise buildings and other mega structures to utilise the resources of land to its fullest, but this cannot be achieved without improving our construction technique and materials. As we know that Concrete is one of the most widely used structural material hence its property and quality influence the construction a lot. Here in my project I have tried to evaluate those properties of concrete and the improvement in those properties by adding silica fume. Silica fume act as a filler material and fills the pores between cement particles, making it more dense and improving the microstructure of concrete and thus improving the mechanical properties of concrete, such as strength, impermeability, durability, elastic modulus and so on. It also improve the concrete by chemically reacting with hydration precipitation of Ca(OH2) and producing hydrated calcium silicate in alkaline conditions thus improving the consistency of concrete and workability. Compressive strength of concrete is the most important property of concrete, because other properties like stress-strain relationship, tensile strength, bond strength, modulus of elasticity, density, impermeability, durability etc. can be inferred from the compressive strength using established correlations. Therefore in this project I have focused on observing the improvement in compressive strength of concrete by adding silica fumes and finding the most optimum proportion of silica fume which gives us the best result. Different mix design are prepared following IS code and different proportion of silica fume (i.e. 0%, 5%, 10%, 15%, 20%) are added and the results of 7 and 28 days compressive strength are found and compared. The result shows a progressive increase in compressive strength of concrete (corresponding to 28 days strength) till 15% of silica fume and then it slightly decreases hence we can correlate that the most optimum proportion of silica fume that should be added in concrete is about 15% of total cementitious material. Adding silica fume also improves the early strength of concrete (i.e. 7days strength), durability etc as discussed in the project.

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HRWA – High Range Water reducing Admixture

OPC – Ordinary Portland Cement

IS Code – Indian Standard Code

ASTM – American Society for Testing and Materials

HPC – High Performance Concrete

M-40 – Mix Design 40

fck – Compressive Strength

fm – Mean compressive strength

CTM – Compression Testing Machine

CaOH – Calcium Hydroxide

RCC – Reinforced Cement Concrete

CaO – Calcium Oxide

SiO_2 – Silicon Dioxide

Al_2O_3 – Aluminium Oxide

$CaSO_4$ – Calcium Sulphate

Fe_2O_3 – Iron Oxide

MgO – Magnesium Oxide

S – Sulphur

Na_2O – Sodium Oxide

K_2O – Potassium Oxide

C_3A – Tricalcium Alumintae

C_4AF – Tera Calcium Alumino Ferate

C_3S – Tricalcium Silicate

C_2S – Dicalcium Silicate

SMF - Sulphonated Malanie Formaldehyde

SNF - Sulphonated Naphthalene Formaldehyde

m – Meter

Kg – Kilogram

mm – Millimetre

wt – Weight

cm – Centimetre

gms – Grams

mints – Minutes

ml – Millilitre

Rpm – Rotation per minute

MPa – Megapascal

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 BACKGROUND

Concrete is a mix of sand, gravel, water, and cement which results in solid mass. Concrete is strong in compression but has low tensile strength. Its tensile strength is approximately $1/_{10}$ of the compressive strength. Lately, everyone is interested in improving properties of concrete by mixing/adding various pozzolanic materials in the concrete mixture. One of such material is silica fumes. Silica fume is also known as Micro silica, condensed silica fume, ”micropoz” (trademark) ,silica dust, volatilized silica etc. Silica fume is being used in a lot many projects now a days due to its favorable effect in concrete for eg Bandra worli sea link in Mumbai used silica fume concrete mainly for better durability. Silica fume is a byproduct of production of ferrosilicon and silicon metal in an electric arc furnace. Silica Fume such extracted is usually composed of more than 90 percent silicon dioxide and traces of other oxide. Silica fume was first collected in 1947 and started testing in 1961. Silica fume particles are very small that gives a fineness of 15000 to 30000 m2/kg. and specific gravity of about 2.22 .It is around 100 times smaller than the particle of cement which makes it easier for micro silica particle to occupy the spaces (voids) left by the cement particles. Hence we can say that proper proportioning of micro silica, cement, HRWRA (high range water-reducing admixture) and aggregate produces a concrete with improved concrete properties.

High Performance Concrete (HPC) containing **micro silica** is one of the most important advanced materials in the present day to grow a nation’s infrastructure. In addition to increased strength and enhanced durability, concrete produced with **micro silica** posses increased resistance to abrasion, chemicals, corrosion, increases toughness and placement and life-cycle cost efficiency. In severe and extreme conditions the life of a RCC structure shortens a lot due to corrosion of reinforcement by chloride and other chemical attacks which can be directly linked to the permeability of concrete and as addition of silica fume to concrete mix reduces the permeability hence it increases the life of a structure which makes the structure more economical in the long run. Silica fume also increase the strength of concrete which in turn make the structure abrasion resistant and also reduces the size of the members which reduces the total volume of concrete to be used in the structure hence reducing the project cost and making the structure more economical. These features allow a civil engineer and architect to have better comfort zone and to design the structure more freely and optimizing the space to the fullest with modern designs.

1.2 CONSTITUENTS OF CONCRETE

Concrete is a composite material in which the voids of coarse aggregate are filled with fine aggregate, the voids of fine aggregates are filled with cement etc. such mechanism leads to a high strength composite material known as concrete

The important ingredients used in concrete are:

1.2.1 Cement

Cement broadly consist of following two types of constituents

Calcareous compounds (Lime, Chalk, Marine shells)

Argillaceous compounds (Clay, Marl, and Shale)

Constituents present in OPC (ordinary Portland cement) are:

- *Lime* (CaO) (62-67%)
  It imparts strength and soundness to the cement, if it is in plenty, it also makes the cement unsound and makes it to expand and break and if it is not in sufficient quantity, it decreases the strength of the cement and causes the cement to set fast.
  Strength→ resistance from impact and gradual loading
  Toughness→ resistance to abrasion
  Hardness → resistance to impact (sudden loading)

- *Silica* (SiO_2) (17-25%)
  It also imparts strength to the cement. If it is in excess, strength of cement in increased but it also increases the setting time of cement. Wherever early setting is required, we need to change the constituents as (silica and lime as they are long setting constituents).

- *Alumina* (Al_2O_3) (3-8%)
  It provides quick setting property to the cement. It acts as a flux and helps in decreasing the clinkering temp. If it is in exceeded, it weakens the cement. The temperature at which clinkers of cement form is known as clinkering temperature.

- *Calcium Sulphate* ($CaSO_4$) (3-4%)
  It is generally available in the form of gypsum and helps in increasing the initial setting time of the cement.

- *Iron Oxide* (Fe_2O_3) (3-4%)
  It imparts strength, hardness and color to the cement.

- *Magnesia* (MgO) (1-3%)
  It also imparts strength, hardness and color to the cement. If its quantity is more than required, it makes the cement unsound

- *Sulphur* (S) (1-3%)
  Sulphur in cement is responsible for volume change, Hence it also leads to unsoundness in cement.

- *Alkalis* (Na_2O, K_2O) (0.2-1%)
  Alkalis in cement are responsible for straining and efflorescence of the structure in which it is used for construction

When these ingredients of cement are intergrinded and burnt. They fuse with each other, leading to the formation of complex chemical compound which are not formed simultaneously and are referred as Bogues Compound.

Following are the Bogues Compounds present in cement.

- *Tricalcium Aluminate* ($3CaO.Al_2O_3$) (C_3A) (4-14%)
  It is known as calcite. It undergoes hydration within 24 hour of the addition of water in the cement. It is responsible for flash setting of the cement and also leads to volume change in it. Thereby is responsible for development of crack in it. It releases maximum

heat of hydration during its formation. Shrinkage takes place because hydration occurs due to C_3A and volume of cement changes takes place.

- *Tetra Calcium Alumino Ferate* ($3CaO.Al_2O_3.Fe_2O_3$) (C_4AF) (10-18%)
  It is known as Felite. It also undergoes hydration within 24 hour of addition of water in it. It is observed to have the worst cementing property. It is of no engineering significance as it does not impart any property in the cement.

- *Tricalcium Silicate* ($3CaO.SiO_2$) (C_3S) (45-65%)
  It is known as Aelite. It undergoes hydration within a week or so, after the addition of water into the cement. It is responsible for development of early strength of concrete. Hence, if in any Engineering Construction, early strength is required, proportion of C_3S is increased considerable. Examples are cold weather concreting, pavement construction, prefabricated construction, where form-work is to be reutilized for speedy construction. It also increases the resistance of the cement against freezing and thawing. It possesses the best cement and property among all the Bogus compounds.

- *Dicalcium Silicate* ($2CaO.SiO_2$) (C_2S) (15-35%)
  It is known as Belite. It undergoes hybridization within a year after the addition of water into the cement hence is responsible for development of progressive strength in it. It also increases the resistance of cement against chemical action. If in any engineering construction progressive strength is required, proportion of C_2S is increased accordingly example dams, hydraulic structure, bridge etc.

1.2.2 Aggregates

Properties of the mix depends upon the following characteristic of the aggregates-

- *Shape*
  Shape of the aggregate affects the workability and strength of the mix. Rounded aggregate lead to the formation of workable mix as it offers lower surface area to be lubricated. Angular aggregate leads to the formation of very strong concrete mix as it offers a better inter-particle bonding and greater bond strength. Use of flaky aggregate result in the formation of bad/poor mix that neither has workability nor strength. Angularity of the aggregate is measured in terms of parameter referred as angularity number that depends upon the percentage of the void in the given sample of aggregate.

The value of angularity number varies in the range of 0 to 11. If percentage void in the sample is 33 the angularity number is taken to be zero and if the percentage void in the sample is 44 the angularity number is taken to be 11

- *Surface Texture*

  Surface texture is the measure of relative degree of the surface area which is smooth or rough. Smooth texture aggregate result in the formation of workable mix as it offers lesser surface area to be lubricated where as the rough texture aggregate results in the formation of very strong mix as it offers increased inter-particle bonding and increased bond strength.

- *Grading*

  A well graded sample of aggregate results in the formation of both workable mix and strong makes. A well graded sample is more dense, hence results in the formation of strong mix, moreover more volume of free cement paste is available in this case for lubrication resulting in higher workability. Gradation of the aggregate is done by sieve analysis. In sieve analysis a parameter referred as fineness modulus is used to indicate the fineness or coarseness of the aggregate. Sand having fineness modulus greater than 3.2 is not considered to be suitable for preparation of concrete.

- *Strength*

  Strength of the aggregate affects the strength of the mixture in which it is used. Strength of the aggregate is defined as the resistance of the aggregate against gradual loading. Strength of the aggregate is determined by aggregate crushing value test which is performed on the particles passing through 12.5 mm sieve and retained over 10 mm sieve. These particles are subjected to the gradual loading of 40 tons with the help of the plunger and the sample is then further passed through the sieve of size 2.36 mm. Weight of these particles passing through the sieve expressed as the % of the original wt of particle is referred as aggregate crushing value. For aggregate to be used in pavement construction it should not exceed 30% and for any other construction it should not exceed 45%.

- *Toughness*

  Toughness of the aggregate is referred as ability to resist impact loading which is determined by aggregate impact value test. In this test the aggregate are given 15 blows with a metallic hammer of 14kg mass from a height of 38cm.The wt of particle passing through 2.36mm sieve is then found out and expressed in terms of total weight, this value is known as aggregate impact value. For aggregate to be used in pavement construction it should not exceed 30% and for other construction it must not exceed 45%.

- *Hardness*

  It is a property of the aggregate by the virtue of which it is able to resist wear and tear on abrasion. Hardness of the aggregate can be determined by Los Angeles test. In this test the sample of the aggregate is placed in cylinder having Steel balls in it. The sample is subjected to the abrasion by rotating the cylinder 500 number of times at a speed of 30 to 33 rpm. The sample is then passed through 1.7 mm sieve & the wt of the particle passing through the same is noted which when express in terms of original wt of the particle is referred as aggregate abrasion value. For the aggregate to be used in pavement construction aggregate abrasion value should not be greater than 30% and for general construction it should not exceed 50%

- *Flakiness Index*

  Flakiness index of the aggregate is defined as percentage by wt of the particle in it, having their least dimension smaller than $3/5^{th}$ of the mean dimension. This test is not applicable for the particle having size smaller than 6.3 mm. In order to perform this is sufficient quantity of aggregate must be considered such that 200 pieces of each fraction can be gauged. Particle of each fraction are passed turn-by-turn through the respective opening and the wt of the particle passing through respective opening is noted which when expressed in terms of original wt of particle is referred as flakiness index.

- *Elongation Index*

  Elongation index is defined as % by wt of the particle present in the sample having their greatest size more than 1.8 times of their mean size. This test is also not applicable for the particles having size smaller than 6.3 mm. In order to perform this test, sufficient quantity of aggregate must be considered such that 200 pieces of each fraction can be gauged. Particles are passed through turn-by-turn through the respective opening over the length Gauge and the wt of the particle retains over the each opening is noted which will expressed in terms of original wt of the particle is referred as elongation.

1.2.3. Admixtures

Admixtures are natural/manmade compounds used as additive in concrete along with cement, aggregate and water to enhance certain specific properties of concrete during casting stage or setting stage or service stage.

Admixtures used may be of following type:

- *Plasticizers*

  Plasticizers are mixtures of organic and inorganic substances which permit the decrease in water cement ratio at the same workability or insure higher workability at same water cement ratio, in either of the cases it proves strong mix or workable mix. These plasticizer act as a deflocculating reagent hence get absorbed over the cement particle thereby make the entrapped water free which modifies the properties of the mix. Dose of plasticizer where is in the range of 0.1 to 0.4% by the weight of the cement permit the reduction in the water content by 5 to 15% or increases the slump value by 30 to 150 mm. Commonly used plasticizer include lignosulphate, Polyglycol Esters, carbohydrates and hydroxylated carboxylic acid.

- *Super Plasticizers*

  Super plasticizer is same as plasticizer in terms of the action but is chemically different from the plasticizer. The effect of superplasticizer is comparatively more than that of the plasticizer as they can permit the reduction in the water content up to 30%. Commonly used super plasticizers include modified lignosulphate, sulphonated malanie, formaldehyde(SMF) sulphonated naphthalene formaldehyde(SNF).

- *Retarders*

  Retarders are the admixtures that slow down the chemical reaction of hydration so that concrete can remain plastic and workable for more duration in comparison to the concrete in which retarders are not added. Retarders are used to overcome the accelerating effect of the temperature over the hydration process. They find their application in the construction of oil Wells at which temperature increases up to 200 degree Celsius. Their normal dose varies in the range of. 05 to. 2% at which they can delay the hydration process up to 72 hours. Commonly used retarders include calcium sulphate, tartaric acid, starch, cellulose and sugar.

- *Accelerators*

  These are the admixtures which increases the rate of gain of development of strength in concrete. They find their application in cold weather concreting, prefabricated construction, emergency repair work, pavement construction where formwork is to be reutilized for speedy construction. Their dose varies in the range of .1 to .2% by weight of cement. Commonly used accelerators include calcium chloride, silicate, floro silicate and tri-ethanol amine.

- *Air Entraining Admixtures*

  These are the type of admixture that entraps millions of air bubble in between the voids of the aggregate which act as flexible ball bearings that slip pass over each other thereby modifying the properties of the concrete with respect to workability, frost action, durability, segregation and bleeding. These admixtures are now a day's used as the 5^{th} ingredient in the preparation of concrete. Use of these admixture allow higher workability, higher resistance against Frost action, higher resistance against the action of acids, higher resistance against segregation and bleeding, higher durability, low Unit Weight. Commonly used air entraining admixtures includes natural wood resins, plant and animal fatty oil, citric acid, oelic acid, hydrogen peroxide, aluminium powder.

1.3 SILICA FUME

Silica fume also known as micro silica is defined as very small non crystalline silica in ultrafine powdered form produced in electric arc furnaces as a byproduct of production of silicon containing alloys. Composition of Silica fume involves 85 to 97% Sio_2, less than 1% CaO content, 2 to 10% others. The specific surface of silica fume is about 15000 to 30000 (m^2/kg), specific gravity of silica fume is 2.2, size of micro silica is about150nm and color is normally light dark grey. The main use of silica fume is as pozzolanic material in making high performance concrete. Silica fume in itself possess very low or no cementitious value but in ultrafine powdered form and in presence of water, reacts chemically with CaOH at ordinary temp to form compound possessing cementetious properties.

Fig1.1 (Silica Fume)

1.3.1Chemical Properties

- *Amorphous*: The silica fume is non crystalline that means it dissolves in concrete and react with it.
- *Silicon dioxide* (SiO2): This is the material of silica fume that reacts with

- *Trace elements*: As silica fume is a byproduct hence these trace elements depend on the material which is being primarily made in the furnace hence the trace element of silica fume is not constant and normally does not change the property of silica fume much.

1.3.2 Physical Properties

- *Particle size.*
  Silica fume particles are very tiny with avg size of 150 nanometer or .15 micrometer. Particle size is extremely important for both the physical and chemical contributions (discussed below) of silica fume in concrete.

- *Unit Weight*.
  Unit wt of silica fume as produced from furnace is very low hence it is not very economical to carry silica fume from one place to another

- *Specific gravity*:
  Specific gravity of silica fume is just the ratio of density of silica fume to that of water which comes out to be 2.2 which is less than the specific gravity of cement (around 3.15)

1.3.3 Reactions in Concrete

- *Physical contributions* — As the size of silica fume is very very small as compared to cement particles hence it works as a filler material and fills the void present within cement particles and thus reduces the permeability a lot, this phenomenon is known as Micro filling or particle packing which in itself improves the concrete properties greatly.

- *Chemical contributions* —High amorphous SiO_2 of silica fume is a very reactive pozzolonic material and reacts with the CaOH released by cement reacting in concrete and forms calcium silicate hydrate which act as additional binding material in concrete hence enhances the concrete properties.

1.3.4 Silica Fume and Fresh Concrete

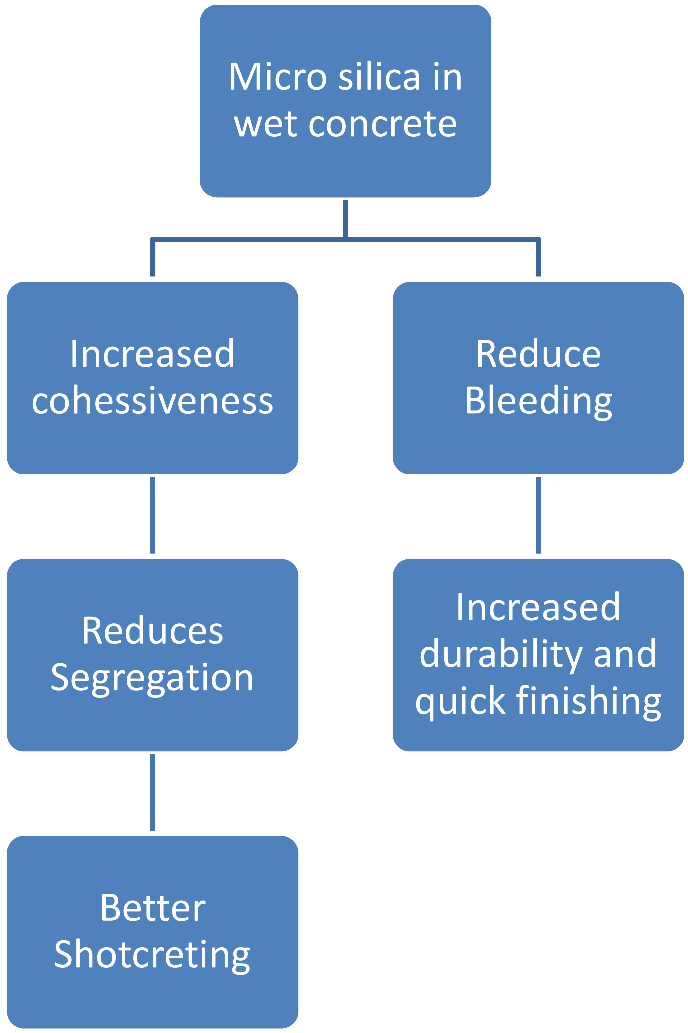

Figure 1.2 Effect of silica in fresh concrete

- Increased Cohesion

In wet concrete silica fume increase the cohesiveness of concrete and makes it less susceptible to segregation while placing and compacting of concrete. These properties allow better shotcreting by reducing the amount of rebound and hence increasing the efficiency of shotcreting.

Figure 1.3 shotcreting

- <u>Reduced Bleeding</u>

The surface area of Micro silica is very large and generally very low water content is used in silica-fume concrete which reduce the bleeding in concrete to minimum. As bleeding reduces the capillaries which gets formed due to bleeding also reduces hence the permeability decreases and the durability increases. This reduce bleeding also allow finishing processes to start early and hence reducing the construction time and increasing the construction efficiency.

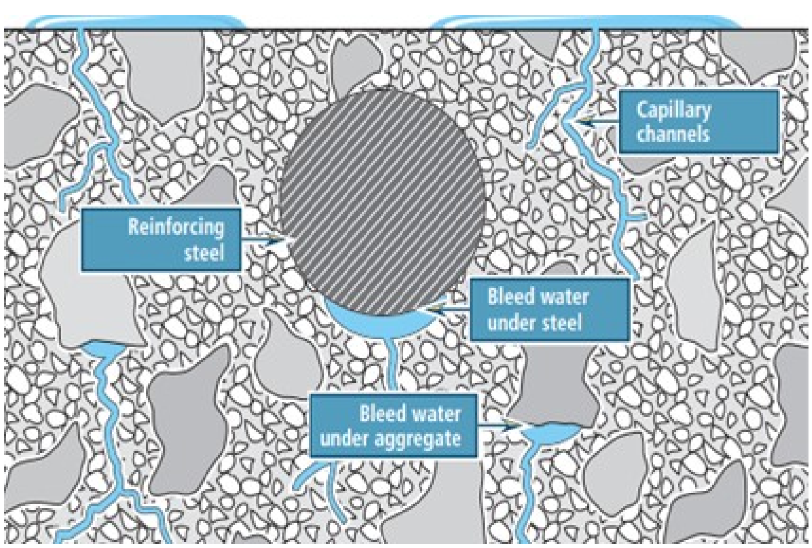

Figure 1.4 Bleeding in concrete

1.3.5 SILICA FUME WITH HARDENED CONCRETE

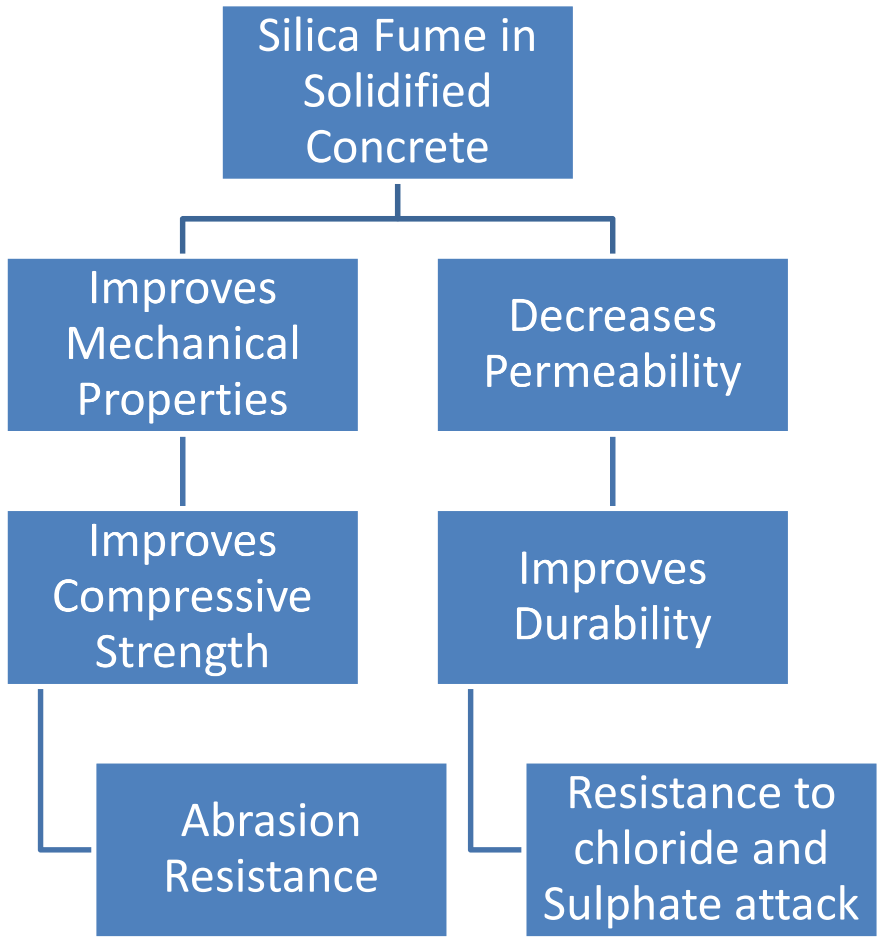

Figure 1.5 Effect of Silica fume in solidified concrete

- *Improved Mechanical Properties*:
  Initially micro silica was basically used to increases the compressive strength of concrete, then its other effect such as improving flexure strength or modulus of elasticity is studied for high rise buildings

- *Reduced Permeability*:
  The durability is also a very important property of concrete which is directly related to its permeability hence by decreasing the permeability by adding silica we can increase the

durability of concrete and hence increase the design life of the structure or maintenance cost

Figure 1.6 Effect of silica fume on permeability

- *Chloride Attack*

RCC fails mainly due to corrosion of reinforcement which occurs due to intrusion of chloride in concrete by ocean or from any other sources. Chloride penetrates inside concrete through the pores present in concrete and corrodes the reinforcement which is minimised/delayed by decreasing permeability by adding silica fumes to concrete mix. Adding silica fume to concrete can add many years to the life of the structure.

- *Workability*

Wet concrete containing micro silica has a higher cohesiveness and low segregation than concrete without micro silica. It was found that silica fume improves the workability of concrete.

CHAPTER 2

MATERIAL USED AND PRELIMINARY TESTING

2.1 MATERIALS USED

The aggregates, cement, and silica fume were supplied by the local supplier in Rohini Sector-17. The Admixture was supplied by Shriram Enterprises (Rajouri Garden).The remaining materials were laboratory stock at the Delhi Technological University.

All of the materials used are described in the following paragraphs:-

- *Cement*

  The cement used is Ordinary Portland Cement (OPC); Grade 43 manufactured by UltraTech Cement Ltd. Cement met all the requirements of American Society for Testing and Materials (ASTM)
  And confirming to IS 8112: 1989.
  Ordinary Portland Cement (OPC) is most commonly used cement for wide range of applications such as
  - High Strength Concrete
  - Masonry and Plastering works
  - Standard strength concrete
  - Pipes and Blocks

- *Aggregate*

  The aggregate used is provided by local supplier according to IS 383 1970 and is of two types described as follows:
  - *Coarse Aggregate*

    The Coarse Aggregate used contained variant of two sizes as 10mm and 20mm. The 20mm aggregate is 69% of total quantity of coarse aggregate and 10mm aggregate is31% of total quantity of coarse aggregate
  - *Fine Aggregate*

    Fine aggregate used was sand from nearby river area which passes completely from 4.75mm sieve and does not contain any lumps and gravels.

- *Silica Fume*

  Silica fume used was fresh and supplied by local supplier and was finely grained (powder).

  Silica fume is by-product of manufacturing silicon metal or ferrosilicon alloys industries. It is also known as Micro Silica and is amorphous polymorph of SiO_2 and also consists of spherical diameter with particle size of 150mm. Because of its physical and chemical properties, it is very reactive pozzolana.

- *Admixture*

  Air-entraining agents, water reducing retarders, water reducers and accelerators are among some of the most commonly used. Admixtures. They are added to provide special properties to wet or hardened concrete. They may improve the workability, durability, characteristic strength etc of a given mixture of concrete.

  The admixture used here was SIKA VISCOCRETE 5101 NS manufactured by Sika India Pvt Ltd. Here admixture used is of water reducer type i.e. it reduces the amount of water required in concrete mixture.

2.2 MATERIAL TESTING

All the material used was tested thoroughly before use. The result of their testing is given below:

2.2.1 Cement

Several tests are performed on cement before using it. The test performed is as follows:

- *Fineness of Cement*

  Fineness of cement is determined by passing it through 90mm sieve and determining the amount of cement retained on it. The result of above test came out to be that only 2% is retained on 90mm Sieve.

- *Specific Gravity Test*:

  Specific gravity of cement is d etermined with the help of Le Chatelier Flask. Initially the weight of flask with half full of cement is determined as W_2 and then kerosene oil is poured in it with continuous stirring for removal of air bubbles in flask. The weight of flask with kerosene oil and cement is determined as W_3. The flask is again emptied and completely filled with kerosene oil and its weight is determined and recorded as W_4. Then the specific gravity of cement is given as:

$$\text{Specific gravity} = \frac{W2-W1}{(W2-W1)-(W3-W4)X0.79} \qquad (2.1)$$

Where,

W_1 = Wt of empty flask

W_2 = Wt of empty flask + cement

W_3 = Wt of empty flask + cement + kerosene

W_4 = Wt of empty flask + kerosene

.79 = Density of kerosene

The specific gravity of cement came out to be 3.150

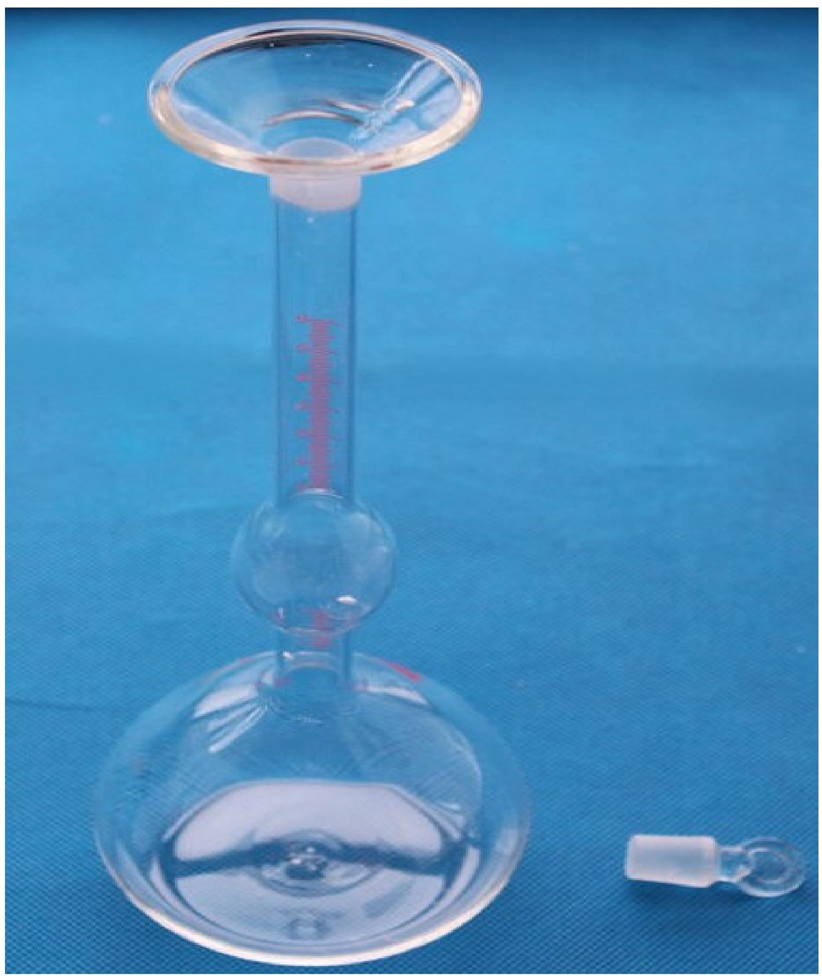

Figure 2.1 1le chatelier flask

- *Normal Consistency Test*

Normal consistency of cement is determined with the help of Vicat Apparatus. 500 gms of cement is taken out and paste is prepared with a weighed quantity of water such as 28%, 30% till 38%. The paste prepared was filled in Vicat apparatus and the plunger is dropped down. The amount of water when plunger penetrates for the depth of 33 – 35 mm from top due to its own weight is known as normal consistency.
The Normal Consistency of cement came out to be 33%.

Figure 2.2 Vicat Apparatus

- *Setting Time*

Setting time is also determined by the help of Vicat Apparatus. In this the cement paste is prepared with the help of 500 gm of cement and 85 times the water required for consistency. The paste made is now filled in Vicat apparatus mould and left for 30 min. The period elapsing between the time when water is mixed and time when needle gets penetrated till the depth of 33 – 35 mm from top is known as Initial Setting Time.
For final; setting time needle is replaced by plunger and the time elapsed between the time when water is mixed to cement and time at which plunger just leave an impression on surface of paste is known as Final Setting Time.

Observations and Calculations:
Standard consistency of cement = 33%

Weight of cement = 400g

Amount of water added = 0.85x0.33x400 = 112.2ml

Initial setting time = 62mints

Final setting time = 180mints

The Initial Setting Time came out to be 62 minutes and
Final Setting Time is determined as 180 minutes.

- *Compressive Strength Test*

Compressive strength is the most important property of cement and is measured by the formation of cubes of sizes 7.06 cm X 7.06 cm X 7.06 cm. The cement paste is made up of cement, sand (fine aggregate) and water. Ratio of cement to sand is 1: 3 and water added is one-fourth of consistency limit plus 3%. Area of each face of cube is 50 sq. cm After 24 hours the cube is taken out of the mould. Three cubes are tested for compressive strength of cement at different time intervals i.e. 7 days and 28 days.

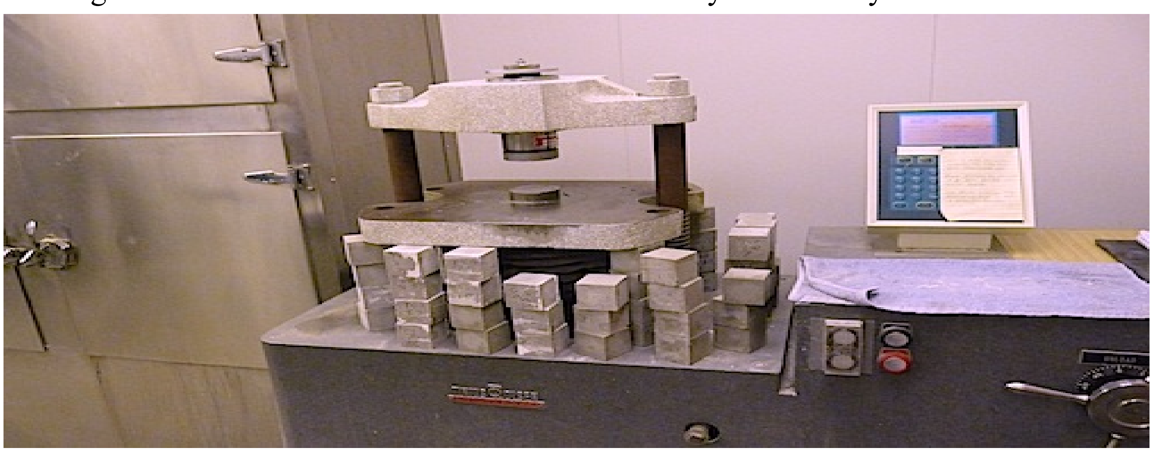

Figure 2.3 Compressive Strength Test

The compressive strength of cement at respective days is as follows:

Table 2.1: Compressive Strength of Cement

DAYS	COMPRESSIVE STRENGTH
7	36 N/mm^2
28	58N/mm^2

2.2.2 Fine aggregate

Grading of Fine aggregate (here sand) is done by Sieve Analysis by passing of fine aggregate by set of sieves in definite order.

Order of sieves is as follows:
10mm → 4.75mm → 2.36mm → 1.18mm → 600microns → 300microns →150microns → PAN.
Proper grading of sand is done by sieve analysis and classified in four categories which are: Zone 1, Zone 2, Zone 3, and Zone 4.

Table 2.2 Properties of Fine Aggregate

Sieve Size	Wt Retained (gm)	Cumulative wt retained (gm)	Cumulative % retained	Cumulative % passing
10 mm	0.00	00	00	100
4.75 mm	62	62	3.1	96.9
2.36 mm	292	354	17.7	82.3
1.18 mm	240	594	29.7	70.3
600 micron	292	886	44.3	55.7
300 micron	844	1730	86.5	13.5
150 micron	224	1954	97.7	2.3
Pan	46	2000	100	0

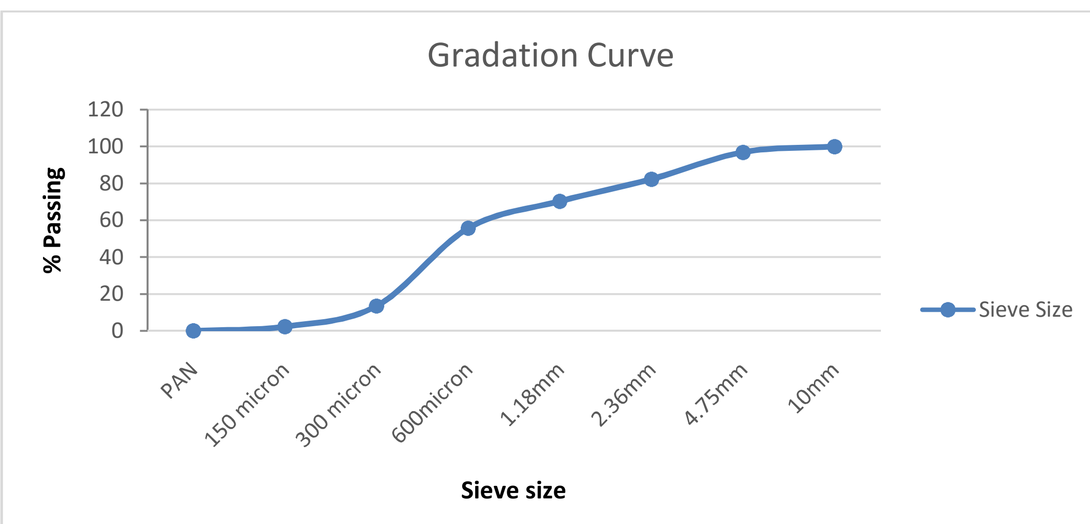

Figure 2.4 Gradation Curve for fine aggregate

The observations shows that the fine sand is in zone II

➢ *Water Absorption Test and Specific Gravity Test*

Amount of water can change the complete result and strength of concrete mix so the amount of water should be perfect in concrete mix. Fine aggregate affects the quantity of water in concrete mixture as they can absorb the water, so to determine the amount of water soaked by the fine aggregates. Water Absorption Test is performed using Pycnometer

Figure 2.5 Pycnometer

W_1= Weight of pycnometer + Sample +Water
W_2= Weight of pycnometer + Sample
W_3 = Weight of Saturated & Surface dry Aggregate
W_4 = Weight of Oven Dry Sample

$$\text{Water Absorbed } = \frac{(W3-W4)}{W4} \text{ X } 100\% = 1.2\% \quad (2.2)$$

$$\text{Specific Gravity} = \frac{W4}{W3-(W1-W2)} = 2.5 \quad (2.3)$$

2.2.3 Coarse Aggregate

- *Water Absorption Test*

Amount of water can change the complete result and strength of concrete mix so the amount of water should be perfect in concrete mix. Coarse aggregate affects the quantity of water in concrete mixture as they can absorb the water, so to determine the amount of water soaked by the aggregates, Water Absorption Test is performed as follows:

Initially the rough amount (nearly 2kg) of coarse aggregate is taken and weighed for proper weight, the weight of dry aggregates is recorded as W_1. After weighing them the aggregates are immersed in water completely for 24 hours. After 24 hours the aggregates are taken out of water and leftover water absorbing cloth for few minutes for drying out their outer surface. Now weight of these aggregates is recorded as W_2. Water Absorption Index (WPI) is now given as:

$$\text{Water Absorbed} = \frac{(W_2 - W_1)}{W_1} \times 100\% \qquad (2.4)$$

Figure 2.6 Water Absorption Test

Water Absorbed is concluded as 0.59%.

- ***Specific Gravity***

Specific gravity test is similar to water absorption test. The process is also similar to the previous test done in case of water absorption.

Specific Gravity of Coarse Aggregate is given as:

$$\text{Specific Gravity} = \frac{W_3}{(W_3 - (W_1 - W_2))} \quad (2.5)$$

Where,

W_1 = Weight of saturated aggregate in water
W_2 = Weight of container in water
W_3 = Weight of saturated surface dry aggregate in air

Specific Gravity of aggregate comes out:

- For 20mm = 2.72
- For 10mm = 2.84

- ***Bulk Density Test***

Bulk density of coarse aggregate is determined with the help of cylindrical vessel. First the volume of cylindrical vessel is determined by pouring water in cylinder and record the volume as 'V'. Now the cylinder is emptied and the aggregates are filled in three layers with 25 number of tamping with each layer. Now the excess of aggregates is removed by the help of tamping rod as straight edge.

Finally, the weight of cylinder plus aggregate is measured and recorded as 'W'. the bulk density of coarse aggregate is given by:

$$\text{Bulk density} = \frac{W}{V}$$

Bulk Density of given Aggregate is 1535 kg/m^3

- ***Sieve Analysis***

Around 5 kg of 10mm and 20mm aggregate is taken and passed through set of sieves.

The Sieve order from top to bottom is as follows:

80mm → 40mm → 20mm → 15mm → 10mm →4.75mm →PAN

For 10mm Aggregate

Amount Taken: Around 5kg

Table 2.3. Properties of 10mm Aggregates

Sieve size (mm)	Wt retained (gm)	Cumulative wt retained (gm)	Percentage retained	Percentage passing
80	0	0	0	100
40	0	0	0	100
20	0	0	0	100
15	23.2	23.2	0.47	99.53
10	4236.7	4259.82	86.36	13.64
4.75	527.7	4787.52	97.06	2.94
Pan	145	4932.52	100	0

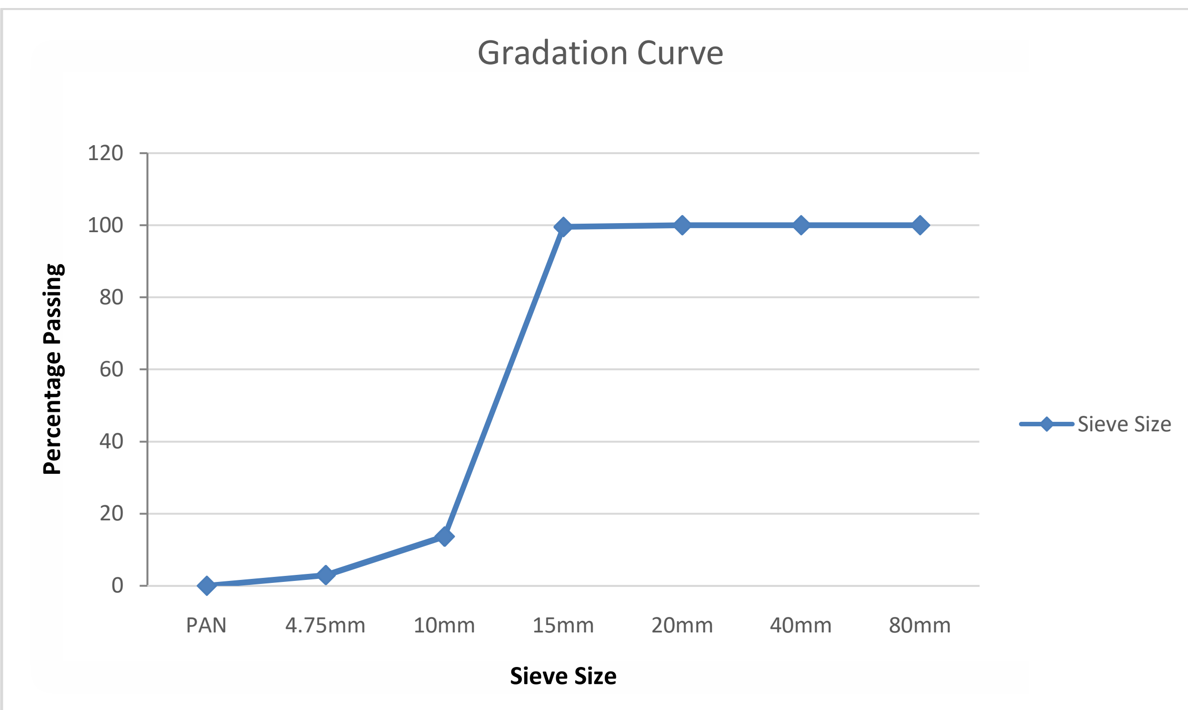

Figure 2.7 Gradation Curve for Coarse Aggregate (10mm)

For 20mm aggregate

Amount Taken: Around 5kg

Table 2.4. Properties of 20mm Aggregates

Sieve size (mm)	Wt retained (gm)	Cumulative wt retained(gm)	Percentage retained	Percentage passing
80	0	0	0	100
40	121	121	2.42	97.58
20	2405.56	2526.56	50.56	49.44
15	1345.2	3871.76	77.48	22.52
10	1125.6	4997.36	100	0
4.75	0	4997.36	100	0
Pan	0	4997.36	100	0

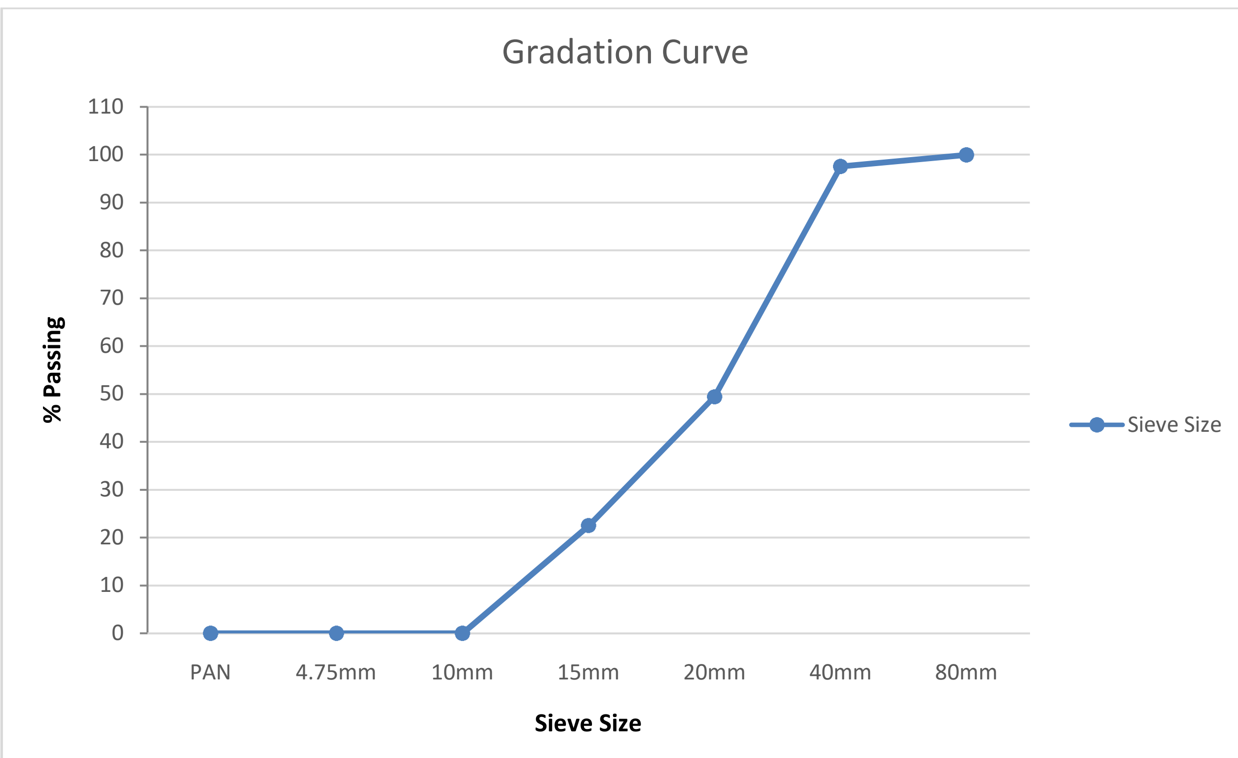

Figure 2.8 Gradation Curve for Coarse Aggregate (20mm)

2.3 TEST REPORT

- *Cement*

Table 2.5: Properties of Cement

PROPERTY	RESULT
Fineness of cement	2% retained
Normal consistency	33%
Specific Gravity	3.150
Setting Time Initial Setting time Final Setting Time	 62.0 Minutes. 180 Minutes.
Compressive Strength 7 Days 28 Days	 $36 N/mm^2$ $58 N/mm^2$

- Fine Aggregate

Table 2.6: Properties of Fine Aggregate

PROPERTY	RESULT
Water Absorption	1.2
Specific Gravity	2.5

The fine aggregate (here sand) used is of Zone 2 according to the IS 383 1970.

- Coarse Aggregate

Table 2.7: Properties of Coarse Aggregate

PROPERTY	RESULT
Water Absorption	0.59
Bulk Density	$1535 kg/m^3$
Specific Gravity For 20mm For 10mm	 2.72 2.84

CHAPTER 3

DESIGN AND TESTING

3..1 TRIAL MIX DESIGN

Design grade of concrete used for testing purpose is M40
Percentages of silica fume used in mix are:

- *0%*
- *5%*
- *10%*
- *15%*
- *20%*

3.1.1 Mix Design for 0% of Silica Fume

Design grade of concrete= M40 that confirms to IS 456 and IS 10262
According to the code, minimum cement content = 320 kg/m3

Maximum water cement ratio = 0.5

Table 3.1 Material used in 0% Silica Concrete Mix

INGREDIENT	SPECIFIC GRAVITY	WATER ABSORPTION
Cement (OPC)	3.15	-
CA 20mm	2.72	0.59
CA 10mm	2.84	0.59
Fine Aggregate	2.5	1.2
Silica Fumes	2.2	
Chemical Admixture (Viscocrete)	1.1	

Target Mean Strength = f_{ck}+ 1.65s (where s= standard deviation = 5

hence, f_m = 40+ 1.65X5

=48.25=49

Water cement ratio= 0.36

Let the free water =160L

∴weight of cementitious content= 160/0.36

=444.44 kg

Percentage of Silica fume used =0%

Weight of silica content = 0 kg

Vol of silica Fumes = 0 m^3

Vol of cement = 444.44 / (3.15 X 1000)

=0.1411 m^3

Vol of water = 160 / 1000

= 0.160m^3

Let the chemical admixture be 1.2% of cementitious content

Hence, wt of admixture = 1.2 X 444.44 / 100

= 5.3 Kg/m^3

Vol of admixture = 5.3 / (1.1 X 1000)

= 0.00485 m^3

Remaining vol for aggregates = 1- (0 + 0.1411 + 0.160 + 0.00485)

= 0.694m^3

From the all in aggregate test, CA = 62%, FA = 38%

Net specific gravity of the aggregate by weighted mean = (0.62 X 2.76) + (0.38 X 2.5) = 2.66

Hence, wt of aggregate = 2.66 X 1000 X 0.694

= 1846.04 Kg/m^3

Net weight of coarse aggregate = 1846.04 X .62 = 1144.5448 kg/m^3

Let 10mm aggregate be 31% and 20mm aggregate be 69% of net weight of coarse aggregate

∴weight of 20mm aggregate = 0.69 X 1144.5448 = 789.736 Kg/m^3

weight of 10mm aggregate = 0.31 X 1144.5448 = 354.81 Kg/m^3

Hence, weight of fine aggregate = 1846.04 - (1144.5448)
= 701.5 Kg/m^3

Now, water for absorption:
20mm = 0.59% X 789.736 = 4.65
10mm = 0.59% X 354.81 = 2.09
Sand = 1.2% X 701.5 = 8.418
total water for absorption = 4.65+2.09+8.418 = 15.158
Hence, total water requirement = 160 + 15.158 = 175.158 L

Final MIX DESIGN

Table3.2 Final design of 0% silica cube

Constituent	Quantity(kg/m^3)
Cement(OPC)	444.44
Water	175.158
20 mm aggregate	789.736
10 mm aggregate	354.81
Sand	701.5
Admixture (Viscocrete)	5.33
Silica	0

3.1.2 Mix Design for 5% of Silica Fume

Design grade of concrete= M40 that confirms to IS 456 and IS 10262

According to the code, minimum cement content = 320 kg/m3

Maximum water cement ratio = 0.5

Table 3.3 Material used in 5% Silica Concrete Mix

INGREDIENT	SPECIFIC GRAVITY	WATER ABSORPTION
Cement (OPC)	3.15	-
CA 20mm	2.72	0.59
CA 10mm	2.84	0.59
Fine Aggregate	2.5	1.2
Silica Fumes	2.2	
Chemical Admixture (Viscocrete)	1.1	

Target Mean Strength = f_{ck}+ 1.65s (where s= standard deviation = 5)

hence, f_m = 40+ 1.65X5

=48.25=49

Water cement ratio= 0.36

Let the free water =160L

∴weight of cementetious content= 160/0.36

=444.44 kg

Percentage of Silica fume used =5%

Weight of silica content = .05x444.44=22.222 kg

Vol of silica Fumes = [22.222/ (2.2x1000)]=.0101m^3

Vol of cement = 444.44 / (3.15 X 1000)

=0.1411 m^3

Vol of water = 160 / 1000

= 0.160m^3

Let the chemical admixture be 1.2% of cementitious content

Hence, wt of admixture = 1.2 X 444.44 / 100

= 5.33 Kg/m^3

Vol of admixture = 5.33 / (1.1 X 1000)

= 0.00485 m^3

Remaining vol for aggregates = 1- (0.0101 + 0.141 + 0.16 + 0.00485)

= 0.684 m^3

From the all in aggregate test,

CA = 62%, FA = 38%

Net specific gravity of the aggregate by weighted mean = (0.62 X 2.76) + (0.38 X 2.5)= 2.66

Hence, wt of aggregate = 2.66 X 1000 X 0.684

= 1819.44 Kg/m^3

Net weight of coarse aggregate = 1819.44 X .62 = 1128.05 kg/m^3

Let 10mm aggregate be 31% and 20mm aggregate be 69% of net weight of coarse aggregate

∴weight of 20mm aggregate = 0.69 X 1128.05 = 778.35 Kg/m^3

weight of 10mm aggregate = 0.31 X 1128.05 = 349.70Kg/m^3

Hence, weight of fine aggregate = 1819.44 - (1128.05)
= 691.39 Kg/m^3

Now, water for absorption:

20mm = 0.59% X 778.35 = 4..59

10mm = 0.59% X 349.70 = 2.06

sand = 1.2% X 691.39 = 8.3

total water for absorption = 4.59+2.06+8.3= 14.95 L

Hence, total water requirement = 160 + 14.95 = 174.95 L

FINAL MIX DESIGN

Table3.4 Final design of 5% silica cube

Constituent	Quantity(kg/m^3)
Cement(OPC)	444.44
Water	175.034
20 mm aggregate	778.35
10 mm aggregate	349.70
Sand	691.39
Admixture (Viscocrete)	5.33
Silica	22.22

3.1.3 Mix Design for 10% of Silica Fume

Design grade of concrete= M40 that confirms to IS 456 and IS 10262

According to the code, minimum cement content = 320 kg/m3

Maximum water cement ratio = 0.5

Table 3.5 Material used in 10% Silica Concrete Mix

INGREDIENT	SPECIFIC GRAVITY	WATER ABSORPTION
Cement (OPC)	3.15	-
CA 20mm	2.72	0.59
CA 10mm	2.84	0.59
Fine Aggregate	2.5	1.2
Silica Fumes	2.2	
Chemical Admixture (Viscocrete)	1.1	

Target Mean Strength = f_{ck}+ 1.65s   (where s= standard deviation = 5)

hence, f_m = 40+ 1.65X5

=48.25=49

Water cement ratio= 0.36

Let the free water =160L

$\therefore$ weight of cementitious content= 160/0.36

=444.44 kg

Percentage of Silica fume used =10%

Weight of silica content = .1x444.44 = 44.444kg

Vol of silica Fumes = [44.444/(2.2x1000)]=.0202 m^3

Vol of cement = 444.44 / (3.15 X 1000)

=0.1411 m^3

Vol of water = 160 / 1000

= 0.160m^3

Let the chemical admixture be 1.2% of cementitious content

Hence, wt of admixture = 1.2 X 444.44 / 100

= 5.3 Kg/m^3

Vol of admixture = 5.3 / (1.1 X 1000)

= 0.00485 m^3

Remaining vol for aggregates = 1- (.1411+.160+.0202+.0085)

= 0.674 m^3

From the all in aggregate test,

CA = 62%, FA = 38%

Net specific gravity of the aggregate by weighted mean = (0.62 X 2.76) + (0.38 X 2.5)= 2.66

Hence, wt of aggregate = 2.66 X 1000 X 0.674

=1792.84 Kg/m^3

Net weight of coarse aggregate = 1792.84 X .62 = 1111.56 kg/m^3

Let 10mm aggregate be 31% and 20mm aggregate be 69% of net weight of coarse aggregate

$\therefore$ weight of 20mm aggregate = 0.69 X 1111.56 = 766.98 Kg/m^3

weight of 10mm aggregate = 0.31 X 1111.56 = 344.58 Kg/m^3

Hence, weight of fine aggregate = 1792.84 - (1111.56)
= 681.28 Kg/m^3

Now, water for absorption:

20mm = 0.59% X 766.98 = 4.53

10mm = 0.59% X 344.58= 2.03

sand = 1.2% X 681.28 = 8.17

total water for absorption = 4.53+2.03+8.17= 14.73 L

Hence, total water requirement = 160 + 14.73= 174.73 L

Final MIX DESIGN

Table3.6 Final design of 10% silica cube

Constituent	Quantity(kg/m^3)
Cement(OPC)	444.44
Water	174.82
20 mm aggregate	766.98
10 mm aggregate	344.58
Sand	681.28
Admixture (Viscocrete)	5.33
Silica	44.44

3.1.*4* <u>Mix Design for 15% Silica Fume</u>

Design grade of concrete= M40 that confirms to IS 456 and IS 10262

According to the code, minimum cement content = 320 kg/m3

Maximum water cement ratio = 0.5

Table 3.7 Material used in 15% Silica Concrete Mix

INGREDIENT	SPECIFIC GRAVITY	WATER ABSORPTION
Cement (OPC)	3.15	-
CA 20mm	2.72	0.59
CA 10mm	2.84	0.59
Fine Aggregate	2.5	1.2
Silica Fumes	2.2	
Chemical Admixture (Viscocrete)	1.1	

Target Mean Strength = f_{ck}+ 1.65s (where s= standard deviation = 5)

hence, f_m = 40+ 1.65X5

=48.25=49

Water cement ratio= 0.36

Let the free water =160L

∴weight of cementitious content= 160/0.36

=444.44 Kg/m^3

Let silica fumes be 15% of the cementitious content

Weight of silica content = 444.44 X 15%

= 66.66 Kg/m^3

Vol of silica Fumes = 66.66 / (2.2 X 1000)

= 0.0303 m^3

Vol of cement = 444.44 / (3.15 X 1000)

=0..1411 m^3

Vol of water = 160 / 1000

= 0.160m^3

Let the chemical admixture be 1.2% of cementitious content

Hence, wt of admixture = 1.2 X 444.44 / 100

= 5.33 Kg/m^3

Vol of admixture = 5.33 / (1.1 X 1000)

= 0.00485 m^3

Remaining vol for aggregates = 1- (0.0303+00485+.1411+.160)

= 0.664 m^3

From the all in aggregate test,

CA = 62%, FA = 38%

Net specific gravity of the aggregate by weighted mean = (0.62 X 2.76) + (0.38 X 2.5)= 2.66

Hence, wt of aggregate = 2.66 X 1000 X 0.664

= 1766.24 Kg/m^3

Net weight of coarse aggregate = 1766.24 X .62 = 1095.07 kg/m^3

Let 10mm aggregate be 31% and 20mm aggregate be 69% of net weight of coarse aggregate
$\therefore$ weight of 20mm aggregate = 0.69 X 1095.07 = 755.6 Kg/m^3

weight of 10mm aggregate = 0.39 X 1095.07 = 339.47 Kg/m^3

Hence, weight of fine aggregate = 1766.24 - (1095.07)
= 671.17 Kg/m^3

Now, water for absorption:
20mm = 0.59% X 755.6 = 4.46
10mm = 0.59% X 339.47= 2.00
sand = 1.2% X 671.17 = 8.05
total water for absorption = 4.46+2.00+8.05= 14.51 L
Hence, total water requirement = 160 + 14.51 = 174.51 L

Final MIX DESIGN

Table3.8 Final design of 15% silica cube

Constituent	Quantity(kg/m^3)
Cement(OPC)	444.44
Water	174.51
20 mm aggregate	755.6
10 mm aggregate	339.47
Sand	671.17
Admixture (Viscocrete)	5.33
Silica	66.66

3.1.5 Mix Design for 20% Silica Fume

Design grade of concrete= M40 that confirms to IS 456 and IS 10262

According to the code, minimum cement content = 320 kg/m3

Maximum water cement ratio = 0.5

Table 3.9 Material used in 20% Silica Concrete Mix

INGREDIENT	SPECIFIC GRAVITY	WATER ABSORPTION
Cement (OPC)	3.15	-
CA 20mm	2.72	0.59
CA 10mm	2.84	0.59
Fine Aggregate	2.5	1.2
Silica Fumes	2.2	
Chemical Admixture (Viscocrete)	1.1	

Target Mean Strength = f_{ck}+ 1.65s (where s= standard deviation = 5)

hence, f_m = 40+ 1.65X5

=48.25=49

Water cement ratio= 0.36

Let the free water =160L

∴weight of cementitious content= 160/0.36

=444.44 Kg/m^3

Let silica fumes be 15% of the cementitious content

Weight of silica content = 444.44 X 20%

= 88.88 Kg/m^3

Vol of silica Fumes = 88.88 / (2.2 X 1000)

= 0.0404 m^3

Vol of cement = 444.44 / (3.15 X 1000)

=0..1411 m^3

Vol of water = 160 / 1000

= 0.160m^3

Let the chemical admixture be 1.2% of cementitious content

Hence, wt of admixture = 1.2 X 444.44 / 100

= 5.33 Kg/m^3

Vol of admixture = 5.33 / (1.1 X 1000)
= 0.00485 m^3

Remaining vol for aggregates = 1- (0.0404+00485+.1411+.160)
= 0.65365 m^3

From the all in aggregate test,
CA = 62%, FA = 38%

Net specific gravity of the aggregate by weighted mean = (0.62 X 2.76) + (0.38 X 2.5)= 2.66

Hence, wt of aggregate = 2.66 X 1000 X 0.65365
= 1738.71 Kg/m^3

Net weight of coarse aggregate = 1738.71 X .62 = 1078.00 kg/m^3

Let 10mm aggregate be 31% and 20mm aggregate be 69% of net weight of coarse aggregate
∴ weight of 20mm aggregate = 0.69 X 1078.00 = 743.82Kg/m^3

weight of 10mm aggregate = 0.31 X 1078.00 = 334.18Kg/m^3

Hence, weight of fine aggregate =1738.71 - (1078.00)
= 660.71 Kg/m^3

Now, water for absorption:
20mm = 0.59% X 743.82Kg = 4.39
10mm = 0.59% X 334.18Kg = 1.97
sand = 1.2% X 660.71 = 7.93
total water for absorption = 4.39+1.97+7.93 = 14.29 L
Hence, total water requirement = 160 + 14.29 = 174.29 L

Final MIX DESIGN

Table3.10 Final design of 20% silica cube

Constituent	Quantity(kg/m^3)
Cement(OPC)	444.44
Water	174.29
20 mm aggregate	743.82
10 mm aggregate	334.18
Sand	660.71
Admixture (Viscocrete)	5.33
Silica	88.88

3.2 PREPARATION OF TEST SPECIMENS

Five concrete mixes were cast with replacement of 0, 5, 10, 15 and 20% silica fume with cement, at a 0.42% w/b ratio. According to IS 10262 and IS 456. Test performed on specimens should be done at specific time intervals after proper curing of specimens. The time intervals which is proposed by the codes are:

- 7 Days
- 28 Days

The test specimen required for each time interval is five (5) i.e. total often (10) specimen for each type of concrete mix.

So total no. of specimens produced should be equal to product of Total Number of test specimen for each concrete m and Number of concrete mix.

i.e.

10 X 5 = 50

So total number of test specimen required are fifty (50) in count.

3.2.1 Specification of Test Specimen

- *Size of Specimen*
  Shape of one test specimen according to code should be Cube of size 15cm X 15cm X 15cm i.e. each side of cube should be equal to 15 cm.

- *Weight of Specimen*
  Weight of each test specimen with iron mould must be equal or greater than 26.5kg and can have maximum weight of 28kg. Weight of one specimen without iron mould can vary in the range of 8.5kg to 10 kg.

3.2.2 Method of Preparation

Test specimen was prepared with the help of Cubical Iron Mould of slightly greater than the size of specimen to get perfect size of specimen. Whole process of preparation consists of following steps:

- The concrete mix is prepared as per the design discussed above.

- All side (interior) of mould was completely cleaned and made free from rust and concrete particles leftover from last usage of mould.

- The mould was completely tight and cleaned base plate was also fastened to the base of cubical mould.

Figure 3.1 Preparation of cube mould

- An oil coating was done at interior of mould to prevent leakage during filling of mix and to prevent the specimen to get stick to mould which would create problem in removal of specimen from mould.

- Now, prepared concrete mix was filled in mould, generally in 3 layers with light vibrations to reduce the air voids which would result in Honeycomb structure of test specimen.

- After filling of mould up to the brim the extra concrete mix was removed from top and a proper finished and furnished surface was made.

Figure3.2 Preparation of concrete cube

This how the entire test specimens were prepared and proper marking was made on them to classify them according to their respective percentage of silica fume present in them.

3.2.3 Removal and curing of prepared cubes

- ***Removal of Cube***

After the completion of 16 hours to 24 hours from the time of casting the cubes, the cubes should be checked, that the upper surface (also known as Free Surface) is wet or dry. If the surface is dry then the cubes should be removed from their respective moulds. But if the upper surface of cube is wet after the given time, the IS 456 and IS 10262 recommends that the cube should be left undisturbed inside the mould for 24 hours more. Again, if the surface is wet, then time for removal is again extended for 24 hours and the process continues till the upper surface of cube completely gets dry

.The cubes casted above were removed after 20 hours from the time of casting of cubes.

- *Curing of Removed Cube*

Curing is the process of maintaining an adequate or sufficient amount of water content and temperature in concrete at early stages. So, after removal of cubes from their moulds, the cubes were kept inside curing tank till the time they were tested.

Figure3.3 Removed concrete cube

Figure 3.4 Curing of concrete cubes

3.3 TESTING OF SPECIMEN

Specimen made by the above processes is tested for its compressive strength at two different times that were:

- 7 Days
- 28 Days

According to IS 456 and IS 10262, 5 specimens should be tested at each time for better accuracy of result.

Testing of specimen was done by the help of Concrete Testing Machine (CTM) manufactured by AIMIL Ltd.The machine was completely digital and electrically controlled with the loading rate of 2000 KN/mm and with a maximum load of 15000 KN/mm.

3.3.1 Process of Testing

Initially the test specimen prepared was taken out from curing tank and left for 10 minutes in sun so that the outer surfaces of cube gets completely moisture free i.e. there should be no adsorbed moisture on surface of cube prior to testing.

After the cube was moisture free from outer surface it was kept in CTM in the centre of base such that the free surface should be perpendicular to plane of force applicable as free surface of cube is weakest part of cube and if kept parallel to plane of force applicable then the result of compressive strength will not be accurate.

After proper placement of test specimen, the cabinet was closed and machine was started which applied load slowly and gradually increasing on the test specimen.

After breaking of test specimen i.e. attainment of its maximum load, the CTM reduced the load on the specimen and displays the maximum load on its monitor in N/mm^2.

3.3.2 Result of 0% silica fume concrete

- *At 7th Day*

Table 3.11 Compressive strength of 0% silica concrete at 7th day

Specimen	1	2	3	4	5
Strength (MPa)	30.62	31.57	29.95	28.82	30.95

$$\text{Mean strength} = \frac{30.62 + 31.57 + 29.95 + 28.82 + 30.95}{5} = 30.25 \text{ MPa}$$

- *At 28th Day*

Table 3.12 Compressive strength of 0% silica concrete at 28th day

Specimen	1	2	3	4	5
Strength (MPa)	45.71	46.98	44.99	45.10	46.87

Mean strength = $\frac{45.71 + 46.98 + 44.99 + 45.10 + 46.87}{5}$

= 45.93 MPa

3.3.3 Result of 5% silica fume concrete

- At 7th Day

Table 3.13 Compressive strength of 5% silica concrete at 7th day

Specimen	1	2	3	4	5
Strength (MPa)	31.25	32.63	32.00	33.30	33.67

Mean Strength = $\frac{31.25 + 32.63 + 32.00 + 33.30 + 33.67}{5}$

= 32.57 MPa

- At 28th Day

Table 3.14 Compressive strength of 5% silica concrete at 28th day

Specimen	1	2	3	4	5
Strength (MPa)	48.90	46.26	47.10	48.35	48.89

Mean Strength = $\frac{48.90 + 46.26 + 47.10 + 48.35 + 48.89}{5}$

= 47.90 MPa

3.3.4 Result of 10% silica fume concrete

➢ At 7th Day

Table 3.15 Compressive strength of 5% silica concrete at 7th day

Specimen	1	2	3	4	5
Strength (MPa)	37.65	38.50	38.20	39.05	39.02

$$\text{Mean Strength} = \frac{37.65 + 38.50 + 38.20 + 39.05 + 39.02}{5}$$

$$= 38.52 \text{ MPa}$$

➢ At 28th Day

Table 3.16 Compressive strength of 10% silica concrete at 28th day

Specimen	1	2	3	4	5
Strength (MPa)	50.30	51.85	49.84	52.63	52.18

$$\text{Mean Strength} = \frac{50.30 + 51.85 + 49.84 + 52.63 + 52.18}{5} = 51.36 \text{ MPa}$$

3.3.5 Result of 15% silica fume concrete

➢ At 7th Day

Table 3.17 Compressive strength of 5% silica concrete at 7th day

Specimen	1	2	3	4	5
Strength (MPa)	44.26	46.65	44.55	42.86	43.02

Mean Strength = $\frac{44.26 + 46.65 + 44.55 + 42.86 + 43.02}{5}$

= 44.80 MPa

- At 28th Day

Table 3.18 Compressive strength of 15% silica concrete at 28th day

Specimen	1	2	3	4	5
Strength (MPa)	50.23	50.35	50.02	50.68	50.92

Mean Strength = $\frac{57.23 + 59.35 + 59.02 + 55.68 + 55.92}{5}$

= 57.44 MPa

3.3.6 Result of 20% silica fume concrete

- At 7th Day

Table 3.19 Compressive strength of 15% silica concrete at 7th day

Specimen	1	2	3	4	5
Strength (MPa)	38.65	38.21	39.80	40.15	38.33

Mean Strength = $\frac{39.65 + 38.21 + 37.80 + 38.15 + 41.89}{5}$

= 39.14 MPa

- At 28th Day

Table 3.20 Compressive strength of 20% silica concrete at 28th day

Y	1	2	3	4	5
Strength (MPa)	47.26	47.67	47.12	46.95	47.85

$$\text{Mean Strength} = \frac{53.26 + 55.67 + 52.12 + 54.95 + 55.85}{5}$$

$$= 54.37 \text{ MPa}$$

CHAPTER 4

COCNCLUSION

The data so observed in here plotted and compared

Table 4.1 Average values of cube strength

Percentage of Silica used (%)	Strength (MPa)	
	7 Days	28 Days
0	30.25	45.93
5	32.57	47.90
10	38.52	51.36
15	44.80	57.44
20	39.14	54.37

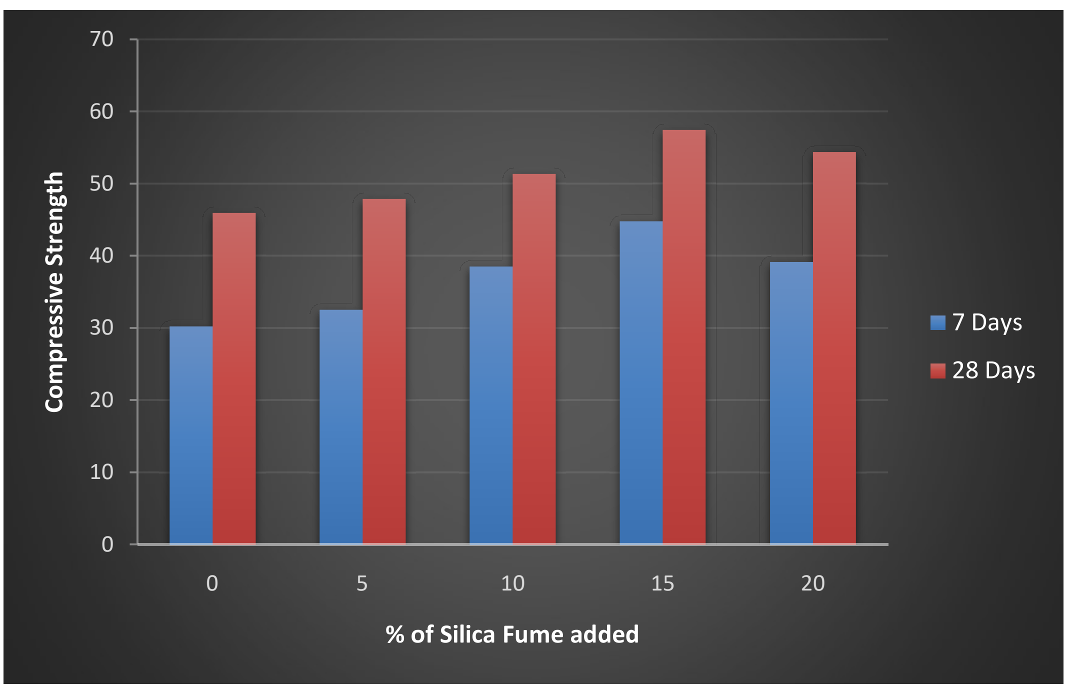

Figure 4.1 Comparison of compressive strength

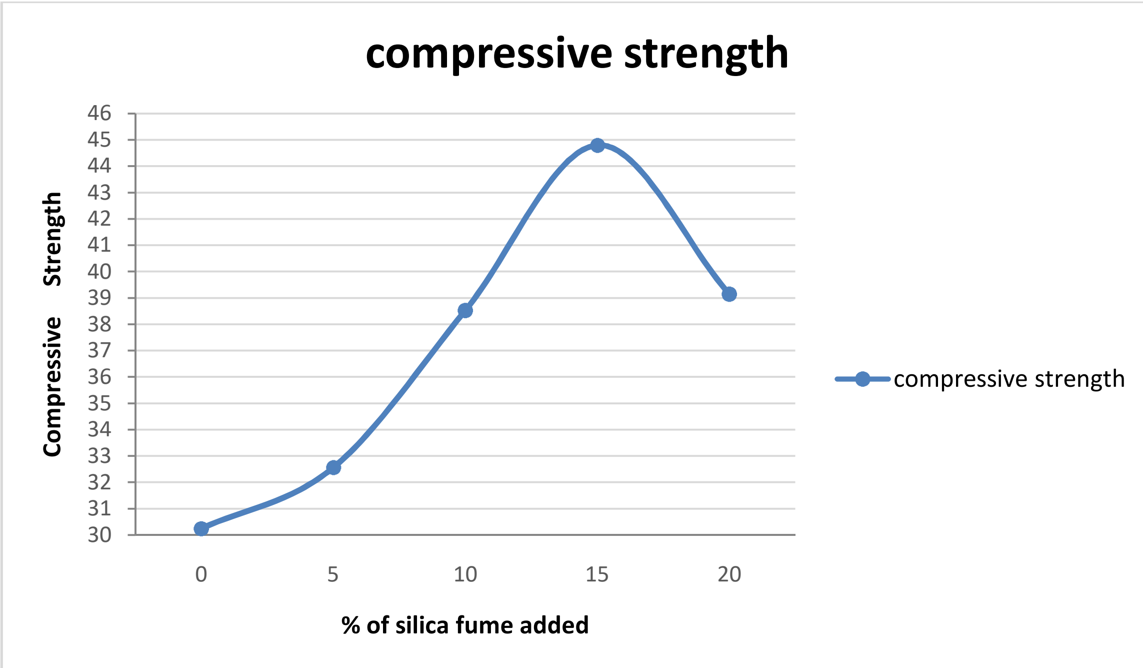

Figure 4.2 Compressive strength for 7th day

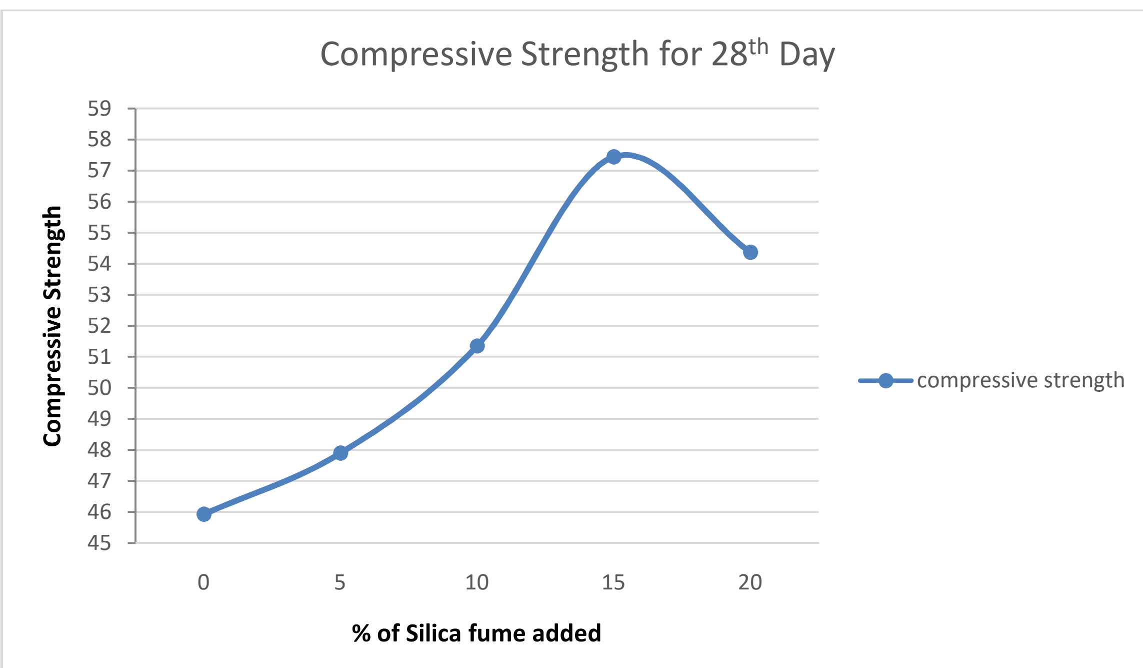

Figure 4.3 Compressive strength for 28th day

The Following conclusions can be made on the basis of this project:

1. Both 7days and 28 days compressive strength increases as percentage of Silica Fume increases .
2. Optimum amount of silica fume to be added is about 15% as at that amount we get the best result.
3. As we know that most of the concrete properties can be correlated to compressive strength, hence it is not wrong to say the other properties like stress-strain relationship, tensile strength, bond strength, modulus of elasticity, density, impermeability, durability etc are also improved.
4. Due to these effects Silica fume concrete is widely used in making high strength and very durable concrete worldwide.
5. As a small amount of silica can impart so many benefits hence it is a very useful addition to the conventional concrete.

CHAPTER 5

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