A

M.TECH

MAJOR PROJECT

On

STUDY OF THE EFFECTS OF PARTIAL REPLACEMENT OF CEMENT BY SILICA FUMES ON THE PROPERTIES OF CONCRETE

Submitted by:

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(2K15/STE/17)

M.TECH (Structural Engineering)

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CANDIDATE'S DECLARATION

I hereby declare that the project work entitled **"Study of the effects of partial replacement of cement by silica fumes on the properties of concrete"** submitted to Department of Civil Engineering, DTU is a record of an original work done by **Sandeep Kalyan** under the guidance of **Dr. Nirendra Dev**, Professor, Department of Civil Engineering, DTU, and this project work has not performed the basis for the award of any Degree or diploma/fellowship and similar project, if any.

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CERTIFICATE

This is to certify that the project entitled **"Study of the effects of partial replacement of cement by silica fumes on the properties of concrete"** submitted by **Sandeep Kalyan,** in partial fulfillment of the requirements for award of the degree of **MASTERS OF TECHNOLOGY(STRUCTURAL ENGINEERING)** to Delhi Technical University is the record of student's own work and was carried out under my supervision.

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.

(**Sandeep Kalyan)**

ABSTRACT

Infrastructure development for a country is a principle development and concrete plays a vital role. Concrete is the world's largest consuming material in the field of construction. From time immemorial research over concrete has been going on to enhance its performance and strength. Nowadays, most concrete mixture contains supplementary cementitious material (SCM) which forms part of the cementitious component. These materials are majority byproducts from other processes. The main benefits of SCMs are their ability to replace certain amount of cement and still able to display cementitious property, thus reducing the cost of using Portland cement. The fast growth in industrialisation has resulted in tons and tons of byproduct or waste materials, which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag, steel slag etc. The use of these byproducts not only helps to utilize these waste materials but also enhances the properties of concrete in fresh and hydrated states. Micro silica or silica fumes, a very fine non-crystalline material is very good as filler material to provide good strength

In the present study, an attempt has been made to investigate the strength parameters of concrete made with partial replacement of cement by Silica Fumes. Here in the experiment an attempt has been made to increase the strength of concrete by replacing cement with 0%,5%,10%,15% and 20% of Micro silica fumes in a design mix of M35 and M40.The materials are taken from the locally available sources. Properties of hardened concrete viz Ultimate Compressive strength, Flexural strength, Splitting Tensile strength has been determined for different mix combinations of materials and these values are compared with the corresponding values of conventional concrete.

The compressive strengths are checked for the mentioned design mixes. It is found that an optimum replacement of 15% of Micro silica to that of cement (by weight) increases the strength of concrete to 30%.Further addition of micro silica shows a decreasing trend.

TABLE OF CONTENTS

LIST OF FIGURES:

LIST OF TABLES

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CHAPTER: 1

INTRODUCTION

1.1 Background

The history of concrete dates back to the rein of the Greeks and Romans, since then till today in the field of concrete technology developments strive towards the achievement of higher and higher strength concrete. Structural concrete is used extensively in various kinds of civil engineering structures. It is the most commonly used construction material consumed at a rate of approximately one ton for every living human being. Concrete is a composite material which essentially consists of cement, coarse aggregate (CA), fine aggregate (FA and water. Coarse aggregate gives the volume to the concrete and fine aggregate makes the concrete denser by filling the voids of coarse aggregate. Water hydrates and sets the cement which thus acts as a binder for all the ingredient particles of concrete. Concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. With increase in trend towards the wider use of concrete for pre stressed concrete and high rise buildings there is a growing demand of concrete with higher compressive strength. The ultimate properties of concrete in terms of its strength, durability and economy depend not only on the various properties of its ingredients but also on the mix design standards, method of preparation, handling and curing conditions. Characteristic strength of concrete depends on its quality control and the extent of quality control is often an economical compromise and depends on the size and type of job. Economization is nowadays done by replacing cement with cheap, waste and recycled products. Mineral additions which are also known as mineral admixtures have been used with cements for many years. There are two types of materials crystalline and non-crystalline.

The use of micro-silica as a pozzolana in concrete was originated in Scandinavia during the early 1950's and was introduced to the United States in 1984. Micro-silica is a by-product from the silicon carbide and metallic industries where it is recovered from exhausts of electric furnaces. Silica fume is an ultrafine airborne material with spherical particles less than 1 μm in diameter, the average being about 0.1 μm. It is approximately a hundred times finer than Portland cement. When it is used in concrete, it acts as a filler and as a cementitious material. The small silica fume particles fill spaces between cement particles and between the cement paste matrix and aggregate particles. The silica fume also combines with calcium hydroxide to form additional calcium hydrate through the pozzolanic reaction. Both of these actions result in a denser, stronger and less permeable material. Verma found that Silica fume increases the strength of concrete more 25%. Silica fume is much cheaper than cement therefore it is very important form economical point of view. Silica fume also decrease the voids in concrete. Pandit concluded that addition of micro silica to concrete increases the strength more than 17% due to their pozzolanic properties and reduces the permeability of concrete. Ghutke found that Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanica properties to a great extent. Additio of silica fume to concrete improves the durability of concrete and also in protecting the embedded steel from corrosion. When fine pozzolana particles are dispersed in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. Therefore, this mechanism makes the paste more homogeneous and dense as for the distribution of the fine pores. This is due to the reaction between the amorphous silica of the pozzolanic and the calcium hydroxide produced by the cement hydration reactions. Because of its chemical and physical properties, it is a very reactive pozzolana. Aginam concluded that, there is a relationship between the aggregate size and quantity to the final strength of concrete. The study revealed a decrease in strength with increase in aggregate quantity and a decrease in strength with decrease in aggregate sizes. Pradhan states a higher compressive strength resembles the concrete incorporating silica fume gives high strength concrete as per IS code recommendations. Improved pore structures at transition zone for silica fume concrete resembles that it may be led to as high performance concrete.

1.2 SUPPLEMENTARY CEMENTITIOUS MATERIAL:

Early SUPPLEMENTARY CEMENTITIOUS MATERIALS consisted of natural, readily available materials like volcanic ash or diatomaceous earth. The engineering marvels like Roman aqueducts, the Coliseum are examples of this technique used by Greeks and Romans. Nowadays, most concrete mixture contains SCMs which are mainly byproducts or waste materials from other industrial processes.

More recently, strict environmental – pollution controls and regulations have produced an increase in the industrial wastes and sub graded byproducts which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag etc. The use of SCMs in concrete constructions not only prevent these materials to check the pollution but also to enhance the properties of concrete in fresh and hydrated states.

The SCMs can be divided in two categories based on their type of reaction :
Hydraulic and Pozzolanic.

- Hydraulic materials react directly with water to form cementitious compound like GGBS.
- Pozzolanic materials do not have any cementitious property but when used with cement or lime react with calcium hydroxide to form products possessing cementitious properities.

1.2.1. Ground granulated blast furnace Slag:

It is hydraulic type of SCM. Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag , a by-product of iron and steel making from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground granulated blast furnace slag (GGBFS) has been utilized for many years as an additional cementitious material in Portland cement concretes, either as a mineral admixture or as a component of blended cement. Granulated blast furnace slag typically replaces 35–65% Portland cement in concrete. The use of GGBFS as a partial replacement of ordinary Portland cement improves strength and durability of concrete by creating a denser matrix and thereby increasing the service life of concrete structures. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength.

1.2.2. Fly ash:

It is pozzalanic SC material. Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces.

Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Fly ash is classified as Class F and Class C types.

The replacement of Portland cement with fly ash is considered to reduce the greenhouse gas "footprint" of concrete, as the production of one ton of Portland cement produces approximately one ton of CO_2 as compared to zero CO_2 being produced using existing fly ash. New fly ash production, i.e., the burning of coal, produces approximately twenty to thirty tons of CO_2 per ton of fly ash. Since the worldwide production of Portland cement is expected to reach nearly 2 billion tons by 2010, replacement of any large portion of this cement by fly ash could significantly reduce carbon emissions associated with construction. It has been used successfully to replace Portland cement up to 30% by mass, without adversely affecting the strength and durability of concrete. Several laboratory and field investigations involving concrete containing fly ash had reported to exhibit excellent mechanical and durability properties. However, the pozzolanic reaction of fly ash being a slow process, its contribution towards the strength development occures only at later ages . Due to the spherical shape of fly ash particles, it can also increase workability of cement while reducing water demand

1.2.3. Silica Fume:

It is also a type of pozzolanic material. Silica fume is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area on the order of 215,280 ft^2/lb (20,000 m^2/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stems from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions .When silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH-ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of silica fume is very significant and the nonevaporable water content decreases between 90 and 550 days at low water /binder ratios with theaddition of silica fume.

During the last decade,considerable attention has been given to the use of silica fume

1.3 Objective

The main objective of this project is to know the behavior of concrete with partial replacement of cement from silica fume at different proportions of replacement in M-35 and M40 concrete and to study the effect of different replacement levels of silicafume on the strength development of masonry mortar ,concrete and to obtain the optimum replacement level of silicafume based on strength requirements.

The objectives of study includes :-

- Study of effects of silica fumes on cement mortar properties
- Design of the standard grades of concrete M35 and M40
- Mix design by partial replacement of cement by 5%, 10%, 15%, 20% silica fumes
- Casting of standard size cubes, beam and cylinder
- Testing of various specimens for compreesive strength flexural strength and split tensile strength
- Test for durability aspects
- Compare the result obtained.

CHAPTER: 2

LITERATURE REVIEW

2.1 Introduction

In this chapter we have given brief history In this part the works of various authors on the use of silica fumes in concrete has been discussed in brief. A great number of researches have been performed to understand the nature of silica fumes and their effect on the properties of concrete. A number of Research & Development work dealing with the use of pozzolonic materials like fly ash, silica fumes, blast furnace slag in cement based materials are discussed in the literature. The pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CSH crystals are prevented from growing and their number reduces. Thus the early age strength of hardened cement paste is increased. A comparative analysis of this work has been presented in the summary of this section which will highlight the significance of each work. Out of the numerous work done in the field only a few relevant works have been highlighted in the next section.

2.2 Overview

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete.

M.D.A. Thomas, M.H.Shehata[1] et al. have studied the ternary cementitious blends of Portland cement, silica fume, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

Sandor Popovics have studied the Portland cement-fly ash – silica fume systems in oncrete and concluded several beneficial effects of addition of silica fume to the fly ash cement mortar in terms of strength, workability and ultra sonic velocity test results.

Jan Bijen have studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica reaction,sulphate attack.

L. Lam, Y.L. Wong, and C.S. Poon in their studied entitled Effect of fly ash and silica fume on compressive and fracture behaviors of concrete had concluded enhancement in strength properties of concrete by adding different percentage of fly ash and silica fume.

Tahir Gonen and Salih Yazicioglu studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states.

Mateusz Radlinski, Jan Olek and Tommy Nantung in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures.

S.A. Barbhuiya, J.K. Gbagbo, M.I. Russeli, P.A.M. Basheer studied the properties of fly ash concrete modified with hydrated lime and silica fume concluded that addition of lime and silica fume improve the early days compressive strength and long term strength development and durability of concrete.

Susan Bernal, Ruby De Gutierrez, Silvio Delvasto[8], Erich Rodriguez carried out Research work in Performance of an alkali-activated slag concrete reinforced with steel fibers. Their conclusion is that The developed AASC present higher compressive strengths than the OPC reference concretes. Splitting tensile strengths increase in both OPCC and the AASC concretes with the incorporation of fibers at 28 curing days.

Hisham Qasrawi , Faisal Shalabi, Ibrahim Asi carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate.Their conclusion is That Regarding the compressive and tensile strengths of concrete steel slag is more advantageous for concretes of lower strengths.

Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis carried out Research work in Effect of slag on the rheology of fresh self-compacted concrete. Their conclusion is that slag can produce good self-compacting concrete.

Tahir Gonen,Salih Yazicioglu carried out research work in the influence of mineral admixtures on the short and long term performance of concrete, hence concluded that silica fume contributed to both short and long term properties of concrete, where as fly ash shows its beneficial effect ina relatively longer time. As far as the compressive strength is concerened, adding of both silica fume and fly ash slightly increased compressive strength, but contributed more to the improvement of transport properties of concrete.

M. Maslehuddin, Alfarabi M. Sharif, M. Shameem, M. Ibrahim and M.S Barry carried out experimental work on comparison of properties of steel slag and crushed limestone aggregate concretes, finally concluded that durability characteristics of steel slag cement concrete were better than those of crushed limestones aggregate concrete. Some of physical properties were better than of crushed lime stones concrete.

J. G. Cabrera and P. A. Claisse carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the flow of oxygen is described by the Darcy equation, but the flow of water vapour is not. The different mechanisms of transmission cause the transmission rates for oxygen to be spread over a far greater range than those for water vapour with some of the SF samples almost impermeable to oxygen.

Houssam A. Toutanji and Tahar El-Korchi carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the increase in compressive strength of mortar containing silica fume as a partial replacement for cement, greatly contributes to strengthening the bond between the cement paste and aggregate. It was also demonstrated that super plasticizer in combination with silica fume plays a more effective role in mortar mixes than in paste mixes.

This can be attributed to a more efficient utilization of super plasticizer in the mortar mixes due to the better dispersion of the silica fume.

M. J. Shannag carried out experimental work on the high strength concrete containing natural pozzolana and silica fume, hence concluded that use of natural pozzolana in combination with silica fume in the production of high strength concrete, and for providing technical and economical advantages in specific local uses in the concrete industry.

Houssam A. Toutanji and Ziad Bayasi carried out experimental work on the Effect of curing procedures on properties of silica fume concrete hence concluded that Steam curing was found to enhance the properties of silica fume whereas air curing exhibited adverse effects as compared to moist curing. Enhancement in the mechanical properties of silica fume concrete caused by steam curing was manifested by strength increase and permeability and permeable void volume decrease.

A. M. Boddy, R. D. Hooton and M. D. A. Thomas carried out experimental work on the effect of product form of silica fume on its ability to control alkali-silica reaction, hence concluded that slurried Silica fumes are significantly better at controlling the expansion of a reactive siliceous limestone aggregate than are densified or pelletized silica fume.

Ha-Won Song, Seung-Woo Pack, Sang-Hyeok Nam, Jong-Chul Jang and Velu Saraswathy carried out experimental work on the Estimation of the permeability of silica fume cement concrete, hence concluded that higher permeability reductions with silica fume are due to pore size refinement and matrix densification, reduction in content of $Ca(OH)_2$ and cement paste-aggregate interfacial refinement. Finally, optimum silica fume replacement ratios that reduce the permeability of concrete reasonably are proposed for durable concrete.

Dilip Kumar Singha Roy, Amitava Sil concluded that use of silica fume is a necessity in production of not only for high strength concrete but also for low/medium strength concrete as this material facilitate the adoption of lower water - cement material ratio and better hydration of cement particles including strong bonding amongst the particles. From the study it has been observed that maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher (by 19.6% and 16.82% respectively) than those of the normal concrete (for cube and cylinder) where as split tensile strength and flexural strength of the SF concrete (3.61N/mm2 and 4.93N/mm2 respectively) are increased by about 38.58% and 21.13% respectively over those (2.6 N/mm2 and 4.07 N/mm2 respectively) of the normal concrete when 10% of cement is replaced by SF.

P Rattish-Kumar, C B K Rao, studied that for a silica fume percentage in between 30 to 40 of total cement plus silica fume in the concrete mix, the savings in the overall cost of concrete mix is about 15%. This is observed in both the case of M15 and M20 design mixes. Based on concrete mix design, the savings obtained in materials and the cost analysiS it is finally recommended that the optimum silica fume content in the cement silica fume mix for both M15 and M20 grade concrete mixes may be kept between 30 to 40%.

Harjinder Singh, Shikha Bansal studied that-

The compressive strength of cement/mortar increases in the range varying between 30-40% with the addition of silica fume by 5-15% when sand is replaced.

The compressive strength of cement/mortar increases in the range varying between 20-30% with the addition of silica fume by 5-15% when cement is replaced.

The compressive strength of silica fume modified mortar increases by 10% (approximately) in the case of sand replaced in comparison to cement replacement by equal proportion in the same mix.

The increase in compressive strength is found to be maximum for the mix proportion 1:3 for all the percentages of silica fume addition. Therefore, richer mix will be more responsive in addition of silica fume.

N. K. Amudhavalli, Jeena Mathew studied that consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases.

The normal consistency increases about 40% when silica fume percentage increases from 0% to 20%. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 10-15 % silica fume replacement level. Increase in split tensile strength beyond 10 % silica fume replacement is almost insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength

Rekha Ambi, Shamila Habeeb studied that silica fume mortar improved many properties such as compressive strength, flexural strength, permeability etc. It was inferred that for attaining workability for silica fume incorporated mortars, the water/binder ratio has to be increased with increase in percentage of silica fume replacement. Thus silica fume mortars demands high water /binder ratio than the normal mortar[8]. Of the five mixes investigated SF10 showed maximum compressive strength with an increase of 50.1% at 28 day and 45.5% at 56 day than SF0.

The increase in strength for SF15 and SF20 was found to be 31.8% and 1.4% for the 28th day compared to control one. Thus the optimum percentage of cement replacement with silica fume is found to be 10%.The increase in strength is mainly due to the aggregate-paste bond improvement and enhanced microstructure.

The reason for low strength in the mixes SF15 and SF20, compared to SF10 is attributed to the high water/binder ratio. The results also showed that silica fume did not produce an immediate strength enhancement; instead, the blended mixtures only achieved higher strength than the control from 7 days onwards. Strength loss in the early ages, was probably due to the dilution effect of the pozzolan and as well as the slow nature of pozzolanic reaction.

Debabrata Pradhan , D. Dutta concluded that There is scope of increasing slump value by increasing dosages of superplasticizers without hampering the strength for further investigation but 0.814 compacting factor is also good for using concrete in the field in control system. Higher compressive strength resembles the concrete incorporating silica fume is high strength concrete as per IS code recommendations. Improved pore structures at transition zone for silica fume concrete resembles that it may be led to as high performance concrete but experiments for durability are yet to be investigated. During the testing of cubes at 28 days the failure plane of cubes cut the aggregates but not along the inter facial zone which is concluded that the interfacial zone attained much higher strength than control concrete i.e. concrete without silica fume.

CHAPTER: 3

MATERIALS AND METHDOLOGY

Introduction

This part is concerned with the details of the properties of the materials used, the method followed to design the experiment and the test procedures followed. The theory is supplemented with a number of pictures to have a clear idea on the methods.

3. 1 Materials

3.1.1. Cement

The cement used is Ordinary Portland Cement of ACC brand of 43 grade in the present study which surpasses BIS Specifications (IS 8112-1989) on compressive strength levels.

Specific Gravity	**Fineness by sieve analysis**	**Normal consistency**
3.0 %	2.01 %	33 %

Table 3.1 Properties of cement

3.1.2. Fine Aggregate

Locally available River sand i.e. natural sand as per IS: 383-1970 is used. The bulk density of sand is 2610 kg/m3. The properties of fine aggregate are shown in tabular form

S NO	PROPERTY	VALUES
1	SPECIFIC GRAVITY	2.61
2	FINENESS MODULUS	3.10

Table 3.2: properties of fine aggregates

3.1.3 Coarse Aggregate

For coarse aggregate, the maximum size of aggregate in between 20mm to 4.75mm. The physical properties of both fine aggregate and coarse aggregate are evaluated as per IS: 2386 (Part III)-1963 and given in Table

S NO	**Property**	**Coarse Aggregate**
1	Specific Gravity	2.72
2	Bulk Density (kg/L)	1.408
3	Loose Bulk Density (kg/L)	1.25
4	Water Absorption (%)	4.469
5	Impact Value	26.910
6	Crushing Value	26.514
7	Fineness Modulus	3.38

.

Table 3.3: properties of coarse aggregates

3.1.4. Water

Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00.

3.1.5. SUPERPLASTICIZER :-

In this experiment for improvement of the workability of concrete, super plasticizer-CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers conforming to IS: 9103-1999 and ASTM 494 type F is used. Conplast SP 430 has been specially formulated to impart high range water reductions up to 25% without loss of workability or to produce high quality concrete of lower permeability. The properties of super plasticizer are shown in Table .

S NO	PHYSICAL PROPERTY	VALUE
1	SPECIFIC GRAVITY	1.224
2	CHLORIDE CONTENT	NIL
3	AIR ENTRAINMENT	11.76 lb/ft3

Table 3.4 : Properties of superplasicizers

3.1.6. SILICA FUMES:-

Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide . It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm.

PRODUCTION

The raw materials for the production of silica fume are by-products from the production of silicon metal, and these by-products are further processed to produce cementitious materials for use in concrete.

Production of silica fume

Silica fume is a by-product of the manufacture of silicon metal and ferro-silicon alloys. The process involves the reduction of high purity quartz (SiO_2) in electric arc furnaces at temperatures in excess of 2,000°C. Silica fume is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns, with a very high specific surface area (15,000–25,000 m^2/kg).

Each microsphere is on average 100 times smaller than an average cement grain. At a typical dosage of 10% by mass of cement, there will be 50,000–100,000 silica fume particles per cement grain.

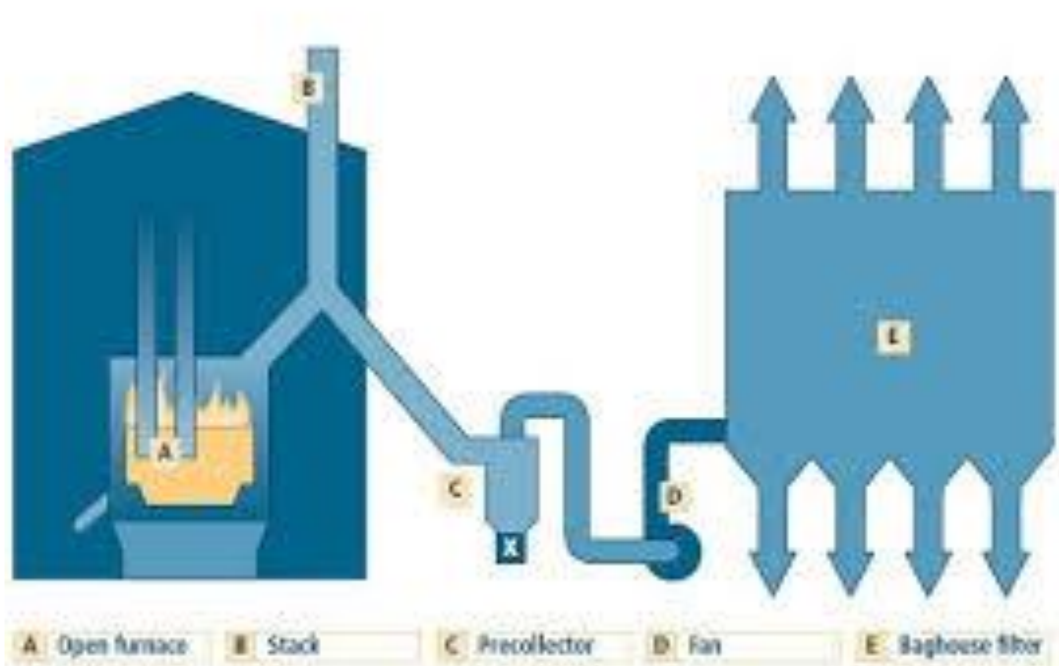


Fig 1: Production of silica fumes

Properties of silica fumes

(a)Physical properties:-

S no	Categories	Description
1	**Size**	**Less than 1 micron**
2	**Shape**	**spherical**

(b) Chemical Properties:-

S NO	INGREDIENTS	PERCENTAGE
1	SILICA	99.886
2	ALUMINA	.043
3	FERRIC OXIDE	.040
4	CALCIUM OXIDE	.001
5	TITANIUM OXIDE	.001
6	POTASSIUM OXIDE	.001
7	SODIAM OXIDE	.003

Table 3.5: Properties of silica fumes

Fig 2 : image of silica fumes used

Working phenomena of micro silica in Concrete:

Improvisation of concrete occurs through two mechanisms-

- **Pozzolanic effect**:

When water is added to OPC (ordinary Portland cement), hydration occur forming two products, as shown below:

$$OPC + H_2O \cdot CSH \text{ (Calcium silicate hydrate)} + Ca(OH)_2$$

In the presence of micro-silica, the silicon dioxide from the micro-silica will react with the calcium hydroxide to produce more aggregate binding CSH as follows:

$$Ca(OH)_2 + SiO_2 \cdot H2O + CSH$$

The reaction reduces the amount of calcium hydroxide in the concrete. The weaker calcium hydroxide does not contribute to strength. When combines with carbon dioxide, it forms a soluble salt which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to +sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide is present in concrete.

- **Micro filler effect:**

Micro-silica is an extremely fine material, with an average diameter 100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete.
This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro-filler effect will greatly reduce permeability and improve the paste to aggregate bond of silica fume concrete compared to conventional concrete. The silica react rapidly providing high early age strength and durability. The

efficiency of micro-silica is 3-5 times that of OPC and consequently vastly improved concrete performance can be obtained.

The Experimental programme was carried out in two stages:-

3. 2 Methodology

TEST PROCEDURE:

Stage 1: Experimental work were conducted on mortar mixes by using different binder mix modified with different percentages of silica fume.

This experimental investigation was carried out for three different combinations of cement and silica fumes. In each combination three different proportion of silica fume had been added along with the controlled mix without silica fume.

Stage2: Experimental works were conducted on concrete mixes by using different binder mix modified with different percentages of silica fume.

3.2.1 STAGE 1:- EXPERIMENTAL INVESTIGATION ON MORTAR.

In this stage the study is done on the effects of silica fume on compressive strength of mortar at the age of 7 and 28 days when a part of cement is replaced by silica fume.

Here we prepared mortar with ratio 1:3 from different types of cement + silica fume replacement as binder mix and sand as fine aggregate. Then its physical properties like consistency, compressive strength can be predicted.

For each mix the compressive strength of (7.06 X 7.06 X 7.06) cube is to be recorded for different percentages of silica fume(cement/sand replaced) for particular mix, average compressive strength of three similar cubes has to be noted.

Tests to study effects of silica fumes on cement paste and mortar:-

(a) Normal consistency of cement

(b) Compressive strength of cement mortar

(c) **Normal Consistency of mortar :-**

This test was performed according to (B.S 12 : 1971). The test was used to estimate the w/c ratio for cement mortar which make vicat needle of normal consistency capable to penetrate a distance of about (5-7) mm from the base of the mold.

Test Requirement:

Cement : Ordinary Portland Cement (Grade 43)

Micro silica : Commercially available micro SiO2 or silica fumes is used.

Apparatus Used:

a) Vicat's Apparatus with plunger of dia 10mm and length 50mm

b) Mould : In shape of frustum of cone

c) Metal Plate

Fig 3: Test for Normal consistency

Test procedure to find Normal Consistency for Mortar:-

Normal consistency of different binder mixes was determined using the following procedure referring to IS 4031: part 4 (1988):

1) 300 gm of sample coarser than 150 micron sieve is taken.

2) Approximate percentage of water was added to the sample and was mixed thoroughly for 2-3 minutes.

3) Paste was placed in the vicat‟s mould and was kept under the needle of vicat‟s apparatus.

4) Needle was released quickly after making it touch the surface of the sample.

5) Check was made whether the reading was coming in between 5-7 mm or not and same process was repeated if not

6) The percentage of water with which the above condition is satisfied is called normal consistency.

Normal consistency of different binder mixes are tabulated in Table

Calculation

Calculate percentage of water (P) by weight of dry cement required to prepare cement paste of standard consistency by following formula, and express it to the first place of decimal.

$$P = \frac{W}{C} \times 100$$

Where,

W=Quantity of water added

C=Quantity of cement used

Mix Proportion

- **Mix 1**

Control mix

Cement (C) : Aggregate/sand (A) = 1:3

SF (P) = 0

- **Mix 2(Cement Replaced by Silica Fume)**

Similarly for cement replacement the same content were selected.

1. 95% cement + 5% SF(SFC1)

2. 90% cement + 10% SF(SFC2)

3 85% cement + 15% SF(SFC3)

Effect micro SiO2 on Compressive Strength of cement

The effect of silica fumes on compressive strength of cement for 7 days and 28 is determined in test.

To find the compressive strength of standard cement sand mortar cubes.

Test Requires:

- Mould- 70.6mmX70.6mmX70.6mm
- Compressive testing Machine
- Cement: OPC (Grade 43)
- Sand
- Water= [(P/4)+3] % of total weight of (cement + sand)

PROCEDURE

Take 200gm of cement and 600gm of standard sand in the proportion 1:3 by weight) in a pan. (The standard sand shall be of quartz, of light, gray or whitish variety and shall be free from silt. The sand grains shall be angular, the shape of grains approximating to the spherical form, elongated and flattened grains being present only in very small quantities.

Standard sand shall pass through 2mm IS sieve and shall be retained on 90 microns IS sieve with the following particle size distribution.

Particle size	%
>1 mm	33.33
<1 mm and >500 microns	33.33
<500 microns	33.33

TEST PROCEDURE

1. Take 200 g of cement and 600 g of standard sand and mix them dry thoroughly.
2. Add (P/4+3) of water (where P is % of water required for preparing paste of standard consistency) to the dry mix of cement and sand and mix thoroughly for a minimum of 3 minutes and maximum of 4 minutes to obtain a mix of uniform colour. If even in 4 minutes uniform colour of the mix is not obtained reject the mix and mix fresh quantities of cement, sand and water to obtain a mix of uniform colour.
3. Place the thoroughly cleaned and oiled (on interior face) mould on the vibrating machine and hold it in position by clamp provided on the machine for the purpose.
4. Fill the mould with entire quantity of mortar using a suitable hopper attached to the top of the mould for facility of filling and vibrate it for 2 minutes at a specified speed of 12000±400 per minute to achieve full compaction.
5. Remove the mould from the machine and keep it in a place with temp of 27±20C and relative humidity of 90% for 24 hours.
6. At the end of 24 hrs remove the cube from the mould and immediately submerge in fresh clean water. The cube be taken out of the water only at the time of testing.
7. Prepare at least 6 cubes in the manner xplained above.

8. Place the test cube on the platform of a compressive testing machine without any packing between the cube and the plates of the testing machine.
9. Apply the load steadily and uniformly, starting from zero at a rate of 14 N/mm2/minute.

CALCULATION

$$CompressiveStrength = \frac{P}{A}$$

Where,

P=Maximum load applied to the cube. (N)

A=Cross sectional area (Calculated from the mean dimensions) (mm2)

- Compressive strength is reported to the nearest 0.5 N/mm2.
- Specimens that are manifestly faulty, or that give strengths differing by more than 10% from the average value of all the test specimen should not be considered.
- Test three cubes for compressive strength for each period of curing.

PRECAUTIONS

- The mould should be oiled before use
- The weighing should be done accurately
- The temperature and humidity must be accurately controlled
- Increase the load gradually during testing.
- The cubes should be tested immediately after taking out of water and not allowed to dry until they fail under testing.
- The gauging time should be strictly observed.
- The cubes should be tested on their sides and not on their face

Result

- Compressive Strength= P/A

Where,

P = maximum load applied on cube

A= Cross sectional area Variation of compressive strength

3.2.2 STAGE 2:- EXPERIMENTAL INVESTIGATION ON CONCRETE:-

Here concrete with different ratio of cement + silica fume replacement as binder mix was prepared. Then its physical properties like water/cement ratio, compressive strength, flexural strength, and wet-dry test was predicted.

Now In order to study the influences of micro SiO2 on the properties of concrete a comparative study has been done.

The main active constituent of concrete is cement and water that are reactive in nature that binds the fine and coarse aggregate. Concrete consist of 1-2% of voids that leads to decrement of compressive strength. The voids of mortar in concrete can be filled by using nano particles or micro particles like silica fumes. A number of reports have demonstrated that concrete containing of micro SiO_2 with Portland cement. Various research have been demonstrated that micro SiO_2 is added in relatively small amount to cement significantly improve early resistance of the concrete

TEST PROCEDURE

The purpose of doing the experiment is to compare the properties of different grade of concrete to concrete which is having partially replaced cement by silica fumes . The main objective of doing this study is to find the effects of silica fumes on properties of concrete. The study is done on M35 and M40 grade of concrete and conclusions are made. Steps involved are:-

1. To produce Standard Concrete and concrete with partial replacement of cement by silica fumes, the major work involves designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained

2. Casting of test specimens and testing ,In the present work, the compressive strengths, flexural strength, cracking pattern of Standard Concrete and concrete with silica fumes will be evaluated .

For comparing strengths for M35 grade, standard concrete and concrete with silica fumes, a total of 15 cubes of 150 mm size , 5 cylinders will be casted. Out of which, 3 cubes, 1 cylinder are tested for each type of concrete.

EXPERIMENTAL PROGRAM:- 4 mixes were casted using silica fumes. Thus there are in all 5 mixes cast out which 1 is for standard concrete and 4 using 5%,10% and 15% 20% silica fumes . The details of the experimental programme are given in Table .

S NO.	MIX DESIGNATION OF M35 and M40	Silica fumes content %	NO OF SPECIMEN CUBE:CYLINDER: BEAM		
1	M0	0	3	1	1
2	M1	5	3	1	1
3	M2	10	3	1	1
4	M3	15	3	1	1
5	M4	20	3	1	1

Table 3.6 Schedule of experimental programme:

3.3 .MIX DESIGN:-

Mix proportioning of grade M35 and M40 was performed as per IS 10262. Then for each case the cement is replaced by 5%, 10%, 15% and 20% of silica fume.

Mix design calculations for M35 grade has been done as per IS 10262:2009 and IS 456:2000. Some values have been assumed here.

As per clause 3.2 of IS 10262:2009

(A)TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days: fck = 35 MPa

Target mean strength fck'= fck+ 1.65 S

= 35+ 1.65*5

= 43.25N/mm2

S= standard deviation from table-1 of IS 10262:2009 according to grade.

(B) **SELECTION OF WATER-CEMENT RATIO:**

From Table 5 of IS: 456-2000, maximum water-cement ratio = 0.50

To start with let us assume a water-cement ratio of 0.43

Water cement ratio has been considered as 0.43 (as per table-5 IS 456:2000).

(C) **SELECTION OF WATER CONTENT**:

Maximum water content per cubic metre of concrete (refer Table 2 of IS: 10262-1982): Wmax = 186L (for 50 mm slump).

Assuming the slump was less than 50 mm, no adjustment was required.

(D) **CALCULATION OF CEMENT CONTENT**:

Mass of water selected per cubic metre of concrete = 186 kg.

Mass of cement per cubic metre of concrete = 186/0.43 = 433 kg.

Minimum cement content = 300 kg/m3 (for moderate exposure condition,

Table 5 of IS 456:2000)

Maximum cement content = 450 kg/m3 (Cl. 8.2.4.2 of IS 456:2000) So, the selected cement content is alright.

(E) **PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT**:

For aggregate size as 20mm, Percentage of coarse aggregate in total all in Aggregate = 0.62. After adjustment this value becomes 0.624.

Percentage of fine aggregate = 1-0.624

= 0.376

Considering 1 cumec of volume of concrete and specific gravity of cement as 3.15.

Volume of cement = 0.137m3

Volume of water = 0.186m3

Volume of all in aggregate = 1- [0.137+ 0.186] = 0.677m3

Specific gravity of Coarse Aggregate= 2.69

Specific gravity of Fine Aggregate= 2.62

And then Mix proportion for M40 has also been calculated considering water cement ratio as 0.41.

MIX DESIGN PROPORTIONS:-

S NO	MIX	W/C	CEMENT	F.A	C.A.
1	M35	.43	1	1.52	2.59
2	M40	.41	1	1.48	2.45

Table 7: Mix Design proportions

COMPOSITION OF M35 PER BAG OF CEMENT:-

INGREDIENTS	**WEIGHT(KG)**
CEMENT	50
WATER	21.5
FINE AGGREGATE(F.A.)	76
COARSE AGGREGATE (C.A.)	129.5

Table 7: Composition of M35 concrete per bag of cement

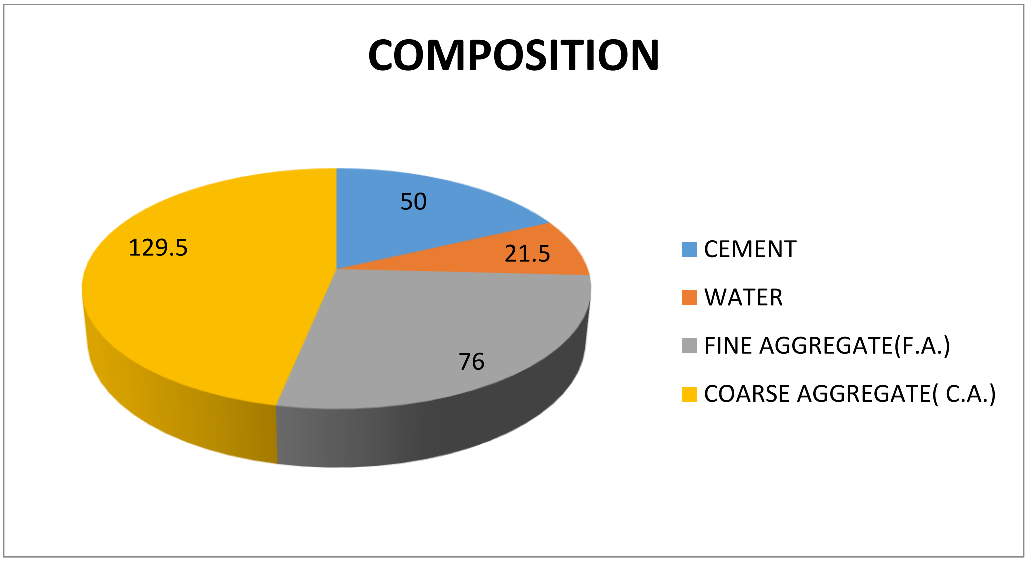
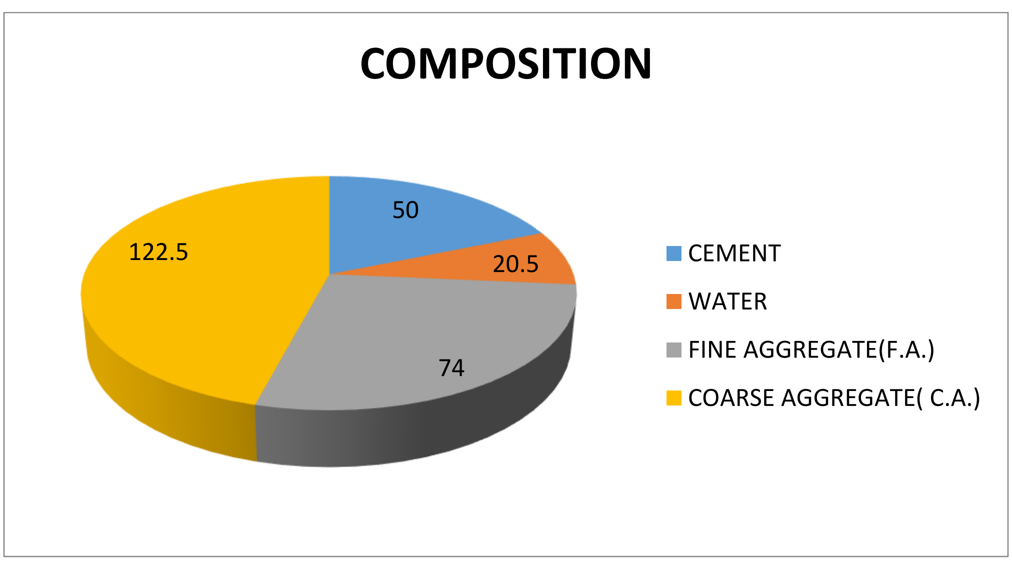


Fig 4: Composition of M35 concrete per bag of cement

COMPOSITION OF M40 PER BAG OF CEMENT:-

INGREDIENTS	WEIGHT(KG)
CEMENT	50
WATER	20.5
FINE AGGREGATE(F.A.)	74
COARSE AGGREGATE(C.A.)	122.5



2. CASTING AND TESTING OF SPECIMENS:-

In order to accomplish the aims and objective of the present study the following experiments are done.

A) TEST FOR COMPRESSVE STRENGTH OF CONCRETE

B) TEST FOR SPLIT TESILE STRENGTH

C) TEST FOR FLEXURAL STRENGTH OF CONCRETE

D) DURABILITY TEST

A) **Compressive strength of concrete:** Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.

Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommends concrete cylinder or concrete cube as the standard specimen for the test.

For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after curing for 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2or 14N/mm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Following are the procedure for testing Compressive strength of Concrete Cubes

APPARATUS

Compression testing machine

PREPARATION OF CUBE SPECIMENS

Preparation of Test Specimen

For conducting compressive strength test on concrete cubes of size 150 150 150 mm are casted. A hand mixing is used for thorough mixing and a vibrator is used for good compaction. After successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 28 days maintaining 27 10 C. Fig. 3.3 shows some concrete specimen casted in laboratory.

Fig 5: Concrete cubes casted in the mould

SPECIMEN

15 cubes of 15 cm size Mix. M35 and M40 each

Procedure:-

MIXING

Mix the concrete either by hand or in a laboratory batch mixer

HAND MIXING

(i)Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color

(ii)Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch

(iii)Add water and mix it until the concrete appears to be homogeneous and of the desired consistency

SAMPLING

(i) Clean the mounds and apply oil

(ii) Fill the concrete in the moulds in layers approximately 5cm thick

(iii) Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)

(iv) Level the top surface and smoothen it with a trowel

CURING

The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

PRECAUTIONS

The water for curing should be tested every 7days and the temperature of water must be at 27+-2oC.

PROCEDURE

(I) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(II) Take the dimension of the specimen to the nearest 0.2m

(III) Clean the bearing surface of the testing machine

(IV) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(V) Align the specimen centrally on the base plate of the machine.

(VI) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(VII) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails

(VIII) Record the maximum load and note any unusual features in the type of failure.

NOTE

Minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected. Average of there specimens gives the crushing strength of concrete. The strength requirements of concrete.

CALCULATIONS

Size of the cube =15cm x15cm x15cm

Area of the specimen (calculated from the mean size of the specimen)=225cm2

B) Split Tensile Strength

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. To determine the split tensile of concrete

Equipment for Splitting Tensile Test of Concrete

- Compression testing machine,
- Two packing strips of plywood 30 cm long and 12mm wide

Procedure of Splitting Tensile Test:

- Take the wet specimen from water after 7 days of curing Wipe out water from the surface of specimen Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
- Note the weight and dimension of the specimen.
- Set the compression testing machine for the required range.
- Keep are plywood strip on the lower plate and place the specimen.
- Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
- Place the other plywood strip above the specimen.
- Bring down the upper plate to touch the plywood strip.
- Apply the load continuously without shock at a rate of approximately 14-21kg/cm2/minute (Which corresponds to a total load of 9900kg/minute to 14850kg/minute)
- Note down the breaking load(P)

CALCULATIONS:

As per IS456, split tensile strength of concrete.= 0.7Fck

The splitting tensile strength is calculated using the formula

Tsp = 2P/ pi DL

Where P = applied load

D = diameter of the specimen

L = length of the specimen

There fore P = Tsp x pi DL/2

Expected load = P x f.s

Range to be selected is…………..

SPLIT TENSILE STRENGTH

T = 2P/ pi DL

C) FLEXURAL STRENGTH TEST

To determine the Flexural Strength of Concrete, which comes into play when a road slab with inadequate sub-grade support is subjected to wheel loads and / or there are volume changes due to temperature / shrinking.

REFERENCE STANDARDS

IS: 516-1959 – Methods of tests for strength of concrete

EQUIPMENT & APPARATUS

- **Beam mould** of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm)
- **Tamping bar** (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm)

- **Flexural test machine**– The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two simila rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

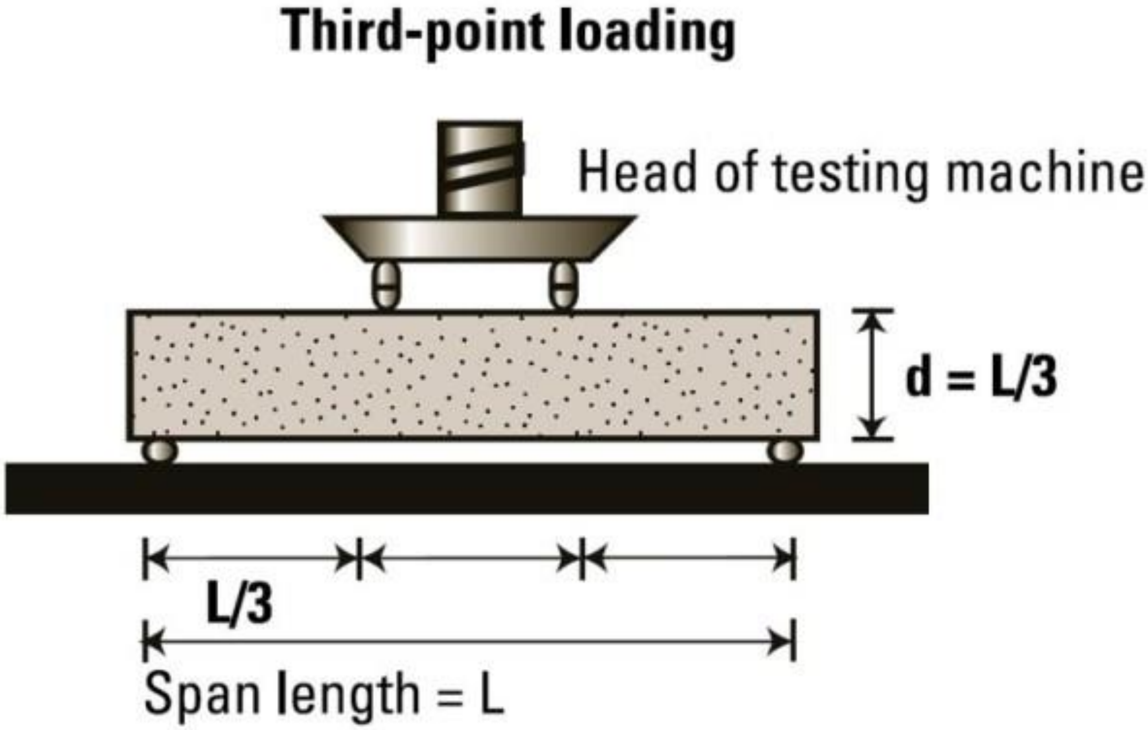


Fig 6 Flexural Strength Test Arrangement

PROCEDURE

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire crossection of the beam mould and throughout the depth of each layer.
2. Clean the bearing surfaces of the supporting and loading rollers , and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The

length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.

5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

CALCULATION

The Flexural Strength or modulus of rupture (**fb**) is given by

fb = pl/bd2 (when **a** > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

fb = 3pa/bd2 (when **a** < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (kg)

SAFETY & PRECAUTIONS:

- Use hand gloves while, safety shoes at the time of test.
- After test switch off the machine.
- Keep all the exposed metal parts greased.
- Keep the guide rods firmly fixed to the base & top plate.
- Equipment should be cleaned thoroughly before testing & after testing.

D) DURABILITY TEST

Acid Attack Test :- The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 30 days after 28 days of curing. Hydrochloric acid (HCL) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 30 days. After 30 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water.

CHAPTER: 4

RESULTS AND DISCUSSIONS

4.1 Test results

Results of compressive strength of cement mortar and hardened concrete with partial replacement of silca fume are discussed in comparison with those of normal cement mortar and normal concrete respectively.

4.1.1. Compressive strength of cement mortar:-

The effect of silica fumes on compressive strength of cement for 7 days and 28 is determined in test. In order to study the effect of silica fume on compressive strength of cement mortar, the silica fume is to be added in different percentages (i.e. 5%, 10%, 15% by weight) replacing the equivalent quantity of cement and sand separately. The proportion of mortar 1:3 has been selected for the study. For each mix the compressive strength of (7.06 X 7.06 X 7.06) cube is to be recorded for different percentages of silica fume (cement/sand replaced) for particular mix, average compressive strength of three similar cubes has to be noted.

Compressive Strength of mortar

WATER : CEMENT = 0.5

CEMENT : SAND = 1:3

MIX	7 Days compressive strength N/mm^2		28 Days compressive strength N/mm^2	
Control mix	27.70	27.10	40.20	43.33
Cement =100%	26.40		41.00	
SF=0%	27.20		39.80	
Cement =95%	29.40	30.20	46.20	46.70
SF=5%	30.20		47.10	

	31.10		46.90	
MIX	7 Days compressive strength N/mm^2		28 Days compressive strength N/mm^2	
Control mix Cement =90% SF=10%	29.40	30	51.20	51.40
	30.20		50.80	
	30.40		52.20	
Cement =85% SF=15%	32.70	32.10	48.80	48.90
	31.80		48.90	
	31.60		49.10	

Table 8: Results for compressive strength of cement mortar

4.1.2 Compressive Strength of concrete:-

The results of compressive strength were presented in Table . The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity . The compressive strength is up to 38.42 N/mm2 and 47.65 N/mm2 at 7 and 28 days. The maximum compressive strength is observed at 15% replacement of silica fume. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the silica fume and its void filling ability.

MIX	% of Silica Fume added	Compressive Strength(N/mm^2)	
		7 DAYS	28 DAYS
M1	0	25.22	38.32
M2	5	29.36	41.35
M3	10	34.23	46.82
M4	15	38.42	47.65
M5	20	35.86	44.36

Table 9: Results for compressive strength of concrete

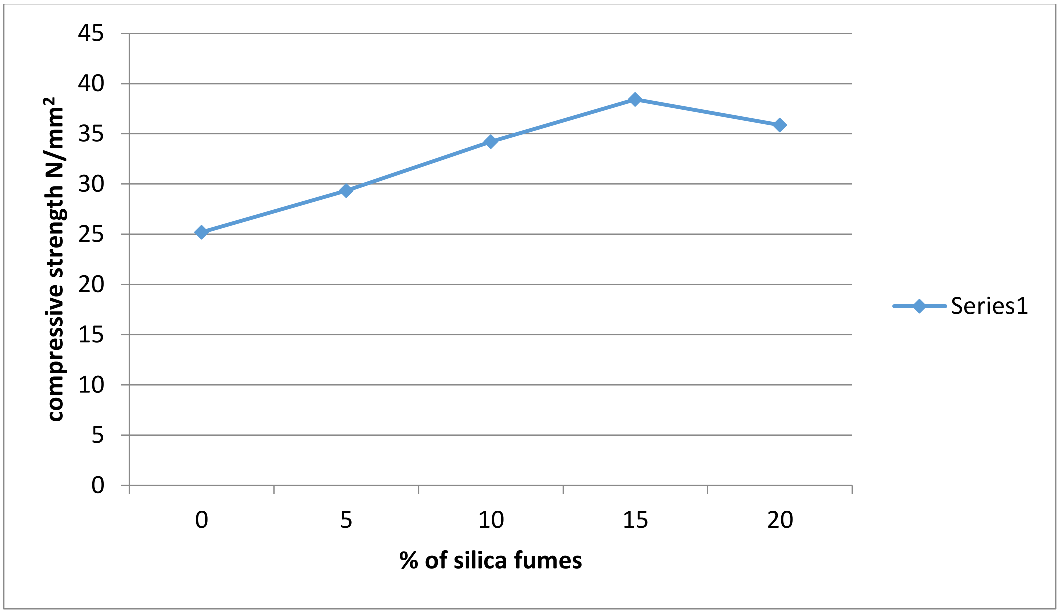


Fig 7: Variation of 7 day Compressive strength

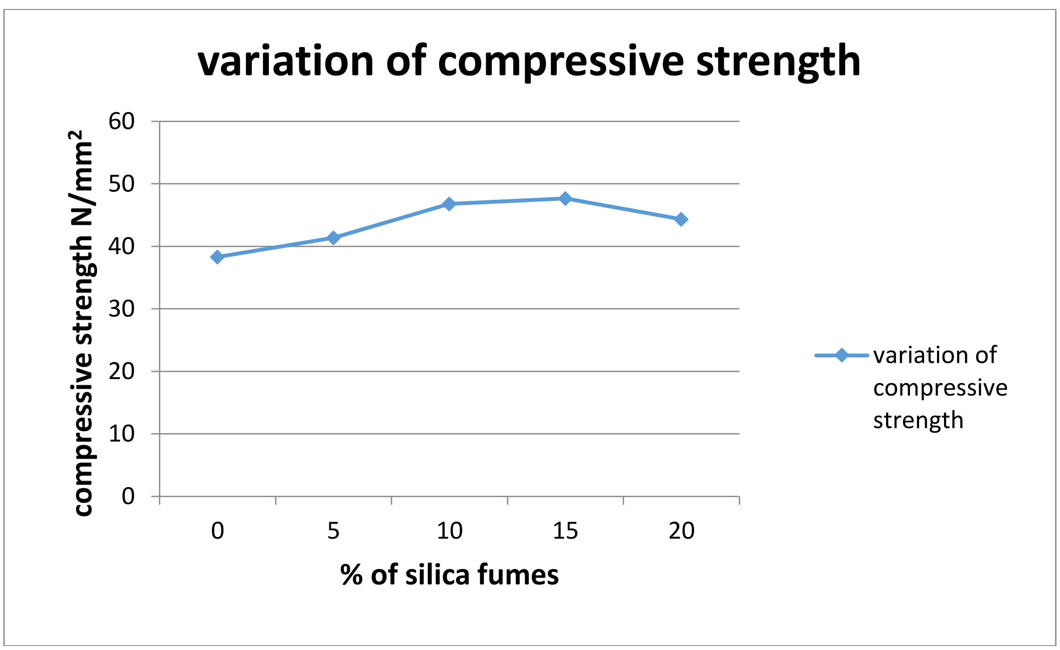


Fig 8: Variation of 28 day compressive strength

4.1.3 Split Tensile Strength

The results of Split Tensile strength were presented in Table . The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000Kn.The increase in strength is 4.10N/mm2 and 4.65N/mm2 at 7 and 28 days. The maximum increase in split tensile strength is observed at 10% replacement of silica fume.

The optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/cm ratio of the mix. The optimum 28-day split tensile strength has been obtained in the range of 5–10% silica fume replacement level, whereas the value for flexural strength ranged from 15% to 25%.

MIX	% of Silica Fume added	Split Tensile Strength(N/mm^2)	
		7 DAYS	28 DAYS
M1	0	3.15	4.63
M2	5	3.68	4.82
M3	10	4.12	4.96
M4	15	3.89	4.65
M5	20	3.69	3.94

Table 10: Effect of silica fume on split tensile strength of concrete

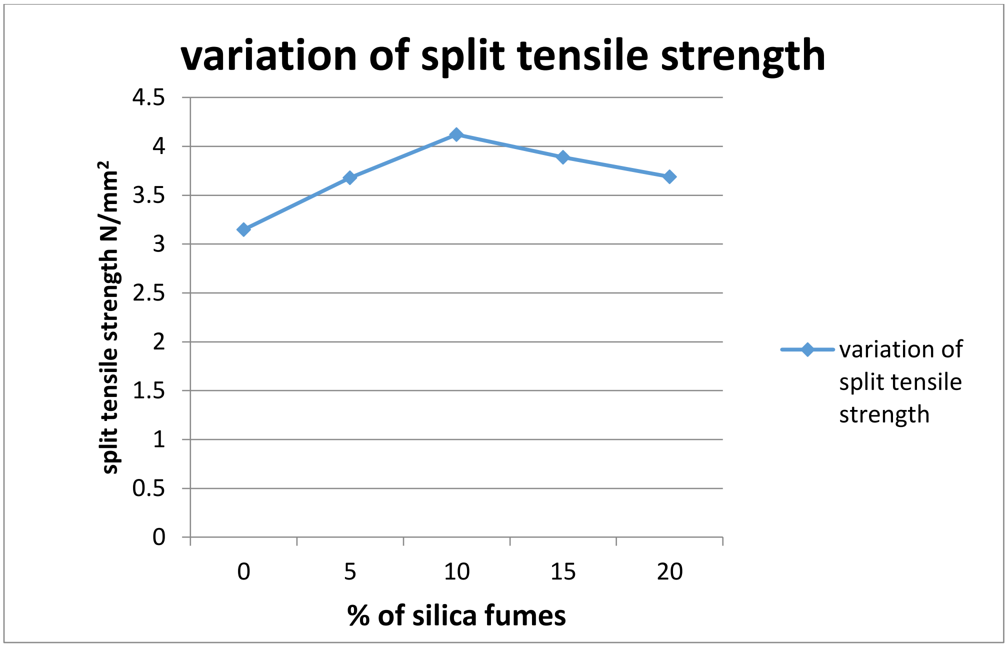


Fig 9: Variation of 7 day split tensile strength

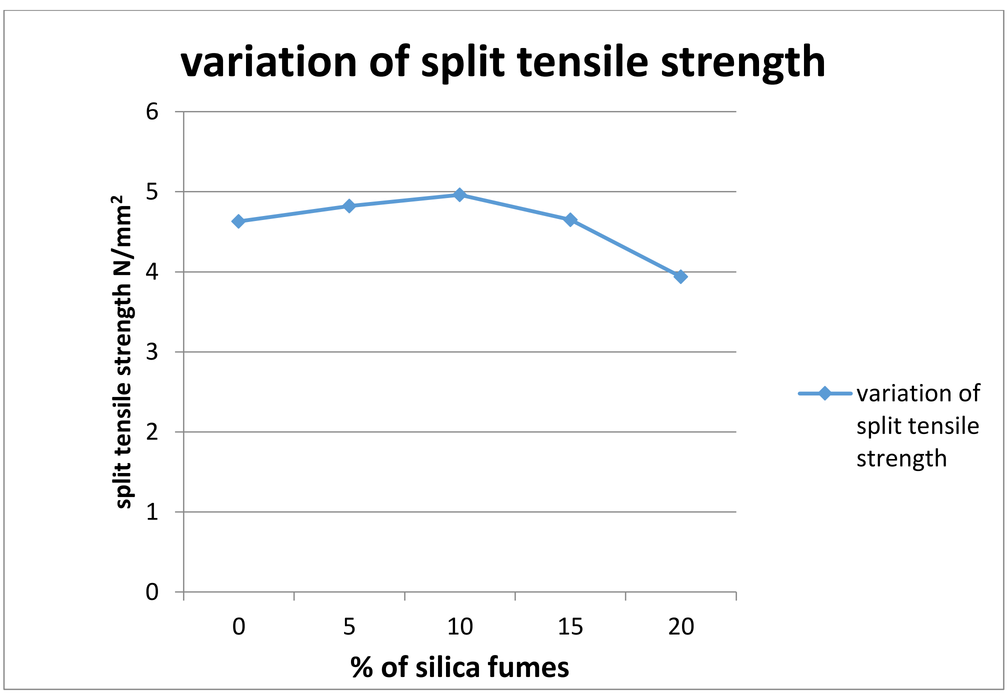


Fig 10: Variation of 28 day split tensile strength

4.1.4 .Flexural Strength

The results of flexural strength of normal concrete and silica fume replaced concrete were presented in Table . The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 7 and 28 days. The cubes were tested using Universal Testing Machine (UTM).The maximum increase in flexural strength is observed as 7.25 N/mm2 and 9.01 N/mm2 at 7 and 28 days when silica fume is replaced by 15%. to that of cement.

The flexure strength at the age of 28 days of silica fume concrete continuously increased with respect to conventional concrete and reached a maximum value of 15% replacement level for M35 grades of concrete .

MIX	% of Silica Fume added	Flexural Strength(N/mm2)	
		7 DAYS	28 DAYS
M1	0	4.87	5.86
M2	5	6.89	7.03
M3	10	7.25	9.01
M4	15	4.65	9.36
M5	20	3.97	7.08

Table 11: Effect of silica fume on flexural strength of concrete

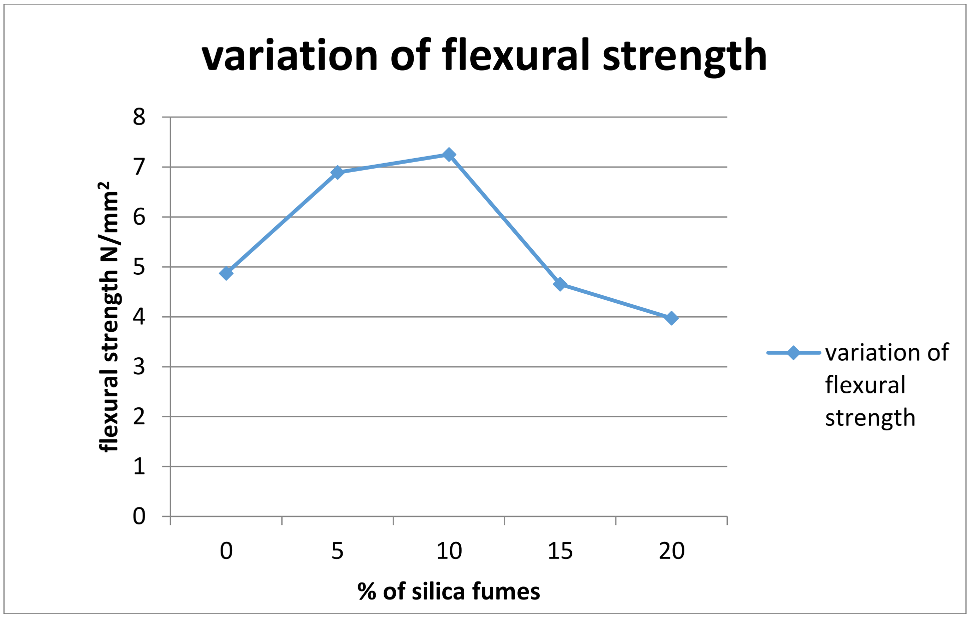


Fig 11: Variation of 7 day flexural strength

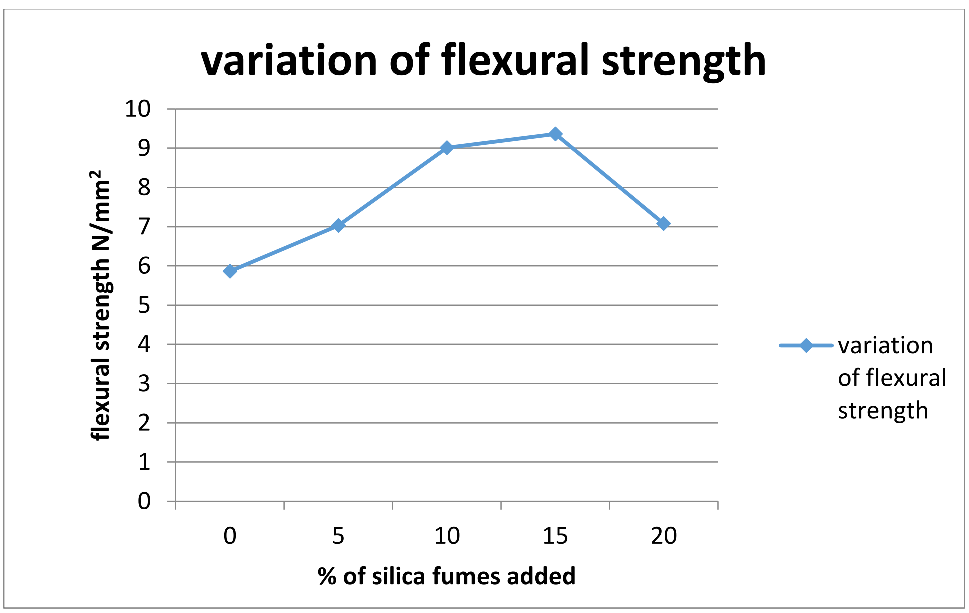


Fig 12: Variation of 28 day flexural strength

4.1.5 Durability Test

A) Acid Resistance

Cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% dilute hydrochloric acid is used. The cubes were to be immersed in acid solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The specimen was tested in the compression testing machine under a uniform rate of loading 140Kg/cm2 as per IS 516. The mass loss and strength of specimen due to acid attack was determined.

B) Acid attack

The action of acids on concrete is the conversion of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. The percentage of loss in compressive strength was 11.91%, 8.18% respectively. Thus replacement of silica fume is found to have increased the durability against acid attack. This is due to the silica present in silica fume which combines with calcium hydroxide and reduces the amount susceptible to acid attack.

MIX	% of Silica Fume added	Loss in weight (%) At 30 Days	Loss in Compressive Strength(%) At 30 days
M1	0	4.2	11.93
M2	5	2.89	8.19
M3	10	2.34	7.65
M4	15	2.76	8.04
M5	20	2.9	8.39

Table 12: Effect of Acid Attack on Weight and Compressive Strength Of Cubes

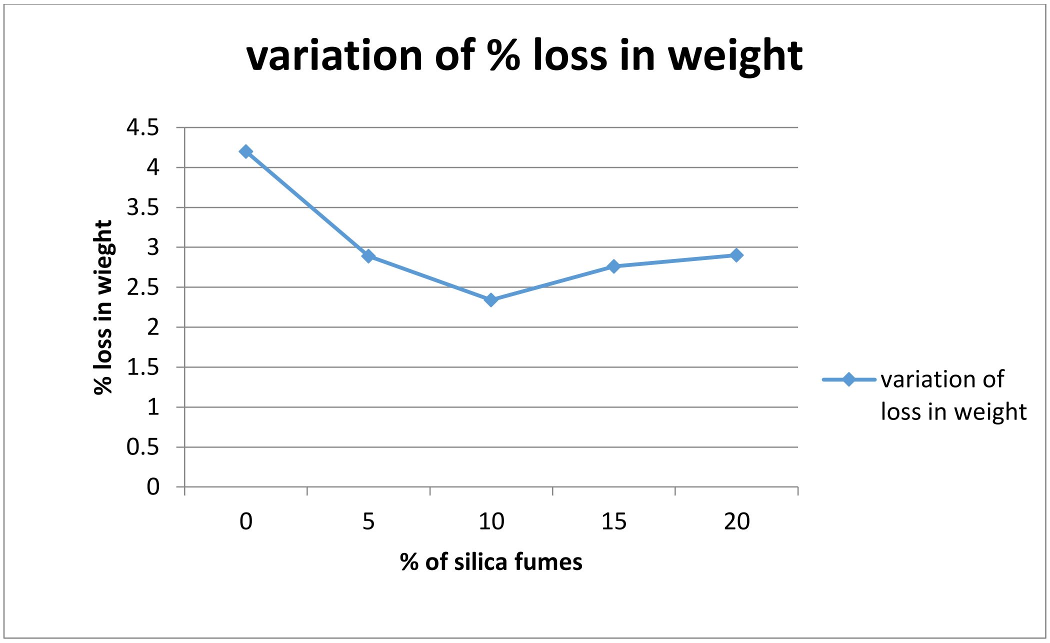


Fig 13: Variation of % loss in weight

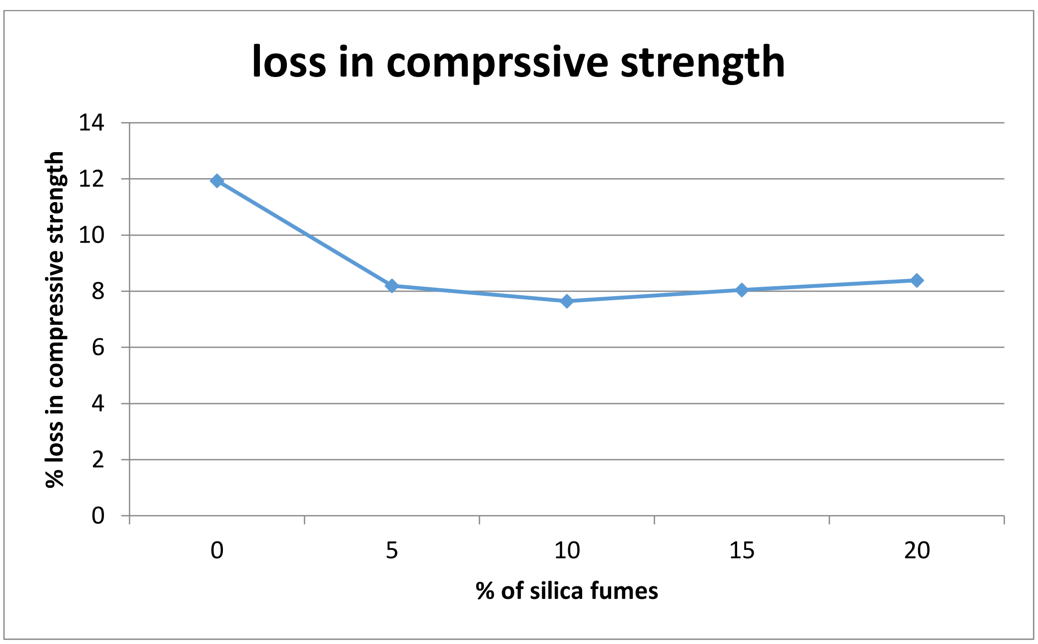


Fig 14: Variation of % loss in compressive strength

4.2 Discussion:

Mix design was performed for M35 and M40 concrete with and without micro silica replacement. Strength of the concrete cubes with replacement of micro silica 5%, 10%, 15% and 20% was found. Result shows an optimum value of 15% of micro silica replacement. Maximum increase in the strength was observed to be up to 30%. The plan is to find out the compressive strength of cubes with different percentage of micro silica for 60 days also. If more no. of cubes can be cast with more no. of results a regression pattern can also be found out.

CHAPTER 5

CONCLUSION & FUTURE SCOPE

5.1 Conclusion

The main objective of this project was to know the behavior of concrete with partial replacement of cement from silica fume at different proportions of replacement in M-35 and M40 concrete and to study the effect of different replacement levels of silica fume on the strength development of masonry mortar ,concrete and to obtain the optimum replacement level of silica fume based on strength requirements

- After performing mix design for M35 and M40 as per S 10262 and replacing the total cement content by different percentages as mentioned earlier for both of the mix design the beneficial effect of micro silica is observed. Concrete acquired a better packing of its constituents due to extremely small particles of micro silica and becomes more impermeable with strong transition zone between aggregate and cement paste.
- In all observation addition of micro silica gives more compressivestrength. It is observed from the test results that corresponding to 15% replacement of cement by micro silica gives the best results. This trend was similar for both M35 as well as M40 concretes. For varying water cement ratios (43 % for M35 and 41% for M40) the increase in the compressive strength was observed.
- Minimum 3 cubes were cast for each proportion and the average values of compressive strength have been presented.
- The flexure strength at the age of 28 days of silica fume concrete continuously increased with respect to conventional concrete and reached a maximum value of 15% replacement level for M35 grades of concrete.
- The replacement of silica fume is found to have increased the durability against acid attack. This is due to the silica present in silica fume which combines with calcium hydroxide and reduces the amount susceptible to acid attack.

5.2 Future Scope

- Although a lot of work has been carried out involving the use of micro silica in concrete. In future, the size effects of micro silica can be studied in detail. A detailed study of the microstructure at specific intervals throughout a year can give a very good idea about the reactions taking place in the concrete

- Further study can be extended on various properties of concrete by changing the particles size of micro SiO_2 and various grade of concrete.

Also a comparative study of deflection and cracking pattern can also be done for beam and slab using silica fumes.

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